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# Effect of Pigeon Pea and Di-ammonium Phosphate (DAP) Fertilizer on Maize Growth and Yield in a Maize-pigeon Pea Intercropping System

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***Authors' contributions***

*This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

Since most subsistence farmers are poorly endowed with resources and capital to buy farm inputs such as fertilizers, developing an integrated soil fertility management strategy in maize cropping systems would contribute to enhanced food security through improved crop productivity. Intercropping maize and pigeon pea is considered to be a good option since pigeon pea is drought-tolerant, can fix nitrogen and uses its deep root system to recycle important minerals such as iron from horizons inaccessible by most shallow rooted crops. The study was conceived to investigate the effects of pigeon pea and Di-ammonium phosphate fertilizer on maize growth and yields in a maize-pigeon pea intercrop.The research was conducted at Kenya Agricultural and Livestock Research Organization (KALRO) research station in Mtwapa (39° 219'E, 4° 347'S) and Pwani University Crop Science farm (39° 44'E and 3° 50'S).The experiment was laid out in a randomized complete block design with three replications. The treatments included application of diammonium phospshate (DAP) fertilizer and two pigeon pea as an intercrop with maize in spatial variation. The following parameters were measured: maize plant height using a tape measure, number of maize plants per plot, number of cobs per plot and maize grain yield using a weighing scale. The data

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collected was subjected to analysis of variance using SAS statistical software and means separated using Fisher's Least Significant difference at 5% level of significance. From the study, it was evident that pigeon pea had effects on maize plant height especially where DAP fertilizer was not applied which resulted in taller maize plants. Where fertilizer was applied, maize plants were shorter. However, intercropping of maize with pigeon pea did not have any significant effects on the number of maize cobs and yields.

*Keywords: Maize-pigeon pea; intercrop; DAP fertilizer; maize yield.*

## 1. INTRODUCTION

Maize (*Zea mays* L.) is an important component of food security in the world and about 158 million hectares of maize are cultivated every year. Maize plays an important role as a source of proteins, energy and some of the essential vitamins and minerals to millions of people in world, especially in Africa, South America and Asia [1]. The world demand for maize is expected to increase and is likely to overtake the demand for rice and wheat by 2030. In underdeveloped countries, the demand was estimated to increase from 282 million tonnes in 1995 to 504 million tonnesby 2020 [2].

In Africa, maize is mostly grown by small-scale farmers for food as well as animal feed [3]. In Sub Saharan Africa (SSA), per capita consumption of maize stands at 42 Kg. The African continentcultivated 29 million hectares of maize, with Nigeria having the highest acreage in SSA with 3%, followed by Tanzania [4]. In spite of the importance of maize in sub-Saharan Africa, farmers realize low yields of 1.5 tons $ha^{-1}$ compared to world average of 6 tons $ha^{-1}$.This has been attributed to a number of constraints such as biotic, abiotic and socio-economic factors [5].

Maize is a major staple food for most households in Kenya and the main source of income and employment for the majority of rural households. Food security and welfare of the farming population are dependent on the production capacity of maize farmers. However, productivity is below the potential for the region and creates serious food deficits due to low production levels. Although improved technologies such as the use of inorganic fertilizer in maize production have been introduced over the years, the adoption rate of these technologies by farmers in the region has been low. The high cost and insufficient supply of fertilizers, lack of knowledge by farmers, and the perception that soil are already fertile are among reasons for minimal fertilizer use [6].

Globally, pigeon pea cultivation covered, on average 5.8 million ha in 2011, out of which 61%was from India [7]. Pigeon peas belong to family fabaceaea and it is an erect shrub. The plants show considerable variations in height, ranging from 1-4 meters [8]. Pigeon pea plants are mainly cultivated for their dry grain, green pods and fodder [9]. Thus, the crop is mainly used as a source of protein and fodder for animals. In addition, the stems are used as fuel wood, while roots fix nitrogen into the soil and release soil bound phosphorus [10,11].

Pigeon pea in Africa is mostly grown as a subsistence crop although some countries export substantial amounts [12,13]. It is a multipurpose legume that provides food, fuel wood and feed for animals mainly for the subsistence farmers [14]. In Kenya, 138,708 ha of pigeon pea were cultivated in 2011. Pigeon pearanks the third most widely cultivated pulse crop, and its production is growing fast, with yearly growth rate of 3% [15].

Since most subsistence farmers are poorly endowed with resources and capital to buy farm inputs such as fertilizers, developing an integrated soil fertility management strategy in maize cropping systems would contribute to enhanced food security through improved crop productivity. Intercropping maize and pigeon pea is considered to be a good option since pigeon pea is drought-tolerant, can fix nitrogen and uses its deep root system to recycle important minerals such as iron from horizons inaccessible by most shallow rooted crops. The woody legume pigeon pea (*Cajanus cajan*) can therefore be an important component of integrated soil management to avail soil nitrogen to crops for growth [16].

Mixed cropping plays an important role in safeguarding farmers from production risks and uncertainty and it is also important in maintaining production per unit area of relatively fertile land [13]. Intercropping systems where maize is

simultaneously intercropped with other crops may have several advantages to small scale maize farmers in Africa. Intercropping systems with carefully selected crops, lead to benefits such as improved soil fertility, increased productivity, reduced risk of total crop failure and healthier diets. Intercropping cereals with legumes can lead to improvement of fertility levels of poor farmlands and increase sustainability of the farming systems. Adeleke and Haruna [17] pointed out that legumes are usually intercropped with cereals and have land yield advantage over soil improvement.

Recent studies have shown that pigeon pea fixes substantial amounts of BNF nitrogen of up to 235 kg N-ha$^{-1}$ [18]. Given that the use and adoption rates of inorganic fertilizers by farmers in the region have been low due to various factors such as high cost of fertilizers and lack of knowledge by farmers, then use of maize-pigeon pea inter-cropping system would appear to be a viable and sustainable option. Thus, this study was conceived to investigate the effects of pigeon pea and Di-ammonium phosphate on maize growth and yields in a maize-pigeon pea intercrop. The specific objectives were to determine i) maize yield increase due to use of pigeon pea in a maize pigeon pea intercrop; ii) maize yield increase due to use of Di-ammonium phosphate fertilizers in a maize pigeon pea intercrop.

## 2. MATERIALS AND METHODS

### 2.1 Description of the Study Site

The experiments were carried out at two sites, namely Kenya Agricultural and Livestock Research Organization (KALRO) research station in Mtwapa and Pwani University Crop Science farm. Mtwapa research station lies at an altitude of 30 m Above Sea Level (ASL), and 39° 219'East and 4° 347' South. The region receive annual average rainfall of about 1100 mm with temperatures ranging from 29°C to 34°C. The soils are predominantly sandy loam [19,20].

Pwani University Crop Science farm is situated 39° 44'East and 3° 50'South, at an altitude of 30 m ASL, and experiences average annual rainfall of 1100 mm with mean monthly minimum and maximum temperatures of 26°C and 34°C, respectively [19]. The two sites have bimodal type of rainfall and the most reliable rainy season i.e.long rains, extends from March to June. The soils in Kilifi are predominantly sandy to sandy loam [21].

### 2.2 Experimental Lay Out and Treatments

The experiment was laid out in a randomized complete block design with three replications (Fig 1). The units of treatment where maize, variety PH4 a medium duration hybrid that is popular and bred to fit within the Kenyan coast agro-ecological zone; then two pigeon varieties, short duration (ICPL87091) bred for the drylands such as Eastern and the Kenyan coast and the medium duration (ICEAP 00557) bred for the mid-altitude agro-ecological zones. The treatments involved intercropping system with two spatial arrangements, namely pigeon pea and maize in same hill (MP-S-H), and maize and pigeon peas in alternating rows (MP-S-B). Each spatial arrangement also had two levels, namely, maize and pigeon peas planted at the same time (MP-S-H-1), and another level whereby pigeon pea was planted two weeks after maize was planted (MP-S-H-1).Besides, each level was planted with (MP-S-H-1-F) and without di-ammonium phosphate (DAP) fertilizer (MP-S-H-1-0F) (Fig. 1). The maize variety used was dry land hybrid 4 maize (DH04) and was planted at a rate of 15kg ha$^{-1}$. Two pigeon pea varieties used were, namely ICPL87091, a short duration variety (SP) and ICEAP 00557, a medium duration variety (MP). Maize was the principle crop while pigeon pea was used as the intercrop.

### 2.3 Agronomic Practices and Management

Land preparation was done manually using jembes and pangas. Maize was planted at a spacing of 0.9 m by 0.6 m with three seeds per hole and thinned to two plants per holetwo weeks after germination. Each experimental unit had 56 maize plants, translating to a sole crop plant population of 37,038 plantsha$^{-1}$. The pigeon pea was planted at a spacing of 0.9 m by 0.6 m, three seeds per hole and thinned to two plants per hole (two weeks after germination) giving a sole crop plant population of 37,038 plantsha$^{-1}$. The same population of pigeon pea and maize plants was maintained in the intercropping treatments. Some intercrops had a ratio of 1:1 i.e. maize: pigeon pea rows, while others had both pigeon pea and maize planted on the same hole. Some plots received 20 gm ofDAP (18:46:0) fertilizer per hole to mimic a common practice among smallholder farmers in the region to determine the effect of planting fertilizer on maize pigeon pea intercrop while others had no fertilizers.

After the first weeding, when the crop was three weeks old, Laibuta foliar feed was applied at a rate of 50 ml per 20 litres in all the experimental plots to boost initial growth of the crops. Weeding for maize crop was done twice, at 3 weeks after planting (WAP) and at 6 WAP planting. For pigeon peas, four weedings were done, at 3 WAP; at 6 WAP; at 9 WAP and at 12 WAP. "Jackpot" insecticide was used to control stalk borer in maize and pod borer in pigeon peas at a rate of 15ml per 20 litres of water.Jackpot 50EC is a broad spectrum synthetic pyrethroid insecticide used for the control of biting and sucking insect pest in crops. It has a quick knock-down effect. The active ingredients are imildachloprid and alpha-cypermethrin [22].

### 2.4 Parameters Collected and their Determination

The following parameters were measured. Maize plant height was measured using a tape measure, from the base of the stem to the flag leaf whereby 10 plants were measured as a representative sample. The measurements were taken 5, 6, and 7 weeks after planting. The number of maize plants and cobs per plot were determined at harvest. Maize grain yields were determined at harvest at 14% moisture content then adjusted to 13%.

### 2.5 Data Analysis

The data collected was subjected to analysis of variance (ANOVA) using General linear model (GLM) of Statistical Analysis System [23] to obtain the treatment means. The means were separated using least significant difference (LSD) at *P*=.05.

## 3. RESULTS AND DISCUSSION

### 3.1 Effects of DAP Fertilizer on Maize Plant Height in a Maize-Pigeon Pea Intercrop

The results indicate that maize crop intercropped with medium duration pigeon pea variety (MP) without fertilizer was significantly (*P*= .05) taller (by 10%) than that planted with fertilizer (Plate 1). Further, maize intercropped with short duration pigeon pea (SP) variety without fertilizer was 12.8% taller (*P*= .05) than that planted with fertilizer (Table 1). Comparison of maize crop intercropped with medium and short duration pigeon pea varieties showed that maize crop intercropped with short duration pigeon pea was significantly taller by 1.4% compared to that intercropped with medium duration pigeon pea (Table 1 and Plate 2). The observed increase in the height of maize crop that was intercropped with short duration pigeon pea variety may have been attributed to less competition for growth factors and less shading effect due to its short architecture. Similar results have been reported by Egbe [14]. On the other hand, it is possible that, where the medium duration pigeon pea variety was inter-planted at the same time with maize, it might have competed for nutrients and shaded the maize plants over time, resulting in reduced photosynthetic efficiency that translated to reduced plant height.

Maize crop that was planted same time with pigeon peas was significantly (6%) taller (*P*=.05) than maize crop where pigeon peas was intercropped two weeks after maize planting (Table 1) where fertilizer was not applied. On the other hand, where fertilizer was applied, maize

**(a) Short duration variety (SP)** **(b) Medium duration variety (MP)**

**Plate 1. Short and medium duration pigeon pea varieties**

(a) Plants in same hole

(b) Plants l alternate rows

**Plate 2. Maize and pigeon pea intercropping: with plants (a) in the same hole and (b) in alternate rows**

crop that was planted same time with pigeon peas was significantly 10.2% taller (*P*=.05) than maize crop where pigeon peas was intercropped two weeks after maize planting. Maize and pigeon pea that were intercropped at the same time were probably more advantaged in resource utilization due to benefits from excreted nitrogen (N) resulting in taller plants. Similar observations were reported by Adesoji et al. [24] who reported that the effects of excreted nitrogen led to increased cell multiplication, cell expansion and elongation leading to increased plant height. Oswald et al. [25] also reported comparative advantage of intercropping legumes and cereals simultaneously which resulted in increased plant height and yields.

Where fertilizer was applied, the maize crop planted in alternating rows with pigeon peas was significantly 10.2% taller (*P*=.05) than that planted in the same hole with pigeon peas (Table 1); while where fertilizer was not used, the maize crop planted in the same hole with pigeon peas was significantly 3.8% taller (*P*= .05) than that planted in alternating rows with pigeon peas (Table 1).

According to Ndakidemi [26], those maize plants intercropped at the same hole with pigeon peas were probably more advantaged in resource utilization due to direct excretion of nitrogen.[24] observed that the increase in the amount of nitrogen transferred in maize intercrop with pigeon pea might have been facilitated by mycorrhizal interactions in the roots of the two crops. Similar findings were also reported by Kureh et al. [27] who observed that maize and soybean intercropping system or cowpea in the same hill gave consistently higher grain yields than intercropping system in an alternating hill on the same ridge.

The results indicate that during the 5$^{th}$ Week, most of the intercrop treatments that had no fertilizer generally had taller maize plants compared to those that had DAP fertilizer applied (Plate 3). This may be explained by the fact that application of fertilizer in the intercrop of maize and pigeon pea resulted in inhibition of nodulation activity which led to reduced nitrogen fixation and therefore limited excretion of nitrogen to maize roots.

**Plate 3. Pigeon pea crop overshadowed by maize crop**

**Table 1. Effect of Di-ammonium phosphate (DAP) fertilizer on maize growth and yield in a maize-pigeon pea intercrop**

| Treatments | Plant height (cm) | | | Ear height (cm) | Grain yield (tons ha-1) | No. of cobs per plot |
|---|---|---|---|---|---|---|
| | 5th Week | 6thWeek | 7thWeek | | | |
| I-MP-B1-0F | 93.1abc | 120.5 | 146.4bc | 61.8bcd | 3.8 | 32 |
| I-MP-B1-F | 81.1dc | 115.7 | 149.4abc | 68.3abcd | 5.4 | 39 |
| I-MP-B2-0F | 105.4abc | 131.9 | 161.6abc | 68.6abcd | 4.7 | 37 |
| I-MP-B2-F | 103.2ab | 146.2 | 180.3a | 74.9ab | 5.0 | 36 |
| I-MP-H1-0F | 108.6a | 136.1 | 159.9abc | 64.5bcd | 3.8 | 36 |
| I-MP-H1-F | 100.8ab | 136.9 | 167.6abc | 69.6abcd | 6.4 | 36 |
| I-MP-H2-0F | 89.2abcd | 118.0 | 141.0c | 56.1d | 4.8 | 36 |
| I-MP-H2-F | 71.4d | 106.9 | 143.6bc | 70.3abcd | 4.4 | 33 |
| I-SP-B1-0F | 108.6a | 138.5 | 162.5abc | 69.8abcd | 5.4 | 41 |
| I-SP-B1-F | 100.5ab | 138.7 | 174.1ab | 82.1a | 5.3 | 39 |
| I-SP-B2-0F | 87.0bdc | 117.7 | 142.8bc | 58.8dc | 4.3 | 35 |
| I-SP-B2-F | 86.8bdc | 126.1 | 161.1abc | 72.6abc | 5.5 | 41 |
| I-SP-H1-0F | 104ab | 132.1 | 140.3c | 62.5bcd | 6.0 | 33 |
| I-SP-H1-F | 93.2abc | 128.6 | 164.6abc | 63.4bcd | 7.5 | 41 |
| I-SP-H2-0F | 107.8a | 140.9 | 160.3abc | 70.1abcd | 5.8 | 41 |
| I-SP-H2-F | 75.80dc | 128.8 | 148.4abc | 70.2abcd | 4.8 | 37 |
| Mean | 94.7 | 129.0 | 156.5 | 67.7 | 5.2 | 37.1 |
| *P* Value | 0.0018 | NS | 0.02 | 0.04 | NS | NS |
| CV Value | 15.22 | 80.21 | 14.98 | 16.88 | 109.2 | 22.71 |

*Note: Figure in the same columns with the same letter are not significantly different at 5%*

**Plate 4. Short duration pigeon pea variety in the intercrop at flowering stage**

The limited availability of excreted nitrogen to maize plants resulted in the observed reduced maize plant height compared to maize crop where fertilizers were not applied in the maize-pigeon pea intercrop. This observation is in agreement with that of [28] who reported that when nitrogenous fertilizer is not applied, intercropped leguminous crops will meet a higher percentage of their nitrogen requirement from the atmospheric fixation, thereby offering no competition to their companion maize crop for nitrogen.

Thus, in this study, intercropped treatments without fertilizer namely, I-SP-H2-0F; I-MP-H1-0F and I-SP-B1-0F treatments had significantly taller maize plants compared to those applied with fertilizers, namely I-MP-H2-F; I-SP-H2-F and I-MP-B1-F treatments. The results indicate that by the 6th and 7th week after maize planting, fertilizer

application did not have significant effect on maize plant height.

### 3.2 Effects of DAP Fertilizer on Maize Yields in a Maize-Pigeon Pea Intercrop

The di-ammonium phosphate (D.A.P) fertilizer did not have significant effect (*P*=.05) on the number of cobs and grain yield (Table 1). This contradicts with the findings of Ademba et al. [29] who noted that phosphate fertilizers and manure application significantly increased maize grain yields and dry matter yields.

## 4. CONCLUSION

The study indicates that pigeon pea had effects on maize plant height especially where DAP fertilizer was not applied which resulted in taller maize plants. Where fertilizer was applied, maize plants were shorter. However, intercropping of maize with pigeon pea did not have any significant effects on the number of maize cobs and yields. Intercropping maize with short duration pigeon pea in the Kenyan coast is therefore possible and that would be lead to diversified farms for food and nutrition security.

## 5. RECOMMENDATIONS

The results from the study indicates that short duration pigeon pea can be recommended for integration to maize cropping systems in the Kenyan coast. In addition, it is recommended that fertilizer can be applied to increase the maize yield as it was evident in the current study. Planting of maize at the same time with the pigeon pea is the most practical given the different growth patterns. Further research need to be done to refine the best spatial arrangement and the quantities of fertilizer that would give maximal economic returns.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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## APPENDIX 1

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **REP 1** | MPSH1F 1 | MPMB10F2 | MPSH20F3 | MPMB1F4 | MPSB1F5 | MF 6 | PMF 7 | MPMH2F8 | MPSB20F9 | MPM B2F 10 | MPSH1 0F 11 | MPM H20F 12 | PSF 13 | MPSB2F 14 | MPSB10F 15 | MPM H10F 16 | MPM B20F 17 | MPM H1F 18 | MPSH2F19 |
| **REP 2** | MPMH10F38 | MPSB1F 37 | PSF 36 | PMF 35 | MPMB2F34 | MPSH20F33 | MPSH10F32 | MPMH2F31 | MPSH2F 30 | MPM B1F 29 | MPMB1 0F 28 | MPM H1F 27 | MPSB2F26 | MPSB2 0F 25 | MF 24 | MPM H20F 23 | MPSB1 0F 22 | MPMB2 0F 21 | MPSH1F20 |
| **REP 3** | MPSB1 0F 39 | MPM H20F 40 | MPSH20F41 | MPSB2F42 | MPSH1F43 | MPSH10F44 | MF 45 | MPMH1F46 | MPM B20F 47 | MPM H10F 48 | MPSB1F 49 | MPM B2F 50 | MPMH2F51 | MPMB1F 52 | MPSH2F 53 | PMF 54 | MPSB2 0F 55 | MPMB1 0F 56 | PSF 57 |

**Fig. 1. Plot layout and design**

*Key: S-sole crop; I-intercrop; MP-medium duration pigeon pea variety; SP-short duration pigeon pea variety; B1-intercrop in alternating rows with crops planted at the same time; B2-intercrop in alternating rows with pigeon pea planted two weeks after maize; F-with fertilizer; 0F-without fertilizer; H1-maize and pigeon pea planted in the same hill at the same time; H2-maize and pigeon pea planted in the same hill but pigeon pea planted two weeks after maize*

## APPENDIX 2

| Chemical attributes of soil at Pwani University farm at the start of the experiment | | | |
|---|---|---|---|
| **Soil pH** | **Total N (%)** | **Extractable P(ppm)** | **Available K(m/100 g)** |
| 6.21 | 0.088 | 7 | Trace |



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