EFFECTS OF NITROGEN LEVELS AND PLANT POPULATIONS ON GROWTH AND YIELD OF CHICKPEA *(Cicer arietinum L.)* UNDER DRYLAND CONDITIONS IN KENYA

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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 for an MSC Degree.

Sign……………………………. Date……………………………

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KM12/1027/03

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 brother Patrick Kamithi, my wife Catherine Njoki and children, Mwangi, Wamaitha and Wanjiku.

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ABSTRACT

Chickpea (*Cicer arietinum L.*), an annual grain legume is a hardy crop well adapted to semi arid areas. Information on optimum fertilizer rates and plant population density has not been developed for the semi arid areas of Kenya. This study conducted in Feb-June 2005 (1st season) and June-October 2005 (2nd season) at National Animal Husbandry Research Centre (NAHRC), Naivasha, determined the effect of applying four different nitrogen fertilizer rates (0, 20, 40 and 60 kg/ha) and four plant population densities (74,074; 89889; 111,111 and 148,148) on growth and yield of chickpea. The general objective was to evaluate the performance of desi chickpea in the drylands of Kenya under varying levels of nitrogen (N)and plant population's (PPD). The experiment was laid out in a Randomized Complete Block Design (RCBD). Data was subjected to analysis of variance using MSTATC computer package and means separated by Duncan Multiple Range Test and Least Significant Difference. Results indicated that increase of nitrogen from 0 to 60 kg/ha significantly increased secondary leaves/m^2, dry matter production at all stages of growth. Interactive effects of nitrogen and PPD had highest dry matter at highest N and PPD levels during crop growth and at final harvest. Application of 40kg N/ha produced highest number of pods/m^2 (ranging between 1020-1549 pods/m^2) and grain yields (1658.7 to 2574.4 kg/ha). Lowest grain yield (1099.6 kg/ha) was realized where no nitrogen was applied. Nitrogen and PPD interaction effects on grain yield were significantly higher under the highest PPD (148,148 plants/ha) and 20, 40 and 60 kg N/ha. It's advisable therefore, to apply 30kgN/ha during sowing and plant at a high plant population density of 148,148 plants/ha to realize over 3.3 tones/ha of grain yield per season. The same treatments gave net benefit ranging from Ksh 93,000.00 to 139,000.00/ha depending on rainfall and crop management

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UNITS OF MEASUREMENTS AND ABBREVIATIONS

Abbreviations used

^{0}C	Degree Celsius
CD (Lsd)	Critical difference/Least significant differences
CU	Seasonal consumptive use of water
DAS	Days after sowing
DMA	Dry matter accumulation
EC	Electrical conductivity
F_1	0kg N/ha
F_2	20kg N/ha
F_3	40kg N/ha
F_4	60kg N/ha
Fig	Figure
ha	Hectare
HI	Harvest index
Hr/h	Hour
KARI	Kenya agricultural research institute
Kg	Kilogram
LAI	Leaf area index
m	Meter
N_0	0kg N/ha
N_{20}	20kg N/ha
N_{40}	40kg N/ha
N_{60}	60kg N/ha
NUE	Nitrogen use efficiency
PAR	Photosynthetic active radiation
PPD	Plant population density
s	Second
TDM	Total dry matter
Ton	Tonne
WUE	Water use efficiency

CHAPTER ONE

1.0 INTRODUCTION

Dry lands experience constraints, which set limits to settled agriculture. These constraints are climatic as well as socio-economic in nature. Some of these include use of inappropriate tools when carrying out farming activities. Others are weeds that grow more vigorously than cultivated crops and out-compete them as well as highly variable response to fertilizers and low organic matter. Lastly, insufficient rain which falls mostly as heavy showers is lost as run off and high rates of evaporation which result in reduced yields (Oguya, 2001).

The semi arid tropics comprise of 50 countries in the world and are home of more than 600 million people. Rainfall in these regions is highly seasonal and quite variable in time and space. The soils are relatively infertile especially with regard to nitrogen and phosphorous and typically form strong surface seals during wetting and drying cycles after tillage. The soils have low water holding capacity and are highly erodible (Mollah *et al.*, 1996). These have led to low crop yields. In Kenya eighty three percent of land is arid and semi arid (ASAL) (MEPND, 1986). Due to harsh climatic conditions in these areas, food production is limited hence food aid by the government is a necessity for peoples' survival. Effort to grow highly nutritious food grain crops that are drought tolerant, need to be selected and cultivated in these marginal lands in order to increase food production and alleviate malnutrition and poverty.

Chickpea is a hardy crop grown on marginal soils with residual moisture on soils not suitable for crops such as wheat, but it's very sensitive to saline, alkaline and waterlogged soils (Fisher and Goldworthy, 1984). The crop is used to relieve diabetes and high cholesterol; acid exudation from the seedpods is used for treatment of dyspepsia (the impairment of digestion), constipation and snakebites; roasted chickpea seeds and roots are also used as coffee substitutes.

Chickpea is believed to have originated from Turkey and was grown as far back as 7450 B.C. in Turkey and 4000 B.C. in India (ACA, 2004). It is believed that the crop then spread to other parts of Asia, Middle East, and North America and later to other parts of the world (Nuts and Seeds, 2004). Today chickpea is popular throughout China, India, North Africa and Australia, and is also gaining popularity in the United States. In 1994, world production was 7.9 million tons from 10.2 million hectares of which 97% was from developing countries (Nut and seed, 2004). There are two types of Chickpea namely Desi and Kabuli. The desi is mainly grown for its seeds, which must be dehulled, and the seeds can be used in whole, split or milled. The Kabuli type is mainly grown to provide salad and vegetable mixes. The produce is also used in preparing a wide variety of snack foods, soups, sweets and condiments.

Chickpea contains 13 to 33% protein, 40 to 55% carbohydrates, and 4 to 10% oil. Fatty acids composition varies with chickpea type but is approximately 50% oleic and 40% linoleic acid, which are unsaturated fatty acids and cannot be synthesized by animals. It is also an excellent source of folate, vitamins B_6, C, and Zinc (ACA, 2004).

Chickpea yields highly (500-600kg/acre) and can be grown successfully on residual soil moisture (ACA, 2004). It is increasingly being grown as a rotation crop to enhance soil nitrogen and break graminaceous disease cycles. It however, develops slowly and has an open canopy architecture and low structure (Knights, 1991, Whish *et al*, 2002) that reduce its competitive ability against weeds and allows high evaporation losses from the soil surface.

Fertilizer use in dry land agriculture is as important as moisture availability (Umrani, 1995). Fertilization does sometimes permit deeper penetration of the soil by roots and thus the amount of water available for extraction is increased (Hedge, 1995). Kanwar (1981) described fertilizer use in dry lands as a key point for increased production. In nitrogen deficient soils, application of nitrogen to the crops brings about considerable increase in the productivity (Umrani, 1995). In chickpea production, positive response to starter nitrogen dose of 15-20 kg/ha has been observed particularly in texturally poor soils (Kumar, 1995). Such responses have not however, been found in soils with improved texture. Response to phosphorous up to 50-70kg/ha has been observed in soils low in phosphorus availability while response to nitrogen was in general more on soils poor in nodulation. On calcareous soils, grain yield of chickpea was significantly increased up to 40kg P_2O_5/ha while there was no response to an additional dose of nitrogen at a rate of 30kg/ha (Kumar, 1995).

Whereas use of landraces and unimproved cultivars with low inherent yield potential and susceptibility to abiotic and biotic stresses continues to be a major yield retardant, (Saxena, 1997), there are many other agronomic factors that prevent full realization of the yield potential at farm level (Saxena, 1997). Inadequate plant population density (PPD) is the most common yield retardant in many production areas in the world (Sheldrake and Saxena, 1999). The effect of inadequate plant population density becomes particularly conspicuous in those cropping variations where the adverse environmental conditions do not permit yield compensation by increased yield per plant productivity.

ICRISAT (1988) reports that chickpea (*Cicer* a*rietinum*), when grown under optimal conditions, can give yields of over 4 ton/ha, however, deviations from such conditions may decrease yields drastically. The introduction of chickpea to Kenya as a food security crop is based on its early maturing and ability to survive under low moisture supplies. Low yields of chickpea are often due to soil water and nutrient stress (Oswal and Sarmah, 1998). A review of the work done on fertilizer requirements under dry land conditions proves that the fertilizer application rates and plant density are tools to optimize the soil moisture availability and utilization for purposes of chickpea growth and yield (Kumar, 1995).

1.1 Statement of the Problem

Kenya has a relatively high population growth rate that was estimated at 2.9%in 1997 (MEPND, 1997) and remains at 2.2 % by 2003 (MEPND, 2003). The demand for food is likely to continue increasing steadily in the near future. In order to meet this ever-increasing demand for food, crop production needs to be enhanced. Increasing the area where crops are grown would seem a logical approach to attain growth in crop production. However, of Kenya’s 44.6 million hectares of land, only 8.6 million hectares (19%) are medium to high potential agricultural land (MEPND, 1986).

Further, the shortage of arable land in the high and medium potential areas due to different competing enterprises and high rising human population means that any increase in the area of crop production must primarily be met from the arid and semi-arid lands (ASALs). The ASAL receive unpredictable rainfall of between 250 - 500 mm per year. Farmers migrating from the high potential areas to ASALs move with their high potential area crops like wheat, barley, hybrid maize, beans, among others, into these marginal areas (ASAL) which results in numerous crop failure due to their inability to tolerate or resist drought. Due to crop failure, food shortage that often leads to low plant protein intake results into human malnutrition problems. There is need to put efforts towards producing food grains that are high in protein nutrients and can be grown in the dry lands of Kenya. Chickpea is one of the crops doing well in drought prone areas but there is lack of knowledge on proper agronomic practices for Kenyan dry highland conditions.

1.2 General Objective

To evaluate the performance of Chickpea in the dry lands of Kenya under varying plant population densities and nitrogen fertilizer application rates with a view of ensuring food security.

Specific Objectives

a. Determine effects of nitrogen fertilizer application rates on growth and yield of chick pea.

b. Determine the effects of plant population density on growth and yield of chick pea.

c. Determine interaction of plant population density and nitrogen fertilizer application rates on growth and yield of chickpea.

d. Determine the Cost Benefit Analysis of chickpea

1.3 Hypothesis (Ho)

a. Nitrogen fertilizer application rates have no effect on growth and yield of chickpea in dry lands of Kenya.

b. Plant population density has no effect on growth and yield of chickpea in dry lands of Kenya.

c. There is no interaction between plant population density and nitrogen fertilizer application rates on growth and yield of chickpea in dry lands of Kenya.

1.4 Justification

Drought stress is the most important factor limiting productivity of most crops. Food productivity in the arid and semi-arid areas does not meet the food demand. Farmers in these regions grow crops that are poorly adapted to these regions like hybrid maize and beans resulting in low grain crop yields.

Chickpea is a hardy crop and grows under low moisture regimes, low soil fertility, fixes atmospheric nitrogen and yields a high nutritious grain to the range of 1.2 to 1.8 tonnes per hectare. The crop is thus a flexible crop with a trait that invites the need to study the extent of the adaptation to unusual conditions.

Review of the work done on fertilizer requirements under dry land conditions show that the fertilizer application is a tool to optimize the crop growth and yields. Among the three macronutrients required by the crops for optimal growth, nitrogen is the one that is most frequently limits growth and yields of crops in the dry lands. Losses of nitrogen from the soil are due to volatilization, leaching, denitrification, soil erosion and plant uptake.

Though chickpea has been grown for centuries in Asian countries, Middle East, North Africa and many other dry areas, little work has been done in the Sub-Saharan regions. There's therefore need to determine the proper agronomic practices for these regions such as plant population, fertilizer requirements, sowing time, weeding frequencies, etc. This will provide nutritious food grain for the dry land

CHAPTER TWO

2.0 LITERATURE REVIEW

In this chapter, an attempt has been made to review in brief the relevant literature available in Kenya and abroad under the following sub-heads:

2.1 Chickpea Adaptation and Growth

A basic question of crop adaptation is whether the thermal requirements (cumulative degree days) for crop maturity can be met in most growing seasons (Miller *et al*., 2002). There are three strategies of crop adaptations to drought stressed environments (Ludlow, 1989): (i) drought escape, where the crop completes it life cycle before the onset of terminal drought, (ii) drought avoidance, where the crop maximizes its water uptake and minimizes its water loss and, (iii) drought tolerance, where the crop continues to grow and function at reduced water content. All the three strategies are useful in low rainfall environment (Zhang *et al*., 2000).

Pulse crops can be categorized into cool and warm season crops based primarily on their ability to emerge in cool soil conditions and on frost tolerance. Cool season crops (dry pea, lentil and chickpea) exhibit hypogeal emergence in contrast to warm season crops (dry bean and soy bean), which exhibit epigeal emergence. Crops that exhibit epigeal emergence are especially sensitive to frost damage because the cotyledon node (shoot growing point) is exposed to ambient air temperatures after emergence. Minimum temperatures for seed germination and crop growth differ among pulse crops, with dry bean and soybean having base temperatures near 5^0 C and 10^0 C respectively (Laing *et al.,* 1984; Raper and Kramer, 1987), compared with base temperatures near 0^0 C for chickpea, dry pea and lentil (Roberts *et al*,. 1988; Summerfield *et al*, 1989; Ney and Turc, 1993). Chickpea, dry pea and lentil tolerate a moderate degree of frost, -2 to $–18^0$C, depending on cultivar, degree of acclimatization, and plant stage (Wery *et al*., 1993; Welbaum *et al.*, 1997; Srinivasan *et al*., 1998).

Miller *et al.* (2003) reported that mean annual precipitation of between 330-460mm as adequate for the production of chickpea. Chickpea may adapt to drought stress by maximizing its water uptake through continuous root growth up to seed filling stages (Brown *et al*., 1989). In addition to these strategies, early sown legume crops (Chickpea, faba bean, and lentil) develops a large green leaf area and rapid canopy cover, absorbs a significant proportion of photosynthetic active radiation (PAR) early in the season hence producing large biomass and grain yield (Siddique and Sedgley, 1998). Similar findings were reported by Lema *et al* (2003) who conducted field experiments in New Delhi to study the interception of photosynthetically active radiation and its utilization in chickpea cultivars. He reported that PAR was highest at the maximum leaf area index (LAI) stages and that intercepted photosythetically active radiation was closely related to total biomass production and the grain yields.

Chickpea adaptation trials need to be carried out under Kenya's dry lands, and successful cultivars demonstrated to farmers before wide acceptance of this valuable crop is achieved. Naivasha, represents a cool (highland) semi arid environment that suffers crop failure perennially, especially where farmers grow maize and beans. Determination of chickpea adaption and its optimum nitrogen application and plant population density levels will therefore; prove useful in the efforts aimed at increased grain production and food self-sufficiency.

2.2 Effects of Nitrogen on Growth and Growth Attributes of Chickpea

Pulses are mainly grown in cropping sequences with non pulse crops because of the assumption that they acquire all or at least part of their required nitrogen from biological nitrogen fixation (BNF) and any excess in their needs is assumed to accumulate in the soil and benefit non pulse crops (People and Craswell, 1995). Pulses have been found to fix varying amounts of nitrogen. Nitrogen balances have been determined for various pulses and examples of such balances range from as little as - 42 to 34 Kg N/ha for chickpea (Doughton *et al*., 1993) and – 32 to 96 Kg N/ha for field peas (Evans *et al*., 1989). Thus, the amount of nitrogen fixed in some pulses is adequate to offset the amount of nitrogen used for growth (People and Craswell., 1995) while in others, nitrogen fixed is inadequate hence need for supplementing.

Chickpea, like other legumes, require only a starter dose of nitrogen ranging from 15 to 25kg/ha depending upon the soil (Mishra and Ram, 1971; Pasriche *et al.*, 1991,). Significantly high straw yield has been reported with the application of 22.5 to 30.0 kg N/ha

(Singh and Yadav, 1971; Singh *et al*, 1972; Mudholker and Ahlawdet, 1979; Panse and Khanna, 1994). The higher dose of N is likely to encourage vegetative growth (branches and leaves), thereby decreasing the grain to straw ratio- drastically. Mahapatrre *et al.* (1973) reported that application of nitrogen alone give low response but when applied with adequate amounts of other nutrients such as phosphorous at 30 to 60 kg P_2O_5/ha, the response to 15 kg N/ha was significantly higher over control. On black cotton soils (clayey in texture), the response to N was not significant (Probhoojan *et al.*, 1973). Similarly, Subramanian and Pallniappan (1979) observed no response even on application of 10 kg N/ha. ICRISAT (1988) reported nitrogen response of chickpea genotype to nitrogen fertilizers with regard to studies with a non-nodulating mutant, ICC 435M. The response to 100 kg nitrogen/ha fertilizer gave grain yield of 1.2 tons/ha that were equal to its parent, ICC 435. Kumar *et al* (2005) reported that dry weight of chickpea plants responded favorably to fertilizer application under normal and water stressed conditions. He also noted that in order to get the best out of the limited moisture, it is essential that nutrient requirements of dry land crops be adequately met.

2.3 Effect of Planting Population Density (PPD) on Growth of Chickpea

Chickpea is largely rain fed and grown on residual and receding soil moisture, and thus may face drought conditions during crop growth (Rupela and Beck, 1990). Sanap *et al.*, (2004) evaluated ten chickpea cultivars in Rahuri, Maharashtra, India to determine growth under drought (T_1) and well irrigated (T_2) conditions. One pre-sowing irrigation and one post sowing irrigation were given under T_1, additional irrigation at flowering and pod development stages was provided under T_2. He reported that dry matter increased slowly at the initial stages of crop growth, then increased rapidly from pre-flowering to maturity (60-90 DAS). Dry matter at harvest ranged from 6.81 to 14.89 grams per plant under drought conditions (T_1) and from 10.20 to 22.19 grams per plant under well irrigated (T_2) conditions.

Ayaz *et al., (*2000) planted chickpea at four different plant population densities (5000, 50,000, 100,000 and 200,000 plants/ha) and reported that dry matters (DM) accumulated over time and were affected by plant population densities. Dry matter ranged from 4300 to 8690 kg DM/ha as population increased. Accumulation of total dry mater (TDM) was highly related to intercepted photosynthetic active radiation (PAR) and green area duration (Anwar *et al.*, 2004). Irrigation increased days to maturity, number of secondary branches/m^2 and biological yield/ha (Ozgun *et al*., 2004). Guto (1997) carried out a one-year cropping sequence study involving Kabuli chickpea or beans *(Phaseolus vulgalis* cv rosecoco) or fallow followed by wheat (*Triticum aestivum* cv paka) at Egerton University. Chickpea and beans were spaced at 45cm between rows and 10cm between plants giving a plant population of 220,000 plants/ha. Chickpea produced 1.85 tons/ha above ground biomass and had accumulated 59.9 kg N/ha while common beans gave 1.44 ton/ha and had accumulated 38.9 kgN/ha. Anwar *et al.* (2004) reported that to maximize chickpea biological yield in the dry seasons of the cool temperate sub humid climate of Canterbury, irrigation should extend across all phenological stages of crop growth and development. There is therefore need to determine the optimal plant population density for the dry lands of Naivasha - Kenya.

2.4 Effect of Nitrogen Fertilizer Applications on Grain Yield and Yield Attributes of Chickpea

The importance of adequate supply of plant nutrients to ensure efficient crop production has been recognized for many years (Guto, 1997). Scientists and farmers are therefore continually striving to overcome nutrient deficiencies of crops in order to increase yields according to their genetic potentials (Tisdale *et al.*, 1990). Fertilization does sometimes permit deeper penetration of the soil by roots and thus the amount of nutrient and water available for extraction is increased (Hedge, 1995). Under dry land condition, the deeper sub soil frequently contains little available plant nutrients and water for exploitation.

Srinivasarao *et al* (2004) investigated the available nutrient status in sub-soil layers (15-30 and 30-45 cm) in relation to that of surface soils of profiles collected from pulse growing regions of India. He reported higher nutrient contents (N, P, K) between top two layers and that many pulse crops like chickpea, pigeon pea and mung bean were deep rooted extending the root system beyond 15 cm hence substantially utilizing nutrients from deep layers. A review of work done on fertilizer requirements under dry land conditions proves that the fertilizer application rates and planting population densities are tools to optimize the soil nutrients and moisture availability (Kumar, 2005). In soils deficient in nitrogen, application of nitrogen fertilizer to crops will bring considerable increase in the productivity (Umrani, 1995). However, crops use nitrogen fertilizers inefficiently (Dobermann and Cassman, 2004).

Nitrogen (N) plays a big role in all metabolic processes. It forms an important constituent of cell structures and is indispensable for the transfer of genetic information. Akram *et al.* (2004) remarked that the addition of even small amounts of nitrogen (N) into agricultural lands can increase the growth and yield of crops effectively. Although N accounts for 78% of the air volume, its availability is relatively poor because only few plants (pulses) can utilize it directly from the atmosphere. Consequently the supply of available N often becomes inadequate especially during the critical growing periods of plants. Hence it has been a long time challenge for agriculturalists to maintain soil N at levels that are adequate for optimum crop production (Krishna *et al.,* 2004). Applications of nitrogen increase the source capacity, namely, leaf area, Leaf area index (LAI), early canopy closure and the rate of photosynthesis (Doughton *et al.*, 1993).

Chickpea responds favorably to low rates of 15 - 20 kg N/ha in nitrogen deficient soils (Singh and Khongaret, 1987; Thaku *et al*., 1989 and Ahlawat, 1990). Substantial increases in yield ranging from 0 to 40% have been obtained with application of 10-20 Kg N/ha (Ahlawat 1990). On calcareous soils, grain yield of chickpea significantly increased with application of 40 kg N/ha whereas there was no response to additional dose of nitrogen irrespective of the source (Kumar 1995). Shri *et al.,* (2004) conducted a field experiment in Kaptur, Uttar Pradesh, India, during the rabi seasons of 1996/97 and 1997/98 to study the interactive effects of nitrogen (0, 15, 30 and 45 kg/ha through urea) and sulphur (0,20,40 and 60 kg/ha) on the grain yield (kg/ha), harvest index (H1), total nitrogen (N) and Sulphur (S) uptake, and protein content of chickpea. He reported that application of 15 kg N/ha and 40 kg S/ha significantly increased grain, N and S uptake, and protein content over the control in both seasons under semi arid conditions.

Raut and Sabale (2003) used four different types of NPK fertilizer (25:50:0, 31.2:60.7:27, 47.45:80.33:33.45 and 126:138:52.8) and reported that number of branches/m^2, dry matters/ha, harvest index (HI), stovers and grain yields increased with increasing fertilizer rates. Lopez (2004) reported that chickpea crop seems incapable of meeting nitrogen demands by fixation and does not even supply an equivalent quantity of 50 kg/ha of nitrogen fertilizer. There is no work done for Naivasha area, therefore, there is need to determine the optimum fertilizer level for optimal growth of desi chickpea in the dry land of Naivasha-Kenya.

2.5 Effect of Plant Population Density (PPD) on Grain Yield and Yield Attributes of Chickpea

In pulses, the optimum plant population density appears to differ with plant, type of cultivars and the environmental conditions (Kumar, 1995). Duncan (1986) defined three phases of pulse crop (e.g. soybean) yield response to increased plant population densities. Phase I covered the range of plant densities where there is no competition among plants and grain yield is directly proportional to plant density (e.g. yield per plant is constant). Phase II begins at a plant population density great enough to intercept essentially all of the insolation at full canopy and is terminated at the density where further increases in density cause no increase in yield. Phase I and II are separated by a range of densities where there is increased competition among plants. In case of chickpea, under unfavorable climatic conditions, genotypes appears to show little variation in grain yield due to plant population density (Kumar, 1995). Under irrigated conditions, the grain yield of chickpea increased up to a density of 50 plants/m^2 that was found to be optimum. At Bellary (India), under dry land conditions, chickpea yields did not increase beyond a plant population density of 185,000/ha. Sanap *et al* (2004), reported average grain yield of 6.10gm/plant under additional irrigation at flowering and pod development stages and this was reduced (grain yields/plant) by 35.73% under drought conditions. Parshuram *et al* (2003) reported that seed yield was positively correlated with pods/m^2, number of branches and leaves/m^2 while Partap *et al*. (2002) reported direct effect on grain yield/ha as exerted by biological yield/ha and number of pods/m^2. Similarly, Ortega *et al*. (1994) performed field experiment trials in the Costa de Hermosillo area in a silt loam soil under two irrigation schedules: pre-planting irrigation (400mm water); and pre-planting irrigation plus 70mm of water at the pod filling stage using two plant population densities (125,000 and 250,000 plants/ha). He reported that higher planting population densities produced higher yields (from 1.5 to 2.4 tonnes/ha) particularly when irrigated at pod filling stages.

Earlier reported findings on direct and indirect effects through path analysis of chickpea were contradictory. Akdag and Sehirali (1992) reported grain yield per plant and biological yield as the major yield determining components; Acikgoz and Acikgoz (1994) reported grain yield per plant, whereas Sharma and Maloo (1988) found that pod number had the most direct effect, followed by primary branches. Singh *et al.* (1990) reported that biological yield and harvest index were major contributors of grain yield. Ozdemir (1996) found out that grain yield per plant, secondary branches per plant and had the highest positive effect in that order on grain yield per hectare.

2.6 The Effect of Plant Population Density (PPD) on Nitrogen Use Efficiency (NUE) of Chickpea

The efficiency with which the crops take and use nitrogen greatly depends upon soils, plant type, climatic and management factors (Mosier *et al*., 2004). Katyal (1989), reports that fertilizer use efficiency is defined as the capacity of the fertilizer N to increase yields over that of the control plot. The synonym to this term is “agronomic efficiency” and is usually expressed as kilogram grain yield (economic yield) increase per kilogram of fertilizer N. His work also shows that the major concerns about the N fertilizer are to quantify the N removed by crops and lost from the crop point of use. Under rain situations, precipitation, water holding capacity of the soil, form of fertilizer N and method of application are the most important factors which determine N use efficiency.

The spatial arrangement for a given population can be adjusted either by changing the inter-row or intra-row distances. Such adjustments have special effects on aspects like utilization of net radiation, root growth, nutrient uptake and water use (Hedge, 1995). Determining the optimum plant population continues to be a challenge for the dry land farmers. Too high or too low plant densities can reduce grain yields as high densities use too much of the available soils nutrients early in the season and low densities do not fully exploit the available nutrients. When plants are spaced closely within the row and increasing distance between rows, the soil moisture and nutrient supply is not exhausted as rapidly as in narrow rows (Hedge, 1995). Deeper and more proliferous root growth has been obtained with wider row planting (Umrani, 1995).

2.7 Effect of Nitrogen Fertilizer Application on Nitrogen Use Efficiency of Chickpea

Aside from climatic influences, crop management practices often affect the apparent adaptation of pulse crops. Management factors under the direct control of producers include seeding date, seeding depth, seeding rate, cultivars, and seedbed conditions (Johnson, 1987; Auld *et al*., 1988; Townley-Smith and Wright, 1994). Other factors that contribute to the variability of pulse crop yields are the result of farm fields that lack a history of pulse crops, dry seedbed conditions, low soil pH, and poor competitive ability with weeds (Clayton *et al*., 1997). However, yield variability has mainly been attributed to the lack of nitrogen in the pulse crop due to ineffective nodulation.

Nitrogen added to the soil through fertilizer, biological nitrogen fixation (BNF), atmospheric deposition, irrigation and or rainwater, animal manures, plant and animal residues passes through various processes of nitrogen cycle in soil-plant-atmosphere systems (Janzen *et al*., 2003). The cycle includes the soil processes (mineralization, immobilization, BNF, nitrification, volatilization, denitrification and nitrogen movement in the soil), the processes pertaining to plant growth and nitrogen uptake by crops, and atmospheric processes such as wet and dry deposition which and plays a key role in supplying nitrogen to crops (Smil, 2002).

The concept of balanced fertilization has significant importance in dry land agriculture where moisture limitation lowers the fertilizer use efficiency and crop yield (Das *et al.*, 1995). Apart from the major nutrients, balanced fertilization is equally important in case of micronutrients. Some soils, which are deficient in micronutrients, should be supplied with these nutrients so that nutrient imbalances are corrected. However, indiscriminate use of micronutrients may lead to nutrient imbalance and may be toxic for plant growth (Venkatesubbaiah *et al.*, 1986). Balanced fertilization is a must for sustaining optimal yield and has been defined by Tandon (1990) as a balance means of a total plant nutrient system which is capable of taking care of all nutrient deficiencies which occur in an area, be they of macro or micronutrients (Das *et al.*, 1995). Crop yields were found to be correlated with levels of fertilizer application (Das *et al.*, 1995). Depending upon the soil characteristics, the recovery was less than 50 percent in case of nitrogen and up to 80 percent in case of phosphorous (Das *et al.*, 1995). Most of the soils were only able to supply a fraction of the nutrients required by the arable crops. Even available nutrients were rarely present in a balanced condition to meet the crop requirement. It is essential to add the limiting nutrients through fertilizer in quantities that ensure balanced nutrition for a given yield of crop. Seed yield of chickpea increased with increase in available moisture and fertilizer application

Whenever moisture deficiency occurs, a level reaches at which water deficiency hinder the plant growth to a greater extent than nutrient deficiency (Das *et al.*, 1995). Water availability thus has an appreciable effect on the availability of nitrogen, phosphorous and other nutrients in dry land soils. Power (1990) found that when water was very limited, dry matter production of grass was quite low, and little or no response to nitrogen fertilizer application occurred.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Materials and Method

Field experimentation's were conducted at The National Animal Husbandry Research Center (NAHRC), Naivasha, Kenya during the two seasons (long and short rains) of year 2005,to evaluate the growth and yield of chickpea under four different levels of nitrogen application and four different plant population densities.

3.2 Climate and Weather Conditions

The center is located on grid $0^0 40^1$S and $36^0 26^1$E, at an altitude of 1940m above sea level (masl), (Jaetzhold and Schmidt, 1982).The experimental site lies in transition between agro ecological zone middle highlands 5 (UM5) and lower highlands (LH4) 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 500mm, with a wide variation between the years. Precipitation is mainly received between late March to June (long rains) and October to December (short rains). Although mean temperature is about 18^0C, daily values range from 7^0C at late night during the wet chilly season (July to August) to about 27^0C during the dry months. The relative humidity varies between 60-75%.

3.3 Soils

The soils are described by Jaetzhold and Schmidt, (1982) as generally imperfect to poorly drained' very deep, dark greyish to brown, silt loam, developed on sediments from volcanic ashes. The chemical soil analysis (Table 1) which was done during the first weeks of the experiment indicate that soils are neutral to slightly alkaline (P^H 7.39). This concurs with the findings of Snijders *et al.* (1992) and Sombroek *et al.* (1980). Soil analysis showed that, the soils are sufficient in nitrogen (N; 0.27%) and phosphorus (P; 11.3ppm). The textural composition was 18% sand, 44% silt and 38% clay between 0 – 60cm profile. The soil bulk density from 0-110 cm soil depths ranged from 1.18-1.46 gms/cm^3. The interpretation and further general recommendations are that, the soil nutrients status and alkaline soil reaction

(P^H) are not favorable for crops growing. In order to improve the soil organic matter and the availability of nutrient elements, it is essential to add either organic manures or use inorganic nitrogen fertilizers at planting time, for extra nitrogen supply.

Naivasha vegetation is highly influenced by the intensive agricultural activities going on around Lake Naivasha. Natural vegetation is however, dominated by star grass (*Cynodon dactylon*) and (*Acacia xanthofloea*).

Table1: Chemical characteristics of soils at the experimental site

Parameters		Comment
Soil pH	7.39	Medium alkaline
Total nitrogen (%)	0.27	Adequate
Organic matter (%)	1.99	Moderate
Phosphorus (ppm)	11.3	Adequate
Potassium (%)	3.47	High
Calcium (%)	21.6	High
Magnesium (%)	4.22	High
Manganese (%)	0.97	Adequate
Copper (ppm)	0.96	Adequate
Iron (ppm)	43.8	Adequate
Zinc (ppm)	8.23	Adequate
Sodium (%)	1.95	Adequate
E.C. (ms/cm)	1.05	High

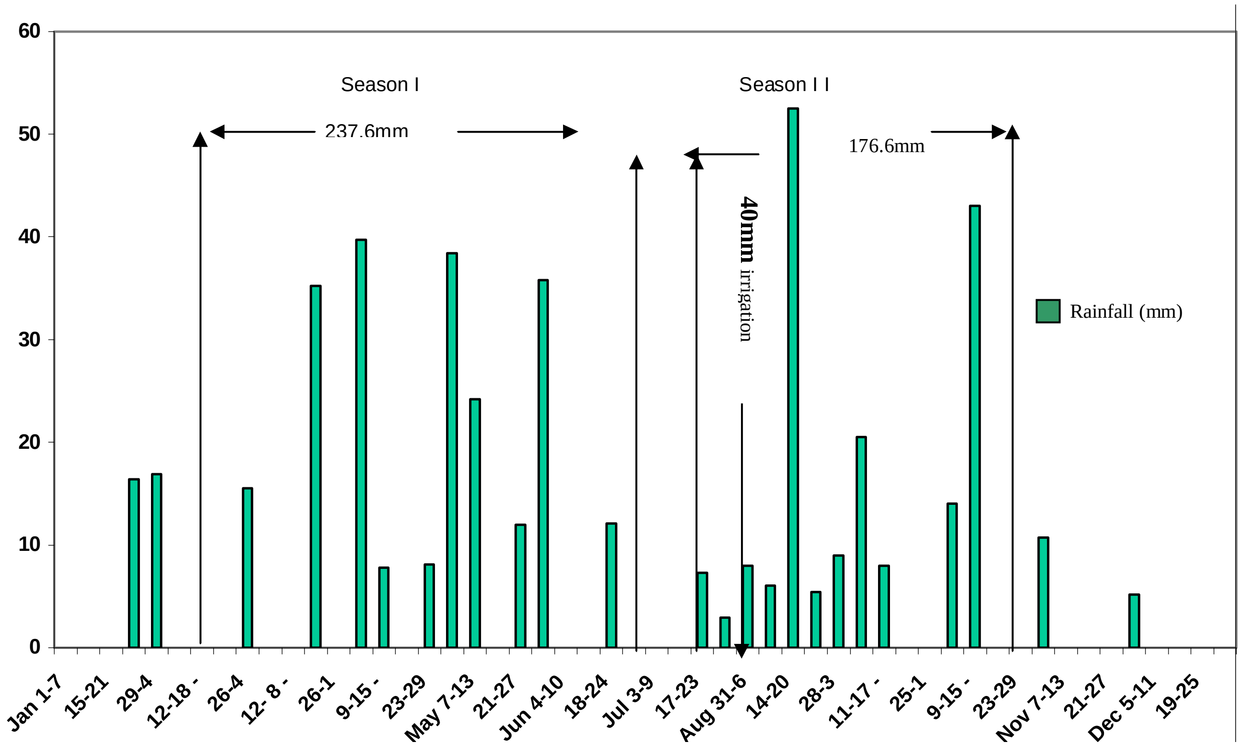

Figure 1: Meteorological weekly rainfall (mm) for the year 2005 at KARI-Naivasha

3.4 Cropping History of the Experimental Field

The history of the experimental field during the preceding three years reveals that year 2002; the field was under Lucerne cultivation. The field was then left fallow during the years of 2003 to 2005 with Kikuyu grass as the main dominant species

3.5 Experimental Design

An experiment testing effects of four different nitrogen fertilizer levels (0, 20, 40 and 60 Kg N/ha) and four different plant population densities (PPD) (148,148; 111, 111; 88.889 and 74,074/ha) on growth and yield of chickpea was conducted. The experimental design was a factorial experiment in Randomized Complete Block Design (RCBD) with 16 treatment combinations replicated three times.

Fertilizer application Rates	**Plant population density/ha**
$F_1 =$ 0 kg N/ha (N_o)	$P_4 =$ 148,148 - (45cm x 15cm)
$F_2 =$ 20 kg N/ha (N_{20})	P_3 = 111,111- (45cm x 20cm)
F_3 = 40 kg N/ha (N_{40})	P_2 = 88,889- (45cm x 25 cm)
F_4 = 60 kg N/ha (N_{60})	P_1 = 74,074 - (45cm x 30 cm)

Treatment combinations were assigned to the plots randomly on each block.

Field layout for single block

Block A

$F_1 P_3$	$F_1 P_2$	$F_2 P_4$	$F_1 P_1$
$F_4 P_4$	$F_2 P_1$	$F_4 P_2$	$F_3 P_2$
$F_3 P_1$	$F_4 P_1$	$F_2 P_2$	$F_2 P_3$
$F_4 P_3$	$F_3 P_4$	$F_3 P_2$	$F_1 P_4$

Block B

$F_1 P_3$	$F_1 P_4$	$F_1 P_1$	$F_2 P_1$
$F_2 P_1$	$F_3 P_1$	$F_3 P_2$	$F_4 P_2$
$F_4 P_4$	$F_3 P_3$	$F_4 P_2$	$F_3 P_4$
$F_2 P_3$	$F_2 P_4$	$F_1 P_2$	$F_4 P_3$

Block C

$F_4 P_4$	$F_4 P_2$	$F_1 P_4$	$F_2 P_2$
$F_4 P_3$	$F_1 P_3$	$F_2 P_1$	$F_3 P_1$
$F_3 P_3$	$F_1 P_1$	$F_3 P_2$	$F_2 P_3$
$F_1 P_2$	$F_2 P_4$	$F_4 P_1$	$F_3 P_4$

Experimental model

$\mathbf{Y_{ijk}}$	**=**	$\mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \acute{Y}_k + \Sigma_{ijk}$
i	**=**	**1, 2, 3, 4**
j	=	1, 2, 3, 4
k	=	1, 2, 3
μ	=	**Overall mean**
α_i	=	**The ith level of fertilizer effect**
β_j	=	**The jth level of plant population**
$(\alpha\beta)_{ij}$	=	**Interaction of ith fertilizer rates and jth level of plant population effect**
$\acute{Y}_k$	=	**kth block effect**
Σ_{ijk}	=	**The error component**

Σ_{ijk}- **N** $(0,\sigma^2)$

3.6 Crop Establishment and Management

Seedbed preparation was carried out in the months of February and March 2005 before the onset of rains in readiness for planting. Conventional tillage, a single disc ploughing followed by a single harrowing was used. Total soil nitrogen was analyzed before sowing and after harvesting at four different soil depths (0-15, 15-30, 30-60 and 60-90cm). Fields were kept weed and pest free. Human labor was used during field layout, planting, weeding, pest control, and data collection and harvesting.

3.7 Fertilizer and Fertilizer Application

At planting triple super phosphate was used in all the treatments at 40kg P_20_5/ha. Calcium ammonium nitrates (C.A.N.) fertilizer was used to supply nitrogen at four different levels (0, 20, 40 and 60 kg N/ha) at planting.

3.8 Plant Population Density (PPD) per Hectare

The experiment occupied an area of 81m x 17m. There were three blocks separated from each other by a path of 2m wide. Each treatment occupied an area of 4m x 3m and separated from each other by 1m.

Four different planting population densities (PPD) on hectare basis were used. These populations were P_4: 148,148 plant/ha (45cm x 15cm), P_3: 111,111 plants/ha (45cm x 20cm), P_2: 88,889 plants/ha (45cm x 25cm) and P_1: 74,074 plants/ha (45cm x 30 cm). Planting population was maintained up to harvesting time. Planting was done after the onset of rain. All the treatments had seven rows of which three inner rows formed the sampling rows, while the remaining four rows formed two guard rows on each side of the central rows. Each treatment had a net plot of (2m x 1m) at the centre. Plant population P_4, P_3, P_2 and P_1 had 196, 147, 119 and 98 plants per treatment respectively. At planting, two seeds were sown per hill. Seven days after emergence, the stands were thinned to one plant per hill. Planting was done on the same day for all the treatments. Desi type, variety ICCV 97105 of chickpea was planted.

3.9 Plant Tagging

After crop emergence, net plot areas of $2m^2$ were selected in the central rows of all the treatments and tagged. The tagged plants were used for data collection (i.e., non-destructive sampling such as height, primary and secondary branches/m^2, etc.

3.10 Parameters Observed/measured

3.10.1 Weather

Weather data was collected from an automatic weather station at the Naivasha Animal Husbandry Research Centre (NAHRC) where the experiment was conducted was used. This helped in determining the amount of rainfall (mm) falling during the growing season using a rain gauge, maximum and minimum air temperatures (^{0}c) using thermometers, solar radiation (MJM^{-2}) per day using sunshine recorders, relative humidity (%) using hygrometer, wind speed (ms^{-1}) using cup anemometer and evaporation rates for each day using evaporimeter.

3.10.2 Soil Measurements

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.

Total soil nitrogen was determined by the Kjedahl method as outlined by Breemmer and Mulvency (1982). Phosphorus (Olsen *et al*., 1967) and potassium (Mehlick, 1978). The micro nutrients (Calcium, magnesium, manganese, copper, iron, zinc and sodium) were determined by use of Mehlick method. 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: There were16 access tubes in each block installed at time g of planting.

3.10.3 Plant Parameters

Days to 50% plant emergence, primary and secondary branches/m^2, primary and secondary leaves/m^2, plant height, leaf area index (LAI) by use of leaf area photometer, days to 50% branching, days to 50% flowering, number of pods/m^2 by physical counting, 100 dry seed weight at harvesting using a weighing balance, seed grain yield per plot by use of weighing balance, total biomass, grain yield /ha, harvest index.

3.10.4 Harvesting

This was done manually in all the treatments at the net plot area of (2x1) m^2. The harvested crop was dried in the sun before threshing. Threshing was done by use of sticks. Winnowing was done to separate grain and chaff. The grains were sun dried to moisture content of about 12%. Grain dry weight was then taken and recorded.

3.11 Biometric Observations

A sampling unit of 1m x 1m (net plot) was selected at the middle (center) of each plot in both seasons for recording growth and yield parameters. For periodic studies of dry matter, plants were harvested from the net plot in each experimental plot. The observations recorded during the course of the experimentation are given below.

Observations recorded

A. Growth

1. Plant height (cm)
2. Primary branches/m^2
3. Secondary branches/m^2
4. Primary leaves/m^2
5. Secondary leaves/m^2
6. Dry matter production (Kg/ha) at 25,55,90,105 and 120 DAS
7. LAI at 90 DAS
8. Pods/m^2
9. 100 seed weight (gm)
10. Grain yield (Kg/ha)
11. Biomass yield at harvest (Kg/ha)
12. Harvest index (HI)

3.11.1 Plant Height

Five plants were randomly selected from the sampling net plot and final height before harvest was measured from the ground level to the tip of the plant. The mean was then computed and recorded in cm.

3.11.2 Number of Primary Branches/m^2

Total number of primary branches/m^2 (net plot) was counted and recorded at harvest from the sampling unit. These are shown in Plate 3.

3.11.3 Number of Secondary Branches/m^2

Total number of secondary branches/m^2 was counted, computed and recorded at harvest from the sampling unit.

3.11.4 Primary Leaves/m^2

These were counted, computed and recorded from the sampling unit at physiological maturity.

3.11.5 Secondary Leaves/m^2

These were leaves on secondary branches was counted, computed and recorded in net plot at physiological maturity of the crop, Plate 3.

3.11.6 Dry Matter Production

Plant samples were taken at 25, 55, 90, 105 and 120 (grain harvest) days after sowing (DAS) from the net plots and the average value was calculated. At each sampling, plants were cut at soil surface, oven dried at 60^{o}C for over 24 hrs until constant weight was obtained.

3.11.7 Leaf Area Index (LAI)

Leaf area index was measured 90 DAS when the crop was observed to have achieved 100% flowering and early pods formation. This was done by use of a leaf area photometer, LI – COR – 3000.

3.11.8 Pods per Meter

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

3.11.9 100 Seed Weight

Hundred grains were randomly picked from amongst grains harvested from each net plot and their weight recorded in grams.

3.11.10 Grain and above Ground 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 grain and above ground biomass were weighed separately and finally expressed in yields per hectare basis.

3.11.11 Harvest Index (HI)

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

3.11.12 Data Analysis and Production Functions

Data was analyzed by analysis of variance (ANOVA) using MSTATC computer package. Least Significance Difference (LSD) and Duncan's Multiple Range Test (DMRT) was used to separate the means at a probability level of < 0.05%. Regression analyses were carried out using computer Excel program and dependent variables like DM and grain yield related to the independent variables (N and PPD). These relationships were quantified by mathematical equations. Regression analysis was done according to *Little and Hill (1978)*. Production functions relating nitrogen and PPD were computed and graphs drawn using Microsoft Excel and PowerPoint. Seasonal nitrogen application rates and plant population densities (PPD)/ha was related to the growth parameters (primary and secondary branches/m^2, primary and secondary leaves/m^2, plant height, leaf area index (LAI) and DM/ha) and grain yield attributes (pods/m^2, 100 seed weight and harvest index) and grain yield by fitting to a second degree quadratic and linear curves.

CHAPTER FOUR

4.0 RESULTS

4.1 Effect of Treatments on Yield Attributes of Desi Chickpea ICCV 97105

4.1.1 Effects of Nitrogen on Primary Branches/m^2 of Chickpea in Season I and II

There were no significant differences on chickpeas number of primary branches/m^2 at all levels of nitrogen fertilizer application in both season one and two. However, there were more primary branches/m^2 (Plate 3) during season two than season one (Figure 2).

The number of primary branches/m^2 were similar during the first season under all nitrogen application levels and ranged from 144 to 149 (Table 2). In the second season, application of 0, 20 and 40kg N/ha also had similar effect on the primary branches/m^2 and at par with each other. The 60kg N/ha treatment had the lowest number of primary branches /m^2 but not significantly different from the 40kgN/ha treatment. It appears that nitrogen application of up to 40kg/ha has no significant advantage on primary branches/m^2 over the no nitrogen application treatment.

The linear regression Figure 2 reveals a very slight insignificant increase in season I and decrease in season II, respectively implying that nitrogen does not affect or increase number of primary branches/m^2. The relationship was linear (Fig 2) and had a (correlation) coefficient of R^2=0.46 and 0.55 in season I and II, respectively.

4.1.2 Effect of Planting Density on Primary Branches/m^2 of Chickpea in Season I and II

Increased plant population/ha significantly ($P \leq 0.05$) increased the number of primary branches/m^2 (Table 2). Chickpea plant populations of 148,148/ha (P_4) and 111,111/ha (P_3) were at par but significantly superior to that of 89,889/ha (P_2) and 74,074/ha (P_1) plants/ha during the first season. However, P_2 produced significantly ($P \leq 0.05$) higher primary branches/m^2 than P_1. During the second season increase in plant population from 74,074/ha (P_1); to 89,889/ha (P_2); 111,111/ha (P_3) and 148,148/ha (P_4) significantly increased the number of primary branches/m^2, respectively (Table 2).

The rate of increase in primary branches/m^2 per unit increase in planting density (PPD) was 15.0 primary branches/m^2 per plant/ha in season I and 16.7 plants/m^2 per plant/ha in season

II. (Though the second season's rate of increase of plants/m^2 was slightly higher it was lower than for season I probably due to lower rainfall). The relationship of planting density to primary branches/ m^2 was linear (Fig 6) with a regression (correlation) coefficient of R^2= 0.82 in the early Feb-June 2005 crop. Where as the later June to Oct 2005 crop had a correlation coefficient of 0.97. This means that primary branches in chickpea are highly correlated/influenced by planting population density (PPD).

Table 2: Effect of nitrogen and plant population density on primary and secondary branches/m^2, primary and secondary leaves/m^2 and leaf area index (LAI)

Nitrogen (kg/ha)	Primary Branches/m^2		Secondary Branches/m^2		Primary Leaves/m^2		Secondary Leaves/m^2		L.A.I	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season1	Season 2
0(No)	144.83a	83.00a	1299.00a	956.58ab	3157.83b	2143.17b	29064.33b	32510.67b	2.62d	2.60d
20(N20)	144.83a	87.67a	1027.83b	1019.33a	3320.17ab	2473.00a	29630.33b	39168.67a	2.98c	2.98c
40(N40)	144.00a	81.50ab	1118.33ab	929.67bc	3436.83a	2113.33b	31949.33ab	33000.33b	3.31b	3.21b
60(N60)	149.33a	75.33b	1227.50a	864.00c	3455.17a	2135.08b	33071.17a	38100.67a	3.52a	3.45a
PPD/ha										
P_1	119.83c	56.67d	1015.33c	453.33d	2832.33c	1640.67d	28392.67c	25920.67d	2.45a	2.34a
P_2	140.83b	74.17c	1096.67bc	741.67c	3233.33b	2035.00c	29550.00bc	29926.67c	2.90b	2.82b
P_3	159.00a	89.33b	1220.67ab	1072.00b	3505.67a	2459.17b	32107.00ab	40635.33b	3.53c	3.43c
P_4	163.83a	107.33a	1340.00a	1502.58a	3435.67ab	2729.75a	34465.50a	46297.67a	3.67d	3.67d
SED	7.7150	3.386	90.801	41.049	111.962	104.53	1444.465	1730.219	0.0381	0.0411
LSD	15.754	6.914	185.415	83.822	228.626	213.467	2949.598	3533.107		
C.V (%)	18.6900	14.33	26.93	15.09	11.93	16.34	16.07	16.79	5.22	2.15

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

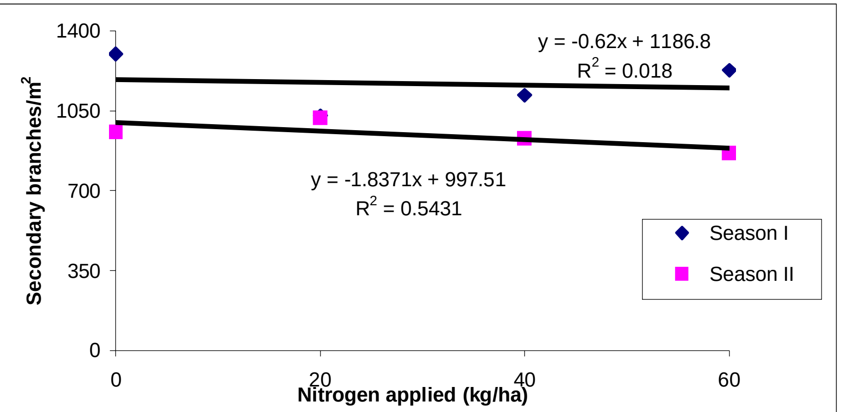

Fig 3: Effect of nitrogen on secondary branches/m^2 of chickpea in seasons I and II

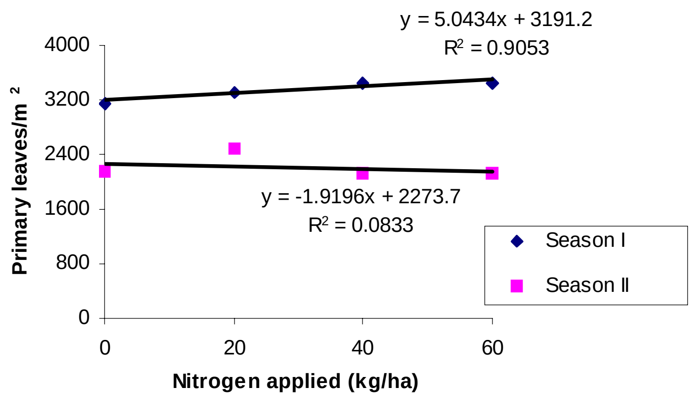

Fig 4: Effect of nitrogen on primary leaves/m^2 of chickpea in seasons I and II

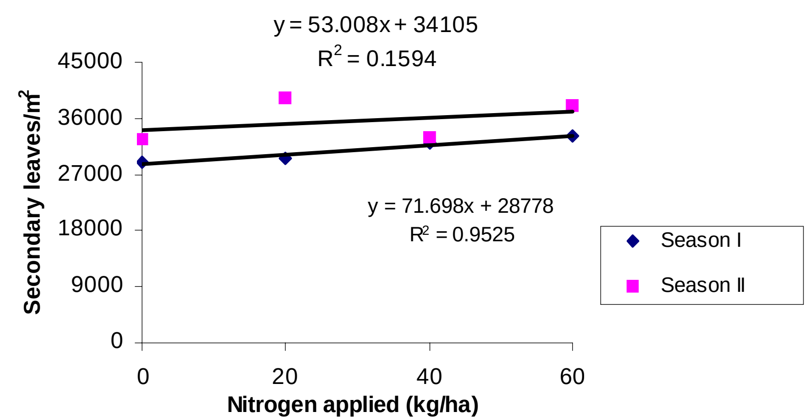

Fig 5: Effect of nitrogen on secondary leaves/m^2 of chickpea in seasons I and II

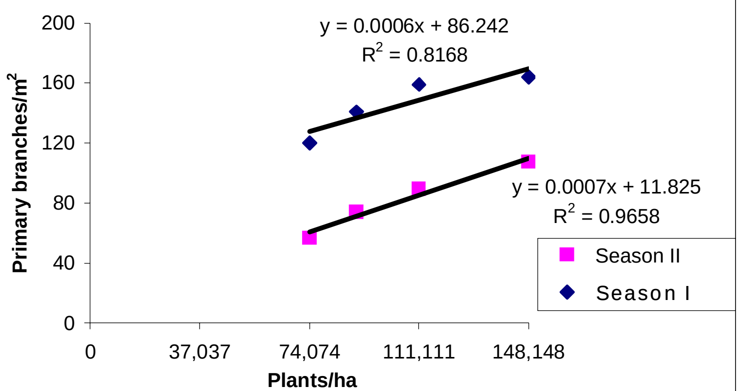

Fig 6:Effect of planting density on primary branches/m^2 in seasons I and II

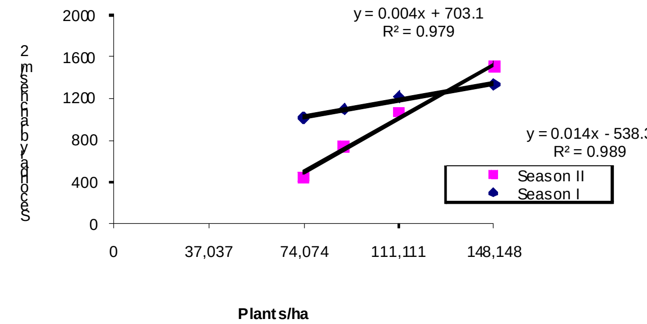

Fig 7:Effect of planting density on secondary branches/m^2 of chickpea in seasons I and II

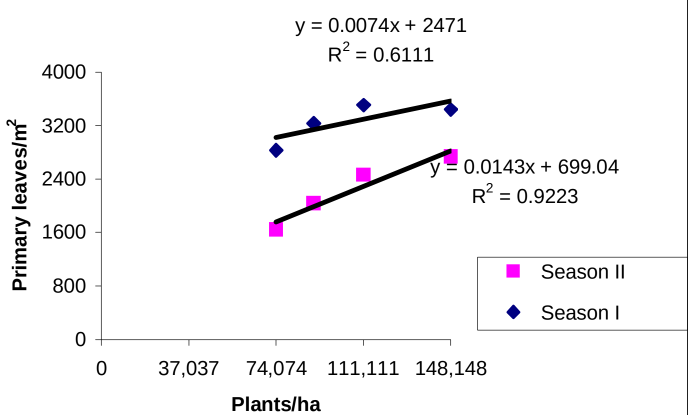

Fig 8:Effect of planting density on primary leaves/m^2 of chickpea in seasons I and II

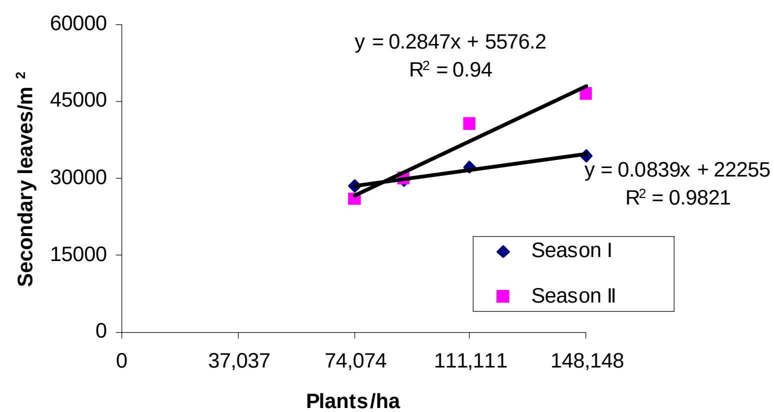

Fig 9:Effect of planting density on secondary leaves/m^2 of chickpea in seasons I and II

Plate 1: Chickpea diagram

Plate 2: Effect of no nitrogen (0 kg N/ha) application

Plate 3: Effect of nitrogen (60kg N/ha) application

Plate 4: Effect of planting population density (74,074 plants/ha)

Plate 5: Effect of planting population density (148,148 plants/ha)

4.1.3 Interaction Effects of Nitrogen Application Rates and Plant Populations/ha on Primary Branches

During the first season (Table 3), increasing nitrogen application rates from 0 to 60kg/ha revealed an increasing trend in primary branches/m^2 at higher plant populations of 148,148 (P_4); 111,111 (P_3) and 89,889 (P_2) per hectare.

At plant population of 74,074/ha (P_1) however, application of no nitrogen had similar number of branches/m^2 compared to the 20, 40 and 60 kg N/ha treatments (Table 3). When comparing effects of plant populations under varying nitrogen levels. It is observed that the lowest population (P_1) of 74074 and P_2 plants/ha were on par, but gave significantly lower primary branches than at higher populations (P_3 and P_4) at 20, 40 and 60kgN/ha levels. Under no nitrogen application, the primary branches were same under all populations.

During the second season, (Table 4) increases nitrogen from 0 to 60kg/ha revealed significant differences at all levels of the four planting populations. At the highest plant populations of 148,148 (P_4), nitrogen application of 0, 20 and 40kg/ha had similar effects. However, application of 60kg N/ha produced the lowest number of primary branches/m^2 which was not significantly different from the 40kg N/ha treatment (Table 4).

Increase in plant populations significantly increased the number of primary branches/m^2 under all nitrogen application rates. The 60kgN/ha treatment on plant populations' 148,148/ha (P_4) and 111,111/ha (P_3) gave similar number of primary branches/m^2 under 0 and 60 kg N/ha levels. These were significantly higher than P_2 and P_1 treatments. Treatments 74,074/ha (P_1) had significantly ($P \leq 0.05$) the least number of primary branches/m^2. Highest number of primary branches ranged from 102-121/m^2under 0, 20 and 40 kg N/ha of 148,148-plants/ha treatments.

Table 3: Interaction effects of nitrogen application rates and PPD/ha on primary branches/m^2 during the first season

PPD	Nitrogen Levels			
	N_o	N_{20}	N_{40}	N_{60}
P_1	136.00ab	112.00b	112.00b	117.00b
P_2	136.67ab	146.67ab	140.00a	140.00ab
P_3	148.00ab	157.33a	158.67a	172.00a
P_4	158.67a	163.33a	165.33a	168.00a
SED	**15.431**		**DMRT**	**44.565**

Table 4: Interaction effects of nitrogen application rates and PPD/ha on primary branches/m^2 during the second season

PPD	Nitrogen Levels			
	N_o	N_{20}	N_{40}	N_{60}
P_1	58.67d	53.33d	61.33d	53.33d
P_2	73.33c	80.00c	76.67c	66.67cd
P_3	88.00a	96.00b	85.33bc	88.00b
P_4	112.00a	121.33a	102.67ab	93.33b
SED	**6.772**		**DMRT**	**20.553**

4.2 Effect of Treatments on Secondary Branches of Chickpea

4.2.1 Effects of Nitrogen Application on Secondary Branches/m^2 of Chickpea in Season I and II

The highest numbers of secondary branches/m^2 (1,299) were obtained under no nitrogen application, followed by 60kgN/ha (1,227) and 40 kg N/ha (1,118) treatments, respectively. Effect of nitrogen application at 40 and 20 kg//ha (1,027 secondary branches/m^2) however, resulted in same number of secondary branches per m^2. The ratio of primary branches to secondary branches was calculated to be 1:8 during the first season.

During the second season, application of 0 kg N/ha and 20kg N/ha produced the highest number of secondary branches/m^2 i.e. 956 and 1,019, respectively, and were on par with each other. However, the 0 kg N/ha treatment was not significantly different from the 40kg N/ha (929 secondary branches/m^2) treatment. Application of 60kg N/ha (864) had the lowest number of secondary branches/m^2 but not significantly different from the 40 kg N/ha treatment (Table 2). The ratio of primary branches to secondary branches during the second season was 1:11.

Therefore primary and secondary branches may not be markedly affected by nitrogen application. However, the leaf growth is affected resulting in poor grain yields under low nitrogen levels. Linear regression lines reveal (Fig.3) that nitrogen does not appear to have much influence on secondary branches/m^2. Infact they appeared to decline with increase in nitrogen levels. The relationship however had poor correlation in first year, R2=0.02 than in second season R^2=0.54

4.2.2 Effect of Planting Density on Secondary Branches/m^2 of Chickpea in Seasons I and II

During the first season a plant population of 148,148/ha (P_4) gave the highest number of secondary branches/m^2 (1,340) along with a plant population of 111,111/ha (1,220). Treatment P_3 had similar number of secondary branches/m^2 as P_2 (Table 2).

Treatment P_1 (1,015 secondary branches/m^2), however was significantly ($P \leq 0.05$) lower than all other treatment effects, but at par with P_2 (Table 2). At the second season, increase in plant population/ha at the four different levels of P_1, P_2, P_3 and P_4 revealed ($p<0.05$) significant increase in the number of secondary branches/m^2.

The rate of increase of secondary branches/m^2 was higher during the second season compared to the first season (Fig. 7). This trend was similar to that observed with primary branches/ m^2 whereby, the 2nd season crop grown under lower moisture ;216.6mm of rainfall and 40mm of irrigation showed an enhanced rate of secondary branches production, i.e. 347.8 secondary branches/ m^2 per chickpea plant (by harvest). In 1st season crop 109.8 secondary branches/ m^2 were produced per plant. The minimum number of secondary branches/ m^2 was 72.7 and 893.9 (12 times higher) in seasons two and one, respectively. Reasons for this large difference could be attributed to the more than 61 mm of rainwater received by the first season of Feb-June crop. An increase of 61 mm rainwater increased primary and secondary branches/m^2 by a factor of 2.5 and 12 in chickpea, respectively.

The relationship of planting density to secondary branches/m^2 was linear (Fig 7) with a correlation coefficient of R^2=0.99 in season I and II respectively.

4.2.3 *Interactions Effects of Nitrogen Application Rates and Plant Populations/ha on Secondary Branches/m^2*

Application of 40kg N/ha gave significantly lower i.e. 1037 secondary branches/m^2 under the plant population treatment of 148148/ha (P_4) during the first season. However application of 0, 20 and 60kg N/ha gave similar secondary branches/m^2 of 1,612; 1106 and 1604 respectively (Table 5). Increasing nitrogen application rates from 0 to 60kg/ha revealed no significant difference at plant population of 111,111/ha. At plant populations of 89,889/ha (P_2) application of no nitrogen and 40kg N/ha gave 1,160 and 1,180 secondary branches/m^2. These were similar and significantly superior to where Nitrogen was applied at 20 (1,063 secondary branches/m2) and 60 (983 secondary branches/m^2) kg N/ha. Highest secondary branches/m^2 ranged from 1180 ($N_{40}P_2$) to 1612(N_0P_4) while the lowest secondary branches were 973($N_{40}P_1$) to 992/m^2 (N_0P_1).

At plant population of 74,074/ha (P_1) application of 60kg N/ha (N_{60}) produced 1,098 secondary branches/m^2. This treatment was significantly ($P \leq 0.05$) superior to where 0 kg/ha nitrogen was applied (997 secondary branches/m^2), 20 (997 secondary branches/m^2) and 60(973 secondary branches/m^2) kg N/ha. Where no nitrogen was applied, P_1 treatments produced 992 secondary branches/m^2 and were significantly lower than for P_4, P_3, and P_2, which were similar. Under the 20kg N/ha treatment, plant population P_1 and P_2 gave the highest number of secondary branches/m^2. Treatment P_3 however was not significantly different from P_2 and P_1 treatments. Where 40kg N/ha was applied, P_3 and P_2 gave similar number of secondary branches/m^2 that were significantly superior to P_4 (1,037) and P_1 (973) treatments, which were also at par with each other. Application of 60kg N/ha and plant population of 89,889/ha (P_2) gave 983 secondary branches/m^2 that was significantly ($P \leq 0.05$) lower than 1,604 branches/m^2 (P_4) 1,224 braanches/m^2 (P_3) and 1,098 branches/m^2 (P_2) treatments.

During the second season, (Table 6) the four plants populations level of 148,148/ha (P_4); 111,111/ha (P_3); 89,889/ha (P_2) and 74,074/ha (P_1) revealed significant ($P \leq 0.05$) effects on the number of secondary branches/m^2. Application of 0 and 20kgN/ha on P_1 treatment produced the highest number of secondary branches/m^2 (1567). However, 0 and 40kg N/ha (N_0P_4&$N_{20}P_4$) treatments produced similar number of secondary branches/$m^{2.}$ Application of 60kgN/ha on P_4 treatment ($N_{60}P_4$) produced comparatively lower number of secondary branches/m^2 but not significantly different from the 40kg N/ha treatment ($N_{40}P_4$). At 111,111 (P_3) and 89,889 (P_2 plants/ha), increase in nitrogen from 0 to 60kg N/ha revealed no significant effect on secondary branches under 74,074 (P_1) treatment. Application of 0, 20 and 60kg N/ha produced similar number of secondary branches/m^2. However, 0 kg N/ha treatment was not significantly different from the 40kgN/ha treatment. It was observed that, increase in plant populations from P_1 to P_2, P_3 and P_4 significantly increased the number of secondary branches/m^2 at all levels of nitrogen application, from a low number of 426 ($N_{20}P_1$) to 1,698 ($N_{20}P_1$) approximately 400% increase.

Table 5: Interaction effects of nitrogen application rates and PPD/ha on secondary branches/m^2 during the first season

PPD	**Nitrogen Levels**			
	N_o	**N_{20}**	**N_{40}**	**N_{60}**
P_1	992.00b	997.33b	973.33b	1098.67a
P_2	1160.00a	1063.33b	1180.00a	983.33b
P_3	1432.00a	1094.00ab	1282.67a	1224.00a
P_4	1612.00a	1106.67a	1037.33b	1604.00a
SED	**181.601**		**DMRT**	**524.464**

Table 6: Interaction effects of nitrogen application rates and PPD/ha on secondary branche/m^2 during the 2nd season

PPD	Nitrogen Levels			
	N_o	**N_{20}**	**N_{40}**	**N_{60}**
P_1	469.33hi	426.67i	490.67h	426.67i
P_2	733.33g	800.00fg	766.67g	666.67gh
P_3	1056.00e	1152.00de	1024.00ef	1056.00e
P_4	1567.67ab	1698.67a	1437.33bc	1306.67cd
SED	**82.097**		**DMRT**	**237.096**

4.3 Effect of Treatments on Primary Compound Leaves

4.3.1 Effect of Nitrogen Application Rates on Primary Compound Leaves/m^2 of Chickpea in Season I and II

During the first season, the number of leaves increased with addition of nitrogen from 0 to 60 kg/ha. No nitrogen application treatment gave the least number of primary compound leaves/m^2 (3,157). This was however at par with when nitrogen was applied at the rate of 20kg N/ha (3,320). Applying nitrogen at the rate of 60, 40, and 20kg N/ha gave the highest number of primary leaves/m^2 (Table 2) i.e. 3,455; 3,436 and 3,320 respectively. In the second season, 20kg N/ha treatment gave the highest number of primary compound leaves/m^2 (2,473). This was significantly ($P \leq 0.05$) superior to all the other treatments, which were at par (Table 2).

Fig. 4 shows the relationship of primary compound leaves/m^2 with increasing nitrogen application rates and had a correlation coefficient of R^2=0.91 and 0.08 in season I and II, respectively.

4.3.2 Effects of Plant Population/ha on Primary Compound Leaves/m^2 of Chickpea in Season I and II

During the first season, plant population's 111,111/ha (P_3) and 148,148/ha (P_4) had the highest number of primary compound leaves/m^2; i.e. 3, 505 and 3,435, respectively. However, P_4 was not significantly different from the 89,889-(P_2) plants/ha treatment that had

3,233 primary compound leaves. The 74,074-plants/ha treatments had significantly ($P \leq 0.05$) the least number of compound leaves/m^2 (2,832) (Table 2).

During the second season, successive increase in plant populations/ha from 74,074 (P_1) to 148,148 (P_4) showed successive significant ($P \leq 0.05$) increases at all the levels; viz. 1,640; 2,035; 2,459 and 2,729 compound leaves/m^2, respectively (Table 2). Fig. 8 depicts effect of planting density on compound primary leaves/m^2 of chickpea. The regression (correlation) coefficient was 0.79 and 0.99 for season I and II, respectively.

4.3.3 Interaction Effects of Nitrogen Application Rates and Plant Populations/ha on Primary Compound Leaves/m

Table 7 shows that increased nitrogen rates from 0 to 60kg/ha had no significant effect on primary compound leaves/m^2 under the 148,148plants/ha (P_4) treatment level during the first season. These treatments were at par with chickpea grown at treatment combinations of N_0P_3/P_2 (3,261 and 3,256) and $N_{40}P_3/P_2$ (3,348 and 3,310) and $N_{60}P_3/P_2$ (3,822 and 3,280), respectively. However, chickpea planted at plant populations of 89,889/ha (P_2) using no nitrogen (N_o P_2) was not significantly different from where 20kg N/ha was used (N_{20} P_2). These (N_oP_2 and $N_{2O}P_2$) were similar with chickpea that were planted at plant population of 74,074/ha (P_1) using 0, 20, 40 and 60kg N/ha. Chickpea ICCV 97105 grown using no nitrogen at plant populations of 148,148/ha (P_4); 111,111/ha (P_3) and 89,889/ha (P_2) gave similar number of compound leaves/m^2. However, P_2 treatment was not significantly ($P \leq 0.05$) different from the P_1 (74,074 plants/ha) treatment.

Crops at treatment combination $N_{20}P_4$ were significantly superior to the crops grown at treatment combinations of $N_{20}P_{1,}$ $N_{20}P_2$ and $N_{20}P_3$. Nitrogen application at rate of 40 and 60kg/ha gave similar number of primary compound leaves/m^2. Plant population of 74,074/ha (P_1) gave significantly lower number of primary compound leaves/$m^{2.}$

During the second season (Table 8), treatment combinations N_0P_4, $N_{20}P_3$ and $N_{20}P_4$ produced significantly the highest number of primary leaves. However, N_0P_4 treatment was not significantly different from the $N_{60}P_4$ treatment. At plant population of 111,111/ha (P_3) use of 20kg N/ha ($N_{20}P_3$) produced significantly ($P \leq 0.05$) higher number of leaves/m^2 compared to N_0P_3, $N_{40}P_3$ and $N_{60}P_3$ treatment combinations, respectively, which were at par with each other. Application of 0, 40 and 60kg N/ha on the 89,889plants/ha (P_2) treatments revealed no significant differences on the number of compound leaves/m^2. However, use of 20kg N/ha ($N_{20}P_2$) produced significantly higher number of leaves/m^2. At plant population of 74,074/ha (P_1), application of 0, 20 and 40kgN/ha produced similar number of compound leaves/m^2. However, $N_{20}P_1$ and $N_{60}P_1$ treatment combinations were not significantly different from each other. When no nitrogen was used, plant population of 148,148(N_0P_4) produced the highest number of leaves/m^2. However, N_0P_4 was not significant different from N_0P_3. N_0P_2 and N_0P_1 treatment combinations were at par and significantly ($P \leq 0.05$) lower than N_0P_3 and N_0P_4. Application of 20kgN/ha to P_4 and P_3 treatments produced significantly ($P \leq 0.05$) higher number of compound leaves/m^2. $N_{20}P_1$ treatment combination produced the least number of leaves/m^2. When 40kg N/ha was applied, $N_{40}P_4$ and $N_{40}P_3$ were at par and significantly ($P \leq 0.05$) higher than $N_{40}P_2$ and $N_{40}P_1$ treatment combinations that were at par with each other. Application of 60kg N/ha showed that $N_{60}P_4$ and $N_{60}P_3$ had similar number of compound leaves/m^2 and significantly higher than $N_{60}P_2$ and $N_{60}P_1$ treatments. N_{60} P_1 treatment combination had significantly ($P \leq 0.05$) the lowest number of compound leaves/m^2.

Table 7: Interaction effects of nitrogen application rates and PPD/ha on primary compound leaves/m^2 during the 1st season

PPD	Nitrogen Levels			
	N_o	N_{20}	N_{40}	N_{60}
P_1	2850.67b	2574.67b	3029.33ba	2874.67b
P_2	3256.67ab	2786.67b	3310.00a	3280.00a
P_3	3261.33a	2890.67b	3348.00a	3822.67a
P_4	3262.67a	3276.67a	3360.00a	3843.33a
SED	**223.924**		**DMRT**	**646.693**

Table 8: Interaction effects of nitrogen application rates and PPD/ha on primary compound leaves/m^2 during the 2nd season

PPD	Nitrogen Levels			
	N_o	N_{20}	N_{40}	N_{60}
P_1	1744.00c	1642.67cd	1656.00c	1520.00d
P_2	1873.33c	2246.67b	2026.67c	1993.33c
P_3	2218.00b	2848.00a	2269.33b	2501.33b
P_4	2737.33ab	3154.67a	2501.33b	2525.67b
SED	**209.077**		**DMRT**	**603.814**

4.4 Effect of Treatments on Secondary Compounds Leaves

4.4.1 Effects of Nitrogen Application Rates on Secondary Compounds Leaves/m² of Chickpea in Season I and II

Increasing nitrogen application rates increased secondary compound leaves/m^2 (Table 2). Nitrogen application at the rate of 60 kg N/ha and 40 kg N/ha gave 33,071 and 31,949 secondary compound leaves/m^2, respectively. These were similar and the highest. However, 40 kg N/ha treatment was not significantly different from the 20 kg N/ha treatment (29,630 secondary compound leaves/m^2). Application of nitrogen at the rate of 0, 20 40 kg N/ha gave 29,064; 29,630 and 31,949 secondary compound leaves/m^2, respectively, and they were at par with each other.

During second season, nitrogen application at the rate of 60kg N/ha and 20kg N/ha gave 38,100 and 39,168 secondary compound leaves/m^2, respectively. These were at par and significantly ($P \leq 0.05$) superior to the other treatments. The 40kgN/ha and 0 kg N/ha treatments gave 33,000 and 32,510 secondary compound leaves/m^2, respectively and were at par with each other. Therefore no nitrogen application resulted in significantly ($P \leq 0.05$) lower number of secondary leaves/m^2. Application of nitrogen at 20kg/ha and above significantly increased the number of primary and secondary leaves/m^2 in chickpea. Fig 5 shows a linear relationship of nitrogen application rates with secondary compound leaves/m^2 with (correlation) coefficient R^2= 0.95 and 0.16 in season I and II, respectively.

4.4.2 Effects of Planting Population Density on Secondary Compound Leaves/m² of Chickpea in Season I and II

Increase in plants/ha increased secondary compound leaves/$m^{2.}$. During the first season, plant populations of 148,148/ha (P_4) and 111,111/ha (P_3) produced 34,465 and 32,107 secondary compound leaves/m^2 and were similar to P_3 treatment. Treatment P_1 (74,074 plants/ha) had the lowest number of secondary compound leaves/m^2 (28,392), but was not significantly different from the P_2 treatment.

During the second season, increase in plant population/ha significantly ($P\leq0.05$) increased secondary compound leaves/m^2. These were 25,920; 29,926; 40,635 and 46,297 respectively (Table 2).

Fig 9 reveals a linear relationship of secondary compound leaves/m^2 with increasing plant populations with coefficient correlation R^2=0.98 and 0.97 season I and II, respectively.

4.4.3 Interaction Effects of Nitrogen Application and Plant Population Density on Secondary Compound Leaves/ m2

Table 9 reveals that increasing nitrogen application levels from 0 to 60kgN/ha on plant populations' of 148,148/ha (P_4); 111,111/ha (P_3) and 89,889/ha (P_2) had no significant effects on the number of secondary compound leaves/ m^2. However, at plant population of 74,074/ha (P_1), application of 60, 40 and 0 kg N/ha produced similar number of secondary compound leaves/m^2 which was not significantly different from where 20kg/ha was applied. During this season, chickpea ICCV 97105 grown using 0, 20, 40 and 60 kg N/ha at all plant populations 148,148(P_4); 111,111(P_3) 89,889(P_2) and 74,074(P_1) produced similar number of secondary compound leaves/ m^2 except for the treatment combination $N_{20}P_1$. This was significantly ($P\leq0.05$) lower than all the other treatment combinations and at par with N_0P_1.

Table 10, shows that during the second season, at 148,148 plants/ha (P_4), application 0, 20 and 60kgN/ha produced the highest number of secondary compound leaves/ m^2. However, 0kgN/ha treatment (N_oP_4) was not significantly different from the 40kg N/ha ($N_{40}P_4$) treatment. When plant populations were 111,111 (P_3), applications of 0, 20, and 60kg N/ha gave similar number of secondary compound leaves/m^2. Treatment N_{20} P_3 had significantly ($P\leq0.05$) higher number of leaves/ m^2. At plants populations P_2 and P_1, increase in nitrogen application from 0 to 60kgN/ha had no significant effect on the number of secondary compound leaves/m^2 during this second season. Where chickpea was grown without nitrogen, P_1, P_2 and P_3 treatments had similar number of secondary leaves/m^2. These were significantly lower than for the P_4 treatment. When 20kg N/ha was applied, P_4 and P_3 treatments produced significantly ($P\leq0.05$) higher number of secondary leaves/ m^2 while P_2 and P_1 were at par with each other. Application of 40kg N/ha revealed that P_4 and P_3 treatments were at par and significantly ($P\leq0.05$) superior to P_2 and P_1 treatments, which were also at par. Application of 60kg N/ha on P_4 treatment resulted in having significantly ($P\leq0.05$) the highest number of secondary compound leaves/m^2. Treatments P_2 and P_1 were at par and significantly lower than P_2.

Table 9: Interaction effects of nitrogen application rates and PPD/ha on secondary compound leaves/m^2 during the 1^{st} season

PPD	Nitrogen Levels			
	N_o	N_{20}	N_{40}	N_{60}
P_1	28816.00ab	24938.67b	29346.67a	30469.33a
P_2	29146.67a	30033.33a	30600.00a	32420.00a
P_3	29934.67a	30336.00a	33864.00a	34293.33a
P_4	34560.00a	33213.33a	33986.67a	36102.00a
SED	**2888.93**		**DMRT**	**8343.23**

Table 10: Interaction effects of nitrogen application rates and PPD/ha on secondary compound leaves/m^2 during the 2^{nd} season

PPD	Nitrogen Levels			
	N_o	N_{20}	N_{40}	N_{60}
P_1	27221.33c	25557.33c	24584.00c	26320.00c
P_2	24893.33c	32653.33c	29900.00c	32260.00c
P_3	34592.00bc	49408.00a	36786.67b	41754.67b
P_4	43336.00ab	49056.0a	40730.67b	52068.00a
SED	**3460.44**		**DMRT**	**9993.75**

4.5 Effect of Treatments on Leaf Area Index (LAI)

4.5.1 Effects of Nitrogen Application Rates on leaf area index (LAI) of chickpea in season I and II

Table 2 shows that increasing nitrogen from 0 to 60 kg/ha significantly increased leaf area index from 2.62-3.52 in season I and from 2.60-3.45 in season II, respectively.

4.5.2 Effects of Planting Population Density on Leaf Area Index (LAI) of Chickpea in Season I and II

Table 2 reveals that increasing plants/ha from 74,074 to 148,148, successively and significantly increased leaf area index (LAI) from 2.44-3.67 in season I and from 2.34-3.67 in season II, respectively.

4.5.3 Interaction Effects of Nitrogen Application and Plant Population Density on Leaf Area Index (LAI) 90 Days after Sowing

Table 11 and 12 shows that treatment combination with highest nitrogen application rates and planting population densities had the highest leaf area index (LAI) in both seasons. Application of no nitrogen and with lowest planting population densities had the lowest leaf area index in both season I and II.

In both seasons planting density of 148,148 plants/ha with 40 and 60kgN/ha was significantly superior to the 20kgN/ha ($N_{20}P_4$). N_0P_4 was significantly lower than the $N_{20}P_4$ treatment. However, $N_{60}P_4$ treatment combinations were at par with treatment combination of 111,111 plants/ha with 60 kg N/ha ($N_{60}P_3$).At plants/ha 111,111 (P_3); 89,889 (P_2) and 74,074 (P_1), increasing nitrogen application from 0 to 60 kg/ha significantly increased LAI during the two seasons (Table 10 and 11).In both seasons also, increase in planting population densities from 74,074 to 148,148 significantly increased LAI.

Table 11: Interaction effects of nitrogen application rates and PPD/ha on LAI 90 days after sowing (DAS) during the 1st season

PPD	Nitrogen Levels			
	N_o	N_{20}	N_{40}	N_{60}
P_1	1.80n	2.25m	2.61k	2.92ij
P_2	2.45l	3.094g	2.81j	3.09gh
P_3	2.99hi	3.32e	3.72b	3.99a
P_4	3.33d	3.50c	3.90c	4.00a
SED	**0.04**		**DMRT**	**0.11**

Table 12: Interaction effects of nitrogen application rates and PPD/ha on LAI 90 days after sowing (DAS) during the 2nd season

PPD	Nitrogen Levels			
	N_o	N_{20}	N_{40}	N_{60}
P_1	1.71m	2.23l	2.54j	2.86hi
P_2	2.41k	3.04g	2.78i	3.05fg
P_3	2.99g	3.20e	3.64b	3.90a
P_4	3.31de	3.46c	3.89a	4.00a
SED	**0.04**		**DMRT**	**0.11**

4.6 Effect of Treatments on Dry Matter Production at 25 Days

4.6.1 Effect of Nitrogen (kg/ha) 25 Days after Sowing (DAS) on Dry Matter Production (kg/ha) of Chickpea for Seasons I and II

Dry matter accumulation by 25 DAS (Table 13) reveals that the highest dry matter was realized where nitrogen application rates were 40 (N_{40}) and 60kg N/ha (N_{60}) during the two seasons (Feb-June and June-Oct 2005). Application of 40 kg N/ha gave 195.372kg/ha dry matter during the first season and 199.778 kg/ha during the second season. Application of 60 kg N/ha produced 187.192kg/ha during the first season and 191.717kg/ha at the second season. These treatments were significantly ($P \leq 0.05$) superior to where 20kgN/ha (165.278 and 181.948 kg/ha dry matter for the first and second season, respectively) and 0 kg N/ha (149.074 and 160.777kgN/ha dry matter for the 1st and 2nd season, respectively) was applied. The least dry matter was produced with no nitrogen application during the two seasons.

The relationship of DM production with increasing nitrogen rates was observed to be linear at all growth stages (Fig 10, 11 12 and 13). Additional levels of nitrogen significantly ($P \leq 0.05$) increased DM production of chickpea at all stages of growth .Dry matter rate of production as affected by N rate increments was observed to be 0.553, 2.47,7.47 and 18.8 kg/ha at the 25,55, 90 and 105 DAS of first Feb to June 2005 season, respectively. In the second season, 0.722, 2.47, 11.12 and 17.6 kg DM/kg N/ha was produced at 25, 55, 90 and 105 growth stages of chickpea, respectively. Regression Correlation coefficients for the nitrogen to above ground DM production by chickpea was high ranging from 0.72 to 0.79 at 25 DAS to 0.83- 0.93 at 105 DAS. This shows the high reliability of the functions in explaining the relationship.

4.6.2 Effect of Planting Density/ha on Dry Matter (kg/ha) of Chickpea at 25, 55, 90 and 105 Days after Sowing (DAS)

Table 13 depicts that increase in plant population significantly ($P \leq 0.05$) increased dry matter (kg/ha) over all the stages of crop growth i.e., 25, 55, 90,105 and 120 days after sowing in both seasons. However, during the first season, at 25 days after sowing, 148,148 plants/ha was significantly superior with dry matter biomass of 200.617kg/ha. At the same time, plant populations of 111,111/ha (P_3) and 89,889/ha (P_2) were at par. Treatments P_3 was not significantly ($P \leq 0.05$) different from the 74,074 plants/ha (P_1) treatment that produced 157.408kg/ha dry matter.

In the first season chickpea DM production (kg/ha) per plant at 25, 90 and 105 growth stages, was observed to be 12.4, 287.7 and 415.6, respectively (Fig 14, 15, 16 and 17). In season II (June-Oct), the DM produced by the crop at same growth stages was 27.9, 118.9, 300.4 and 320 kg /plant/ha, respectively. These relationships (Fig 14-17) show that DM production by chickpea increased with growth of crop and were also significantly ($P \leq 0.05$) influenced by increasing planting population densities

Table 13: Effects of nitrogen application and plant population density (PPD) on (dry matter) growth and yield of chickpea

	25DAS		55 DAS		90DAS		105 DAS		120 DAS	
	Season 1	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**
Nitrogen (kg/ha)										
0 (No)	149.074c	160.777c	281.177d	274.907d	1352.407c	1301.122c	2122.159d	2047.416d	3122.016d	2594.437d
20(N20)	165.278b	181.948b	336.56c	337.264c	1647.760b	1628.459b	2803.025c	2880.205c	3583.416c	3212.683c
40(N40)	195.372a	199.778a	392.01b	385.44b	1797.222ab	1941.028a	3006.944b	2955.658b	4465.277b	3356.064b
60(N60)	187.192a	191.717a	447.43a	423.558a	1800.371a	1937.222a	3307.872a	3197.742a	5063.422a	4369.581a
PPD/ha										
P_1	157.408c	146.041d	244.13d	203.144d	1233.33d	1264.061d	2148.397d	2316.822d	3428.692d	2954.632d
P_2	172.223b	168.016c	289.99c	276.657c	1458.335c	1540.767c	2585.745c	2534.043c	3822.114c	3186.485c
P_3	166.667bc	187.776b	434.985b	374.644b	1841.203b	1839.100b	3052.744b	2999.114b	4294.442b	3537.577b
P_4	200.617a	232.388a	579.98a	566.723a	2063.888a	2165.893a	3378.085a	3231.042a	4688.883a	3854.072a
SED	6.281	4.08	15.213	12.689	54.233	51.278	62.576	26.624	88.959	44.678
LSD	12.826	8.331	34.332	29.111	110.744	104.71	127.78	54.366	181.654	91.232
C.V (%)	12.49	7.7	10.92	12.37	11.93	10.43	8.09	3.33	7.78	4.57

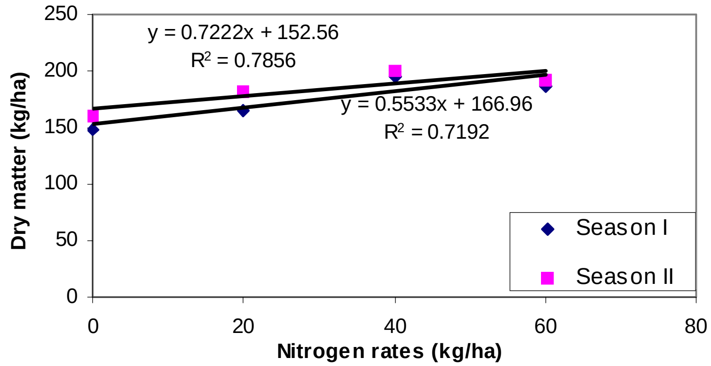

Fig 10: Effect of nitrogen (kg/ha) on dry matter (kg/ha) of chickpea 25 DAS

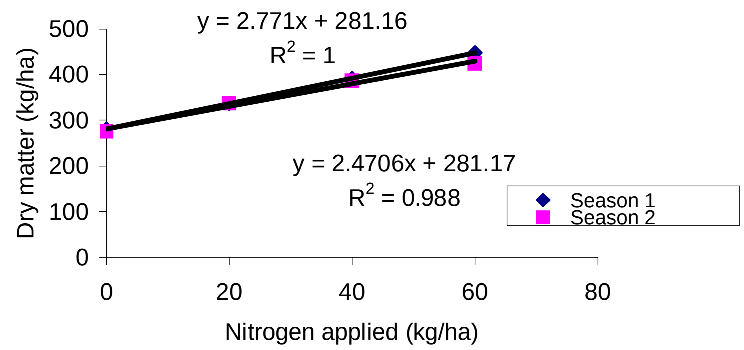

Fig 11:Effect of nitrogen application on dry matter production (kg/ha) of chickpea 55 DAS in season I and II

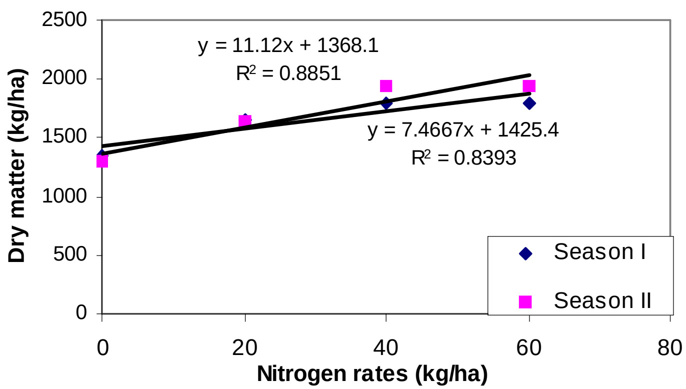

Fig 12: Effect of nitrogen (kg/ha) on dry matter (kg/ha) of chickpea 90 DAS

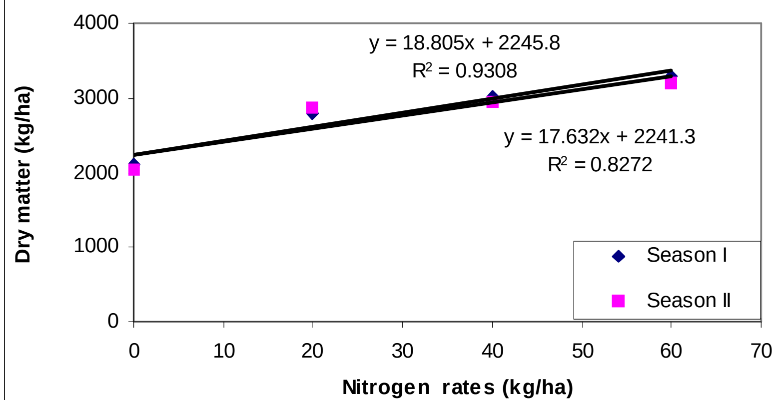

Fig 13: Effect of nitrogen (kg/ha) on dry matter (kg/ha) of chickpea 105 DAS

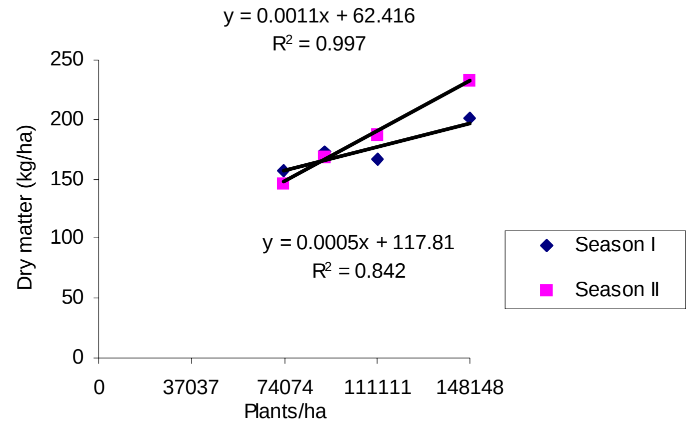

Fig 14: Effect of planting density/ha on dry matter of chickpea at 25 DAS in seasons I and II

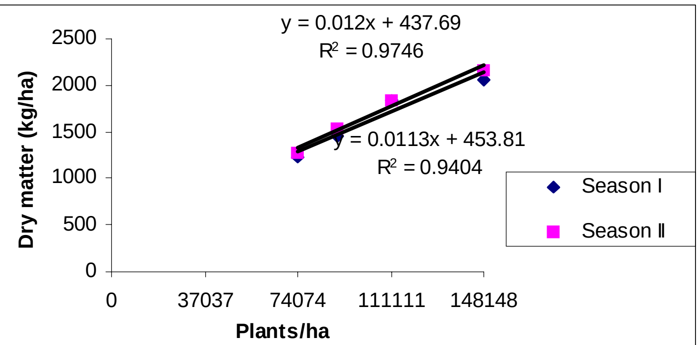

Fig 16: Effect of planting density/ha on dry matter of chickpea at 90 DAS in seasons I and II

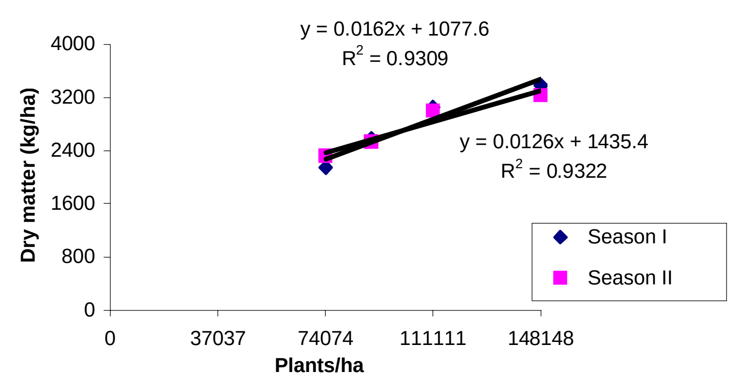

Fig 17: Effect of planting density/ha on dry matter of chickpea at 105 DAS in seasons I and II

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4.6.3 Interaction Effects of Nitrogen and Plant Population Density (PPD) on Dry Matter 25 Days after Sowing (DAS)

Table 14 shows that nitrogen and plant population interactive effect on dry matter (DM). The interaction of nitrogen application and plant population 148,148/ha (P_4) showed that dry matter (246.910kgN/ha) at 60kgN/ha (N_{60} P_4) was significantly ($P \leq 0.05$) superior during the first season (Table 14). Application of 0, 20 and 40kgN/ha had effect on similar dry matter at 25 DAS. At plant population of 111,111(P_3), application of 20, 40 and 60kgN/ha had similar dry matters, which were significantly ($P \leq 0.05$) higher than the no nitrogen treatment. Where plant populations of 89,889/ha (P_2) were used, application of 40kgN/ha resulted into significantly highest dry matter of 244.447kg/ha followed by 60kgN/ha application (N_{60} P_2) (177.780 kg N/ha dry matter). Application of 0 and 20kgN/ha had lower dry matter than the 60 and 40 kg N/ha treatments in that order. At plant population 74,074/ha (P_1), application of 0 and 40kgN/ha gave similar dry matter. However 0 kg N/ha treatment was not significantly different from dry matter obtained under 20kgN/ha application treatment.

Application of 60 kg N/ha produced significantly ($P \leq 0.05$) the lowest dry matter (129.6 kg/ha) under the P_1 treatment ($N_{60}P_1$). Where no nitrogen was applied, plant population N_0P_4 and N_0P_1 produced similar dry matter when compared with all other treatment combinations. However, N_0P_1 was not significantly different from N_0P_2 treatment. N_0P_3 had the least dry matter but not significantly different from P_2 treatment. Application of 20 kg N/ha, N_{20} P_4 and $N_{20}P_3$ produced similar dry matter that was significantly ($P \leq 0.05$) superior to $N_{20}P_2$ and $N_{20}P_1$ treatment, which were also at par with each other. Under the 40 kg N/ha (N_{40}), treatment combinations of $N_{40}P_2$ gave significantly ($P \leq 0.05$) highest dry matter yield of 244.447kg/ha when compared with all other treatment combinations. However, N_{40} P_4, $N_{40}P_3$ and $N_{40}P_1$ treatments had similar dry matter. Where 60 kg N/ha was applied, P_4 (N_{60} P_4) gave significantly ($P \leq 0.05$) superior dry matter (246.910kg/ha) yield. This was followed by $N_{60}P_3$ and $N_{60}P_2$ treatments that were similar. $N_{60}P_{30}$ had dry matter that was significantly lower than for $N_{60}P_2$ treatments.

During the second season (Table 15) application of nitrogen at the rate of 20, 40 and 60 kg N/ha under the highest planting density 148,148 (P_4), produced significantly ($P \leq 0.05$) the highest dry matter (ranging from 238.5 to 251.1kgDM/ha), at 25 DAS. The second highest plant population of 111,111plants/ha (P_3) produced similar trend as for P_4 when nitrogen was applied at the rates of 20, 40 and 60kg N/ha respectively. At plant population of 89,889/ha (P_3), use of 40kg N/ha produced the highest dry matter that was however not significantly different from the 60kgN/ha treatment ($N_{60}P_3$). Dry matter produced under N_0P_3 and $N_{20}P_3$ treatment combinations were similar. However, N_0P_3 had significantly ($P \leq 0.05$) lower dry matter yields than $N_{40}P_3$ and $N_{60}P_3$ treatments. Treatment with plant populations of 74,074(P_1) produced high dry matter at 20 and 40 kg N/ha application levels. These were similar and significantly ($P \leq 0.05$) higher than the 0 and 60kg N/ha treatments that were also at par. Under all nitrogen application levels, increase in planting density was seen to result in significant increase in dry matter yields by 25 DAS in second season.

Table 14: Interactions effects of nitrogen application rates and PPD/ha on dry matter (DM) 25 days after sowing (DAS) during the 1st season

PPD	Nitrogen Levels			
	N_o	N_{20}	N_{40}	N_{60}
P_1	166.67bc	148.15c	185.19b	129.63d
P_2	133.33cd	133.33cd	244.45a	177.78b
P_3	111.11d	194.44b	166.67b	194.45b
P_4	185.19b	185.18b	185.19b	246.91a
SED	**12.56**		**DMRT**	**36.28**

Table 15: Interactions effects of nitrogen application rates and PPD/ha on dry matter (DM) 25 days after sowing (DAS) during the 2nd season

PPD	Nitrogen Levels			
	N_o	N_{20}	N_{40}	N_{60}
P_1	129.02e	151.14d	170.65cd	133.33e
P_2	150.63de	154.21d	183.87b	183.35bc
P_3	170.70c	184.20bc	197.18b	199.02b
P_4	192.75b	238.25a	247.41a	251.15a
SED	**8.16**		**DMRT**	**23.57**

Plate 6: Crop growth and development 35 DAS

Plate 7: Crop growth and development 70 DAS

Plate 8: Crop growth and development 90 DAS

Plate 9: Crop growth and development 105 DAS

4.7 Effect of Treatments on Dry Matter at 55 Days

4.7.1 Effects of Nitrogen Application on Dry Matter 55 Days after Sowing (DAS)

Effects of nitrogen application on dry matter 55days after sowing (DAS) is given in Table 11. Dry matter increased significantly ($P \leq 0.05$) with increase in nitrogen application levels. 60 kg N/ha treatment produced 423.558-kg/ha dry matter followed by 40kg/N/ha (385.440 kg/ha dry matter), 20kgN/ha (337.264 kg/ha dry matter) and 0 (274.9 kg/ha dry matter), respectively.

4.7.2 Interaction Effects of Nitrogen Application Rates and Plants/ha at 55 Days after Sowing (DAS)

With plant populations of 148,148 (P_4), application of 60 and 40kgN/ha produced similar dry matter of 653.090 and 611.617-kg/ha in the first season and 615.620 and 657.111 kg/ha in second season, respectively at 55 DAS (Table16 and 17). However, during first season, the 40kgN/ha treatment was not significantly different from the 20kgN/ha (549.100kg/ha dry matter). The no nitrogen application N_0P_4 treatment produced significantly lower dry matter yield in both seasons. Similarly, in both seasons, planting population of 111,111(P_3) revealed similar effects and trends. Application of 40 and 60kg N/ha at plant populations of 89,889/ha (P_2) produced similar amount of dry matter (kg/ha). No nitrogen application still produced significantly ($P \leq 0.05$) low amount of dry matter. At plants population of 74,074/ha, $N_{40}P_1$ and $N_{60}P_1$ produced similar amount of dry matter and significantly ($P \leq 0.05$) higher than N_0P_1.Treatment N_0P_1 and $N_{20}P_1$ were at par with each other during the first season. However, during the second season (Table 17), $N_{40}P_1$ treatment was not significantly different from the $N_{20}P_1$ treatment. Applying nitrogen at the rate of 20, 40 and 60 kg/ha under all planting population levels resulted in significantly different dry matter production, 55 days after sowing (Table16 and 17).

Table 16: Interactions effects of nitrogen application rates and PPD/ha on dry matter (DM) 55 days after sowing (DAS) during the 1ST season

PPD	Nitrogen Levels			
	N_o	**N_{20}**	**N_{40}**	**N_{60}**
P_1	150.23i	190.33hi	241.78gh	258.23g
P_2	205.69h	261.09g	296.99fg	351.23ef
P_3	297.87f	357.67e	401.44de	450.32cd
P_4	462.17c	555.13b	615.62a	657.11a
SED	**20.21**		**DMRT**	**58.38**

Table 17: Interactions effects of nitrogen application rates and PPD/ha on dry matter (DM) 55 days after sowing (DAS) during the 2nd season

PPD	Nitrogen Levels			
	N_o	**N_{20}**	**N_{40}**	**N_{60}**
P_1	152.56h	187.39fgh	238.89f	233.34fg
P_2	204.69g	265.91f	295.88e	340.15de
P_3	288.89ef	346.66d	395.37cd	467.65c
P_4	453.09c	549.10b	611.62ab	653.09a
SED	**25.38**		**DMRT**	**73.29**

4.8 Effect of Treatments on Dry Matter at 90 Days

4.8.1 Effect of Nitrogen 90 Days after Sowing (DAS)

Nitrogen application rates of 60kg/ha and 40kg/ha gave the highest dry matter of 1,800.371kg/ha and 1,797.222kg/ha, respectively during the first season while 1,937.222kg/ha and 1,941.028kg/ha dry matter was produced during the second season, respectively (Table 13). Application of 40 and 20kgN/ha however, produced similar dry matter yields at 90 DAS during the first season. Where no nitrogen was used, dry matter was 1,352.407kg/ha during the first season and 1,303.112kg/ha for the second season. These were significantly ($P \leq 0.05$) lower than all the other treatments. During the second season 20 and 0kg N/ha treatments were significantly different from each other. Both treatments that received 40and 60kgN/ha were at par and significantly ($P \leq 0.05$) superior to the rest (N_{20} and N_0).

4.8.2 Interaction Effects of Nitrogen Application Rates and Plant Populations/ha 90 Days after Sowing (DAS)

Table 18 reveals that application of nitrogen at the rate of 20 to 60kg N/ha on plant population of 148,148(P_4) produced dry matter that was significantly ($P \leq 0.05$) superior to the other treatment combinations during the first season. These were followed by dry matter produced by $N_{40}P_4$ treatment, which was also significantly ($P \leq 0.05$) different from N_0P_4 treatment. Under populations of 111,111(P_3), application of 40kg N/ha produced the highest dry matter (2,144.443kg/ha) that was not significantly different from the 60kg N/ha treatment (1,855.557kg/ha). Treatment that received N_0P_3, $N_{20}P_3$ and $N_{60}P_3$ produced similar but lowest dry matter compared to the first season. Where the plant population was 89,889(P_2), Treatments $N_{40}P_2$ and $N_{60}P_2$ produced similar dry matter that was higher than N_0P_2 and $N_{20}P_3$. However, treatment $N_{40}P_2$ was at par with $N_{20}P_2$. No nitrogen application levels produced the lowest dry matter but not significantly different from the 20 kg N/ha treatment at plant population of 74,074(P_1). Treatment $N_{40}P_1$ and $N_{60}P_1$ produced similar dry matter that was significantly higher than the N_0P_1 and $N_{20}P_1$ treatments which were also at par. Where no nitrogen was applied, N_0P_3 treatment produced significantly ($P \leq 0.05$) higher dry matter than N_0 P_4. Treatments N_0P_2 and N_0P_1 had the lowest dry matter that was lower than the N_0P_3 treatment. Application of $N_{20}P_4$ treatment combination produced the highest dry matter (241.1kg/ha) that was significantly ($P \leq 0.05$) different from all the other treatments at 90 DAS. This was followed by the 111,111plants/ha (P_3) that was also significantly different from the 89,889 plants/ha (P_2) treatment at all nitrogen levels. Treatments P_2 and P_1 were similar. Where 40kgN/ha was applied a planting density of 111,111/ha (P_3) produced the highest dry matter compared to other nitrogen levels. However this was not significantly different from P_4 treatment. $N_{40}P_2$ and $N_{40}P_1$ treatment were at par and significantly ($P \leq 0.05$) lower than $N_{40}P_4$ treatment. Where 60kgN/ha was applied, P_4 treatment produced the highest dry matter (2281.5kg/ha) that was significantly higher than$N_{60}P_3$ treatment effects. Treatment $N_{60}P_3$ and $N_{60}P_2$ were however at par. Treatment $N_{60}P_1$ produced the lowest dry matter (1422.2kg/ha) and was significantly lower than the rest.

During the second season (Table 19), application of $N_{40}P_4$ and $N_{60}P_4$ gave similar dry matter that was significantly ($P \leq 0.05$) superior to all other treatment combinations viz (2,469.9 and

2,415.7 kg/ha). At plant densities of 111,111(P_3), application of 40 and 60kg N/ha treatment ($N_{40}P_3$ and $N_{60}P_3$) was not significantly different from the treatment $N_{20}P_4$. No nitrogen application (N_0) treatment at plant populations P_2 and P_1 was significantly ($P \leq 0.05$) low. When 40 kg/ha and 60kgN/ha was applied under a plant population of 89,889 /ha (P_2) treatment, similar dry matter was realized ranging from 1744 to 1794 kg/ha. Application of N_oP_2 and N_{20} P_2 produced similar dry matter that was significantly ($P \leq 0.05$) lower than the $N_{40}P_2$ and $N_{60}P_2$ treatments. Plant densities of 74,074(P_1) produced the lowest dry matter (997.8-1,498.4 Kg/ha). Application of $N_{40}P_1$ and $N_{60}P_1$ produced similar dry matter that was significantly ($P \leq 0.05$) higher than where 0 and 20kgN/ha was applied. However, 0 and 20 kg N/ha (N_oP_1 and N_{20} P_1) were at par.

During second season where no nitrogen was applied, plant populations P_4 P_3 and P_2 produced similar dry matter (1,247 to 1,513 kg/ha). Application of 20, 40 and 60 kg N/ha on P_4 P_3, P_2 and P_1 revealed significant ($P \leq 0.05$) differences at each level of plant populations and treatment combination (Table19).

Table 18: Interaction effects of nitrogen application rates and PPD/ha on dry matter (DM) 90 days after sowing (DAS) during the 1st season

PPD	**Nitrogen Levels**			
	N_o	**N_{20}**	**N_{40}**	**N_{60}**
P_1	1000.00e	1103.70e	1407.41d	1422.22d
P_2	1280.00e	1311.12de	1600.00cd	1642.22c
P_3	1603.70c	1761.11c	2144.44ab	1855.56bc
P_4	1525.93d	2411.11a	2037.04b	2281.48a
SED	**108.47**		**DMRT**	**313.25**

Table 19: Interaction effects of nitrogen application rates and PPD/ha on dry matter (DM) 90 days after sowing (DAS) during the 2nd season

PPD	Nitrogen Levels			
	N_o	N_{20}	N_{40}	N_{60}
P_1	997.77f	1095.87f	1471.24e	1498.37e
P_2	1247.12ef	1378.22e	1744.01d	1793.72cd
P_3	1433.40e	1794.01c	2078.91b	2050.08bc
P_4	1532.16de	2245.74ab	2469.95a	2415.72a
SED	**102.56**		**DMRT**	**296.19**

4.9 Effect of Treatments on Dry Matter at 105 and 120 Days

4.9.1 Effect of Nitrogen on Dry Matter (DM) 105 and 120 Days after Sowing of Chickpea in Season I and II

Dry matter (kg/ha) increased significantly ($P \leq 0.05$) with every successive increase in nitrogen application rates at the four levels of N application; viz. 0; 20; 40 and 60 kg N/ha during the two seasons (Table 13 and Fig 23). Relationship of nitrogen to above ground biomass was shown to be curve linear with correlation coefficient R^2 =0.98 and 0.94 for seasons I and II, respectively. This signifies the reliability of using these functions in predicting grain yields of chickpea grown in Naivasha.

It was evident that 25% (59.9mm) of rainwater received in season I fell in the last month of crop growth (i.e. May 26-30th; 47.6mm and 19-21st June, 12.1mm) thus, the reproductive stage of chickpea growth. Therefore pod setting and grain filling was enhanced (as crop exhibited an indeterminate) habit and assimilates were partitioned to floral development and biomass production. This ultimately resulted into higher grain yield production and hence higher HI. Nitrogen applied above 20-25 kg /ha tended to cause a decline in HI.

4.9.2 Effect of Planting Density on above Ground Biomass (kg/ha) of Chickpea 120 Days after Sowing in Seasons I and II

Increase in planting density from 74,074 to 148, 148 significantly ($P \leq 0.05$) increased above ground dry matter production (kg/ha) in both seasons (Fig. 6). The relationship of dry matter

(DM) production to plant population was linear. Season I had more biomass production due to more and well distributed rainfall compared to season II (Fig 24).

Above ground dry matter (DM) increased linearly with increase in planting densities. At planting time 425 and 304 kg DM/ha was observed to accumulate with every increase in planting population/ha. This is explained by equations depicted in Fig 24. The relationship of DM production and plant population was highly correlated at 0.999 and 0.994 in seasons I and II, respectively. It was evident that the higher the above ground dry matter production (Fig.23 and 24) the greater the grain yields production (Fig 21 and 22).

4.9.3 Interaction Effects of Nitrogen Application Rates and Plants Populations' Density (PPD) on Dry Matter (DM) 105 Days after Sowing (DAS)

Table 20, reveals that at plant population of 148,148 (P_4), and the application of 60kg N/ha, chickpea produced the highest dry matter (4,000.0kg/ha) in the first season. This was significantly ($P \leq 0.05$) superior to all other treatment combinations. Application of $N_{40}P_4$ and $N_{20}P_4$ produced non-significant effects on dry matter yield at 105 DAS. At plant population of 111,111/ha (P_3), application of nitrogen revealed a similar trend as for the P_4 treatment. In the same season dry matter produced at plant population of 89,889/ha (P_2) showed that application of 20, 40 and 60kgN/ha had similar effect. Where no nitrogen was applied (N_0P_2), dry matter produced was significantly ($P \leq 0.05$) lower than the rest. Under the 74,074 planting density (P_1) treatment, application of 60kg N/ha ($N_{60}P_1$) produced significantly higher dry matter (2,570.4 kg/ha). Treatment $N_{40}P_1$ was also significantly higher than where $N_{20}P_1$ and N_0P_1 were used. Where no nitrogen was used, combinations with P_4 and P_3 produced similar dry matter. These were significantly ($P \leq 0.05$) higher than P_2 and P_1 treatments that were at par with each h other. When 20kg N/ha was applied, P_4 produced the highest dry matter (3,333.3 kg/ha). However this was not significantly different from the P_3 treatment. Plant population P_3 and P_2 produced similar dry matter. Treatment $N_{20}P_1$ produced significantly the lowest amount of dry matter than the rest. Application of 40kgN/ha revealed significantly ($P \leq 0.05$) differences in dry matter production with P_4, P_3, P_2, and P_1 levels during the first season. When 60kgN/ha was applied, combination with P_4, P_3 and P_2 were significantly different from each other. However, $N_{60}P_1$ produced the least dry matter but not significantly different from $N_{60}P_2$ treatment during the first season by the 105 DAS.

At the second season (Table 21), increasing nitrogen from 0 to 60kg N/ha revealed significant ($P \leq 0.05$) difference in all the four different plant population. $N_{60}P_4$ treatment produced the highest dry matter (3,738.150kg/ha). Application of no nitrogen (N_oP_4) produced significantly ($P \leq 0.05$) the least dry matter while 20 and 40kgN/ha had similar effects. When planting population decreased to 111,111plants/ha (P_3), application of 0, 20, 40 and 60kgN/ha caused significant differences (Table 21). At 89889(P_2), application of $N_{20}P_2$, $N_{40}P_2$ and $N_{60}P_2$ caused non-significant effects on dry matter. However, where no nitrogen was applied, dry matter produced was significantly ($P \leq 0.05$) lower than the other treatment combinations. Further decrease in plant population to 74,074/ha, $N_{60}P_1$ treatment produced significantly higher dry matter different from the rest. Application of $N_{20}P_1$ and N_{40} P_1 resulted into similar effects. Where no nitrogen was used (N_0 P_1), dry matter was significantly ($P \leq 0.05$) low and at par to dry matter produced at N_0P_2 treatment.

Table 20: Interaction effects of nitrogen application rates and PPD/ha on dry matter (DM) 105 days after sowing (DAS) during the 1st season

PPD	**Nitrogen Levels**			
	N_o	**N_{20}**	**N_{40}**	**N_{60}**
P_1	1851.85g	1871.37g	1800.00f	2570.37e
P_2	1791.12g	2898.30d	2177.78d	2777.78de
P_3	2277.77f	3111.11cd	3238.89c	3583.33b
P_4	2567.90ef	3333.33bc	3611.11b	4000.01a
SED	**125.15**		**DMRT**	**361.44**

Table 21: Interaction effects of nitrogen application rates and PPD/ha on dry matter (DM) 105 days after sowing (DAS) during the 2nd season

PPD	**Nitrogen Levels**			
	N_o	**N_{20}**	**N_{40}**	**N_{60}**
P_1	1749.46j	2448.15h	2420.23h	2649.46g
P_2	1833.34j	2704.47fg	2749.47f	2848.90ef
P_3	2216.13i	2998.91e	3226.96d	3554.47b
P_4	2390.74h	3369.30cd	3425.98bc	3738.15a
SED	**53.43**		**DMRT**	**154.30**

4.9.4 Interaction Effects of Nitrogen Application Rates and Plant Population/ha 120 Days after Sowing (DAS)

Table 22 shows that, increasing nitrogen application from 0 to 60kg/ha caused significant ($P \leq 0.05$) increase in dry matter at 120 DAS during the two seasons. At the first season, application of 40 and 60kg N/ha revealed similar effects at planting populations of 148,148(P_4). These were significantly ($P \leq 0.05$) different from the 20 and 0kg/ha treatment. Where no nitrogen was applied (N_o P_4), dry matter (3270.4 kg/ha) was significantly lower than the rest. At 111,111planting density (P_3), application of nitrogen from 0 to 60kg N/ha revealed significant effects (Table 22). Each treatment was significantly ($P \leq 0.05$) different from the other. When plants/ha were further lowered to 89,889/ha (P_2) application of 0 and 20kgN/ha showed similar effects. These were significantly lower than when 40 and 60kg N/ha was applied. Treatments N_0P_2 and $N_{60}P_2$ caused similar effects. At planting population of 74,074(P_1), application of 20 and 40kg N/ha had similar effect. Where no nitrogen was used (N_OP_1), dry matter was significantly ($P \leq 0.05$) the lowest (2814.8kg/ha). During this first season, application of 0 and 20kgN/ha on plant population of 148,148 (P_4); 111,111(P_3) and 89,889(P_2) caused similar effects. Treatment with 74,074plants/ha (P_1) produced the lowest dry matter (2814.8 kg/ha) though not significantly different from the P_2 treatment. Application of 40kg N/ha to plant population P_4 produced significantly ($P \leq 0.05$) superior dry matter (5,811.107kg/ha). Plants population of P_3 and P_2 caused similar effects while $N_{40}P_1$ treatment was significantly the least. When 60kg N/ha was applied, $N_{60}P_4$ and $N_{60}P_3$ treatments were significantly ($P \leq 0.05$) superior. $N_{60}P_1$ and $N_{60}P_2$ were significantly different from each other with $N_{60}P_{30}$ having the least dry matter (3963kg/ha).

During the second season (Table 23), increase in nitrogen levels from 0 to 20, 40 and 60kg N/ha significantly ($P \leq 0.05$) increased dry matter under plant population of 148148(P_4). At 111,111 (P_3); 89,889(P_2); and 74,074(P_1) plants/ha, application of 60kg N/ha produced significantly superior dry matter (viz 4,525; 4,200 and 3,996.2 kg/ha). Application of 40 and 20kg N/ha caused similar effects while application of N_0P_3 produced significantly the least dry matter (2350 kg/ha). Where no nitrogen was used, N_0P_1 and N_0P_2 treatments produced significantly ($P \leq 0.05$) the least dry matter. Treatment P_4 produced more dry matter that was significantly higher than the P_3 treatment. Application of 20 and 40kgN/ha caused significant ($P \leq 0.05$) difference on dry matter produced at the P_4, P_3, P_2 and P_1 treatments. When 60kg N/ha was applied, $N_{60}P_4$ and $N_{60}P_3$ treatments were at par and produced significantly

($P \leq 0.05$) the highest dry matter of 4757 and 4525 kg/ha, respectively. Also P_2 and P_1 were at par but significantly lower than the P_4 and P_3 treatments, respectively.

Table 22: Interaction effects of nitrogen application rates and PPD/ha on dry matter (DM) 120 days after sowing (DAS) during the 1st season

PPD	**Nitrogen Levels**			
	No	**N20**	**N40**	**N60**
P_1	2814.81e	3437.00d	3500.00d	3962.96c
P_2	3164.00de	3568.89cd	4022.23bc	4533.34b
P_3	3238.89d	3616.66c	4527.78b	5794.44a
P_4	3270.37d	3711.11c	5811.11a	5962.95a
SED	**177.92**		**DMRT**	**513.83**

Table 23: Interaction effects of nitrogen application rates and PPD/ha on dry matter (DM) 120 days after sowing (DAS) during the 2nd season

PPD	**Nitrogen Levels**			
	No	**N20**	**N40**	**N60**
P_1	2194.41h	2759.31g	2868.52fg	3996.29b
P_2	2350.01h	3075.56f	3120.37ef	4200.01b
P_3	2777.78g	3371.42de	3476.11cd	4525.00a
P_4	3055.55f	3644.45c	3959.26b	4757.03a
SED	**89.356**		DMRT	

4.10 Effect of Treatments on the Pods

4.10.1 Effects of Nitrogen Application Levels on the Number of Pods/m^2 of Chickpea in Season I and II

Number of pods/m^2 were highest (1,549 and 1,488) under 40 and 20kg N/ha application levels, respectively during the first season (Table 24). Application of the nitrogen at the rates of 20, 60 and O kg/ha showed no differences in the number of pods/m^2. These were 1,488; 1,415 and 1,398 pods/m^2, respectively. During the second season, application of nitrogen from 0 to 60 kg/ha revealed no significant differences on the number of pods/m^2 (Table 24). Figure 18 shows poor linear relationship of nitrogen application rates with number of pods/m^2 (R^2=0.044 and 0.32) in both seasons, respectively. The functions reveal that 11.3 and 2.8 pods/m^2 were produced for every kg N/ha applied to the crop.

4.10.2 Effect of Planting Density on Pods/m^2 of Chickpea in Season I and II

Table 24 depicts that increase in plant populations significantly ($P \leq 0.05$) increased the number of pods/m^2. Increasing plant populations from 74,074(P_1) to 148,148 (P_4) plants/ha successively and significantly ($P \leq 0.05$) increased the number of pods/m^2 from 1,103; 1,340; 1,577; and 1,829 under P_1, P_2, P_3 and P_4 treatments, respectively, during the first season. The second season pods/m^2 under the respective treatments was 875; 962; 1,105 and 1,230 (Table 24). Season one had more pods/m^2 at all plant densities as compared to that of season two due to higher rainfall during the season (237.6mm).

4.10.3 Interaction Effects of Nitrogen Application Rates and Plants/ha on the Number of Pods/m^2

Table 25 shows that increasing plant population from 74,074 to 148,148 plants/ha at all nitrogen application levels had significant effects on the number of pods/m^2 in season one. Highest pods/m^2 was observed under all levels of nitrogen application when combined with the 148,148plants/ha treatment combinations. This was the same in season two also (Table 26). However, 60 kg N/ha-treatment ($N_{60}P_4$) was not significantly different from $N_{40}P_3$, $N_{20}P_3$ and N_0P_3.treatment. The number of pods/m^2 at all plant population levels showed no significant differences with increasing nitrogen rates (from 0-60 kg/ha) in season one. In season two however, treatment combinations effects differed significantly only in the case of $N_{20}P_3$ and $N_{60}P_1$ (i.e.at the P_3 and P_1 plant population levels), respectively; whereby pods/m^2 were higher than their respective nitrogen levels.

Table 24: Effect of nitrogen application and planting density/ha on pods/m^2, 100 seed weight (gm), grain yield (kg/ha) and Harvest index (HI)

Nitrogen (kg/ha)	Pods/m2		100seed weight (gm)		Grain yield (kg/ha)		Harvest index (HI)	
	Season 1	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**season 2**	**season 1**	**Season 2**
0(No)	1398.500b	1052.333a	26.200b	25.425a	2149.554b	1099.554b	0.689	0.424
20(N20)	1488.000ab	1034.667a	26.625b	26.083a	2353.716ab	1570.532a	0.657	0.489
40(N40)	1549.500a	1020.167a	27.000b	26.250a	2574.41a	1658.692a	0.577	0.494
60(N60)	1415.750b	1066.500a	28.167a	25.825a	2165.125b	1675.777a	0.428	0.384
PPD/ha								
74,074	1103.750d	875.833d	27.083a	26.375a	1273.849d	1027.420d	0.372	0.348
89,889	1340.833c	962.500c	27.417a	26.792a	2079.244c	1300.069c	0.544	0.408
111,111	1577.333b	1105.000b	27.792a	26.325a	2718.209b	1682.860b	0.633	0.476
148,148	1829.833a	1230.333a	27.208a	24.092b	3271.207a	1994.205a	0.698	0.517
SED	47.462	32.887	0.48	0.658	120.478	72.865		
LSD	96.918	67.155	0.98	1.344	246.016	148.72		
C.V (%)	11.24	10.92	6.08	8.81	17.86	16.81		

The highest number of pods/m^2 ranged from 1,966($N_{40}P_4$) to1, 732 ($N_{60}P_4$). This translates to i.e. 173 to 144 pods/plant which were at par. Lowest number of pods/m^2 ranged from 1,172 ($N_{40}P_1$) and 1,034(N_0P_1) i.e. 196-172 pods/plant. Meaning that highest pods/m^2 is obtained by the highest plant populations (of 148,148). However, this translates to lower number of pods/plant (173 to 144) whereas a lower plant population of (P_1 and P_2) results into more pods/plant (196 to 172), which were also heavier (Table 25). In season two (Table 26), pods/m^2 were highest at all levels of nitrogen application under 148,148-plants/ha (P_4). It ranged between 1,181 to 1,293; which translates to 98 to 108 pods/plant, respectively.

Table 25: Interaction of nitrogen application rates and PPD/ha on the number of pods/m^2 during 1st season

PPD	Nitrogen Levels			
	N_o	**N_{20}**	**N_{40}**	**N_{60}**
P_1	1798.67a	1822.00a	1966.67a	1732.00ab
P_2	1457.33bc	1568.00b	1672.00b	1612.00b
P_3	1303.33c	1390.00c	1410.00c	1260.00cd
P_4	1034.67d	1172.00d	1149.33d	1059.00d
SED	**94.93**		**DMRT**	**274.14**

Table 26: Interaction of nitrogen application rates and PPD/ha on the number of pods/m^2 during 2nd season

PPD	Nitrogen Levels			
	N_o	**N_{20}**	**N_{40}**	**N_{60}**
P_1	908.00c	857.33c	782.67c	955.33b
P_2	940.00bc	940.00bc	990.00b	980.00b
P_3	1068.00b	1160.0a	1080.00b	1112.00ab
P_4	1293.33a	1181.33a	1228.0a	1218.67a
SED	**65.75**		**DMRT**	**189.90**

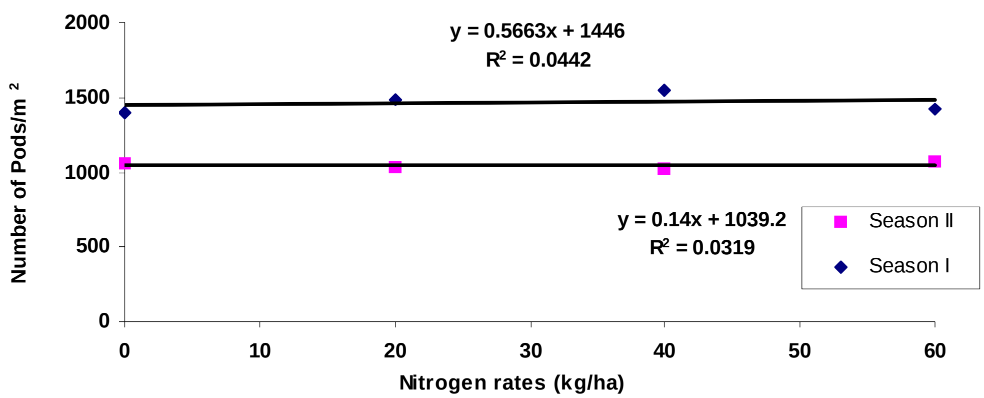

Fig 18: Effect of nitrogen on pods/m^2 of chickpea for seasons I and II

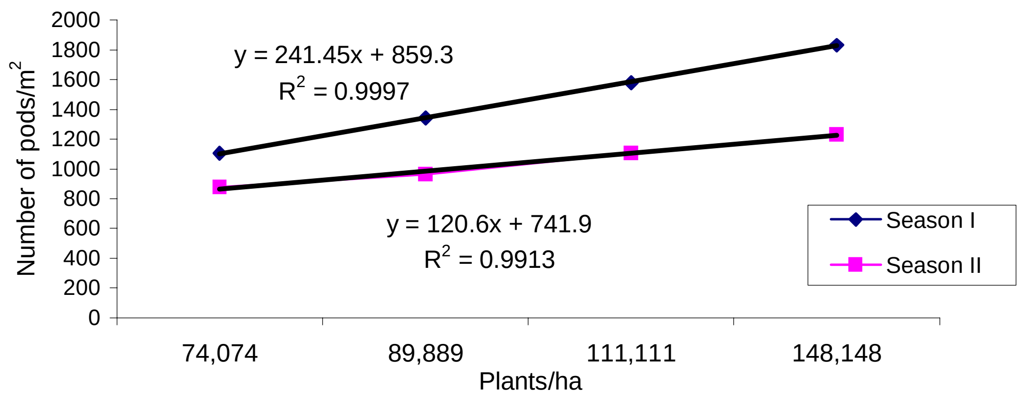

Fig 19: Effect of planting density on pods/m^2 of chickpea for seasonss I and II

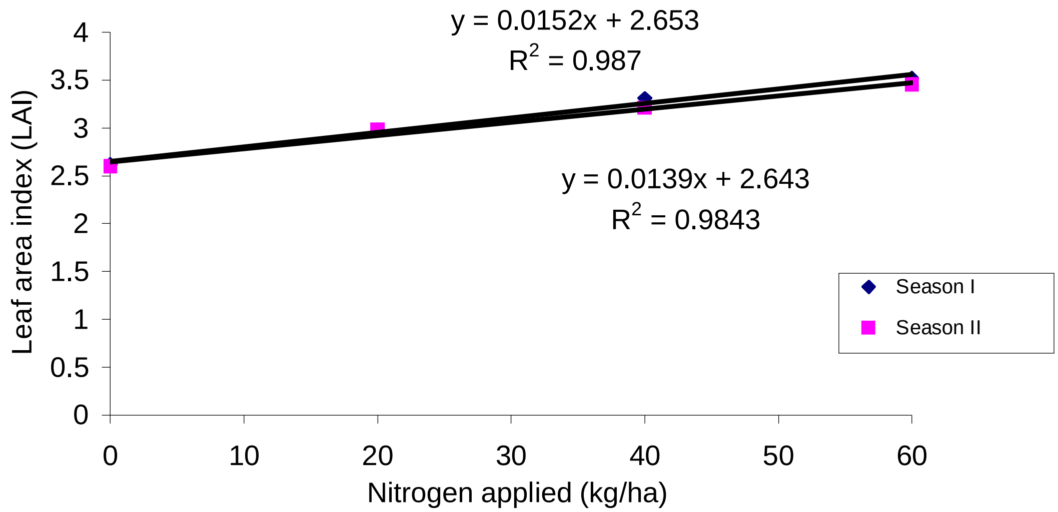

Fig 20: Effect of nitrogen application (kg/ha) on leaf area index (LAI) 90 DAS in season I and II

4.11 Effect of Treatments on 100 Seed Weight

4.11.1 Effect of Nitrogen on 100 Seed Weight of Chickpea on Seasons I and II

Table 24 shows that increase in nitrogen application rates increased 100 seed weight during the first season. The highest 100 seed weight was realized under 60kgN/ha (28.167gms) treatment. The treatment gave significantly ($P \leq 0.05$) superior 100 seed weight when compared to the rest. Application of O (26.200gms), 20(26.625gms) and 40(27.00gms) kg N/ha however did not show any significant differences. During the second season (Table 24), increase in nitrogen application from O to 20, 40 and 60kg N/ha showed no significant ($P \leq 0.05$) effects on 100 seed weight. These ranged between 25.4gms to and 26.3gms.

Fig. 26 depicts effect of nitrogen rates on 100-grain weight of chickpea. In season I where moisture was higher (237.6 mm) than in season II (176.6mm + 40mm of irrigation) and where 25% (59.9mm) of rain fell during the reproductive phase, the grain was higher than for season II and was observed to increase at the rate of 0.63gms/kgN applied. There was significant ($P \leq 0.05$) gain under the 60kg N levels in season I. This could have probably contributed to the higher HI observed in season one (Fig 28).

In season II limited water availability could have caused a decline in the 100 seed weight of chickpea. A maximum 100 seed weight was observed under 40kgN/ha and was shown to decrease by 0.14gm/kgN applied, when a linear graph was fitted on the data. Application of 60kgN /ha appeared to depress grain weights in season II because of lower nitrogen use efficiency in later stages (i.e. reproductive) of crop growth which were relatively dry. Rains that fell on 14th and 15th Oct (43mm-24.4%) were non-effective as crop was harvested a week later i.e. (23rd Oct 2005) Fig. 1.

4.11.2 Effects of Planting Density on 100 Seed Weight of Chickpea in Season I and II

Increasing of plant population/ha from 74,074 (P_1) to 148,148 (P_4) showed no significant effects on 100 seeds weight during the first season. The seed weight ranged between 27.08 to 27.79gms/100 seed weight. During the second season, 100 seed weight under P_4 (24.09gms) was significantly ($P \leq 0.05$) lower than all other treatments. However, P_3, P_2 and P_1 treatments were similar with 100 seed weights of 26.33, 26.79 and 26.38gms, respectively (Table 24). Planting density was observed (Fig 20) to follow a curvilinear curve with correlation coefficient of R^2 =-0.83 and 0.99 in season I and II, respectively. The seed weight increased with increasing planting densities to attain a maximum of (28.8 and 26.8) at 89,889 and 111,111 plants /ha in seasons I and II respectively. Increasing populations beyond this point resulted in a decline in grain weights. This is probably due to nutrients and moisture limitations at higher plant populations.

4.11.3 Interaction Effects of Nitrogen Application Rates and Plant Populations/ha on 100 Seed Weight

At plant population of 148,148/ha (P_4), application of 0, 20 and 60 kg/ha gave similar 100 seeds weight means during the first season (Table 27). However, $N_{60}P_4$ treatment was not significantly different from the $N_{40}P_4$ treatment during the first season. Increasing nitrogen from 0 to 60kg N/ha for plant populations of 111,111/ha (P_3) and 89,889/ha (P_2) gave similar 100 seed weights. At low plant population of 74,074/ha (P_1), nitrogen application at the rate of 0 and 20kgN/ha gave significantly ($P \leq 0.05$) the lowest 100 seed weight.

Chickpea ICCV 97105, grown using no nitrogen at plant population/ha of 74,074 (P_1), during the first season had significantly lower 100 seed weight. Although 100 seed weight increased with increase in plant populations N_0P_4, N_0P_3, and N_0P_2 were at par. Application of 20kg N/ha gave similar 100 seed weight at plant populations/ha of 148,148 (P_4); 111,111 (P_3) and 89,889 (P_2) while 100 seed weight from plant populations of 74,074/ha ($N_{20}P_1$) was the lowest but not significantly different from the $N_{20}P_2$ (26.500gms) treatment. Chickpea grown using 40 and 60kg N/ha at all plant populations of P_4, P_3, P_2 and P_1 gave similar 100 seed weight except at the treatment combination of $N_{40}P_4$ (26.00gms) that was significantly ($P \leq 0.05$) lower than the rest.

During the second season (Table 28), treatment combinations of $N_{40}P_4$ and $N_{60}P_4$ produced the highest 100 seed weights of 25.667 and 24.667 gm, respectively. However, $N_{60}P_4$ treatment was not significantly different from the $N_{20}P_4$ and N_0P_4 treatment. At plant population of P_3, P_2 and P_1, increase in nitrogen from 0 to 60 kg/ha did not reveal any significant effects. Chickpea grown using N_0P_4 and $N_{20}P_4$ treatment combinations had significantly ($P \leq 0.05$) low 100 seed weight at P_4 treatments. 100 seed weight under $N_{60}P_4$ was high but not significantly different from the $N_{20}P_4$ treatment. Application of nitrogen from 0 to 60 kg/ha at plant populations of P_3, P_2 and P_1 did not show any significant effect.

Table 27: Interaction effects of nitrogen application rates and PPD/ha on 100 weights (gm) during the 1st season

PPD	Nitrogen Levels			
	N_o	**N_{20}**	**N_{40}**	**N_{60}**
P_1	26.33b	26.00b	26.83a	29.17a
P_2	27.00a	25.50ab	27.67a	28.50a
P_3	28.00a	26.67a	27.50a	28.50a
P_4	29.00a	27.33a	26.00b	26.50ab
SED	**0.96**		**DMRT**	**2.77**

Table 28: Interaction effects of nitrogen application rates and plants/ha on 100 weights (gm) during the 2nd season

PPD	Nitrogen Levels			
	N_o	N_{20}	N_{40}	N_{60}
P_1	25.00a	25.83a	27.83a	26.83a
P_2	28.17a	27.17a	25.00a	26.83a
P_3	26.00a	27.83a	26.50a	24.97a
P_4	22.53b	23.50b	25.67a	24.67ba
SED	**1.32**		**DMRT**	**3.80**

4.12 Effect of Treatments on Grain Yield

4.12.1 Effect of Nitrogen on Grain Yield of Chickpea in Seasons I and II

Table 24, reveals that application of 20 and 40 kg N/ha gave the highest grain yield of 2,574.4 and 2,353.7 kg/ha, respectively during the first season. Application of nitrogen at the rate of 20 (2,353.7 kg/ha grain), 0 (2,249.3 kg/ha grain) and 60 (2,165.3 kg/ha grain) kg/ha showed no significant difference in grain yield. However, during the second season, increase in nitrogen application rates revealed a relative in increase in grain yields. Application of 0, 20, 40 and 60kgN/ha produced 1,099.6; 1,570.5; 1,658.7 and 1,675.8kg/ha of grain, respectively. Treatments with no nitrogen were significantly ($P \leq 0.05$) lower while the other treatments were at par with each other.

Fitted quadratic relationship (Fig.21) revealed that application of up to 30kg N/ha increased grain yields production (kg/ha) in both seasons. Nitrogen application above 30kg/ha resulted in a decline in grain yield (kg/ha) production. Relationship of nitrogen application with grain yield as depicted in Fig 21, revealed that increase in N application to a maximum under 20 and 40 kg N/ha in season one and with 20, 40 and 60 kg/ha in season two. The relationship had high reliability accounting for 70.3 to 97.8 % of the variation in seasons I and II, respectively.

Nitrogen use efficiency (NUE) as shown in Fig. 23 reveals a quadratic relationship (Fig 17). Increase in nitrogen application from 20-60 kg/ha resulted in a decline in NUE in both seasons. The quadratic fits were perfect with R^2=1. Fig. 30 shows the Crude Protein

Content (CPC) of chickpea grains, pods and haulms (without grains). Chickpea can be used as a health food /grain due to its high CPC (22-28%) in its grain. Crop residues can be used as green manure or livestock feeds due to its high shoot protein contents ranging from 12-18%.

The highest NUE of over 118 and 75 kg grain /kg N applied to chickpea was obtained with 20 kg N/ha application rate in seasons I and II, respectively. This implies that on average of the two seasons for every kg of nitrogen applied a farmer would realize a mean yield of 96.5 kgs grain. With higher moisture availability (as in the case of season I), higher NUE can be realized.

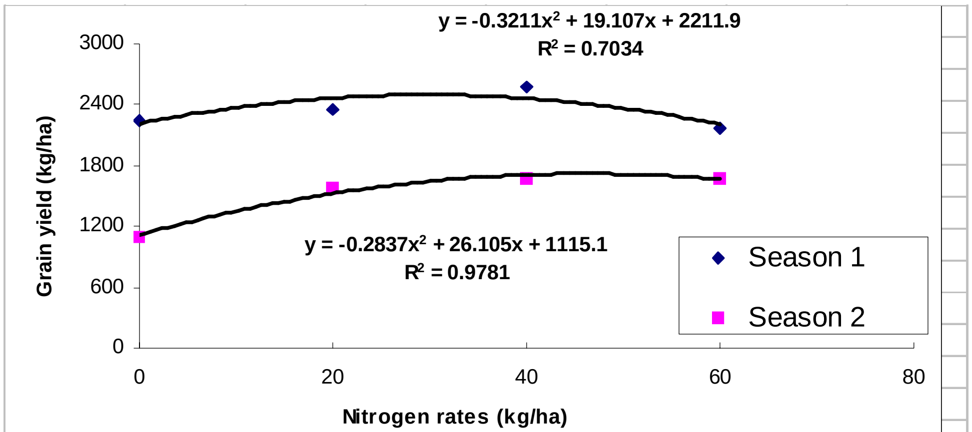

Fig 21: Effect of nitrogen (kg/ha) on grain yield (kg/ha) of chickpea in seasons I and II

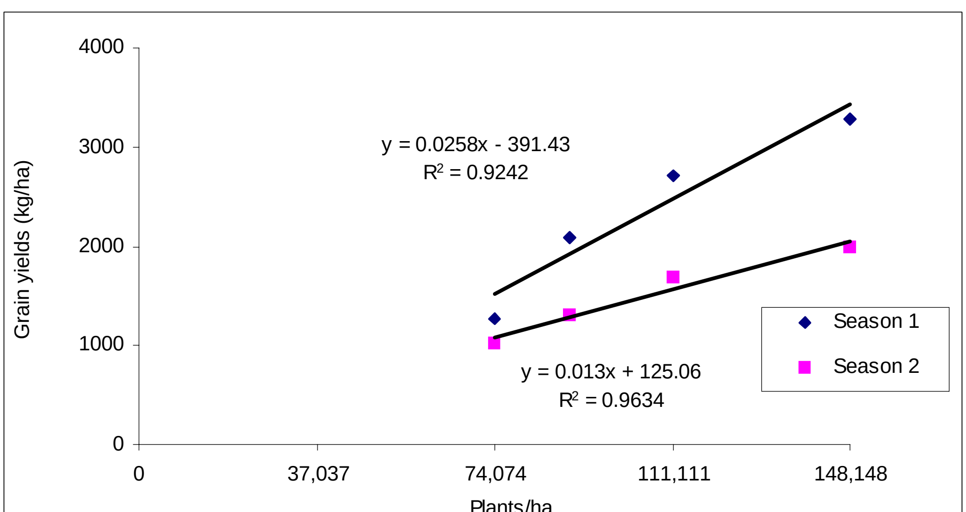

Fig 22: Effect of planting density on grain yield (kg/ha) of chickpea in seasons I and II

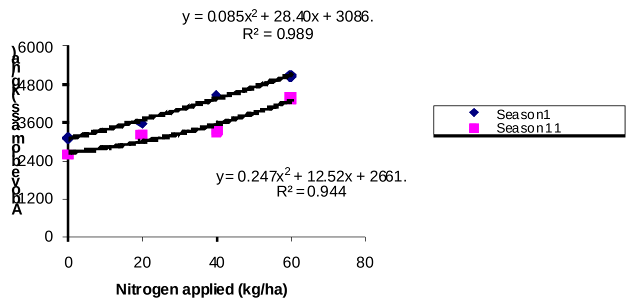

Fig23:Effect of nitrogen (kg/ha) on above ground biomass (kg/ha) in seasons I and II

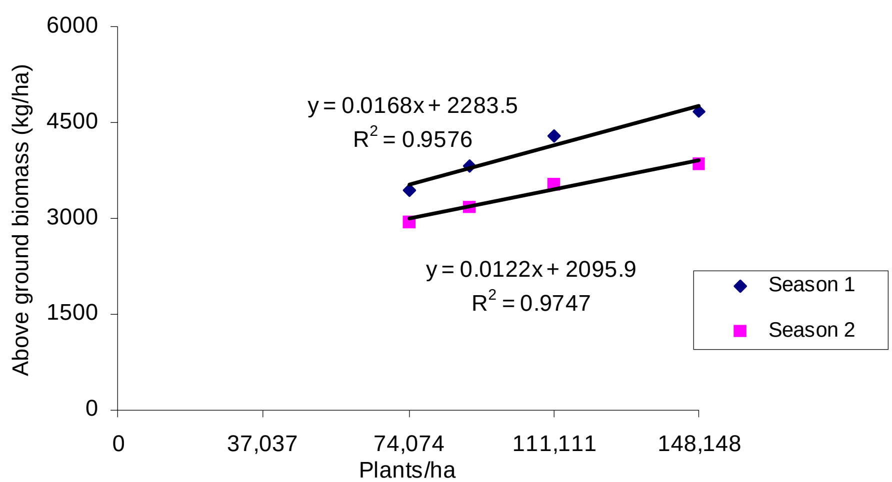

Fig 24: Effect of planting density on above ground biomass (kg/ha) of chickpea in seasons I and II

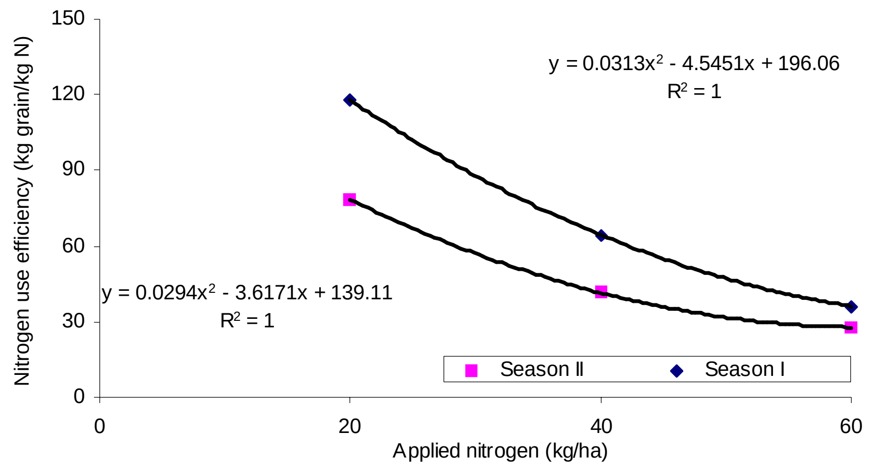

Fig 25: Nitrogen use efficiency (kg grain/kg N used) by desi chickpea in Naivasha

4.12.2 *Effect of Plant Population Density (PPD) on Grain Yield (kg/ha) of Chickpea in Seasons I and II*

In both seasons, increase in plant population successively and significantly ($P \leq 0.05$) increased grain yields (kg/ha) (Table 24). Increase in plant population from 74,074 (P_1) to 89,889(P_2); 111,111(P_3) and 148,148/ha (P_4) produced 1,273.849; 2,079.244; 2,718.209 and 3,271.207kg/ha grain yield, respectively during the first season. In the second season P_1, P_2, P_3 and P_4 produced 1,027.420; 1,300.069; 1,682.860 and 1,994.205kg/ha of grain, respectively (Table 24).

The season I and II, increasing in planting density/ha from 74,074 to 148,148 vegetation/ha significantly ($P \leq 0.05$) increased grain yield (Table 24) of chickpea linearly (Fig 22). Favorable rainfall that was well distributed during the first season amounting to 237.6mm (Fig 1) led into higher grain yields compared to season II that had only 176.6mm.

4.12.3 *Interaction Effects of Nitrogen Application Rates and Plants/ha on Grain Yields of Chickpea*

Application of 0, 20, 40 and 60 kg N/ha revealed no significant differences in grain yields during the first season at 148,148-plants/ha (P_4) treatment. However, these were at par with chickpea grown at a plant population of 111,111/ha and grown with 40 (3,096kg/ha) and 20

(2,890 kg grain/ha) kg N/ha, respectively. Highest yield ranged between 2,890 ($N_{20}P_3$) to 3,426kg/ha ($N_{20}P_4$). At 111,111 plants/ha. Application of 0, 40 and 60kg N/ha gave similar grain yields of between 2,700 and 2,486kg/ha (Table 29). These gave similar grain yield to the treatment combination $N_{40}P_{25}$. At low populations of 89,889 plants/ha (P_2) and 74,074plants/ha (P_1), increasing of nitrogen application rates from 0 to 60kg N/ha did not result into significant ($P \leq 0.05$) increase in grain yields.

At all levels of nitrogen fertilizers, increase in plant populations from 74,074(P_1) to 148,148 plants/ha (P_4)) significantly ($P \leq 0.05$) increased grains yields in both seasons (Table 29 & 30). Chickpea ICCV 97105 grown at 74,074 plants/ha (P_1) and 89,889 plants/ha (P_2) and under no nitrogen application gave similar yields. Chickpea grown with only 20kg N/ha gave non-significant grains yields when crop was grown at P_4 and P_3 plants/ha. Growing chickpea with 40kg N/ha gave similar grain yields when crop was grown at P_4 and P_3 plant population levels during first season.

During the second season (Table 30), application of 60 (2,477.953kg/ha grain) and 20 (2,103.973 kg N/ha grain) produced the highest grain yield at plants populations of 148,148/ha (P_4). However, 20kg N/ha treatment grain yield of 2104kg/ha was not significant different from the 40 kg N/ha (1,999.997 kg/ha grain) treatment. The lowest grain yield was where no nitrogen was applied and was significantly ($P \leq 0.05$) the lowest at the P_4 plant populations.

At 111,111 plants/ha (P_3) $N_{20}P_3$ and $N_{60}P_3$ treatment combinations yielded 1,754.630 and 1,971.230 kg/ha grain which were non significant. However, N_0P_3 treatment produced significant lower grain yield (1,170.781 kg/ha). When chickpea was planted at plant population of P_2, application of 20 (1,509.383 kg/ha grain) and 40 (148,148kg/ha grain) kg N/ha produced similar grain yields/ha. These were significantly ($P \leq 0.05$) higher than those produced using $N_{60}P_2$ and N_0P_2 treatment combinations. Application of 0kg N/ha-produced grain yields that were significantly ($P \leq 0.05$) the lowest compared to all other treatment combinations at all levels of plant populations. For treatments planted at plant populations of 74,074/ha (P_1), application of 0, 20 and 60kg N/ha produced similar grain yields/ha. These produced the lowest grain yield. Growing the crop using 20kg N/ha reveled that P_1 treatment produced significantly ($P \leq 0.05$) the lowest while P_4 and P_3 were at par and produced significantly higher than the P_2 treatment. Application of 40kg N/ha showed that P_4 and P_3

treatment were at par and significantly higher than P_2 and P_1 treatments. Treatment combination $N_{40}P_{30}$ produced significant the lowest grain yield at the 40kg N/ha treatments. When 60kgN/ha was applied, plants/ha P_1 and P_2 produced significant the lowest grain yield/ha. Plant population 148,148/ha (P_4) produced significantly ($P \leq 0.05$) the highest grain yield/ha ($N_{60}P_4$) in both seasons.

Table 29: Interaction effects of nitrogen application rates and PPD/ha on grain yield of chickpea during the IST season

PPD	Nitrogen Levels			
	N_O	N_{20}	N_{40}	N_{60}
P_1	1338.070d	1272.997d	1415.787d	1068.563d
P_2	1752.837cd	2125.123c	2429.623bc	2009.393c
P_3	2700.000b	2890.430ab	3096.297a	2486.110b
P_4	3206.133a	3426.333a	3355.933a	3096.427a
SED	**240.96**		**DMRT**	**695.88**

Table 30: Interaction effects of nitrogen application rates and PPD/ha on grain yield of chickpea during the 2nd season

PPD	Nitrogen Levels			
	N_O	N_{20}	N_{40}	N_{60}
P_1	863.460e	914.140e	1318.410d	1013.670e
P_2	969.077e	1509.383c	1481.563c	1240.253d
P_3	1170.781d	1754.630bc	1834.800b	1971.230b
P_4	1394.897cd	2103.973ab	1999.997b	2477.953a
SED	**145.73**		**DMRT**	**420.87**

4.13 Effect of Treatments on Harvest Index (HI) of Chickpea

4.13.1 Effects of Nitrogen Application Rates on Harvest Index (HI) of Chickpea in Season I and II

Increasing nitrogen application rates from 0 to 20, 40 and 60kgN/ha caused a decline in harvest index viz., 0.689, 0.657, 0.577 to 0.428, respectively during the first season (Table 24). However during the second season, 40kg N/ha treatment had the highest harvest index followed by 20kg/ha, 0kgN/ha and 60kgN/ha i.e. 0.494, 0.489, 0.424 and 0.384, respectively. Lower HI at high nitrogen levels is due to increased biomass production due to growth of chickpea (resulting from increased primary and secondary leaves).

HI in the first season (0.42-0.69) was higher than the second season (0.38-0.49) probably due to the higher moisture availability in seasons I (237.6mm) than in season II (176.6mm) rainfall. It was evident that 25% (59.9mm) of rainwater received in season I fell in the last month of crop growth (May 26-30th; 47.6mm and 19-21st June, 12.1mm) thus, the reproductive stage of chickpea growth. Therefore pod setting and grain filling was enhanced (as crop exhibited an indeterminate habit and assimilates were partitioned to floral development and production. This ultimately resulted into higher grain yield production and hence higher HI. Nitrogen applied above 20-25 kg /ha tended to cause a decline in HI. The soils had adequate N(0.27%) for crop growth therefore, the 0 kg N/ha treatment had adequate nitrogen for crop growth and development (so long as soil moisture required for nutrient uptake was adequate as observed in season I.

The higher HI observed under 0kg N/ha of season I (Fig 28) was due to lower biomass production in later stages (90 and 105 DAS) of crop growth (Fig14 &15). At 90 DAS, season I crop produced 7.47 kg DM/kg N/ha as compared to 11.1kg DM/kg N/ha of season II. At 105 DAS rate of increase of dry matter per kg N/ha were 17.6 and 18.8 for season I and II, respectively, which was almost the same. Therefore, DM accumulation was almost same.

HI in the first season (0.43-0.69) was higher than the second season (0.38-0.49) probably due to the higher moisture availability in seasons I (237.6mm) than in season II (176.6mm) rainfall. The higher HI observed under 0kg N/ha of season I (Fig 28) was due to lower biomass production in later stages (90 and 105 DAS) of crop growth (Fig14 &15). At 90 DAS, season I crop produced 7.47 kg DM/kg N/ha as compared to 11.1kg.

DM/kg N/ha of season II. At 105 DAS rate of increase of dry matter per kg N/ha were 17.6 and 18.8 for season I and II, respectively, which was almost the same. Therefore, DM accumulation was almost same.

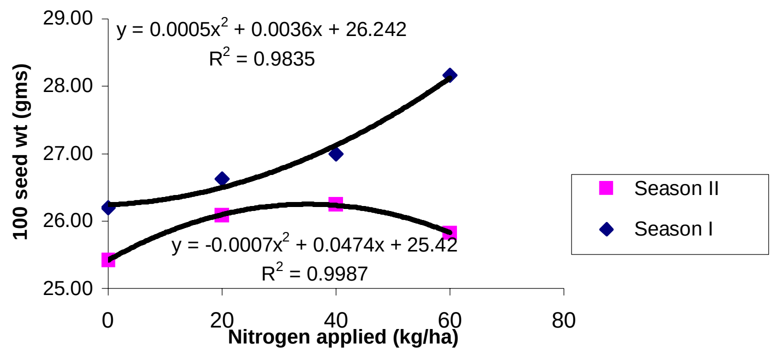

Fig 26: Effect of nitrogen (kg/ha) on 100 seed weight of chickpa in seasons I and II

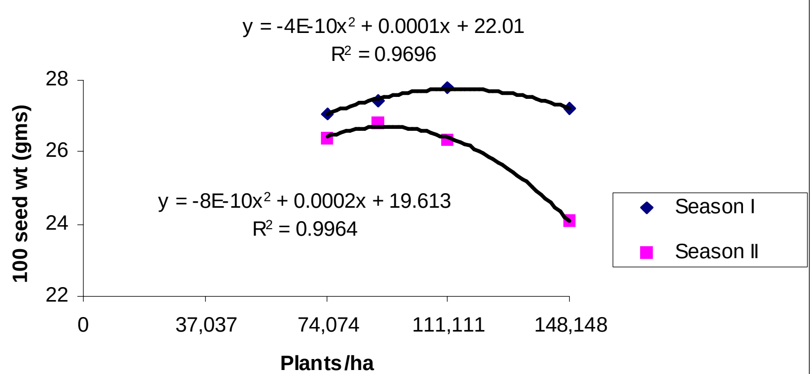

Fig 27: Effect of planting density/ha on 100 seed weight of chickpea in seasons I and II

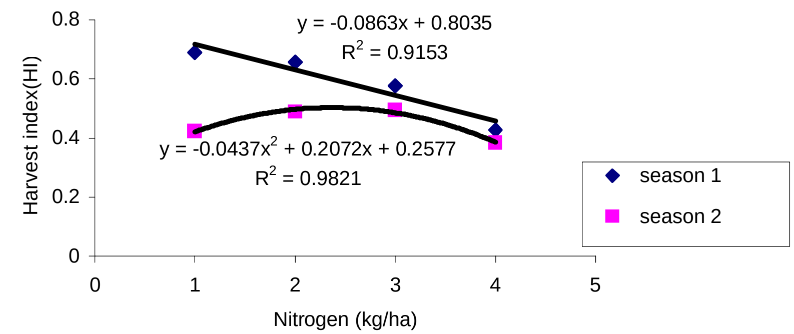

Fig 28:Effect of nitrogen (kg/ha) on harvest index (HI) of chickpea in season I and II

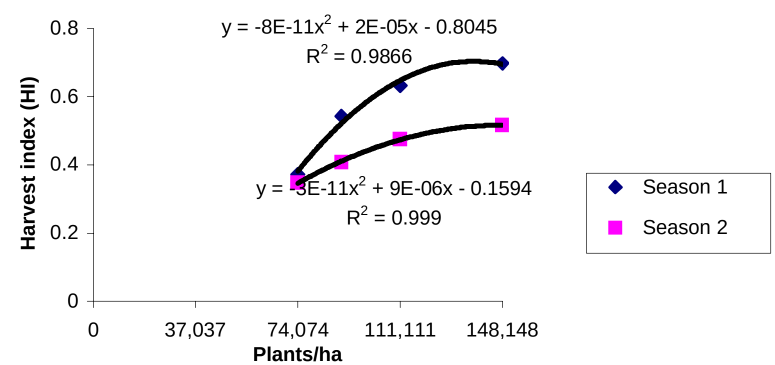

Fig 29: Effect of chickpea planting density/ha on the harvest index in seasons I and II

4.13.2 Effect of Planting Density on Harvesting Index (HI) of Chickpea in Season I and II

Table 24 depicts that the harvest index increased with increase in plant population during the two seasons. Increasing plant population from 74,074 (P_1) to 89,889 (P_2) to 111,111 (P_3) and 148,148 (P_4) per hectare resulted in significant ($P \leq 0.05$) increase of harvest indices from 0.372, to 0.544, 0.633 and 0.698, respectively during the first season and from 0.348 to 0.408, 0.476 to 0.517 respectively, at the second season.

Fig 29 reveals a quadratic (curve linear) relationship of planting density and harvesting index of chickpea. HI increased with increase in planting density attaining highest HI with approximately 130,000 plants/ha. Beyond these planting densities, HI remained same or appeared to decline. The correlation coefficient (R^2=0.987 and 0.999) was very high.

4.14 Effect of Treatments on Mean Crude Protein content

4.14.1 Effects of Nitrogen and Plant Population Density (PPD) on Mean Crude Protein (%) in Chickpea Grain, Pods and Haulms

The highest crude protein (CP) content (%) in grain ranging from 22-28 % followed by haulms (12-16%) and then pods (6-11%) (Fig 30). Fig 30 also reveals that the mean average (%) crude protein content in whole plant ranged between 12 and 16% (12-16 mg/g N), which was close to the CP content observed in haulms (i.e. shoot with pods and grain). $N_{40}P_2$, $N_{40}P_3$ and $N_{40}P_4$ treatment combinations appeared to comparatively have chickpea grains with higher percentage CP amounting to 27%. This was done for season II crop only.

4.15.0 DISCUSSION

The current study was carried out with the aim of evaluating the effect of nitrogen application and planting population density (PPD) on growth and yield of chickpea (*Cicer arietinum* L.) under dry land conditions of Naivasha. The results emanating from the study were presented above in chapter four and an attempt has been made in this chapter to discuss the causes of the variations induced by the said treatments.

4.15.1 Effects of Nitrogen Application on Dry Matter Yields of Chickpea

The highest biomass (DM) production by chickpea grown at Naivasha was obtained with 60 kg N/ha application level at 5,063.4 and 4,369.6 kg DM/ha in season I and II, respectively. These observations were in agreement with earlier findings of Ayaz *et al* (2004), Hakoomet *et al*. (2004) and Raut and Sabale (2003) who reported above dry matter yields of chickpea ranging between 4,300-8,690kg/ha.

For every successive increment in nitrogen levels i.e. from 0 to 20, 40 and 60kg/ha, dry matter yields were observed to increase significantly ($P<0.05$) by the 105 and 120 days after sowing (DAS), stages of chickpea growth (Table 13). By applying 0 kg N/ha, biomass yield of 3,122.0 and 2,594.4 kg DM/ha was realized in season I and II, respectively which was 38.3 % and 40.6% lower than that produced using 60kg N/ha. These results concurred with those reports earlier by Giunta and Motzo (2003) who noted that nitrogen application revealed a positive effect on above ground biomass by increasing conversion of solar radiation into dry matter.

Season I dry matter yields were higher than season II yields by 710kg/ha (16.3%) probably due to higher and better distribution of rainfall in season I (236mm) as compared to that of season II (216mm). Kumar *et al*. (2005) reported that rainfall affected soil moisture and ultimately the crop biomass (8750 kg/ha DM) production. Therefore, higher rain water in season I would have influenced production of higher dry mater than in the case of season II. Over 22.16% (50.7mm rain) of total rain received in season I fell at branching time (Figure 1). This would have increased growth of primary (149) and secondary branches (1,227) per square meter and number of primary leaves (3,455) per m^2 (Table 2). For season II however, only 0.06% (10.2mm) of rainfall was received over the same period. Primary (88), secondary (1,019) branches/m^2 and primary leaves (2,473) per m^2 were much lower by 40.9%, 21.6% and 28.4 % respectively as compared to season I data.

Relationship of nitrogen to above ground biomass was curvilinear with high regression coefficients of 0.98 and 0.94 for season I and II, respectively (Fig 23). The relationship reveals that biomass production can be further increased by additional nitrogen application rates. This corroborated Muhammad *et al.* (2004) who reported that fertilizer levels had significant effects on dry matter yields of chickpea. Furthermore, he reported that yields increased with increase in fertilizer rates from 0-0-0 to 35-87.5-0 kg NPK/ha. Similarly, Giunta and Motzo (2003) reported that nitrogen and water availability have to be taken into account when above ground matter of chickpea production is being estimated. Therefore, higher water availability (Season I) at highest N rates gave highest DM production.

Linear regression lines were found to account for 71-99% variations in dry matter with regard to nitrogen application at the 25, 55, 90 and 105 DAS in both seasons (Fig 10, 11, 12 and 13). Serraj *et al.* (2004) reported similar linear relationships. For every additional kg of nitrogen application beneficial gains in dry matter (DM) production at 25,55,90 and 105 DAS, were estimated to range between 0.553 to 0.722; 2.47-2.61; 7.47-11.1 and 17.6-18.8kg DM/kg N/ha, respectively, depending on crop environment. This means that the rate of dry matter production per Kg N applied increased with maturity of the crop, varying from over 0.55 at 25 DAS to 18kg DM/kg N/ha at 105 days, respectively. Therefore, the effectiveness of every unit N application on biomass production, increased with maturity of desi chickpea.

4.15.2 Effect of Planting Population Density on Dry Matter Production by Desi Chickpea at Naivasha

At final harvest (120days), the maximum dry matter production as influenced by plant population density ranged from 3,429 to 4,689kg DM/ha in season I and 2,955 to 3,854kg DM/ha in season II under 74,074 to 148,148 plants/ha, respectively (Table 13 and Fig 24). Similarly, Ayaz *et al.* (2000) reported that desi chickpea planted at plant population densities of 50,000, 100,000 and 200,000/ha produced from 4,300 to 8,690kg DM/ha as population increased.

Increasing planting population density from 74,074 to 148,148 significantly ($P<0.05$) produced higher dry matter (at 120DAS stage) by 26.7% and 23.3% in season I and II, respectively. Also, increasing plant population density successively from 74,074 to 148,148 was observed to significantly ($P<0.05$) increase the number of primary (119-163) and secondary branches/m^2 (1,015-1,340), primary leaves (2,832-3,235) and secondary leaves (28,392-34,465) per m^2 in season I. This revealed a percentage increase of 40%, 32.0%, 21.3 and 21.4%, respectively for every successive increase in plant population density from 74,074 to 89,889 to 111,111 to 148,148 plants/ha. In season II, increasing plant population density from 74,074 to 148,148 plants/ha increased primary, secondary branches/m^2 and primary and secondary leaves/m^2 by 91.1%, 231.6%, 66.4% and 78.6%, respectively. Arora *et al* (2003) and Roval *et al.* (2003) reported that primary branches/m^2 had high significant positive relationship with biological yield of plants/m^2. Similarly, Anwar *et al.* (2004) reported that accumulation of total dry matter was highly related to intercepted photosynthetic active radiation (PAR). Therefore, higher primary and secondary branches/m^2 and leaves/m^2 correlated with higher yields.

Relationships of planting population density to dry matter yield at all stages of plant growth (Fig. 14,15,16,17 and 23) were found to be linear. In the first season, chickpea dry matter production (gms/PPD/ha) per plant at 25, 55, 90 and 105 growth stages were observed to be 12.4, 124.9, 287.7 and 415.6, respectively (Fig. 14, 15, 16 and 17). In season II, the DM produced in grams per plant was 27.9, 118.9, 300.4 and 320 gm/PPD at 25, 55, 90,105 DAS, respectively. Rates of DM production/PPD therefore increased with maturity (as in the case of N effects) ranging from 12.4 to 27.9 (by 25 DAS), 118.9 –120.1(by 55 DAS), 287.5 – 300.4 (by 90DAS), 320.8 –415.6 (by 105 DAS) and 304.9 – 425.3 (by 120 DAS) kg DM/PPD, respectively depending on crop environment (Fig. 14-17 and 24). These linear regressions could account for 74.4 to 99.9% of dry matter variations as influenced by planting population densities. These relationships reveal that above ground biomass can be increased further when chickpea is grown under higher planting population density. This confirms earlier reports by Ayaz *et al.* (2004) who stated that increased planting population densities (PPD) are functions of greater total dry matter production. This was also in agreement with earlier findings of Hussian *et al.* (2000), who also attributed increasing dry matter with increasing level of planting population densities. It can therefore be concluded that higher plant population densities produced higher vegetative growth (i.e. branches and leaves), which intercepted greater amounts of solar radiation and consequently produced high dry matter.

4.15.3 Effects of Nitrogen Application on Grain Yield of Desi Chickpea at Naivasha

Highest grain yield production by desi chickpea at Naivasha was 2,574.4 and 2,353.7kg grain/ha under 20 and 40kgN/ha, respectively in seasons I (Table 24 and fig. 21). During the second season, increasing nitrogen application rates also increased grain yield successively. Application of 0, 20, 40 and 60kgN/ha produced 1,099.6; 1,570.5; 1,658.7 and 1,675.8 kg/ha of grain respectively (Table 24). Treatment with 0 kg N/ha was significantly ($p<0.05$) lower while the other treatments were at par with each other. Suresh (2004) and Hosseini *et al*. (2003) reported average grain yields of 2,501.9 and 2,878.3 kg/ha respectively, under plant population density of 460,000 per ha.

In season I, regression curves revealed (Fig 21) that nitrogen application from zero to 30kg/ha increased grain yield. However, above 30-40 kg/ha resulted in decline in the rate of grain yield production. Similar finding was reported by Akram *et al*.(2004) who reported that chickpea yield increased with increase in the fertilizer rates from 0-0-0 to 35-87.50 –00 NPK kg/ha. Beyond 35 kg m/ha the grain declined.

Season I yields were higher than season II yields by 1,150(104.6%); 783.18(49.9%); 915.72(55.2%) and 489.35(29.2%) at the 0, 20, 40 and 60kgN/ha rates, respectively. This could probably be due to higher and better distribution of rainwater in season I (237.6mm) as compared to that of season II (216.6mm). Chickpea seed yield was reported by Lopez *et al*. (2004) to strongly depend on rainfall during flowering and seed filling stages.

In the current study, over 94.7% (approximately 216.6mm) of total rainfall received in season I fell between branching, flowering, pod formation and grain filling stages (Fig. 1). This rain would have increased growth of primary (149) and secondary (1,227) branches /m^2, primary and secondary leaves /m^2 (Table 2), above ground dry matter (Table 13 and Fig. 10,11,12,13 and 24) and pods/m^2 (Table 24 and Fig. 18) which would have contributed to increased grain yield production. For season II however, only 62.05 %(109.6mm) of the total seasons rain (216.6mm) was received over the same stages of crop growth and development. This corroborates the work by Arora *et al.* (2003) who reported that biological yield, primary and secondary branches/m^2, pods/m^2 and 100 seed weight had highest significant positive relationship with chickpea seed yields at the semi-arid conditions of Central Andra Pradesh.

The relationship of N to grain yield was curvilinear with high regression coefficients of 0.70 and 0.98 for season I and season II, respectively (Fig. 21). The relationship reveals that highest grain yields can be realized by application of 30kg/ha at Naivasha. Beyond this, application of additional N levels resulted in reduced rates of increase in grain yield production by chickpea. Chickpea has been reported not to fully supply its N needs through atmospheric fixation (Lopez *et al*, 2004). Therefore, 30kgN/ha would be sufficient to obtain 2.33 to 2.57 tons grain/ha depending on available rainwater. Therefore, higher yields are likely to be obtained when sufficient rainfall (over 210mm) is received during and after branching stages of chickpea.

4.15.4 Effect of Planting Population Density on Grain Yield Production of Desi Chickpea at Naivasha

At harvest (120DAS), grain yields as influenced by planting population densities ranged from 1,273.8 to 3,271.2 kg/ha in season one and 1,027.4 to 1,994.2kg/ha in season two under 74,074 to 148,148 plants/ha, respectively (Table 24 and Fig 22). Increasing planting population densities from 74,074 to 148,148 significantly ($P<0.05$) produced higher grain yield by 24.0% and 64.0% in season I and II, respectively. Similarly, Liu *et al.* (2004) reported that as plant population increased from 200,000 to 500,000 plants/ha, the seed yield increased by 20% for desi and 27% for small seeded Kabuli.

Increasing plant population density from 74,074 to 148,148 plants/ha was observed to significantly ($P<0.05$) increase the number of primary (119-163) and secondary (1,015-1,340) branches/m^2 and primary (2832-3435) and secondary leaves (28,392-34,465) per m^2 (Table 2). The ratio of primary to secondary branches/m^2 was on average 1:8 (at maximum growth), while it was 1:10 for primary to secondary leaves/m^2.

The above ground dry mater yield at 120 DAS ranged between 3,428.7-4,688.9kg/ha (Table 24) while pods/m^2 was 1,103-1,829 (Table 24) in season I. These revealed a percentage increase by 37.0, 32.0, 21.3, 21.4, 36.8 and 65.8% primary and secondary branches/m^2, primary and secondary leaves/m^2, above ground dry matter yields at 120 DAS and pods/m^2 respectively in season I. The highest percentage increase (65.8%) was on pods/ m^2. In concurrence, Gan *et al* (2003) reported earlier that seed yield potential of desi chickpea could be increased by increasing planting population to produce more pods per unit area, where as the seed yield potential of Kabuli chickpea would be increased by shortening the period of vegetative growth, promoting the number of pods per plant and increasing mean seed weight. Therefore, the higher grain yields observed under higher plant population densities could be attributed to increased number of pods/m^2 that resulted from higher number of branches/m^2.

In season II, increasing PPD from 74,074 to 148,148 plants/ha caused a percentage (%) increase of 11.1, 231.5, 66.4, 78.6, 30.4 and 40.6%, respectively for primary and secondary branches/m^2, primary and secondary leaves/m^2, above ground dry matter yields at 120 DAS and pods/m^2, respectively. It was observed that greater effects of increasing PPD were mainly on the number of secondary leaves/m^2 as was the case of nitrogen effects. This was followed by the impact on DM (40.6%) production. Raval and Doboriya (2003) similarly reported that chickpea seed yield was positive and significantly correlated with biological yield, pods/m^2, number of primary and secondary branches/m^2 and 100 seed weight.

The first season grain yields were higher than the second season probably due to higher and well-distributed rainfall during season one crop growth period. Kurmar *et al*. (2004) reported that chickpea seed yield under moisture stress significantly lowered biomass production, number of branches/m^2 and pods/m^2. Therefore, the relatively lower second season grain yields would have been as a result of lower and poorer distribution of precipitation during the season.

4.15.5 Cost Benefit Analysis

The highest gross benefit in both seasons was with treatment combinations of 20 kg N/ha and plant population of 148,148/ha ($N_{20}P_4$). The gross benefit was Ksh 171,315.00 and 154,820.00 for season one and two, respectively. However, the highest net (profit) benefit of Ksh 137,465.00 and 88,650.00 for seasons one and two was realized with treatment combinations of 60 kg N/ha and

Table 31. Season I Total Variable Costs (Kshs/ha) of desi chickpea production as

								Labor Cost		
Season I Feb-Jun 2005		**Gross**	**Land preparation**		**Planting and Fertilization**		**Seed rates**	**Weeding**	**Pest &**	**Harves**
	Grain yield	**Benefits**	**Plough**	**Harrow**	**TSP (29.35)**	**CAN (85.75)**		**30 & 60DAS**	**Diseases**	
	Kg/ha	**Shillings**	**20 Man-days**	**10 MD**	**25 man-days**			**17mdx150**	**8MDx800**	**10 MD**
N0P1	***1338.1***	***66905***	3000	1500	1174	0	1218	5000	6400	150(
N0P2	***1752.8***	***87640***	3000	1500	1174	0	1479	5000	6400	150(
N0P3	***2700.0***	***135000***	3000	1500	1174	0	1830	5000	6400	150(
N0P4	***3206.1***	***160305***	3000	1500	1174	0	2436	5000	6400	150(
N20P1	***1273.0***	***63649***	3000	1500	1174	1715	1218	5000	6400	150(
N20P2	***2125.1***	***106255***	3000	1500	1174	1715	1479	5000	6400	150(
N20P3	***2890.4***	***144520***	3000	1500	1174	1715	1830	5000	6400	150(
N20P4	***3426.3***	***171315***	3000	1500	1174	1715	2436	5000	6400	150(
N40P1	***1415.8***	***70790***	3000	1500	1174	3430	1218	5000	6400	150(
N40P2	***2429.6***	***121480***	3000	1500	1174	3430	1479	5000	6400	150(
N40P3	***3096.3***	***154815***	3000	1500	1174	3430	1830	5000	6400	150(
N40P4	***3355.9***	***167795***	3000	1500	1174	3430	2436	5000	6400	150(
N60P1	***1068.6***	***53430***	3000	1500	1174	5142.6	1218	5000	6400	150(
N60P2	***2009.4***	***100470***	3000	1500	1174	5142.6	1479	5000	6400	150(
N60P3	***2486.1***	***124305***	3000	1500	1174	5142.6	1830	5000	6400	150(
N60P4	***3096.4***	***154820***	3000	1500	1174	5142.6	2436	5000	6400	150(

DAS: Days after sowing; MD: Man days; TSP: Triple Super Phosphate 29.35 Kshs/kg); CAN: Calcium Ammonium Nitrate (85.75 Kshs/kg); Kshs: Kei

Table 32. Season II (Jun-Oct 2005) Total Variable Costs (Kshs/ha) for chick

Season II Feb-Jun 2005	Grain yield	Gross Benefits	Land preparation		Planting and Fertilization		Seed rates	Weeding	Pest &
			Plough	Harrow	TSP (29.35)	CAN (85.75)		30 & 60DAS	Diseas
	Kg/ha	Shillings	20 Man-days	10 MD	25 man-days			17mdx150	8MDx8
N0P1	*1398.9*	*69945.0*	3000.0	1500.0	1174.0	0.0	1218.0	5000.0	6400
N0P2	*1170.8*	*58540.0*	3000.0	1500.0	1174.0	0.0	1479.0	5000.0	6400
N0P3	*969.1*	*48455.0*	3000.0	1500.0	1174.0	0.0	1830.0	5000.0	6400
N0P4	*863.5*	*43175.0*	3000.0	1500.0	1174.0	0.0	2436.0	5000.0	6400
N20P1	*2104.0*	*105200.0*	3000.0	1500.0	1174.0	0.0	1218.0	5000.0	6400
N20P2	*1754.6*	*87730.0*	3000.0	1500.0	1174.0	1715.0	1479.0	5000.0	6400
N20P3	*1509.4*	*75470.0*	3000.0	1500.0	1174.0	1715.0	1830.0	5000.0	6400
N20P4	*914.1*	*45705.0*	3000.0	1500.0	1174.0	1715.0	2436.0	5000.0	6400
N40P1	*2000.0*	*100000.0*	3000.0	1500.0	1174.0	1715.0	1218.0	5000.0	6400
N40P2	*1834.8*	*91740.0*	3000.0	1500.0	1174.0	3430.0	1479.0	5000.0	6400
N40P3	*1481.6*	*74080.0*	3000.0	1500.0	1174.0	3430.0	1830.0	5000.0	6400
N40P4	*1318.4*	*65920.0*	3000.0	1500.0	1174.0	3430.0	2436.0	5000.0	6400
N60P1	*2478.0*	*123897.5*	3000.0	1500.0	1174.0	3430.0	1218.0	5000.0	6400
N60P2	*1971.2*	*98560.0*	3000.0	1500.0	1174.0	5142.6	1479.0	5000.0	6400
N60P3	*1240.3*	*62015.0*	3000.0	1500.0	1174.0	5142.6	1830.0	5000.0	6400
N60P4	*1013.7*	*50685.0*	3000.0	1500.0	1174.0	5142.6	2436.0	5000.0	6400

DAS: Days after sowing; MD: Man days; TSP: Triple Super Phosphate 29.35 Kshs/kg); CAN: Calcium Ammonium Nit plant populations of 148,148/ha. In season one,the highest grain yield of 2.9 tons/ha, was produced with the application of 60 kg N/ha to chickpea grown at a density of 148,148 plants per hectare. The cost of production was 34,896 Kshs and net benefit (profit) was 137,465.00 Kshs/ha.

In the June to October season II, the highest grain yields of 2.1 tons/ha, was obtained with the same treatment of 60 kg N/ha and a spacing of 45 x 15 cm (148,148 plants/ha). This yielded the highest net benefit of Kshs. 88,650.00 only. The cost of production or investment was 32, 912/- Kshs only. The least cost benefit of Ksh 34,249.00 in season one and Ksh 10,677.00 in season two were realized with N_0P_1.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

a) Desi chickpea ICCV 97105 grain yield ranged between 1,099.6 to 3271.2 kg/ha

b) Increase in N from 0 to 60 kg/ha and PPD from 74,074 to 148,148 plants/ha, significantly ($P \leq 0.05$) increased dry matter at all stages of desi chickpea growth

c) Highest N and PPD treatment combination gave the highest DM ranging between 5.96 to 4.76 tons/ha.

d) Increasing nitrogen application from 0 to 60Kg/ha significantly increased 100 seed weight, and consequently the grain yield.

e) Nitrogen and planting population density interaction effects on grain yields were higher under the highest plant population densities (148,148 plants/ha) and 20, 40 and 60 kg N/ha.

f) Functional relationships developed were useful in explaining the responses of yield to treatments imposed with an accuracy of 70 to 98% accuracy.

g) The optimal N rate for Naivasha was established as 30kg/ha by use of functional relationships.

h) Desi chickpea variety 95107 can be grown successfully and profitably in the dry highland regions of Naivasha, Kenya. It is recommended that farmers plant chickpea at high plant population densities of 148,148 plants/ha (i.e., 40x15cm) and apply up to 60 Kg N/ha, in order to get net benefits ranging between 93,000 and 139,000 Kshs/ha per growing season, depending on rainfall and management practices

5.2 RECOMMENDATIONS

a) For farmers to realize optimal grain yield of chickpea, it's advisable to apply 30kgN/ha during sowing and plant at a high plant population density of 148,148 plants/ha to realize over 3.3 tones/ha of grain yield per season.

b) Farmers plant chickpea at high plant population densities of 148,148 plants/ha (i.e., 40x15cm) and apply up to 60 Kg N/ha, in order to get net benefits ranging between 93,000 and 139,000 Kshs/ha per growing season, depending on rainfall and management practices

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APPENDICES

Appendix 1

Naivasha in 2005											
aivasha in 2005											
ary	February	March	April	May	June	July	August	September	October	November	December
0	5.1	2.1	0	0	0	0	0	9	0	10.7	0
0	3.8	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	5.2
0	0	0	0	0	0	0	0	0	3.1	0	0
0	0	0	0	7.4	0	0	0	7.5	5.9	0	0
0	0	0	25.3	13	0	0	0	6	0	0	0
0	0	0	9	0	0	0	0	0	0	0	0
0	0	0	5.4	8	0	0	0	0	5	0	0
0	0	0	3	16.2	0	0	0	7	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	3.3	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	8	0	0	0
0	0	0	1.5	0	0	0	6	0	0	0	0
0	0	0	0	0	0	0	0	0	38.4	0	0
0	0	0	0	0	0	0	0	0	4.6	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	7.3	30	0	0	0	0
0	0	2.6	0	0	3.5	0	17	0	0	0	0
0	0	0	0	0	3.8	0	5.5	0	0	0	0
0	0	3.6	0	0	4.8	0	0	0	0	0	0
0	0	29	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	5.4	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	12	0	0	0	0	0	0	0
4	10.3	0	3	0	0	2.9	0	0	0	0	0
6	3.1	0	5.1	8	0	0	0	0	0	0	0
8		0	0	13	0	0	0	0	0	0	0
0		0	18	14.8	0	0	0	0	0	0	0
0		0		0		8	0			0	0
4	**22.3**	**37.3**	**73.6**	**92.4**	**12.1**	**18. 2**	**63.9**	**37.5**	**57**	**10.7**	**5.2**
1	**5.6**	**9.3**	**8.2**	**11.6**	**4**	**6.1**	**12.8**	**7.5**	**11.4**	**10.7**	**5.2**
4	**4**	**4**	**9**	**8**	**3**	**3**	**5**	**5**	**5**	**1**	**1**

Appendix 2

Percentage relative humidity

Dates	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	(
1	**65.3**	**58.5**	**63.3**	**59.3**	**75.0**	**75.8**	**72.7**	**80.7**	**66.2**	**5**
2	**58.6**	**66.4**	**58.4**	**47.9**	**69.1**	**78.1**	**73.0**	**79.9**	**67.4**	**5**
3	**55.0**	**59.7**	**65.4**	**56.6**	**65.9**	**74.5**	**72.5**	**70.9**	**69.0**	**5**
4	**48.2**	**49.7**	**55.9**	**71.7**	**67.8**	**74.3**	**71.1**	**72.3**	**67.3**	**5**
5	**58.8**	**71.1**	**57.8**	**82.6**	**73.5**	**80.4**	**65.2**	**70.6**	**65.1**	**6**
6	**55.6**	**71.4**	**56.7**	**83.1**	**59.0**	**91.0**	**69.5**	**65.6**	**62.0**	**5**
7	**53.2**	**70.4**	**60.4**	**85.7**	**70.9**	**78.1**	**68.7**	**73.0**	**60.1**	**5**
8	**57.5**	**58.9**	**67.7**	**88.2**	**71.7**	**74.4**	**80.9**	**67.0**	**63.7**	**4**
9	**60.5**	**56.8**	**69.9**	**79.7**	**74.5**	**66.8**	**68.4**	**71.1**	**69.8**	**5**
10	**65.3**	**51.9**	**57.5**	**76.7**	**67.7**	**69.7**	**70.4**	**77.5**	**67.2**	**5**
11	**58.1**	**51.7**	**56.9**	**75.4**	**72.0**	**64.6**	**64.5**	**70.7**	**55.6**	**5**
12	**57.0**	**58.2**	**59.9**	**76.8**	**71.1**	**63.2**	**70.0**	**74.1**	**59.1**	**5**
13	**60.5**	**62.6**	**65.0**	**79.9**	**66.1**	**71.6**	**68.8**	**73.4**	**60.8**	**6**
14	**63.7**	**64.4**	**66.8**	**84.4**	**67.4**	**77.9**	**64.3**	**75.9**	**57.3**	**6**
15	**65.1**	**72.3**	**59.5**	**84.6**	**67.9**	**73.8**	**62.8**	**72.2**	**59.1**	**5**
16	**65.1**	**64.3**	**53.8**	**42.6**	**67.7**	**73.8**	**71.7**	**77.8**	**68.6**	**5**
17	**42.0**	**55.9**	**60.1**	**77.3**	**58.5**	**72.3**	**73.1**	**78.2**	**71.4**	**6**
18	**43.3**	**52.7**	**59.6**	**72.8**	**66.4**	**70.2**	**75.6**	**70.5**	**70.2**	**6**
19	**48.5**	**48.5**	**65.9**	**68.1**	**59.7**	**75.4**	**76.8**	**75.3**	**63.9**	**6**
20	**54.1**	**52.0**	**77.5**	**73.0**	**65.3**	**77.3**	**67.1**	**63.5**	**62.4**	**6**
21	**68.7**	**48.5**	**73.3**	**82.9**	**86.4**	**85.0**	**78.4**	**64.9**	**57.6**	**6**
22	**84.5**	**42.0**	**76.3**	**88.1**	**71.3**	**82.2**	**69.1**	**54.3**	**64.7**	**7**
23	**69.2**	**43.3**	**69.0**	**80.4**	**74.7**	**76.0**	**72.1**	**54.9**	**59.3**	**6**
24	**52.0**	**48.5**	**70.5**	**83.3**	**87.1**	**76.6**	**61.9**	**68.2**	**57.9**	**6**
25	**54.3**	**54.1**	**67.5**	**88.4**	**81.1**	**67.0**	**65.9**	**67.0**	**61.6**	**6**
26	**58.7**	**68.7**	**63.8**	**87.0**	**83.3**	**75.4**	**65.9**	**73.3**	**56.0**	**8**
27	**67.7**	**55.3**	**62.4**	**83.9**	**86.4**	**75.5**	**68.5**	**72.0**	**57.1**	**6**
28	**58.5**	**65.8**	**63.1**	**84.9**	**81.7**	**67.9**	**76.5**	**64.6**	**62.4**	**5**
29	**66.4**		**66.8**	**77.4**	**78.2**	**66.2**	**77.8**	**58.5**	**70.4**	**5**
30	**59.7**		**74.2**	**78.0**	**77.8**	**72.6**	**78.9**	**75.8**	**60.2**	**5**
31	**65.3**		**66.2.**		**76.5.**		**78.9**	**59.7**		**8**
	59.4	58.0	64.2	76.7	72.3	74.3	71.0	70.1	63.1	6

Appendix 3

Maximum and minimum temperatures (°C)for the period January to May 2005

Dates	**January**		**February**		**March**		**April**		**May**	
	Max	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
1	28	14	29	17	30	16	27	12	27	
2	27	15	27	14	30	17	30	12	26	
3	28	16	28	15	29	17	30	13	26	
4	30	16	29	17	29	16	28	16	27	
5	29	17	26	14	29	16	28	15	27	
6	28	16	26	13	29	15	26	16	27	
7	31	16	26	14	28	15	24	16	26	
8	29	17	29	15	26	15	26	15	27	
9	30	16	29	13	26	16	25	16	26	
10	29	17	29	13	27	16	27	13	26	
11	29	13	29	14	27	15	26	16	26	
12	29	13	28	14	28	16	26	15	25	
13	29	14	28	14	28	16	27	15	25	
14	30	13	27	15	28	17	26	15	26	
15	30	14	25	17	28	16	26	16	25	
16	29	16	26	15	29	16	25	14	25	
17	29	14	28	14	29	17	26	14	26	
18	31	11	30	13	30	16	25	11	26	
19	32	16	30	14	29	17	28	12	27	
20	31	13	29	16	27	16	28	14	27	
21	32	15	29	14	26	17	22	14	25	
22	28	17	31	11	27	15	23	15	23	
23	28	16	32	15	27	16	24	15	25	
24	29	16	31	13	29	15	22	16	24	
25	29	17	32	15	27	16	23	15	24	
26	30	16	30	16	28	16	23	16	20	
27	29	17	31	15	28	13	20	16	25	
28	31	18	28	17	28	14	23	16	23	
29	29	17	.	.	28	16	24	15	25	
30	27	14	.	.	27	17	24	16	23	
31	28	15	.	.	28	16	25	15	24	
	29.29032	**15.32258**	**28.64286**	**14.53571**	**28.03226**	**15.87097**	**25.3871**	**14.67742**	**25.29032**	**13.**

Appendix 4

Maximum and minimum temperatures (°C)for the period June 1 to October 2005

Date	June Max	June Min	July Max	July Min	August Max	August Min	September Max	September Min	October Max	October Min
1	24	15	22	11	20	13	22	13	27	
2	24	15	21	10	19	13	25	14	27	
3	24	13	22	10	21	13	23	11	27	
4	24	12	22	10	20	11	26	12	29	
5	21	11	24	9	19	13	27	11	26	
6	19	11	20	8	23	13	26	10	27	
7	21	15	24	8	22	13	26	12	26	
8	24	15	19	14	22	13	24	12	27	
9	25	14	21	13	24	9	21	13	28	
10	24	14	22	9	20	14	22	13	29	
11	25	12	21	11	22	14	24	13	29	
12	24	9	20	11	21	14	24	13	28	
13	25	9	23	10	21	13	25	12	27	
14	21	10	23	11	21	14	25	12	26	
15	24	14	24	7	25	14	25	14	27	
16	23	15	23	9	22	14	22	13	27	
17	23	15	23	9	21	13	21	13	25	
18	23	14	22	8	23	13	22	14	25	
19	20	17	19	13	20	11	25	13	26	
20	21	14	22	12	27	8	25	9	26	
21	18	15	21	10	27	14	25	13	28	
22	19	14	21	14	29	10	25	13	27	
23	20	14	26	12	28	9	25	13	26	
24	23	14	23	13	25	10	27	8	26	
25	21	13	24	11	25	11	23	13	25	
26	23	12	23	13	22	11	27	10	21	
27	21	12	25	10	24	10	28	11	25	
28	24	13	24	14	22	12	28	15	27	
29	23	13	18	14	23	11	26	16	27	
30	23	10	18	12	22	7	25	13	27	
31	22	12	18	12	24	10	26	13	26	
	22.45161	**13.09677**	**21.87097**	**10.90323**	**22.70968**	**11.87097**	**24.67742**	**12.41935**	**26.58065**	**13.**