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EFFECTS OF BIOFORTIFIED FERTILIZER APPLICATION RATES ON PRODUCTIVITY OF SELECTED BEAN VARIETIES UNDER FIELD CONDITIONS IN SEMI-ARID SOUTH EASTERN KENYA

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ABSTRACT

Bean (Phaseolus vulgaris L.) is one of the most important crops in (ASALs) as they provide food and prevent malnutrition among people. However, production has been declining due to low soil moisture which affects absorption of nutrients in the soil. An experiment was carried in field at Kalro-Katumani, to determine the effects of foliar fertilizer application rates on productivity of four commonly grown varieties (Wairimu, Wairimu dwarf, Piriton and KAT B9) in a complete randomized block design. Data was collected on grain yield, biomass yield and harvest index. The data was subjected to analysis of variance (ANOVA) using SAS (version 8.0) to detect differences between treatments. The results showed that grain yield increased with increasing foliar fertilizer application rate. Wairimu had the highest grain yield (1440.87kg) followed by Wairimu dwarf (1367.64kg), Piriton (1364.38kg) and KAT B9 (1195.15kg) produced the lowest yields and were not significantly different from each other. KAT B9 and Piriton had the highest and lowest biomass respectively. Wairimu had the highest harvest index (1.18) followed by Wairimu dwarf (1.05), Piriton (1.09) and KAT B9 (0.93).

Keywords: Micro nutrients, Foliar fertilizer, Phaseolus, Food Security

1. INTRODUCTION

Food security forms an important part of global efforts on development and poverty reduction(Vink, 2012). One billion people are still food hungry despite of enough food being produced in the country (CGIAR, 2011). Kenya still suffers from perennial food shortages even though it is the leading economy in East Africa (GoK, 2011). In Kenya, many types of legumes are grown to alleviate food insecurity problem. The common bean (*Phaseolus vulgaris* L.) is one of the most important legumes in the pulses category and is second only to maize as a food crop in Kenya (Anon, 2010). Compared to cowpeas (*Vigna unguiculata* L.) and green grams (*Vigna radiata*.L), beans occupy the largest acreage in areas where it is grown (Kenya Econominc Review, 2010). Kenya is ranked the seventh largest world producer of dry beans which is the second most important staple food nationally (Kirimi *et al*., 2010) hence having a great relevance to national food security. In spite of its importance, dry bean yields in developing countries are still said to be among the lowest in the world, producing an average of 0.5 tons ha^{-1} (FAO, 2007) compared to 1–2 tons ha^{-1} commonly reported in experimental fields. The low yields of beans in arid areas are associated with moisture stress, soil infertility, pests and diseases (Katungi *et al*.,

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2010). In the semi-arid areas of south eastern Kenya, where rainfall is bimodal, drought is the most serious abiotic factor affecting bean production (Itabari *et al.*, 2004) and it is a challenge affecting beans within and among seasons. Among seasons, the probability of occurrence is 60% (Katungi *et al*., 2010, Mungai *et al*., 2000). Due to poorly structured soils in ASALs, water infiltration is low leading to excessive run-off, low moisture retention and soil degradation. Evapotranspiration rates are 4-6 mm per day (Stewart and Faught, 1984; Anon, 2009). Mid-season rainfall gaps aggravate moisture deficiency in the soil which affects bean growth, development and yield of beans. Deficit in soil moisture (Beebe *et al*., 2013; Miller *et al*., 2003) coupled with deficiency in available nutrients for plants (Wortman *et al*., 2004) constitute major challenge of dry bean production in arid and semi arid areas. Owing to climatic change the problem of low bean production is expected to increase (Beebe *et al.*, 2013; Boko *et al*., 2007). It has become usual for Kenya to import beans as domestic demand outweighs production. The country imports the deficit mainly from Uganda, Tanzania and Central Africa (Waluse, 2012). Macronutrients and Micronutrient deficiencies, a major cause of low bean production in arid and semi arid areas, do occur in soil during the growing season as a result of low absorption occasioned by low moisture content and therefore their unavailability negatively affects crops yield.

Even though nutrients can be supplied directly in soil, lack of sufficient moisture in ASALs limits their uptake after application. Furthermore, other nutrients may be leached, while others may be chemically bound (fixed) by soil components (Sanchez and Uehara, 1980; Slaton *et al.*, 2002). According to Mallarino *et al.* (2005) foliar fertilization at vegetative phase of dry beans increases grain yield by 15 to 30% in the field depending on the year. Therefore, the objective of this study was to evaluate the response of four commonly grown dry bean varieties to foliar fertilizer application in semi arid south eastern Kenya.

2.0 MATERIALS AND METHODS

2.1 Description of the study Sites

The experiment was in Ithookwe Kenya Agricultural and Livestock Organization (KALRO) field substation located at 38° 02’E, 1° 37’S. The elevations for Ithookwe is 1150 and the site has long term annual rainfall of 1010mm in bimodal pattern with long rains (LR) occurring in March to May and the short rains (SR) from October to December with peaks in April in the LR and October in the SR. Mean temperatures are 22.5° C. The dominant soils in both stations are chromic Luvisols, which are deficient in organic carbon and low in N and P and generally have poor structure (NAAIAP, 2014)

2.2 Experimental Design

The experiment was carried out in the field. The beans were sown in thirty six plots each measuring 1.5 by 1.5 meters. Field capacity was determined following the procedure described by Cong *et al*., (2014). Field capacity was used as a reference value to guide on quantity of water required for watering (Rodríguez and Porporato, 2004).Two bean seeds were sown per hill with spacing of 10cm within the rows and 50 cm between the rows and thinned to one plant per hill

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two weeks after germination. The experiment comprised four varieties (Wairimu, Wairimu dwarf, Piriton, KAT B1) commonly planted in the ASALs of south eastern Kenya.. Weeds were removed by hand as they appeared and monitoring for pests and diseases was done throughout the growing period.

Three foliar fertilizer rates (0g/L, 2.5g/L and 5g/L of water) were replicated three times. The composition of the foliar fertilizer was NPK 12:0:0 with 12.8% CaO, 2.6% MgO, 750ppm copper, 1500ppm Iron,750ppm zinc, 750ppm manganese, 105ppm molybdenum,1500 ppm boron. The first foliar fertilizer application was done by the 16th day after germination, second application was done after one week and the third application was done a week after the second application. The fourth and the final foliar fertilizer application was done at early podding stage. Harvesting was carried out at physiological maturity and all yield components dried to constant weight in an oven at 60° C. Total above ground biomass was determined by average weight of dry whole plants cut at soil level following the procedure described by Donald (1962). Pods from each plant in each treatment were removed and separated into empty pod, grain and their weights recorded. The harvest index was calculated by dividing the yield per plant with biomass of the same plant according to procedure described by Donald (1962).

Beans management practices were done through all the vegetative and reproductive phases. These included removing weeds by hand, foliar fertilizer application and close monitoring of pest and diseases throughout the growing period.

2.3 Data analysis

The analysis of variances (ANOVA) of the yield components was done using SAS (version 8.0) where significant F-test was determined and means comparison tests carried out using Least Significant Difference (LSD) at $p \leq 0.05$ to separate treatment means.

3.0 RESULTS AND DISCUSSION

3.1 Effect of foliar fertilizer application rates on Leaf Area Index of different bean varieties

Leaf Area Index (LAI) increased with increase in foliar fertilizer application rate. (Tables 1) Increase in LAI increased with increase in foliar fertilizer application. Overall, Wairimu had the highest LAI compared to all other bean varieties followed by Wairimu dwarf, Piriton and KAT B9.

Table 1: Effect of foliar fertilizer application rates on Leaf area index

	Fertilizer application rates			
Bean variety	**0 mls/L**	**2.5mls/L**	**5mls/L**	**Means**
Wairimu	0.06Ca	0.08Ba	0.09Aa	0.08a
Wairimu dwarf	0.06Ca	0.07Bb	0.08Ab	0.07b
Piriton	0.04Cb	0.05Bc	0.06Ac	0.05c
KAT B9	0.03Cc	0.04Bd	0.05Ad	0.04d

Means	0.05C	0.06B	0.07A
LSD in columns= 0.005 in rows=0.004, C.V= 8.89			

Means in the same row followed by different upper case letters (A, B,C) or in the same column followed by different lower case letters (a, b ,c, d) are significantly different at (P < 0.05) using Fisher's LSD

3.2 Effect of foliar fertilizer application rates on grain yield of bean varieties

Wairimu had significantly (p<0.05) the highest grain yield across all treatments followed by Wairimu dwarf, Piriton, and KAT B9 (Table 2). Increase in grain yield among the bean varieties increased with the increase in foliar fertilizer application rate.

Table 2. Effect of foliar fertilizer application rate on grain yield (kg) per hectare

	Fertilizer application rates			
Bean variety	**0 mls/L**	**2.5mls/L**	**5mls/L**	**Means**
Wairimu	1212.88Ca	1344.71Ba	1765.02Aa	1440.87a
Wairimu dwarf	1197.77Cb	1294.48Bb	1610.66Ab	1367.64b
Piriton	1192.88Cc	1291.82Bc	1608.44Ac	1364.38c
KAT B9	1144.00Cd	1180.88Bd	1260.57Ad	1195.15c
Means	1186.90C	1277.97B	1561.17A	
C.V= 0.55 LSD in columns=1.62; in rows=1.40				

Means in the same row followed by different upper case letters (A, B ,C) or in the same column followed by the different lower case letters (a,b,c,d) are significantly different at (P < 0.05)

3.3 Effect of different application rates of foliar fertilizer on dry biomass production in bean varieties under

Increase in the rate of foliar fertilizer application rate resulted to significant (p<0.05) increase of above ground biomass of bean varieties (Table 3). Overall, KAT B9 had the highest above ground biomass in all levels of treatment followed by Wairimu dwarf, Wairimu and Piriton.

Table 3. Effect of foliar fertilizer application rates on biomass (kg) per hectare

	Fertilizer application rate			
Bean variety	**0 mls/L**	**2.5mls/L**	**5mls/L**	**Means**
KAT B9	1330.80Ca	1389.91Ba	1426.04Aa	1382.25a
Wairimu dwarf	1326.71Cb	1274.66Bb	1322.66Ab	1308.01b
Wairimu	1197.15Cc	1206.35Bbc	1224.88Cc	1209.46c
Piriton	1215.55Cd	1234.22Bd	1260.44Ad	1236.73d

Means	1267.55	1276.28	1308.50
C.V=0.35	**LSD in columns=0.983;**	**in rows=0.85**	

Means in the same row followed by different upper case letters (A, B ,C) or in the same column followed by the different lower case letters (a,b,c,d) are significantly different at (P < 0.05)

3.4. Effect of foliar fertilizer application rate on harvest index of bean varieties under field conditions

Increasing rates of foliar fertilizer application led to significant ($p<0.05$) increase in harvest index of bean varieties (Tables 4). Overall, Wairimu had the highest harvest index followed by Wairimu dwarf, Piriton and KAT B9 (Table 4).

Table 4. Effect of foliar fertilizer application rates on harvest index of bean varieties

	Fertilizer application rate			
Bean variety	**0 mls/L**	**2.5mls/L**	**5mls/L**	**Means**
Wairimu	1.01Ca	1.11Ba	1.44Aa	1.18a
Wairimu dwarf	0.90Cc	1.05Bb	1.21Ac	1.05b
Piriton	0.98Cb	1.04Bb	1.27Ab	1.09c
KAT B9	0.85Cd	0.85Bc	1.09Ad	0.93d
Means	0.94	1.01	1.25	
C.V=1.09	**LSD in columns =0.011; in rows=0.011**			

Means in the same row followed by different upper case letters (A, B ,C) or in the same column followed by the different lower case letters (a,b,c,d) are significantly different at (P < 0.05)

DISCUSSION

4.1 Effect of foliar fertilizer application rates on Leaf Area Index of different bean varieties

The increase in LAI with the increase in foliar fertilizer application rate in the current study may be attributed to synergistic effects of micronutrients and nitrogen in the foliar fertilizer. Werner and Newton (2005) observed that LAI increased with increase in foliar fertilizer application rate. In another study by Chaillou *et al* (2003) found that LAI of bean varieties studied increased with the increase in foliar fertilizer application rate.

4.2 Effect of foliar fertilizer application rates on grain yield of bean varieties

The observed trend of increases in grain yield with foliar fertilizer application rate corroborates findings by Ali *et al.,* (2007) who observed that foliar application of nitrogen increased seed number per pod and consequently grain yield due to the increased concentration of photosynthates in the bean plant. Similar findings were also reported by Schon and Blevins (1990) and Fernández-Luqueño *et al.,* (2010) who observed that the grain yield increased with increasing rates of foliar fertilizer application rate. In a study by Aaid (2012) increase in bean grain yield was attributed to nitrogen foliar fertilizer application. The current increase in grain yield may therefore be attributed to application of foliar Nitrogen fertilizer.

4.3 Effect of different application rates of foliar fertilizer on dry biomass production in bean varieties under

The increase in dry biomass production with foliar fertilizer application rates is in agreement with the findings of Mitova and Stancheva (2013) who reported that biomass production increased with the increase in foliar nitrogen fertilizer application which led to increased vegetative growth among the bean varieties. This was also in agreement with the study conducted by Kushwaha (2001), Kamithi *et al*., (2009) who reported an increase in biomass due to increasing foliar fertilizer application in bean varieties.

4.4. Effect of foliar fertilizer application rate on harvest index of bean varieties under field conditions

The observed trend of the increase in harvest index in the current study could be attributed to nutrient partitioning in the bean varieties studied. According to a study by Urzúa (2005) on beans, an increase in harvest index was due to increase in nutrients supply to beans. In another related study, Beebe *et al*. (2014) also explained that increase in harvest index could be due to nutrient partitioning in beans varieties studied.

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