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Effects of nitrogen fertilizer and plant population on growth, yield and harvest index (HI) of chickpea *(Cicer arietinum* L.) under dryland conditions in Kenya

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ABSTRACT

Objective: To evaluate the dry matter, grain yield and harvest index of chickpea under four different levels of nitrogen fertilizer and plant population density of chickpea within the dryland areas of Kenya.

Methodology and results: Field experiments were conducted at the National Animal Husbandry Research Center (NAHRC), Naivasha, Kenya, during the long (season 1) and short (season 2) rains of the year 2005. Four different nitrogen fertilizer levels (0, 20, 40 & 60 Kg N/ha) and four plant population densities (PPD) (74,074; 88, 889; 111, 111 and 148,148 plants/ha) of chickpea were evaluated. The experiment was laid out as a factorial design. Laid out in a Randomized Complete Block Design (RCBD) and replicated three times. It had 16 treatment combinations. At final harvest (120 Days After Sowing -DAS), there were significant effects of nitrogen fertilizer application ($P<0.05$) on dry matter throughout the growth stages. The dry matter production varied with plant population density ranging from 3,429 to 4,689kg DM/ha in season I and 2,955 to 3,854 kg DM /ha in season II. The highest grain yield was 2,574.4 and 2,353.7kg grain/ha under 20 and 40kgN/ha, respectively in seasons I. Grain yields as influenced by planting population densities ranged from 1,273.8 to 3,271.2 kg/ha in season I and 1,027.4 to 1,994.2 kg/ha in season II. Nitrogen fertilizer application at 0, 20, 40 and 60kgN/ha produced an average of 1,099.6; 1,570.5; 1,658.7 and 1,675.8 kg/ha of grain, respectively. Plots without nitrogen fertilizer (0 kg N/ha) had significantly ($p<0.05$) lower yield while the other treatments showed no difference in terms of grain yield. An interaction of nitrogen fertilizer rates and plant population density caused a significant ($P<0.05$) increase in both dry matter and grain yield. Increasing nitrogen application rates from 0 to 20, 40 and 60kgN/ha caused a decline in harvest index from 0.689, 0.657, 0.577 to 0.428, respectively, during the long rain season. During the short rain season, 40kg N/ha treatment had the highest harvest index followed by 20kg/ha, 0kgN/ha and 60kgN/ha (0.494, 0.489; 0.424 and 0.384), respectively. The harvest index only increased with an increase in plant population during the second season. Increasing plant population density 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 ($P\leq0.05$) increases of harvest indices from 0.372, to 0.544, 0.633 and 0.698, respectively, during the long rains and from 0.348 to 0.408, 0.476 to 0.517 respectively, in the short rains season.

Conclusion and application of findings: Increasing fertilizer rates and plant population increased dry matter at all stages and also the grain yield. However, increasing nitrogen doses lowered the harvest index (HI), whereas an increase in plant population density increased the harvest index (HI). These findings should be considered when determining the optimal conditions to maximize chickpea yields in dryland areas.

Key words: Nitrogen, plant population, grain yield, chickpea, dryland

INTRODUCTION

Dry lands experience several constraints, which limit agricultural productivity. These constraints are climatic as well as socio-economic and they include use of inappropriate tools, weeds, highly variable response to fertilizers and low organic matter. In addition, the areas receive insufficient rain which falls mostly as heavy showers, and thus is lost as run off. Dry lands also have high rates of evaporation, which result in reduced yields (Oguya, 2001).

The semi arid tropics comprise of fifty countries of the world and are home of more than six hundred million people (Thomas & Middleton, 1996). 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 83% 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 survival. Efforts to grow highly nutritious food grain crops that are drought tolerant need to be accelerated in order to increase food production and alleviate malnutrition and poverty.

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 Seeds, 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 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.

Chickpea is a hardy crop grown on marginal soils with residual moisture that may not be suitable for legumes and cereals, but it's very sensitive to saline, alkaline and waterlogged soils (Fisher & 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 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). 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 factor for increased production. In nitrogen deficient soils, application of nitrogen to the crops brings about considerable increase in 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 by 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 the 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. Inadequate plant population density (PPD) is the most common yield retardant in many production areas in the world (Sheldrake & 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.

ICRISAT (1988) reported that chickpea, 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 maturity and ability to survive under low moisture levels. Low yields of chickpea are often due to soil water and nutrient stress (Oswal & 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 that can be manipulated to optimize use of the soil moisture available for chickpea growth and yield (Kumar, 1995).

The objective of this study was therefore to evaluate the dry matter, grain yield and harvest index of chickpea under four different levels of nitrogen fertilizer and plant population of chickpea within the drylands of Kenya.

MATERIALS AND METHOD

Experimental site: Field experiments 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 populations. 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 (m asl), (Jaetzhold & Schmidt, 1983).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%. 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) done during the first weeks of the experiment indicate that soils are neutral to slightly alkaline (pH 7.39). This concurs with the findings of Snijders *et al.,* (1992) and Sombroek *et al.,* (1980). 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. The interpretation and further general recommendations are that, the soil nutrients status and alkaline soil reaction (pH) are not favorable for crops. 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.

Experimental design and layout: An experiment testing the effects of four different nitrogen fertilizer levels (0, 20, 40 & 60 Kg N/ha) and four different plant population densities (PPD) of desi chickpea (148,148; 111, 111; 88,889 and 74,074/ha) on growth and yield of chickpea was conducted. The experimental design was a factorial arranged in a Randomized Complete Block

Design (RCBD) with 16 treatment combinations replicated three times.

Upon plant maturity (120 days after sowing), the harvested 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 net materials were threshed and the grains were cleaned. The grain and above ground biomass were weighed separately and finally expressed on yield per hectare basis. The grain yield/ha was expressed as percentage of the total harvested biomass yield and reported as harvest index (ratio of grain yield to total above ground biomass).

Data analysis: Data were subjected to Analysis of Variance (ANOVA) and means were separated using the Duncan's Multiple Range Test (DMRT) as described by Steel and Torrie (1981).

RESULTS AND DISCUSSIONS

Nitrogen fertilizer levels had significantly different effects ($P<0.05$) on dry matter yield of chickpea (Table 1). The dry matter produced by chickpea with 60 kg N/ha was 5,063.4 and 4,369.6 kg DM/ha in the long ans short rain seasons, respectively. These yields were in the range reported by Ayaz *et al.,* (2004); Hakoomet *et al.,* (2004); Raut and Sabale (2003) between 4,300-8,690kg/ha. For every successive increment in nitrogen level i.e. from 0 to 20, 40 and 60kg/ha, dry matter yields were observed to increase significantly by the 105th and 120th days after sowing (DAS). When no N was applied (0 kg N/ha), dry matter was 3,122 and 2,594.4 kg/ha for the long and short rains, respectively which was 38.3 % and 40.6% lower than that produced using 60kg N/ha. These results concurred with those reported earlier by Giunta and Motzo (2003) who noted that nitrogen application had a positive effect on above ground biomass by increasing conversion of solar radiation to dry matter.

Dry matter yields in the long rains was higher than in the dry season by 710kg/ha (16.3%), probably due to higher and better distribution of rainfall (236mm) as compared to 216mm. Kumar *et al*. (2005) reported that rainfall affected soil moisture and ultimately the crop biomass production. Over 22.16% (50.7mm rain) of total rain received in the long rain season fell at branching time and thus was more utilized by the plants.

Nitrogen fertilizer application also had significant effects ($P<0.05$) on chickpea grain yield (Table 1). The 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 the long rain seasons. During the short rain season, increasing nitrogen application rates also increased grain yield. 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. Hosseini *et al*. (2003) and Suresh (2004) reported average grain yields of 2,501.9 and 2,878.3 kg/ha respectively, under plant population density of 460,000 plans/ha. A similar finding was reported by Akram *et al*., (2004) who said that chickpea yield increased with increase in the fertilizer rates. Nitrogen fertilizer application beyond 35 kg N/ha caused a declined in the grain yield.

Grain yields for the long rain season were higher than for the short rain season by 1,150(104.6%); 783.18(49.9%); 915.72(55.2%) and 489.35(29.2%) at 0, 20, 40 and 60kgN/ha rates, respectively. This could probably be due to higher and better distribution of rainwater (237.6mm) in the long season, as compared to 216.6mm in the short season.

Chickpea seed yield was reported by Lopez *et al*. (2004) to strongly depend on rainfall during flowering and seed filling stages. This is corroborated by the work of Arora *et al.*, (2003) who reported that biological yield had the highest significant positive relationship with chickpea seed yields at the semi-arid conditions of Central Andra Pradesh. Indeed, chickpea has been reported not to fully supply its N needs through atmospheric fixation (Lopez *et al.*, 2004). Therefore, 30 kg N/ha would be sufficient to obtain 2.33 to 2.57 tons grain/ha depending on available rainwater. That shows that higher yields are likely to be obtained when sufficient rainfall (over 210mm) is received during and after branching stages of chickpea.

Table 1: Effect of nitrogen fertilizer on dry matter (kg/ha) and grain yield (kg/ha) of chickpea in Naivasha, Kenya during the long and short rain seasons in 2005.

Levels of nitrogen fertilizer (kg/ha)	Dry matter		Grain yield	
	Long rains	Short rains	Long rains	Short rains
0	3122[d]	2594[d]	2149.5[b]	1099.5[b]
20	3583[c]	3212[c]	2353.71[ab]	1570.5[a]
40	4465[b]	3356[b]	2574.4[a]	1658.6[a]
60	5063[a]	4369[a]	2165.1[a]	1675.7[a]
SED	88.9	44.6	120.4	72.9
LSD	181.6	91.2	246	148.7
CV (%)	7.78	4.6	17.9	16.8

Plant population density had significantly different effects (P<0.05) on chickpea dry matter yield (Table 2). At final harvest (120 DAS), the maximum dry matter produced ranged from 3,429 to 4,689kg/ha in the long rain season and 2,955 to 3,854kg DM/ha in the short rain season under 74,074 to 148,148 plants/ha, respectively. 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 plant population density from 74,074 to 148,148 produced significantly (P<0.05) higher dry matter (at 120 DAS) by 26.7% and 23.3% in the long and short seasons, respectively. This was an 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. Arora *et al* (2003) and Roval *et al.* (2003) reported that the number of 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 photosynthetically active radiation (PAR).

Relationships of planting population density to dry matter yield at all stages of plant growth were found to be linear. In the first season, chickpea dry matter production (g/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. In the short rains season, the DM produced 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 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. This is in tandem with earlier studies by Ayaz *et al.* (2004) who stated that increased planting population densities (PPD) leads to 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.

Plant population density also had significant differences (P<0.05) on chickpea grain yield (Table 2). At harvest (120 DAS), grain yields ranged from 1,273.8 to 3,271.2 kg/ha in the long rain seasonand 1,027.4 to 1,994.2kg/ha in the short rain season, under 74,074 to 148,148 plants/ha, respectively. Increasing planting population densities from 74,074 to 148,148 produced significantly (P<0.05) higher grain yields by 24.0% and 64.0% in the long and short rain seasons, respectively. 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.

The highest percentage increase (65.8%) was on pods/ m^2. In concurrence, Gan *et al.* (2003) reported that seed yield potential of desi chickpea could be increased by increasing planting population to produce more pods per unit area, whereas 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 the short rains season, 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% for the 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 grain yields in the long rain season were higher than in the short rain season, probably due to higher and well-distributed rainfall during the former. 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.

Table 2: Effect of plant population density on dry matter (kg/ha) and grain yield (kg/ha) of chickpea in Naivasha, Kenya during the long and short rain seasons in 2005.

Levels of Plant Population (plants/ha)	Dry matter		Grain yield	
	Long rains	Short rains	Long rains	Short rains
P1	3428^d	2954^d	1273.8^d	1027.4^d
P2	3822^c	3186^c	2079.2^c	1300^c
P3	4294^b	3537^b	2718.2^b	1682.8^b
P4	4688^a	3854^a	3271.2^a	1994.2^a
SED	85.9	39.6	110.4	68.9
LSD	171.6	81.2	236	138.7
CV (%)	7.18	4.1	16.9	15.8

An interaction of nitrogen fertilizer rates and plant population on chick pea caused a significant ($P<0.05$) increase in dry matter (Table 3). Dry matter and grain yield increased as either fertilizer level or plant density increased. A similar trend has been reported by Roval and Doboriya (2003).

Table 3: Interaction effects of nitrogen rates and plant population density on dry matter of chickpea at harvest.

Plant population level (plants/ha)	Nitrogen Levels (kg/ha)			
	O	20	40	60
P1	2814.8^a	3437^a	3500^a	3962^a
P2	3164a^b	3568.8^{ab}	4022a^b	4533^b
P3	3238.8^c	3616.6^b	4527^c	5794^c
P4	3270.3^c	3711.1^b	5811^d	5962^c
SED	177.9			
DMRT	513.8			

In regard to nitrogen fertilizer application, there were higher harvest indices of chick pea in the long rain season than in the short rain season (Fig. 1). This was attributed to lower biomass (DM) during the later stages of growth. For instance at 90 DAS the DM was 7.5 kg DM/kg N/ha in the long rain season compared to 11 kg DM/kg N/ha in the short rain season. At 105 DAS the increase of dry matter per kg N/ha were18 and 19 for the long and short rain seasons, respectively. This is probably explained by the higher precipitation during the long rains (237.6 mm) compared to 176.6 mm for the short rains. This result agrees with that of Kumar *et al.* (2004) indicating that chick pea seed yield under moisture stress significantly lowered biomass production.

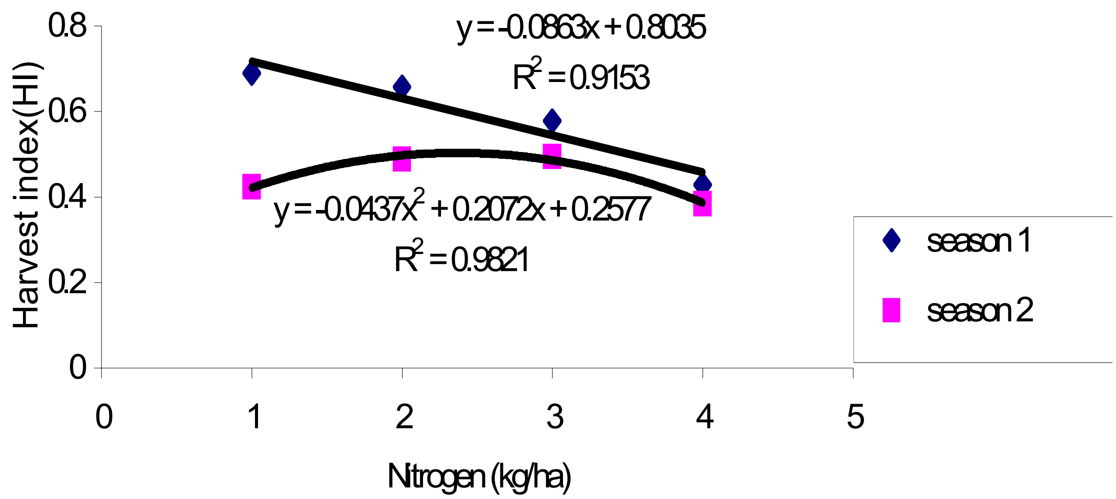

Figure 1: Effect of nitrogen (kg/ha) on harvest index (HI) of chickpea in the long and short rain seasons in 2005 at Naivasha, Kenya.

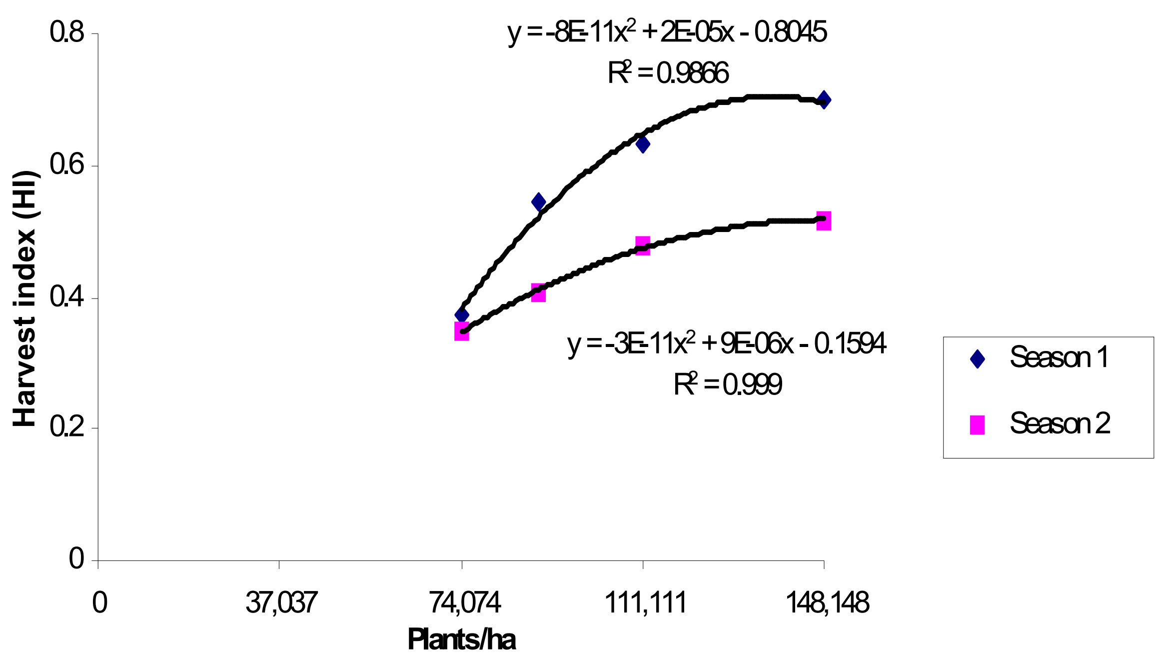

Figure 2: Effect of chickpea planting density on the harvest index in the long and short rain seasons in 2005 in Naivasha, Kenya.

There was a curvilinear relationship of planting density and harvest index of chick pea (Fig. 2). Harvest indices increased with increase in planting density peaking at approximately 130 000 plants/ha. Beyond this point, there was flattening out and then a decline.

CONCLUSION

Increases in fertilizer rates and plant population increased dry matter and grain yield. Increasing nitrogen doses lowered the harvest index (HI), whereas an increase in plant population density increased the harvest index (HI). Based on these results, for maximum chickpea yields, the optimal combination would be N fertilizer application at about 32.5 kg/ha and a density of 130 000 plants/ha.

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