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Production Potential of Desi Chickpea Grown under Various Nitrogen and Planting Densities at Naivasha

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Abstract: The erratic nature of rainfall in the Kenyan semi arid highland regions, such as Naivasha, coupled with the high dependency on maize grain, usually results in relatively low and unstable yields. Chickpea is mainly cultivated as a rain-fed crop and water stress often affects both productivity and yield stability. Potential seed yield has been reported not to exceed 1.5 t ha^{-1} in other countries but information on optimum nitrogen and Plant Population Density (PPD) has not been developed for Naivasha region. Therefore, a desi chickpea variety ICCV 97105 was grown in two seasons at NAHRC, KARI (Naivasha). Viz., February 27th-June 24 and June 30th to Oct 26th of 2005; in a RCBD with 4 levels of nitrogen (0; 20; 40 and 60 kg N^{-1}) and 4 planting densities (i.e., 74,074; 89,889; 111,111 and 148,148 seeds ha^{-1}). Maximum above ground biomass obtained was 5.06 and 4.37 tones ha^{-1} for the first and second seasons, respectively. Application of 60 kg N^{-1} produced 62 and 68% more biomass (DM) than the no N application treatment. The curvilinear response of above ground biomass to added levels of N with high coefficients of 0.944 and 0.989 in respective seasons signifies the possibility of increasing further chickpea biomass. Maximum grain yields were 2.57 and 1. 66 t ha^{-1} in season I and II, respectively, a difference of 54.8%. This was attributed to the higher rainfall of 235 mm received in Season I as compared to 176.8 for season II, a difference of 76.2 mm water. The response of above ground biomass and grain yield to increasing PPD was found to be linear with very high regression coefficients of over 0.993 in both seasons. This revealed the strong dependency of chickpea grain yields on PPD. Harvest Indices (HI) ranged between 0.42 and 0.72. Application of 20 kg N^{-1} produced a HI of about 0.6 and 0.5, in seasons I and II, respectively. Increase in planting population up to approximately 105,000 plants ha^{-1} was observed to increase the harvest index of chickpea to over 0.6 and 0.41 in seasons I and II, respectively. Further increase in plant density beyond 110,000 plants ha^{-1}, however caused a decline in the rate of increase in HI of chickpea. Chickpea can be successfully grown in Naivasha during February to June and June to October seasons. Further research work is however, recommended with the aim of determining chickpea productivity under higher PPD, various watering regimes and agro-ecological environments.

Key words: Chickpea, planting population density, nitrogen, yield, regression

INTRODUCTION

Globally, amongst the cool-season food legumes, chickpea occupies the highest area of over 12 million hectares, which collectively contribute approximately 60% of the world pulse production in an area of about 28 million ha (Prasad, 2002). Over 50% of all chickpea grown in Africa are grown in Ethiopia on about 212,000 ha. Chickpea has been found to be a useful crop when grown to occupy cereal fallow that used to lie idle in South Asian countries and Ethiopia. In Bangladesh's Barind tracts, farmer's income has been doubled. In Ethiopia, it is exported to Pakistan, India, Dubai and Afghanistan, where demand is found to outstrip supply by far (ICRISAT Annual Report, 2002).

Chickpea is mainly cultivated as a rain-fed crop and water stress often affects both productivity and yield stability (Kurdali, 1996). The erratic nature of rainfall in the Kenyan semi arid highland regions, such as Naivasha, coupled with the high dependency on maize grain, usually results in relatively low and unstable yields. Kumar and Abbo (2001) report that potential seed yield does not exceed 1.5 t ha^{-1}. This yield potential is better than the average obtained from maize grown in Kenyan dry lands. Intensifying and diversifying from the maize bean inter-cropping system by use of short season legume crop like chickpea would provide rotational benefits such as N fixation, increased soil organic matter and increased surface soil stability; as well as alleviate monoculture insect, disease and weed problems (Power, 1987).

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Information on optimum nitrogen and Plant Population Density (PPD) has not been developed for Naivasha region. Preliminary results on chickpea adaptation trials in Njoro had however indicated that the optimum PPD was approximately 90,000 plants ha^{-1} (unpublished). Generally, spring-sown chickpea displays considerable annual variations in biomass; seed yield and yield components. The maximum biomass yield does not usually reach 7 t ha^{-1} and seed yield ranges from 0.6-3 t ha^{-1}. Harvest index also varies substantially, with mean values ranging between 35 and 60%; values tend to be higher in desi than in kabuli chickpeas in winter sowing (Khanna and Sinha, 1987; Saxena, 1987; Marcellos *et al*., 1998; Carranca *et al*., 1999). Pods per plant is the most influential yield component and the most closely correlated with seed yield.

Therefore, a trial was conducted on a loamy soil at the National Animal Husbandry Research Center, (NAHRC), Naivasha, to evaluate the production potential of a desi chickpea variety 97105, under varying nitrogen rates and planting densities.

MATERIALS AND METHODS

A desi chickpea variety ICCV 97105 was grown in two seasons at NAHRC, KARI (Naivasha). Viz., February 27th-June 24 and June 30-Oct 26th of 2005; in a RCBD with four levels of nitrogen (0; 20; 40 and 60 kg N^{-1}) and four planting densities (i.e., 74,074; 89,889; 111,111 and 148,148 $seeds^{-1}$). A rainfall of 235 mm and 176.8 mm was received (Fig. 1) in seasons I (Feb-Jun 2005) and II (Jun-Oct 2005), respectively. Irrigation water of 70 mm was given 14 days after planting in both seasons to supplement the rainfall. Total soil N was sufficient at 0.27%. Periodic dry matter during plant growth and grain yield data was taken, then analyzed using MSTATC and means separated by DMRT ($p \le 0.05$). Linear and quadratic regressions were performed by use of Microsoft excel program on all above ground biomass and grain yield data collected to determine production functions (nitrogen-yield and planting density-yield). The best functions were fitted on data to explain the relationships of nitrogen or Planting Population Densities (PPD) with dry matter and grain yields.

RESULTS AND DISCUSSION

Biomass production potential of chickpea under varying nitrogen levels: Maximum above ground biomass obtained was 5.06 and 4.37 $tones^{-1}$ for the first (February to June 2005) and second (June to October 2005) seasons, respectively (Fig. 2). The above ground biomass yields increased from 2595 and 3122 kg^{-1} under no N application to 4369 and 5063 kg^{-1} under 60 kg N^{-1} in seasons II and I, respectively: an increase by 62 and 68% over the no N application, respectively. The biomass yields were in agreement with those reported earlier by Lopez *et al.* (2004) which did not exceed 7 tons ha^{-1} for the Mediterranean region.

Biomass yields from season I was higher than that obtained from season II by 20.3% at 0 kg N^{-1} and 15.9% at 60 kg N^{-1} levels. The higher yields obtained for season I could be attributed to the higher total rainfall of 235 mm received over the Feb-June season as compared to that received (176.8 mm) in the second Jun-Oct season. Above ground biomass production was reported also correlate positively with rainfall during chickpea's growth period (Lopez *et al*., 2004) in the Mediterranean region of Spain, showing a maximum yield at about 400 mm and a drop in yield when rainfall exceeded this figure.

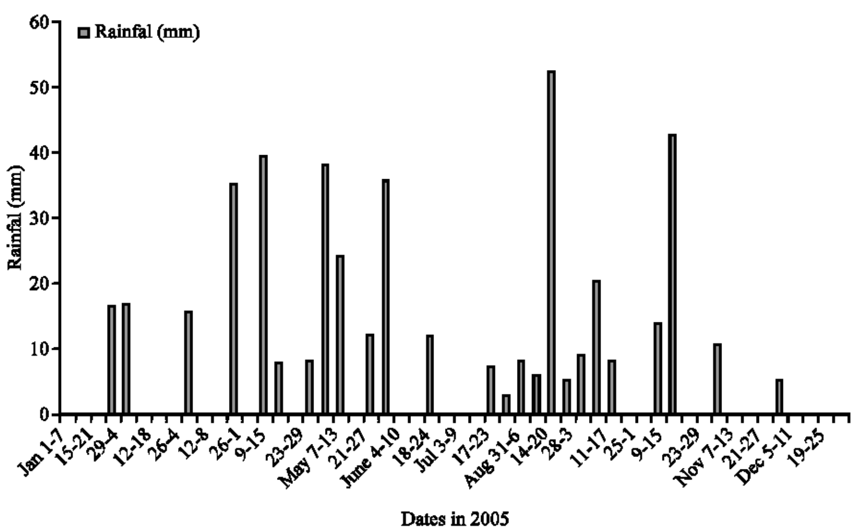

Fig. 1: Meteorological weekly rainfal (mm) for the year 2005

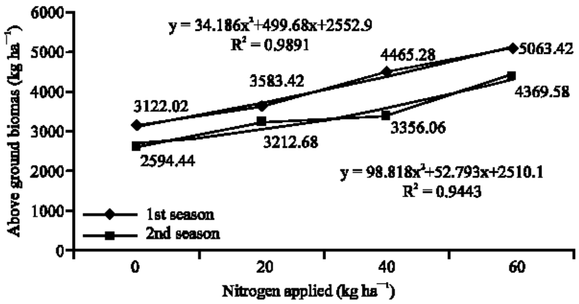

Fig. 2: Effect of nitrogen on total above ground biomas of chickpea (kg ha^{-1}) at harvest in seasons I and II at Naivasha

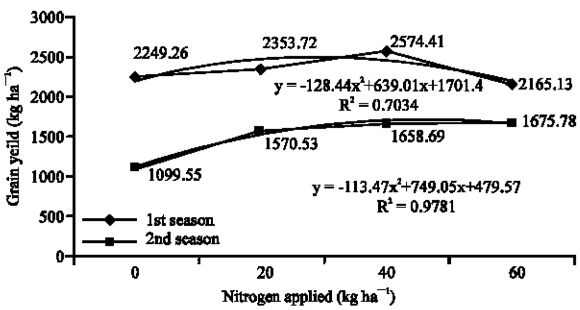

Fig. 3: Effect of nitrogen on the grain yeild of chickpea (kg ha^{-1}) in season 1 (Feb-May 05) and II (Aug-Nov 05)

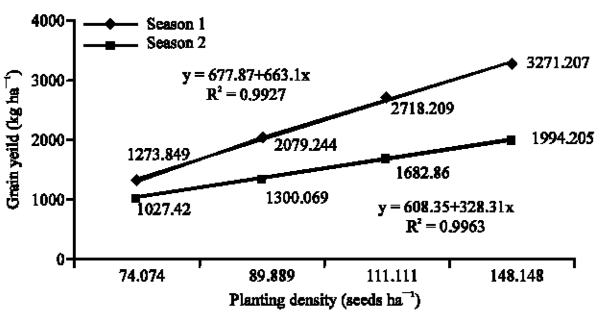

Fig. 4: Effect of planting density on grain yeild (kg ha^{-1}) of chickpea in seasons I and II

The response of above ground biomass could be explained by quadratic equations with regression coefficients of 0.944 and 0.989 for season I and II, respectively (Fig. 2). The curvilinear response of above ground biomass to added levels of N implies the possibility of increasing further chickpea biomass. Therefore, the production potential of chickpea biomass can be enhanced by adding higher rates of N levels and providing more water during its growth at Naivasha.

Grain yield production potential of chickpea under varying nitrogen levels: Maximum grain yields were 2.57 and 1.66 tones^{-1} in season I and II, respectively, a difference of 54.8%. This was probably because Season I received higher rainfall (235 mm) than season II (176.8 mm) (Fig. 1). The production potential of chickpea grain yield was probably limited by rainfall because grain yield of chickpeas has been found to correlate significantly with total rainfall received during crop growth (Dalal *et al*., 1997; Miller *et al*., 2002).

The response of grain yield production to added N levels however, revealed a peak grain yield at approximately 20-30 Kg N^{-1} in sowing I (235 mm rainfall) and 40-50 Kg N^{-1} rates in season II (177 mm rainfall) (Fig. 3). This may imply that under higher rainfall regimes, utilization of available N is enhanced and therefore even lower N application levels would be sufficient in enhancing optimum grain yield production by chickpea, within it's growing environmental limits. Lopez *et al.* (2004) however, reported that seed yield was maximized with around 390 mm rainfall over the growth period in the Mediterranean region of Spain. Within the environmental (rainfall) limits of our present study, it was evident (Fig. 3) that further increments of N levels resulted in a decline in grain yields from both seasons. The quadratic functions could account for 70.3 and 97.8% of the variations for seasons I and II data, respectively (Fig. 3); which was lower than that observed with respect to nitrogen effects on above ground dry matter (Fig 2). These high coefficients show the reliability of these functions in explaining the relationships. Therefore, increasing water availability, either through irrigation or growing in higher rainfall environments can enhance the biomass and grain yield production potential of chickpea, as well as increase the utilization efficiency of total soil N. Further work aimed at investigating this is therefore recommended.

Chickpea biomass and grain production potential relationships under varying planting densities: Maximum grain yields by chickpea (Fig. 4) under varying planting population densities for season I and II were 3.27 and 1.99 t ha^{-1}, respectively.

The response of above ground biomass (Fig. 5) and grain yield (Fig. 4) to increasing planting density was found to be linear with very high regression coefficients of over 0.993 in both seasons. This reveals the strong dependency of chickpea grain yields on plant population density and also signifies the high dependability of these production functions in predicting yields. These relationships reveal that increasing planting population

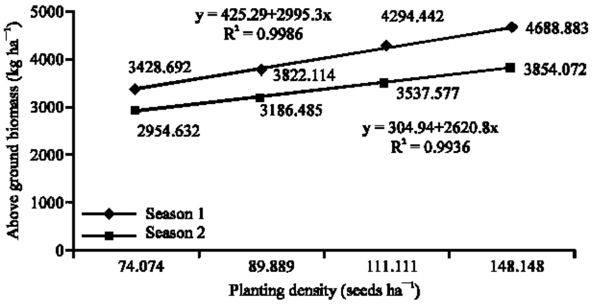

Fig. 5: Effect of planting density on above ground biomass (kg ha^{-1}) of chickpea in two seasons

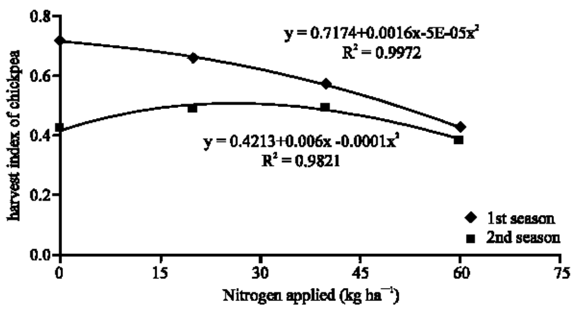

Fig. 6: Effect of nitrogen on harvest index of desi chickpea in two seasons

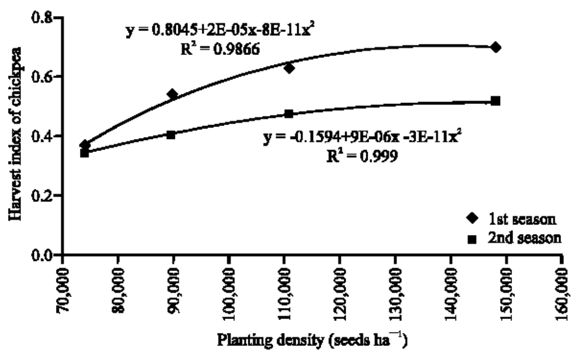

Fig. 7: Effect of planting density on the harvest index of desi chickpea in two seasons

density from 74,074 plants^{-1} (7.4 plants m^{-2}) to 148,148 plants^{-1} (14.8 plants m^{-2}), increased biomass and grain yield production (Fig. 5). Rate of increase of Dry Matter (DM) biomass production per unit plant increase in a hectare was estimated to be 17 kg DM/plant^{-ha} and 12.1 kg DM/plant^{-ha} in seasons I and II, respectively. This translates to 17 and 12.1 g DM m^{-2}, respectively, which was much lower than that reported by Ayaz *et al.* (1999) who noted that Chickpeas produced from 430-869 g DM m^{-2} as population increased.

Grain yield production (Fig. 4) increased from 1274-3271 in season I and 1027 to 1994 kg grain^{-ha} in season II. As plant population increased from 74,074-148,148 plants ha^{-1}, grain yield increased by 156.7 and 94.2%, in seasons I and II, respectively. The higher rate of increase estimated at 26.96 kg grain/plant^{-ha} from season I compared to 13.05 kg grain/plant^{-ha} in season II can be attributed to the higher rainfall received in season I that exceeded that of season II by about 60 mm of rainwater. Similarly, Liu *et al.* (2003) concluded that in the semiarid northern Great Plains of Canada, seed yield potential of desi and small-seeded kabuli chickpea can be increased by increasing plant population density, whereas the seed yield of large-seeded kabuli can be improved by increasing percentage pod fertility. As plant population increased from 20-50 plants m^{-2}, the seed yield m^{-2} increased by 20% for desi and 27% for small-seeded kabuli, but only 17% for the large-seeded kabuli chickpea. Gan *et al.* (2003) reported that the Planting Population Density (PPD) that produced the highest seed yields in Saskatchewan, Canada (ranged from 40-45 plants m^{-2} for kabuli and 45-50 plants m^{-2} for desi chickpea and from 75-80 plants m^{-2} for dry pea. When the legumes were grown on wheat stubble, the PPD that gained optimum seed yield ranged from 35-40 plants m^{-2} for kabuli chickpea, from 40-45 plants m^{-2} for desi chickpea and from 65-70 plants m^{-2} for dry pea. Hussain *et al.* (1998) concluded that higher plant populations increased both the total dry matter and the seed yield due to higher radiation interception and utilization.

These results show the degree to which desi chickpea production potential can be enhanced at Naivasha by simply increasing the planting population density and water regimes. Further research on effects of planting population densities and water regimes on the productivity of desi chickpea is therefore recommended.

Effects of nitrogen and planting density on harvest index: The harvest indices ranged between 0.42 and 0.72, with the higher HI resulting from the firs Feb-Jun season which had more rainfall especially in the later stages of crop growth (Fig. 1). It was noted that a substantial amount of rain (over 100 mm or 40%) fell over the pod formation and grain filling stages (May-June) in season I, which would have led to the higher HI. In the June-Oct season however, this growth phase was accompanied by a dry spell, which led to enhanced maturity and thus, the lower HI. The rains that fell in the last week before harvest i.e., late October were considered not effective. Khanna and Sinha (1987) Saxena (1987) Marcellos *et al.* (1998) and Carranca *et al.* (1999) noted stated that harvest index also varies substantially, with mean values ranging between 35 and 60%; values tend to be higher in desi than in kabuli chickpeas in winter sowing. Ayaz *et al.* (2004) also noted that in chickpea, HI was affected more by population than peas. It was 0.31 and 0.63 at the lowest and the highest population, respectively.

When Harvest Index (HI) data was regressed on nitrogen application rates (Fig. 6) and planting densities (Fig. 7) and fitted with second degree polynomial curves, the coefficients of determination were very high, i.e., R^2 = 0.999 for seasons I and R^2 = 0.982 for season II, respectively. These quadratic curves reveal that even at no N application, HI was over 40%. This was attributed to the high initial inherent soil N found in the soils that was approximately 26% and therefore sufficient for crop growth. For this reason, additional application of N was found to enhance above ground DM production, especially where water was relatively in abundance (as in season I) and thus, permitting higher nutrient uptake and assimilation. Harvest index being a ratio of grain to total biomass production therefore appeared to decline with additional nitrogen application rates (Fig. 6). In an earlier study, Ayaz *et al.* (2004) also reported that increased seed yield in response to increased population was a function of greater total dry matter production and HI. Therefore, application of 20 kg N^{-1} would to provide a HI of about 0.6 and 0.5, respectively, under the prevailing seasons I and II weather conditions. Further additions of N rates, however, would increase the DM and thus, reduce grain: DM ratio, resulting into lower HI.

Increase planting population to approximately 105,000 plants ha^{-1} was observed (Fig. 7) to increase the harvest index of chickpea to over 0.6 and 0.41 in seasons I and II, respectively. Further increase in plant density beyond 110,000 $plants^{-1}$, however caused a decline in the rate of increase in HI of chickpea. It may be inferred that increase in PPD beyond $110{,}000^{-1}$ caused the DM assimilates to be diverted to biomass production in the initial stages of crop growth, which ultimately resulted in lowering grain yield accumulation in the later stages of crop growth. Thus, HI appeared to decline with increasing PPD in both seasons. It might be worthwhile studying the effects of split application of N fertilizer on the assimilate partitioning in chickpea when grown under varying PPD.

CONCLUSION

Chickpea can be successfully grown in Naivasha during February to June and June to October seasons.

Grain yields would range from 1.994 and 3.271 tones ha^{-1}. This would give an average of 2.633 tones grain ha^{-1} per season when grown with 30-40 kg N^{-1} and at planting densities of over 148,000 plants ha^{-1} (i.e., 40×15 cm spacing).

Relationship of nitrogen application to above ground biomass (DM) and grain yield were curvilinear, with high predictability values of over 90%.

Additional nitrogen rates increased biomass production progressively: Whereas, with regard to grain yield production, maximum yields were reached with N application rates ranging between 30 and 40 kg N^{-1}. Beyond this N was used to increase biomass at the expense of grain yields. Thus, grain yield and consequently harvest index declined.

Relationship of planting density with above ground biomass and grain yield was linear. Therefore, increasing the planting population density can further increase biomass production and grain yield.

Thus, regression analyses are useful tools that assist us understand growth and yield relationships for chickpea cultivars under varying agronomic practices. Further research work is therefore, recommended with the aim of determining chickpea productivity under higher PPD, various watering regimes and environments. The use of the production functions in prediction of chickpea growth and yield in various agro-ecological zones of Kenya would prove worthwhile in our future adaptation trials and technology transfer.

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