Effects Of Different Legumes On The Growth And Grain Yield Of Amaranth In Kitui County, Kenya

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Abstract: Amaranth is an important crop owing to its highly nutritious grains and leaves. The grains are rich in proteins and leaves have high calcium and vitamins levels. Amaranth flour is used to fortify other flours due to its high digestible proteins. Some medicinal properties and industrial use have also been associated with amaranth grains and leaves. Common beans, green grams and cowpeas are important sources of plant proteins. This makes them valuable and cheap substitute for meat and other animal proteins. In this study, common bean (Phaseolus vulgaris L.) KB9, green gram (Vigna radiata) N-26 and cowpeas (Vigna unguiculata) M66 were intercropped with amaranth (Amaranthus hypochondriacus), KAM 01 to establish and compare their effects on the growth and grain yields of amaranth. Pure stands of the three legumes and the amaranth were also established for comparison purposes. The study was carried out in March-May 2017 rainy season. Treatment combinations were tested in a randomized complete block design (RCBD); with four replicates. Analysis of variance was carried out and treatment means were differentiated at 95% confidence level (P<0.05). Post-hoc tests were carried out using Fishers’ Least Significant Difference (LSD). This study found that intercropping amaranth with common beans, green grams and cowpeas had a significant effect (P<0.05) on grain yields and above ground biomass. Grain yields were highest (1,741 kg/ha) when amaranth was intercropped with green grams and least (1,088 kg/ha) in the amaranth-common beans intercrop. Green grams intercrop gave the highest (4.159 kgs/ha) above ground biomass and common beans intercrop giving the least (2.241 kgs/ha). Common bean intercrop had the highest (0.37) harvest index followed by green gram intercrop (0.34) with cowpeas intercrop giving a harvest index of 0.29. It was concluded that legume intercropping with amaranth was better than sole cropping and that green gram was the most appropriate legume for intercropping with amaranth in Kitui central sub county. It was therefore recommended for use by farmers.

Keywords: Grain amaranth, harvest index, intercropping, legumes.

I. INTRODUCTION
Amaranth (Amaranthus spp.) is an herbaceous annual belonging to the family Amaranthaceae with green or red leaves and branched flower stalks (heads) bearing small seeds, variable in colour from cream to gold and pink to shiny black. It is a C4 plant with an upright growth habit that grows optimally under warm conditions (day temperatures above 25°C and night temperatures not lower than 15°C, bright light and adequate availability of plant nutrients. According to Ouma (2004), there are about 60 species of Amaranthus, but only a limited number are of the cultivated types, while most are considered weedy species and hence rarely preserved. Amaranth is an important crop owing to its highly nutritious grains and leaves. The have high levels of essential micronutrients like carotene, vitamin C, iron and calcium (Pospisil, Varga & Svecnjack, 2006). The leaves are rich in calcium, iron and vitamins A, B and C, but fairly low in carbohydrates (Ouma, 2004). It is also rich in lysine and essential amino acid that is lacking in other diets based on cereals and tubers. The leaves are cooked alone or combined with other local vegetables such as spider plant, African nightshade and pumpkins. Amaranth grains can be ground into flour, popped like popcorn or cooked into porridge (Lara & Ruales, 2002). Some medicinal properties and industrial use have also been associated with amaranth grains and leaves. Kunyanga, Imungi, Okoth, Biesalski, and Vadivel (2012) reported amaranth as an important food for people living with HIV/AIDS and diabetics in most sub-Saharan Africa. Amaranth has also been said to lower cholesterol levels owing to its high content of squalene (He, Cai, Sun & Corke, 2003). Squalene is also an important ingredient of skin cosmetics due to its photo protective properties and is used as a lubricant in high technology applications, such as computer disks, because of its thermostability (He et al., 2003). Squalene is usually extracted from shark livers. Intercropping amaranth with other crops has been done with varying results in grain yields, leaf yield and pest control. For example Ng’ang’a , Ohiokpehai, Muasya and Omami (2011) showed that intercropping amaranth and soya beans (Glycine max) significantly increased amaranth grain yield compared to mono-cropping. An intercrop study of amaranth and cowpea carried out by Myers (1996) also showed a higher land equivalent ratio (better yield response) than for other intercropping arrangements. Amaranth has also been found to have no allelopathic effects in an intercropping system (Myers, 1996). The main advantage of intercropping is the more efficient utilization of the available resources and the increased productivity compared with each sole crop of the mixture. Intercropped legumes fix most of their nitrogen from the atmosphere and do not compete with cereals for nitrogen resources (Amanullah et al., 2016). Although a number of studies have been done to establish the potential
of intercropping amaranth with other crops, very little has been done to compare the effects of intercropping common bean, green gram and cowpeas on the growth and grain yield of amaranth. This study therefore sought to establish and compare the effects of intercropping these three legumes on the growth and grain yields of amaranth (KAM 01) in Kitui central sub county in Kitui County, Kenya.

2. MATERIALS AND METHODS

2.1 Plot establishment
The study was carried out within the 2017 long rains (March – May, 2017) at Kitui Agricultural Training Centre (ATC) in Kitui central sub county. The plot was tractor- ploughed and harrowed to achieve a fine tilth ideal for crop growth. Seven plots representing three treatment combinations and four pure stands was mapped out per block and replicated four times. A uniform basal application of TSP fertilizer (46%) at a rate of 23kg P₂O₅ per Ha was applied on the rows of amaranth before planting. Each plot measured 4.5m x 3.0m. Farm yard manure was also applied uniformly at a rate of 4 tons per Ha before ploughing. Amaranth (‘KAM 01’) was sown by drilling in rows spaced 90 cm apart. Fourteen (14) days after emergence, the plants were thinned out to achieve a spacing of 90cm x 30cm. The total amaranth plants per plot was therefore fifty. Rainfall and temperature data during the growing season were collected from Kitui Meteorological weather station and Kitui Agricultural Training Centre station. A total of 493.1mm of rainfall was received in 17days during the season. Temperatures ranged between 22°C to 30°C.

2.2 Treatment
Treatment combinations of the three legumes L₁ - L₃ (Common beans L₁, Green grams L₂ and Cowpeas L₃); and one amaranth variety; V (KAM 01) plus pure stands of each crop were applied in the seven plots within the block. The plots had grain amaranth as the main crop. Common beans (KB1 variety), green grams (N26 Variety) and cowpeas (M66 variety) were planted in single rows between amaranth rows at spacing of 15cm, 20cm and 20cm intra plants, respectively. The spacing in sole crops was 90cm x 30cm for amaranth variety, 30cm x 15cm for common bean, 45cm x 20cm for green gram and 60cm x 20cm for cowpeas. These were replicated four times. Appropriate pesticides were used to control pests. Plots were kept weed-free by shallow weeding.

<table>
<thead>
<tr>
<th>LEGUME INTERCROP (L)</th>
<th>AMARANTH VARIETY( V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common bean (L₁)</td>
<td>VL1</td>
</tr>
<tr>
<td>Green grams (L₂)</td>
<td>VL2</td>
</tr>
<tr>
<td>Cowpeas (L₃)</td>
<td>VL3</td>
</tr>
</tbody>
</table>

Treatments and Treatment Combinations
VL1, VL2, VL3, V, L1, L2, L3.

Legend
Legume 1 (Common bean)- L1
Legume 2 (Green grams) – L2
Legume 3 (Cowpeas) – L3
Amaranth variety – V

2.3 Data Collection
During data collection, one outer row of grain amaranth at each end of all the plots was discarded as border. Thus only 3 middle rows of grain amaranth per plot were harvested. Harvesting of amaranth was done by cutting off the heads with a sharp knife. The heads were then threshed, winnowed and weight of grains per plot determined using a digital weighing scale. The whole stalks of the harvested amaranth were then cut from the base (above the ground), dried under shade for 30 days and their weights determined per plot.

The parameters measured were:

i. Amaranth grain yield (g) – Average grain yield from 30 plants per plot were measured after threshing, winnowing and sun dried to a constant moisture level of 13.5%

ii. Amaranth above ground biomass (g) - Amaranth shoots were cut above the ground after harvesting, dried under shade for 30 days and weight measured.

2.4 Data Analysis
Data collected was summarized in an excel package and exported for analysis using SPSS Version 22.0 (statistical package for social sciences). Analysis of variance (ANOVA) was carried out for the three intercropping systems and for the amaranth pure stand. Treatment means were differentiated at 0.05 level of significance (P<0.05). Post-hoc test was done using Fishers’ Least Significant Difference (LSD). Harvest Index was determined as a ratio of grain yield per plot to above ground biomass.

Harvest index (HI) = Weight of grain per plot / Weight of above ground biomass

This was in line with Arya, Arya, Arya and Kumar (2015) who expressed Harvest index as a relationship of economic yield (yield of main product) and total biological yield (yield of main product + by products). Higher harvest index means superior plant type.

3. RESULTS AND DISCUSSION

3.1 Grain yields per Plot

![Figure 1: Effects of intercropping on yields of amaranth per plot](image-url)
From figure 1, amaranth grain yields per plot were highest in green gram intercrop followed by cowpea intercrop; while common bean intercrop had the least grain yields.

**Table 1: ANOVA table for the effects of intercropping on amaranth grain yield**

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blocks</td>
<td>177447.188</td>
<td>3</td>
<td>59149.063</td>
<td>9.771</td>
<td>.003</td>
</tr>
<tr>
<td>Intercropping systems</td>
<td>572958.687</td>
<td>3</td>
<td>190986.229</td>
<td>31.54</td>
<td>.000</td>
</tr>
<tr>
<td>Error</td>
<td>54482.063</td>
<td>9</td>
<td>6053.563</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>804887.937</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. R Squared = .932 (Adjusted R Squared = .887)

From the ANOVA table 1, there were significant differences (P<0.05) in amaranth grain yields among the three intercropping systems. Post-hoc analysis Table 2 shows that amaranth yields per plot in the green gram intercrop, cowpeas intercrop and pure stand amaranth were significantly higher than that of common bean intercrop. There was also significant difference in amaranth yields between green gram intercrop and amaranth pure stand. Yields were higher in green intercrop than in amaranth pure stand. However, yields in cowpeas intercrop and pure stand amaranth had no significant differences.

**Table 2: LSD table for the effects of intercropping on amaranth yield per plot**

<table>
<thead>
<tr>
<th>amaranth common beans intercrop</th>
<th>amaranth green grams intercrop</th>
<th>amaranth cowpeas intercrop</th>
<th>amaranth pure stand</th>
</tr>
</thead>
<tbody>
<tr>
<td>amaranth common beans intercrop</td>
<td>-529.00</td>
<td>-317.50</td>
<td>-238.25</td>
</tr>
<tr>
<td>amaranth green grams intercrop</td>
<td></td>
<td>211.30</td>
<td>290.75</td>
</tr>
<tr>
<td>amaranth cowpeas intercrop</td>
<td></td>
<td></td>
<td>79.25</td>
</tr>
<tr>
<td>amaranth pure stand</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*. The mean difference is significant at the 0.05 level

Higher amaranth yields in green grams and cowpea intercrops are as a result of more nitrogen available to amaranth due to higher biological nitrogen fixation by green gram and cowpeas. The significantly lower amaranth yields in common bean intercrop on the other hand is as a result of low nitrogen available to amaranth due to poor biological nitrogen fixation by beans. This is because common bean is a poor fixer of nitrogen (Fynn & Idowa, 2015). These results are also in conformity with findings of Senaratine et al., (1995) and also Ng’ang’a et al., (2011). This implies that green grams and cowpeas were able to meet most of their nitrogen needs through biological N fixation thus leaving the available soil nitrogen for use by amaranth. Amaranth was therefore able to grow with higher vigor and develop larger heads which translated to higher grain yields. The significantly higher amaranth yields in green grams and cowpeas intercrop were also attributed to ‘direct N transfer’ from green grams and cowpeas to amaranth (Stern, 1993 & Eaglesham et al., 1981 as cited by Matusso et al., 2012). This agrees with the findings of Walley et al., (1996) as cited by Fynn and Idowa (2015) which showed that most of the nitrogen fixed by legumes goes directly into the plant, but some nitrogen is “leaked” or “transferred” into the soil for neighboring non-legume plants.

**3.2 Above Ground Biomass**

From figure 2, amaranth above ground biomass was highest in the green gram intercrop followed by cowpea intercrop; while common beans intercrop had the least biomass.

**Table 3: ANOVA table for the effects of intercropping on above ground biomass**

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blocks</td>
<td>2893515.250</td>
<td>3</td>
<td>964505.083</td>
<td>13.53</td>
<td>.001</td>
</tr>
<tr>
<td>Intercropping systems</td>
<td>6324739.250</td>
<td>3</td>
<td>2108246.417</td>
<td>29.57</td>
<td>.000</td>
</tr>
<tr>
<td>Error</td>
<td>641529.250</td>
<td>9</td>
<td>71281.028</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>989783.750</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. R Squared = .935 (Adjusted R Squared = .892)

The ANOVA found that there were significant differences (P<0.05) on the above ground biomass among the various intercropping systems. From the post-hoc analysis Table 4, the above ground biomass for amaranth was significantly higher in the green grams and cowpeas intercrops compared to common bean intercrop. There was no significant difference between the above ground biomass for the green grams and cowpeas intercrops. The same was true for the pure stand amaranth which had no significant difference compared to both green grams and cowpeas intercrops.
The significant higher above ground biomass for amaranth in green grams and cowpea intercrops was as a result of higher availability of soil nitrogen to the amaranth from green grams and cowpeas through biological nitrogen fixation. This is in comparison to common beans which is a poor fixer of nitrogen. These results are in conformity with the findings of Senaratine et al., (1995) and those of Fynn and Idowa (2015). High fixation of biological nitrogen by green grams and cowpeas allowed the two legumes to meet their nitrogen needs and leaving the available soil nitrogen for amaranth use. Common bean on the other hand competed for the available soil nitrogen with amaranth. Insufficient nitrogen to the amaranth in common bean intercrop led to reduced growth vigor, fewer branches and less vibrant leaves hence low above ground biomass. These findings agree with those of Masvanhise (2015).

### 3.3 Harvest Index

#### Table 5: Effects of intercropping on Harvest Index

<table>
<thead>
<tr>
<th>Intercropping system</th>
<th>Grain yield (g)</th>
<th>Above ground Biomass (g)</th>
<th>Harvest Index (HI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amaranth-common bean intercrop</td>
<td>881</td>
<td>2372</td>
<td>0.37</td>
</tr>
<tr>
<td>Amaranth-green grams intercrop</td>
<td>1410</td>
<td>4133</td>
<td>0.34</td>
</tr>
<tr>
<td>Amaranth-cowpeas intercrop</td>
<td>1005</td>
<td>3455</td>
<td>0.29</td>
</tr>
<tr>
<td>Amaranth pure stand</td>
<td>1130</td>
<td>3259</td>
<td>0.34</td>
</tr>
</tbody>
</table>

From table 5, the harvest interval (HI) in common bean - amaranth intercrop was the highest (0.37), while cowpeas-amaranth intercrop had the least HI (0.29). The results agree with Sa-nguansak et al., (2007). Gelinas (2007) also showed a positive correlation between harvest index and grain yield. The high harvest index in common bean intercrop compared to other intercrops was due to low above ground biomass in amaranth as a result of low nitrogen supply to amaranth through N fixation and transfer from common bean. Reduced biomass in amaranth therefore translated to increase in harvest index ratio.

### 4. Conclusions and Recommendations

From this study, it was found that intercropping common beans, green grams and cowpeas had significant effects on growth and grain yields of amaranth. Amaranth-green grain intercrop performed better followed by cowpeas intercrop while common bean intercrop had the least grain yields. The study also found out that the above ground biomass was least when amaranth was intercropped with common beans; and highest when amaranth was intercropped with green grams. Based on the findings of this study it is recommended that farmers in Kitui central sub county be encouraged to intercrop amaranth with green grams to increase amaranth grain yield and to improve the general soil fertility.

**Acknowledgement**

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**References**


[7] Lara, N. & Ruales, J. (2002). Popping of amaranth grain (Amaranthus caudatus) and its effect on the functional, nutritional and sensory properties.. Retrieved from
James Gitonga received a B.Sc. degree in Horticulture from Egerton University, Kenya in 2002 and is currently pursuing a M.Sc. degree in Agricultural and Rural Development from Kenya Methodist University. He worked with flower and export vegetable industries from 2003 to 2006. Currently he is working as an Agricultural officer, in the Ministry of Agriculture, Kenya, since year 2006.


