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ABSTRACT
Common bean (*Phaseolus vulgaris L.*) is an important food crop in Kenya but its productivity in the semi-arid areas is limited by low soil fertility. Although beans obtain nitrogen derived from atmospheric fixation, they still require external supply of nitrogen at the early stage of establishment for maximum production. Assessment of three bean varieties (GLP 585, GLP 1004 and Pinto) was carried out at Longonot for two years between 2003 and 2004 to evaluate the crop yield and water use efficiency in response to nitrogen fertilizer application. The experimental design was a randomized complete block laid out as split plot and replicated three times. Phosphorus was applied as basal fertilizer in form of triple superphosphate at planting at the rate of 18 kg P/ha. Nitrogen was applied in form of Urea at the rate of 0 and 18 kg N/ha and was applied in two equal splits at 20 and 40 days after crop emergence. Fertilizer application was main plots while bean varieties were sub-plots. There was no significant difference in bean yield amongst the varieties, but there was significant difference in yield between seasons. There was no significant yield response to nitrogen fertilizer in all the seasons due to inadequate rainfall that was poorly distributed. The bean crop was harvested in three out of four seasons. In the season with the lowest rainfall of 189 mm, there was harvest of beans because the rainfall was well distributed within the growing season.

Key words: Bean yield, nitrogen fertilizer, semi-arid, Kenya

INTRODUCTION
One of the greatest challenges in Kenya is to produce enough food to feed the increasing population, which has been growing at 2.5 % per annum (Shiluli et al., 203). The population pressure in the limited high rainfall areas has led to migration of people to the arid and semi-arid lands (ASALs) in search for land to settle and produce food. When people migrate to the ASALs, crop cultivation is a priority in order to meet the food requirements for the family. Beans are the most commonly grown food crops by majority of people in Kenya. The common bean (*Phaseolus vulgaris L.*) is the leading legume in both production and consumption in Kenya (Martis, 1989). The annual production capacity is approximately 42,000 tons. The average yields range between 500 to 800 kg/ha (Muigai and Ndegwa, 1991), which is far below the potential production of 2 t/ha
Beans require less water than maize and therefore suitable in spreading the risk of crop failure in the ASALs (Stewart and Faught, 1984).

Under rainfed conditions, planting just before the onset of rains would guarantee crop harvest because of early establishment and growth before the period of moisture stress. Limited soil moisture and low crop yields discourage widespread use of fertilizer in the ASALs (Vlek et al., 1981). However, with an ever-increasing demand for food, the potential of the drylands will need to be exploited to the fullest (FAO, 2005; Too and Onkware, 2002). With the introduction of drought tolerant crop varieties, fertilizer nitrogen has been used in an attempt to increase crop yield (Novoa and Loomis, 1984). The yield increase depends on the amount of soil water available at the time of fertilizer application (Nadar and Faught, 1984; Muli et al., 2000). Nitrogen fertilizer promotes rapid leaf growth early in the season, thereby covering the soil surface and reducing evaporative losses (Gregory, 1989). Nitrogen is depleted from the soil at the rate of 40-100 kg/ha/year through various ways such as crop uptake, volatilization, leaching, wind and water erosion. There is therefore need for its replenishment (Sombroek et al., 1982; Vlek et al., 1981; Rao and Muthuva, 2000). With adequate amount of soil moisture, yield response to nitrogen is significant. However during severe drought, fertilizer application may result in reduced yields (Wild, 1988).

Although beans can form nitrogen fixing symbiotic association with various rhizobia, they still require external supply of nitrogen at the early stage of establishment for maximum production (Simmonds et al., 1999). The results by Too and Onkware (2002) shows that bean varieties GLP 1004 and GLP 585 could achieve good yields without fertilizer and thus suitable cultivars for ASALs (Maina et al., 1997).

Water use efficiency is defined as the amount of dry matter produced per unit of water lost in both transpiration and evaporation (Sinclair et al., 1984). It is difficult to determine crop transpiration accurately under field conditions. Most research has therefore tended to describe water use efficiency on the basis of evapotranspiration (ET). This can, with assumption be deduced from changes in the soil water profile (Bolton 1981; Pilbeam et al., 1995). The balance of water loss may be altered in favour of transpiration, by reducing losses through evaporation from the soil surface and drainage (Steiner, 1994). The choice of crop may also influence effective water use because of species differences in both root and shoot growth (Brown et al., 1987; Brown et al., 1989). Due to limited water availability in the ASALs the main focus in crop production is on the efficiency with which water is used (Gregory et al., 2000). The crop that uses water most efficiently will be the one best adapted to ASALs (Gregory, 1988). Much of the rainwater received in the ASALs is inaccessible to the crop due to poor rainfall distribution and losses through runoff, drainage and surface evaporation (Rockstrom et al., 1999; Malin et al., 2001). Water use efficiency can be improved by increasing soil moisture storage and reducing evaporation losses, planting better adapted crop varieties and improved agronomic practices (Shangguan et al., 1999; Mahmoud and Chalavi, 2004).

This research was aimed at evaluating the response of common bean (Phaseolus vulgaris L.) to nitrogen fertilizer under semi-arid environment in relation to the rainfall amount and distribution, for increased crop yields. The main objective of the research was to evaluate the performance of selected bean varieties at Longonot. The specific research objectives were to:

i. Evaluate the crop yield and water use efficiency in beans.
ii. Evaluate the yield of bean varieties under conditions of no nitrogen fertilizer and with nitrogen fertilizer in the semi-arid environment.
MATERIALS AND METHODS

Field experiments were carried out for two years at farmers’ fields in Longonot, which has an average annual rainfall of 630 mm received in two rainy seasons. Short rains come in October – December, while the long rains come in March – May period. The long rains are more reliable than the short rains in terms of amount and distribution (Fig1). The soils are classified as Ando-CalcericRegosols and are shallow to moderately deep, 20-100 cm and are well drained. They are developed from volcanic ash and are highly susceptible to wind and water erosion, when vegetation cover is removed.

Longonot is a semi-arid area where people migrated in the 1970s from high rainfall areas in central province. When people settled in the area, the land use was changed from purely grazing to cultivated agriculture. Due to the low and poorly distributed rainfall, farmers have been experiencing frequent crop failure, inadequate food supply and low income level.

Three bean varieties were used for performance evaluate. The three bean varieties tested were Red Haricot commonly known as Wairimu (GLP 585), Mwezimoja (GLP 1004) and Mwitemania (Pinto). The experimental design was randomized complete block laid as split plot and replicated three times. Nitrogen fertilizer was applied to the main plot while bean varieties were allocated to the sub-plots. The sub-plots were 5 m by 4 m and spacing was 45 cm by 10 cm between and within rows, respectively. Two seeds per hole were planted and later thinned to one plant, resulting in a population of 110,000 plants/ha. Phosphorus was applied at the time of planting as a basal fertilizer in all research plots as triple superphosphate (TSP) at the rate of 18 kg P/ha to supplement phosphorus. Nitrogen fertilizer was applied to the main plots as urea (46 % N) at 0 and 18 kg/ha. The application was done in two equal splits as side dressing soon after rains at around 20 and 40 days after emergence.

Cumulative dry matter was determined by harvesting four plants per plot at fifteen-day intervals after emergence. The fresh weight was recorded and a sample of chopped plants was dried in the oven at 80 °C for 24 hours to a constant weight. The grain yield was determined by harvesting one square metre at the middle of the plot in all the plots. The bean seeds were separated by hand and the seed dry weight was adjusted to 12 % moisture content. Water use efficiency was calculated by dividing the total grain or seed yield (kg/ha) by the total rainfall received during the entire cropping period (Bolton, 1981). The data was analysed using Genstat version 6.1. Analysis of variance (ANOVA) was done and the means separated using least significant difference (LSD). The coefficient of variation (CV %) was used as an indicator of error variance due to soil or other differences within the research site (Kelly et al., 2001). Since it is impossible to control all variability, a CV value of 10 % or less implies excellent error control and is reflected in lower LSD values (Steel and Torrie, 1981).

RESULTS AND DISCUSSIONS

Within the two years of field research, planting of beans was done in four seasons, short rains; October 2002-February 2003, October 2003-February 2004, and long rains; March-September in 2003 and 2004. Beans were harvested in three seasons; one short rain season (2002/2003) and the two long rain seasons (2003 and 2004). The short rain season of 2003/2004 was a total crop failure and the crop dried within 20 days after emergence due to inadequate rainfall (Fig 2 and Fig 3).
Rainfall analysis at Longonot indicated that the highest amount of rainfall was received within the first month of bean crop development. Bean is a short duration crop and mostly matures in two and a half months. Bean growth was divided into two major phases, phase (I) before 50% flowering, which was mainly vegetative growth and the reproductive phase (II) after 50% flowering up to full maturity. About 80% of seasonal rainfall in both 2003 and 2004 was received before 50% flowering, while 20% was received after 50% flowering. In the three seasons that beans were harvested (SR 2002, LR 2003 and LR 2004), the crop experienced water stress at around flowering or just immediately after 50% flowering. This is a critical stage that determines the final yield (Fig 4). Although there was no significant difference \( (P \leq 0.05) \) in phenological changes among the varieties, GLP 1004 had a longer flowering period and matured earlier than the two other varieties. It also emerged slightly earlier after sowing than the other varieties (Table 1). Total dry matter (TDM) yields of the three bean varieties increased from emergence and reached maximum at physiological maturity. The increase was almost linear during the vegetative phase and at diminishing rate during the reproductive phase (Fig 5).

Bean crop was harvested for three seasons (SR 2002/2003, LR 2003 and LR 2004) out of four. There was total crop failure in one short rain season (October 2003-March 2004) due to very low seasonal rainfall (201 mm). Pinto had the highest yield in all the three harvested seasons compared to the two other varieties. There was significant difference \( (P \leq 0.05) \) in yield between GLP 1004 and GLP 585 (Table 2).

There was positive correlation between seed yield and the amount of total rainfall and between seed yield and rainfall amount before and after 50% flowering. This implies that there was variation of seed yield due to rainfall distribution. The highest variation was due to rainfall after 50% flowering, which is the reproductive phase. The total rainfall and the amount before 50% flowering had almost the same influence on yield variation (Fig 6). The critical period of high crop water requirement was after 50% flowering where the water stress during this period would lead to low yields. The seed yield would almost double \( (4 \text{ kg ha}^{-1} \text{ mm}^{-1}) \) with more rain after 50% flowering than the total seasonal rainfall or rain before 50% flowering.

There was no significant difference \( (P \leq 0.05) \) in yield response to nitrogen fertilizer application in all the three harvested seasons (Fig 7), due to insufficient rainfall that was 205 mm, 504 mm and 189 mm in SR 2002/2003, LR 2003 and LR 2004 respectively.

**CONCLUSION**

There was no significant yield response to fertilizer application at Longonot due to low and poorly distributed rainfall. Water availability was therefore more critical in yield increase than fertilizer application. Water harvesting technology like tied ridges would increase soil moisture storage and hence crop yields.

There was no significant difference in phenological changes amongst the bean varieties. Flowering for all the varieties was within one month after emergence. Bean is a short duration crop and the chance of harvesting a crop was higher than for maize that takes longer to reach physiological maturity. The seed yield among the varieties was not significantly \( (P \leq 0.05) \) different and so the choice of varieties would depend on farmers’ preference.

The amount of soil moisture and its distribution was a more critical factor in yield response than fertilizer application. Bean crop has high probability of getting harvest because it reaches reproductive phase before soil moisture is heavily depleted. The soil water demand of beans is also lower than that of maize.
ACKNOWLEDGEMENTS

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Fig 1. Long-term (39 years) monthly rainfall distributions and open pan evaporation during short and long rain seasons at Longonot.
Fig 2. Rainfall distribution (5 day totals) during two short rain (SR) seasons in (a) Oct.2002-March 2003 and (b) Oct. 2003-March 2004 at Longonot. Negative sign indicates days before sowing.
Fig 3. Rainfall distribution (5 day totals) during long rain (LR) seasons in April-September (a) 2003 and (b) 2004 at Longonot. Negative sign indicates days before sowing.

Fig 4. Seasonal rainfall distribution and bean growth stages. (Pooled data in LR 2003 and 2004) at Longonot.
Fig 5. Cumulative dry matter yield of three bean varieties in (a) 2003 and (b) 2004 long rain seasons at Longonot. The error bars represent least significant difference (LSD) of means (P<0.05).
Fig 6. Influence of seasonal rainfall distribution on bean yield (a) total rainfall (b) rainfall before 50 % flowering and (c) rainfall after 50 % flowering (pooled data for 2003 and 2004) at Longonot.
Fig 7. Bean yield response to nitrogen fertilizer in (a) short rains 2002/03, (b) LR 2003 and (c) LR 2004 at Longonot. The error bars represent least significant difference (LSD) of means ($P \leq 0.05$). N0 = 0 kg N/ha and N1 = 18 kg N/ha
Table 1. Phenology of three bean varieties in LR 2003 at Longonot.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Days to 50 % emergence</th>
<th>DAE to 50 % flowering</th>
<th>DAE to 50 % podding</th>
<th>DAE to physiological maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLP 1004</td>
<td>7</td>
<td>34</td>
<td>39</td>
<td>67</td>
</tr>
<tr>
<td>Pinto</td>
<td>6</td>
<td>32</td>
<td>39</td>
<td>62</td>
</tr>
<tr>
<td>GLP 585</td>
<td>7</td>
<td>31</td>
<td>39</td>
<td>66</td>
</tr>
<tr>
<td>LSD</td>
<td>1.1</td>
<td>0.65</td>
<td>1.81</td>
<td>1.5</td>
</tr>
<tr>
<td>CV%</td>
<td>10.9</td>
<td>1.3</td>
<td>2.1</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Table 2. Seed yield (kg/ha) of three bean varieties in three seasons at Longonot

<table>
<thead>
<tr>
<th>Variety</th>
<th>SR 2002</th>
<th>LR 2003</th>
<th>LR 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLP 1004</td>
<td>630</td>
<td>493</td>
<td>280.5</td>
</tr>
<tr>
<td>Pinto</td>
<td>925</td>
<td>660</td>
<td>330.1</td>
</tr>
<tr>
<td>GLP 585</td>
<td>705</td>
<td>561</td>
<td>246.4</td>
</tr>
<tr>
<td>LSD</td>
<td>83.1**</td>
<td>69.5ns</td>
<td>34.8*</td>
</tr>
<tr>
<td>CV%</td>
<td>14.2</td>
<td>11.2</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Note: * = Significant difference (P ≤ 0.05)
** = Significant difference (P ≤ 0.01)
ns = not significant
LR = Long rains
SR = Short rains
REFERENCES


http://www.ppi-far.org/far/farguide.nsf


