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Effect of Spatial Arrangement on Growth of Okra in Maize/Okra Intercrop in Kilifi, Kenya

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Authors' contributions

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

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ABSTRACT

Okra is an important vegetable cultivated for both local and export market in Kilifi County. The demand for the vegetable has recently been increasing. On the other hand, maize is the staple food crop for most households in Kenya, but yields have been on the decline due to limitations of poor soils, unpredictable rainfall and its cultivation in small parcels of land, resulting in poor yields and low income that exacerbate food insecurity and poverty in the County. In Kilifi, the two crops are intercropped in random mixtures and with inconsistencies in planting density. Field trials were undertaken during short rains (October 2020 - January 2021) and long rains season (April - July 2021), at Industrial Crops Research Institute (ICRI) research farm situated at Kenya Agricultural and Livestock Research Organization (KALRO) - Mtwapa in Kilifi County, Kenya. The objective was to evaluate the effect of spatial arrangement on growth of okra in maize/okra intercropping system in

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Kilifi County. There were four treatments consisting of sole maize, sole okra, maize/okra intercrop arranged in alternating rows of 1:2, and maize/okra intercrop arranged in 2:2 patterns, replicated three times in a randomized complete block design (RCBD). Data collected in maize included: plant height, number of days to 50% tasseling, number of maize plants per plot; and number of leaves per maize plant. Data in okra included plant height, number of leaves per plant, leaf area, number of branches per plant, number of plants per plot, and days to 50% flowering. Okra plant height, number of okra leaves per plant, okra leaf area, number of branches per plant, number of days to 50% flowering, were significantly affected ($P \leq 0.05$) by spatial arrangement. Intercropping increased okra plant height after the sixth week. Leaf area, number of leaves and number of branches per plant, were negatively affected by intercropping. Intercropped okra took longer days to flower compared to sole okra. Maize is more competitive compared to okra. However, both two arrangements can be suitable for intercropping okra with maize.

Keywords: Spatial; intercropping; arrangements; Kilifi, Okra; maize.

1. INTRODUCTION

Okra belongs to malvaceae family (Sachan et al. 2017). In India, it is referred as bhindi, krajiab in Thailand, lady's finger in United Kingdom, and gumbo in Southern parts of USA. The Angolans and Portuguese call it quiabo, while Cubans call it quimbombo (Aminu et al. 2019). The Swahili in East African Coast call it mabenda or bamia (Virchow, 2008). There are 12 cultivated species of okra namely: *Abelmoschus moschatus, Abelmoschus manihot, Abelmoschus esculentus, Abelmoschus tuberculatus, Abelmoschus ficulneus, Abelmoschus crinitus, Abelmoschus angulosus, Abelmochus tetraphyllus, A. enbeepeegearense, A. palianus and Abelmochus caillei* (Nieuwenhuis et al. 2024). Four species have economic value and include *A. caillei (A.Chev.) Stev. A. esculentus (L) Moench* and *subspecies A. moschatus* var*, moschatus* (Li et al. 2020).

Ethiopia is presumed to be the origin of Okra (*Abelmoschus esculentus* (L.) Moench), and was thought to have been cultivated in Egypt, by the ancient Egyptians around 1200 BC (Binalfew et al. 2016). Its cultivation spread throughout Middle East and North Africa (Temam et al. 2020). Today, the crop is grown all over the world, both in sub-tropical and tropical countries (Chowdhury and Kumar, 2019). It is cultivated commercially in Japan, India, Iran, Bangladesh, Turkey, Western Africa, Pakistan, Myanmar, Yugoslavia, Afghanistan, Malaysia, Thailand, Brazil, India, Ethiopia, the United States of America and Cyprus, (Fufa, 2019). Annual production of okra globally is approximately 11.2 million tons, with India being the largest producer in the world, producing more than 6.9 million tons (FAO, 2022).

The main okra producing counties in Kenya are Kwale, Kilifi, Makueni, Mombasa, Kakamega, Taita Taveta, Machakos, Turkana, Murang'a, Kajiado, Meru, Tana River, Kitui, Kiambu and Vihiga (Agriculture and Food Authority Validated Report, 2020). Total acreage under okra cultivation in 2022 was 1,560 ha, producing 18,664 tons, and the country is ranked position 24 globally in terms of production (FAO, 2022). Okra is one of Kenya's leading Asian vegetable and the third foreign exchange earner after eggplant and dudhi (Agriculture and Food Authority Validated Report, 2020). Smallholder farmers produce 80% of the crop mainly under contract farming. The average farm size of these smallholder farmers is usually below 0.3 ha (Aluko, et al. 2020). The most common varieties that are cultivated in Kenya include; Clemson Spineless, Pusa Sawani, Dwarf Green Long Pod, White Velvet and Green Emerald; with Pusa Sawani being the most preferred variety. Market demands dictate variety preference by smallholders (Kalsa et al. 2019). Taita Taveta, Kwale and Kilifi counties have been leading in okra farming with 1,242 ha under production. Kilifi County produced 2,213 metric tons on 270 ha, valued at Sh. 107,450,000 in 2020 (Agriculture and Food Authority Validated Report, 2020). The crop is mainly produced for export market and local consumption (Varela and Seif, 2004).

In Kilifi County, okra popularity has recently been on the rise due to its increased demand in the tourist hotels, good export market, nutritional and medicinal value (Agriculture and Food Authority Validated Report, 2020). It provides carbohydrates, minerals, vitamins with anti-oxidant properties, proteins and substantial amounts of fibre that are indispensable for human nutrition and health (Liu et al. 2021b).

Thus, okra as a vegetable can be used to address problems of malnutrition and hidden hunger (Aminu et al. 2019). The area dedicated to okra in Kilifi County has increased from 170 ha in 2012 to 270 ha in 2020 (Agriculture and Food Authority Validated Report, 2020).

Okra makes a compatible mixture in an intercropping system (Olasantan 2005). Intercropping okra with suitable crops such as cereals, leads to better utilization of growth and yield factors leading to higher yield advantage than sole cropping of component crops (Ijoyah, 2012 and Maduwanthia et al. 2019). Okra is a short duration vegetable and can be harvested before the canopy of long duration crop closes (Olasantan, 2005). This promotes higher productivity and better utilization of land, than when it is grown as sole crop (Ijoyah, 2012). As a versatile crop, okra can therefore, be intercropped with various crops including cereals, vegetables, legumes, cucumbers and root crops (Adeniyi, 2011 and Nwamini,et al. 2020). Poor soils as a limiting factor of production can result in low okra yields (Maduwanthia & Karunarathna, 2019). Legumes help in fixing nitrogen and accumulation of nutrients in soil that can improve crop growth and production when intercropped with other suitable crops including cereals and vegetables (Ananthi et al. 2017). Intercropping cowpea (*Vigna unguiculata*) with okra has significant positive effect on growth and yields of okra (Ajayi, et al. 2017). Okra plant height, dry and fresh weights, leaf area and leaf area index, canopy width, total yield, and Land Equivalent Ration (LER) were reported to be higher when intercropped with cowpeas in different spatial arrangements [(Maduwanthia & Karunarathna, 2019). Intercropping okra with groundnut (*Arachis hypogaea*) was found to increase number of leaves, leaf surface area and stem length of okra (Ajayi et al, 2017). Leaf area and stem diameter of okra are also positively or negatively affected by intercropping with groundnuts, depending on the plant density (Ajayi, et al. 2020). Although sole okra produces the highest fruit yield, it has no significant difference from okra intercropped with groundnut (Ajayi et al. 2017).

In cassava-okra mixture, okra plants height increases hence becoming taller due to struggle for light. Number of okra leaves per plant and leaf area index (LAI) are also reduced because of inter specific competition for growth resources (Muoneke & Mbah, 2007). The effects on both growth and yields depend on the plant densities of the component mixture of crops grown (Ijoyah et al. 2013). Cassava intercropped with okra affects both leaf production, leaf area index (LAI) of okra, number of fresh okra fruit, fruit length, fruit weight and fruit diameter (Muoneke et al. 2007). When different plant densities are used, okra maximum density of 35,000 plants per hectare positively improves okra growth and pod yield (Olasantan, 2001) Land equivalent ratio (LER) of cassava-okra intercrop is always greater than 1. However, different plant densities give different LER, with highest LER of 1.30 obtained when cassava is intercropped with okra at 42,000 plants per hectare (Ijoyah & Usman, 2013).

While studies have been done on intercropping systems in cereals and leguminous crops, there is limited literature on performance of maize and okra with respect to intercropping, spatial arrangement and associated economic benefits under Kilifi conditions. The aim of this study was to assess the effects of plant arrangements on growth rate of okra crop in maize and okra intercrop. Overall objective was to enhance maize and okra intercrop production systems for better returns in terms of food security and economic benefits in Kilifi County.

2. MATERIALS AND METHODS

2.1 Experimental Site Description

The study was conducted at Industrial Crop Research Institute (ICRI) farm at the Kenya Agricultural and Livestock Research Organization (KALRO), Mtwapa center which is in the south of Kilifi county, Kenya. The site is situated in the Coastal lowland, Agro-ecological Zone three (CL-3), 39° 219’ East and 4° 347’ South at an altitude of 30 m above sea level (ASL) (Weru 2016). It experiences an annual average rainfall of between 1100 to 1200 mm and temperature ranges from 29°C to 34°C (Muli, 2019). Rainfall experienced is bimodal, where long rains season start towards the end of March and attain peak in mid-May, and thereafter decrease gradually to minimum. The short rains season start around October, and last until December or January with no pronounced end, but variability is high (Weru, 2016). The soils are predominantly sandy loam (Shisanya et al. 2009). The experiment was carried out in two cropping seasons, short rains - October/December of 2020, and long rains season - April/July of 2021.

2.2 Experimental Materials

Maize variety tested was Dryland Hybrid (DH02), while that of okra was Pusa Sawani, all produced by Kenya Seed Company Ltd.

2.3 Crop Establishment and Experimental Layout

The two crops, maize and okra, were planted at the same time. To enhance germination and emergence, okra seeds were soaked in water for 24 hours and then planted to a depth of 2 cm (Singh et al. 2014). Two seeds of each crop were planted per hole.

There were four treatments which included, T1: Sole maize crop; T2: Sole okra crop; T3: maize-okra intercrop in the ratio 1:2; and T4: maize-okra intercrop in the ratio 2:2. Sole and intercropped maize were planted at a spacing of 90cm between rows and 30 cm between plants; sole okra and intercropped okra were planted at 45 between rows and 30cm between plants. Intercropped plots in the ratio 1:2, had one row of maize alternating with two rows of okra. The distance between maize and okra plants was 22.5 cm. For the ratio 2:2 planting arrangement, two rows of maize were planted in alternating patterns with two rows of okra. The distance between okra and maize was 22.5 cm. The experiment was laid in a randomized complete block design (RCBD) with three replications per treatment. A path of 1.5m separated the blocks. Each plot was 5m x 5m, separated by a path of 1 m. There were 12 plots in total. The two crops, maize and okra, were planted at the same time. An inter-row spacing of 90 cm and intra row spacing of 30 cm were maintained for sole maize crop; while for sole okra crop an inter row spacing of 45 cm and intra row spacing of 30 cm were used.

2.4 Crop Husbandry and Cultural Practices

Thinning was done two weeks after emergence and only one seed per hole was retained. Hand weeding was done 2 weeks and 4 weeks after sowing, and thereafter the plots were maintained weed free. All plots received Diammonium Phosphate (DAP) fertilizer (phosphate and nitrogen at 18% and 46% respectively) at a rate of 50kg/acre during planting and top dressing was done using Calcium ammonium nitrate (CAN) fertilizer (27% nitrogen and 8.6% calcium) at a rate of 100kg/acre when the maize had reached a height of 60cm (KALRO-KCEP, 2016).

Pest and disease management was carried out using Kenya's Pest Control Products Board (PCPB) approved pesticides for both preventive and curative measures. For maize stalk borer and fall armyworm, Belt 480SC (Flubenidiamid 48g/l) from Bayer East Africa Ltd, was used at the rate of 2ml/20l of water. Spraying was done as a protective spray two weeks after emergence, second at 60cm crop height, and third spray during tasseling. Beetles, leaf hoppers, aphids, cutworms and bollworms were controlled using Bestox 10EC (Alpha-cypermethrin 100g/l) from Juanco SPS KE, at the rate of 10mls/20l of water, four weeks after emergence and repeated 6 weeks after emergence as preventive spray. In okra, leafhopper, corn earworm, beetles, pink bollworm, whitefly and southern green stink bug were managed using Bestox 10EC (Alpha-cypermethrin 100g/l) from Juanco SPS KE, at the rate of 10mls/20l of water two weeks after emergence and repeated every two weeks, and whenever infestation was detected. For red spider mites, Twigamectin 18EC (Abamectin 18g/l) from Twiga Chemicals Industries Ltd, was applied at the rate of 10ml/20l of water at two weeks, four weeks and eight weeks after emergence as preventive sprays. In management of okra diseases, Ortiva 250SC (Azoxystrobin 250g/l) from Syngenta E.A Ltd, was used against leaf spot, fusarium wilt, and powdery mildew, at the rate of 20ml/20l of water, four weeks and six weeks after emergence as protective spray (Pest Control Products Boad, 2019).

2.5 Data Collection and Analysis

Sampling was done by randomly selecting five plants within 3 x 3 demarcated from each 5 x 5 plot. Selected plants were tagged from which data on growth rate parameters were collected every fortnight (Baw et al. 2017).

2.5.1 Parameters measured

Data for each parameter was collected from five plants that had been randomly selected and tagged in each plot. Parameters measured for maize included: number of plants per plot: maize plant height; number of leaves per plant; and number of days to 50% tasseling. For okra, parameters measured were: number of plants per plot; okra plant height; number of leaves per plant; number of branches; leaf area per plant; and number of days to 50% flowering.

Maize plant height was measured from the base of the plant at soil level to the tip of the longest leaf before tasseling, using a tape measure; while final plant height was measured from the base of the plant touching the ground to the first node of the tassel (Abuzar et al. 2011). Number of days to 50% tasseling was taken from the day of germination to the day when half of the plants per plot had flowered (Joudaki et al. 2016). Number of grown leaves, starting from the lowest (the coleoptile leaf with a rounded tip) to the last leaf whose tip pointed downwards, per plant were counted and their mean recorded (El-Beltagi et al. 2022). On okra, data recorded included plant height measured in cm from the soil surface to the tip of top most leaf. Number of plants were counted for each plot and their total taken. Number of branches per plant were counted and their mean recorded. Number of days to 50% flowering were recorded as the time it took for half of the plants to flower (Ijoyah et al. 2015). Leaf area was measured at 50% flowering using multiple regression equation for predicting the leaf area (Ijoyah, 2012 and Musa et al. 2016) as a non-destructive method of estimating the leaf area of okra leaves per plant, as; $Y = -3.616 + 0.604X1 + 0.882X2$; where Y= leaf area; X1= length x breath and, X2= number of leaves per plant.

2.5.2 Data analysis

The data collected was subjected to Analysis of Variance (ANOVA), using General Linear Model (GLM) of MINITAB Version 16 (Karimi et al. 2014). The means obtained were separated and compared using Tukeys Honest significant test at P values of 0.05 level of significance.

3.RESULTS

3.1 Okra Plant Height

The results indicated that spatial arrangement did not affect plant height during the first six weeks after planting (Table 1). However, from the eighth week, the intercropped okra was significantly taller ($P \leq .05$) by 15.23% compared to sole okra, reaching an average height of 68.15 cm, compared to the sole crop with an average height of 57.9 cm.

3.2 Number of Okra Leaves

Spatial arrangement significantly ($P \leq .05$) affected the number of leaves per plant from the sixth to eighth week. The sole okra crop had a greater number of leaves per plant compared to maize/okra intercrop. Spatial arrangement patterns of 1:2 and 2:2 had 2.59 % and 5.17 % less number of leaves compared to the sole crop. At the same period, the maize/okra intercrop pattern of 2:2 had significantly ($P \leq 0.05$) 2.7 % more number of leaves per plant than the maize/okra intercrop arrangement of 1:2 where one row of maize was alternated with two rows of okra (Table 1).

3.3 Okra Leaf Area

The leaf area of okra planted as sole crop was significantly ($P \leq .05$) higher at 50% flowering than in intercropped okra crop. The sole okra crop had significant ($P \leq .05$) 22.8 % and 19.1 % more leaf area than the intercropped okra in the 1:2 and 2:2 maize/okra intercrop arrangement respectively. However, leaf area of okra crop in the 2:2 maize:okra intercrop pattern were of comparable area to that of 1:2 maize:Okra intercrop pattern.

3.4 Number of Okra Branches Per Plant

The number of branches per plant was significantly ($P \leq .05$) higher in sole planted okra crop than in intercropped. The sole okra crop had significant ($P \leq 0.05$) 38.8 % and 44.9 % more branches per plant than the intercropped okra in the 1:2 and 2:2 maize:okra intercrop respectively. However, the okra crop in the 2:2 maize:okra intercrop was of comparable number of branches per plant to that from 1:2 maize:okra intercrop.

3.4.1 Number of days to 50% flowering in okra

The number of days it took for 50% of okra plants to start flowering was significantly ($P \leq .05$) more by 7% in the intercropped okra crop than in the sole okra crop. Thus, the sole okra crop attained 50% flowering 3.5 days earlier than the intercropped okra. However, the okra crop in the 2:2 maize:okra plant spatial arrangement pattern and that of 1:2 maize: Okra intercrop pattern flowered almost the same time.

4. DISCUSSION

During the first six weeks of growth, spatial arrangement in the maize/okra intercrop did not affect the height of okra crop. It was only during the eighth week when intercropped okra crop grew taller than sole okra crop.

Table 1. Effect of spatial arrangement on growth rate of okra in maize okra intercrop in Kilifi

Treatment	Okra plant height (cm)				No. of leaves per plant			Leaf area at 50% flowering (cm^2)	No. of branches 8WAP	No. of days to 50% flowering
	2WAP	4WAP	6WAP	8WAP	4WAP	6WAP	8WAP			
Sole okra	12.5a	37.9a	47.9a	57.9b	9.1a	10.2a	11.6a	215a	4.9a	49b
1maize:2okra	12.3a	38.4a	50.5a	68.3a	6.8a	7.4b	11.3b	166b	3b	52.7a
2maize:2okra	11.8a	36.7a	48.4a	68a	7.2a	7.8b	11b	174.2b	2.7b	52.5a
Mean	12.2	37.7	48.9	64.7	7.7	8.5	11.3	185	3.5	51.4
P-Value ≤.05	0.10	0.44	0.75	0.03	0.1	0.02	0.01	0.02	0.002	0.02
CV (%)	2.96	2.32	2.82	9.15	15.96	17.82	2.65	14.21	34.09	4.05

**Means sharing the same letter on the same column are not significantly different at 5% level of significance*
Key: WAP - Number of Weeks After Planting; CV - Coefficient of Variance

This could be explained by the fact that during early part of the growth up to the sixth week, the leaf canopies structure of maize and okra were comparable. However, as growth progressed and maize plant approached flowering, the maize tassels over-towered over okra plants, thus over shadowing them. This made the okra plant to increase in height in an effort to compete for light. Similar observation was made by Maduwanthia & Karunarathna (2019) who found that intercropping okra and cowpeas had significant effect on growth behaviour of okra including plant height. Intercropping maize and okra resulted in reduced number of leaves of okra plants, especially after the fourth week. This could be due to the fact that as the maize crop approached tasseling, morphological changes in maize canopy structure occurred which resulted in increased shading of the okra plant thereby affecting light intensity. This finding is in concurrence with that of Muoneke & Mbah (2007) who reported that intercropping cassava and okra affected leaf production of okra in Umudike, Southern Nigeria.

On leaf area, intercropping maize and okra resulted in smaller leaves of okra plant, and therefore reduced leaf area compared to when okra was planted as sole crop. This could have been as a result of competition for growth resources by the different species in the intercropped system leading to smaller leaf area compared to the sole okra. This finding is similar to that reported by Ajayi et al. (2020) who observed that leaf area of okra is positively or negatively affected by intercropping with groundnuts, depending on the plant density. It was also reported that when cassava was planted together with okra, both leaf production and leaf area index (LAI) of okra significantly reduced compared to sole crop, as a result of interspecific competition for growth resources (Muoneke & Mbah, 2007). The number of branches per okra plant was negatively affected by intercropping. The sole okra crop had more branches per plant than the intercropped okra. This could be explained by the fact that in the intercrop, the okra plant could have experienced shading by the surrounding maize plants. Inhibition of lateral growth meant reduction in number of branches since branches tend to grow laterally. The results are in agreement with findings reported by Ajayi, et al. (2017) who observed that when cowpea (*Vigna unguiculata*) was intercropped with okra, the intercropping had significant effect on growth components of the okra crop. However, the findings contradict those reported by Olasantan & Bello (2004) who reported that the number of branches per plant of okra was not affected, when it was intercropped with cassava. Intercropping maize and okra resulted in more days to flowering in the okra. Maize crop in the intercrop exerted excess demand for growth resources due to its high competitiveness, including light, which ultimately delayed the period okra plant took to attain 50% flowering. The finding is in agreement with Ijoyah et al. (2015) who observed that okra planted together with egusi melon at the same time significantly prolonged the number of days for okra to attain 50 % flowering.

5. CONCLUSION

Growth rate and growth attributes of okra namely plant height from 8 WAP, number of okra leaves per plant, leaf area, number of branches per plant, and days to 50% flowering, were significantly influenced by spatial arrangement. However, other okra growth attributes including okra plant height from 1st WAP to 6th WAP**,** and number of leaves per plant 1st to 4th WAP were not significantly affected. Therefore, some growth attributes of okra plant are affected by intercropping with maize under 1:2 and 2:2 spatial arrangements, while others are not affected.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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