Original Research Article

Effect of Spatial Arrangement on Grain and Fruit Yield of component crops in Maize/Okra Intercrop in Kilifi County, Kenya

ABSTRACT

Maize production in Kilifi County, Kenya has been on the decline due to limitations of poor soils, unpredictable rainfall and its cultivation in small parcels of land. Okra is one of the high value crops intercropped with maize in the County. The area under okra cultivation has been on the rise due to increased demand, good export market, nutritional and medicinal value. Intercropping has considerable benefits of maximizing productivity. In Kilifi County, intercropping maize and okra is done in various mixtures, with inconsistence in plant density. Field studies were undertaken in two seasons: short rains (October 2020 - January 2021) and long rains (April - July 2021), at Industrial Crops Research Institute (ICRI) farm, Kenya Agricultural and Livestock Research Organization (KALRO) - Mtwapa in Kilifi, Kenya. The objective was to evaluate the effect of spatial arrangement on grain and fruit yield of maize and okra respectively in maize/okra intercropping system. There were four treatments consisting of sole maize, sole okra, maize/okra intercrop in alternating rows of 1:2, and maize/okra intercrop in 2:2 patterns, replicated three times in a randomized complete block design (RCBD). Maize yield data measured included: number of cobs per plant, cob diameter, cob length, cob weight, number of grains per cob, 1000 grain weight, and total grain yield. Okra yield parameters included number of fruits per plant, fruit diameter, fruit weight, fruit length and fruit yield (t/ha). Results showed that the number of okra fruits per plant, fruit weight and fruit length were significantly affected ($P \le 0.05$) by spatial arrangement. However, spatial arrangement did not significantly ($P \le 0.05$) effect the number of cobs per plant, cob length, cob diameter, cob weight, number of grains per cob, 1000 grain weight and total maize grain yield. Moreover, okra fruit diameter, and total okra yield were not significantly ($P \le 0.05$) affected by spatial arrangement. This study recommends that farmers in Kilifi County can combine maize and okra as intercrop in the ratio 1:2 and 2:2. Intercropping maize and okra can enable them get their staple food of maize, and have okra vegetable to meet their dietary requirements, and increase land utilization.

Keywords: Maize, Okra, spatial arrangement, intercrop, yield, productivity

1.0 INTRODUCTION

Intercropping is a more efficient means of exploiting available ecological resources than mono-cropping (Ananthi et al., 2017). This is because when two different species of crops are combined, there is efficient resource uptake, utilization and conversion, which leads to improved growth and yield advantages of the component crops (Maitra et al., 2019). Thus, intercropping maize and okra can considerably increase productivity by efficiently exploiting ecological resources that would otherwise not have been fully utilized under mono-cropping of either crop (Layek et al., 2018). Intercropping also helps in averting risks in a situation where one crop fails, and enhances conservation of soil, improves soil fertility, weed management, and meets nutritional needs of the people (Bitew and Abera, 2019).

Okra (*Abelmoschus esculentus* (L.) Moench), is a fibrous, semi-woody, annual herbaceous plant with an indeterminate growth habit (Antwi-Arhinwaa, 2017). It can grow to a height of 91 cm – 244 cm (Syfullah, 2017). The plant has taproot that penetrates deeply, with shallow, dense feeder roots within 45 cm of the soil (Antwi-Arhinwaa, 2017). It has alternate, large, palmate leaves that have small stipules, and leaf margin differ from being wavy to lobed margins (Syfullah, 2017). The plant's flowers are acute apex, solitary, auxiliary and produce upright fruits. Flower buds grow at the axil areas of each leaf, from between six to eight-leaf stage, and produces five large showy, white to yellow petals (Moosavi et al., 2018).

The crop is a short duration vegetable (Olasantan, 2005). It takes between 4 – 7 days after sowing to germinate (Nana et al., 2019). Vegetative period last for less than 60 days after sowing (Fajinmi and Fajinmi, 2010). Harvesting can be done before the canopy of long duration crop closes (Olasantan, 2005). As a versatile crop, okra can therefore, be intercropped with various crops including cereals, vegetables, legumes, cucumbers and root crops (Nwamini et al., 2020).

Okra makes a compatible mixture in an intercropping system (Olasantan, 2005). Intercropping it 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; Maduwanthia and Karunarathna, 2019).

Maize (*Zea mays*) is one of the leading cereal crops globally (Maqbool and Beshir, 2019). The crop is adaptable in diverse ecological conditions, with a wide variety of uses (Pawar et al., 2020). In third world countries, it is consumed directly as principal diet for about 900 million people globally (Hossain et al., 2019). The cereal accounts for over 30% of protein consumed by population in Sub-Saharan Africa (Sharma et al., 2020).

Since maize is an important source of human diet and animal feed in most areas of the world, it is produced by farmers in both developed and developing countries (Huma et al., 2019). Total world production of this cereal crop is above 1.2 billion tons, with the United States of America being the major producer followed by People's Republic of China, Brazil and Argentina. In Africa, the average maize production is 90 million tons, with South Africa leading at 16.8 million tons. Kenya is ranked at position 7 with a total production of 3.3 million tons. (FAOSTAT, 2023).

Monocotyledonous cereals such as maize have erect canopies that effectively absorb supplementary radiation on both two leaf surfaces, making the crop suitable to intercrop with other crops like legumes (Layek et al., 2018). Differences in canopies of maize and leguminous plants can affect how the plants efficiently use growth factors such as light (Dwivedi et al., 2015). Better yields and good economic returns are obtained when maize is intercropped with garden pea with a spatial arrangement of three rows of pea sandwiched between two rows of maize plants (2:3). Higher yield is obtained among the intercropped, compared to sole maize and sole garden pea (Sarker et al., 2013). Mwajoha (2017) reported that intercropping pigeon pea and maize does not have any significant effects on yields of maize; but then again, when the components crops were planted at the same time in the same hole, there was remarkable increase in yields of maize grain. Intercropping cereals and pulses enhance soil fertility through nitrogen fixation; provides greater ground cover, which increases soil conservation and provides better water logging resistance for crops highly susceptible to lodging, compared to when the crops are grown in monoculture (Bybee and Ryan, 2018).

Maize can also be intercropped with cassava. The two crops create a canopy architecture that does not affect their growth and yields (Osaigbovo, 2016). It has also been reported that maize intercropped with cowpeas suppresses thrips population due to enhanced activities of natural enemies, thus, reducing spraying regimes and subsequent reduction of production cost (Bybee and Ryan, 2018). When maize is intercropped with groundnut, maize becomes dominant crop and leads to poor yield of the groundnut as a result of the effects of shading by the maize crop.. Generally, intercropping groundnut and maize increases total yields, land equivalent ratio and land use efficiency (Belel et al., 2014).

It is evident that intercropping can be beneficial in terms of efficient utilization of land resources and increased food security (Maitra et al. 2019). Maize (Gramineae) can be intercropped with okra (Malvaceae) because the two crops have different heights, which allow both plants to utilize different layers of available sunlight (Kebede et al., 2016). Their different root structures can reduce competition for available water and nutrients (Arshad, 2021). Combining the two crops in an intercropping system can disrupt pest cycle and reduce diseases spread. It may improve soil health through contribution of varied organic matter, thus enhancing soil structure and fertility (Kebede et al., 2016).

While maize forms a major diet of the population in Kilifi County (Ong'ayo, 2017), okra on the other hand has become an important vegetable in the County, both as a source of nutrients, and an income generating activity for farmers (AFA, 2020). While intercropping studies of okra with other crops has been reported with mixed outcomes, there are limited studies have been conducted or documented about its intercropping benefits with maize, particularly under Kilifi conditions. It is for this reason that this study was conceived to evaluate the interactive effects of spatial arrangement in maize and okra intercrop in Kilifi County, Kenya.

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, 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 480g/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. Maize yield parameters measured included: number of cobs per plant, cob diameter, cob length, cob weight, number of grains per cob, 1000 grain weight, and total grain yield. Okra yield parameters included number of fruits per plant; fruit diameter, fruit weight; fruit length and fruit yield (t/ha).

2.5.2 Determination of measured parameters

Numbers of cobs in each plot were counted during harvesting and their mean recorded. Cob length of five cobs were measured using tape measure and their mean recorded per treatment. The widths of five cobs from each plot were measured by removing the husks and measuring the bottom, middle and top parts of each cob using tape measure; and their mean calculated for each treatment (Wasaya et al*.,* 2017). The five dehusked maize cobs from each plot were weighed and their mean taken as cob weight. The dehusked maize were sun dried for 3 days and then shelled by hand. Shelled grains were then sun dried for 14 days in open air sun drying, as used by most small-scale farmers in Kenya (De Groote et al., 2021). The sound characteristics produced by the impact of falling maize grains from a height of 20 cm, as used by small scale farmers, was used to determine the dryness of maize (Chibane et al., 2021).

The weight of 1000 grains were taken by physically counting 1000 grains from the composite shelled maize per plot, and weighed using a weighing scale, and mean from each treatment calculated. Total grain yield (t/ha) was measured by weighing the total shelled maize of each plot using a weighing scale, and the mean from each treatment calculated (Wasaya et al., 2017). Length of okra fruit was measured as the distance from the fruit cap scar at the base to the tip end of the pod. The diameter (cm) of the fruits in the peduncle insertion zone was measured using a string. Fresh okra fruit weight (g) of okra was determined by weighing harvested fruits on a sensitive weighing scale and their mean taken (Olivera et al., 2012). Total okra yield (t/ha) was measured by weighing total harvested okra from treatment and their means recorded.

2.5.3 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 yield parameters

3.1.1 Fruit weight

Spatial arrangement had significant ($P \leq 0.05$) effect on fruit weight of okra. Sole okra crop, and intercropped okra in the spatial arrangement of 2:2 maize/okra, produced 17.6 % and 20 % higher fruit weight compared to okra crop in the 1:2 maize/okra intercrop.

3.1.2 Number of okra fruit per plant

The number of fruits per plant was significantly ($P \leq 0.05$) higher in sole planted okra crop than in intercropped okra crop. The sole okra crop had significantly ($P \leq 0.05$) 25.9 % and 28.7 % more fruits per plant than the intercropped okra in the 1:2 and 2:2 maize/okra intercrop, respectively.

3.1.3 Fruit length

On fruit length, okra fruits from sole okra were significantly longer ($P \leq 0.05$) by 15.7% and 14.9% compared to those from 1:2 and 2:2 maize/okra the intercrop respectively.

3.1.4 Fruit diameter

Planting okra in different spatial arrangements did not have significant effect ($P \leq 0.05$) on fruit diameter.

3.1.5 Total okra fruit yield

Spatial arrangement did not significantly affect ($P \leq 0.05$) total yield of okra fruit (Table 2).

3.2 Maize yield parameters

Spatial arrangement did not significantly ($P \leq 0.05$) effect on the number of cobs per plant, cob length, cob diameter, cob weight, number of grains per cob, 1000 grain weight and total maize yield, in a maize/okra intercrop (Table 1).

Table 1: Effect of spatial arrangement on grain yield of maize in maize/okra intercrop in Kilifi

Treatment	Number of cobs per plant	Cob length (cm)	Cob diameter (cm)	Number of grains per cob	Cob weight (g)	1000 grain weight (g)	Total grain yield tons/Ha	LER
Sole maize	1a	15.7a	4.4a	409.3a	133.2a	278.5a	2.6a	
1maize:2okra	1a	14.4a	4.4a	400.8a	133.9a	264.5a	1.85a	1.71a
2maize:2okra	1.1a	14.7a	4.5a	399.1a	136.5a	277.8a	2.5a	1.47a
Mean	1.03	14.9	4.4	403.1	134.5	273.6	2.3	1.59
P- Value ≤ 0.05	0.500	0.104	0.500	0.698	0.780	0.322	0.066	0.682
CV (%)	5.61	4.57	1.32	1.36	1.29	2.88	3.31	17.71

*Means sharing the same letter on the same column are not significantly different at 5% level of significance
Key: LER - Land Equivalent Ration; CV - Coefficient of Variance

Table 2: Effect of spatial arrangement on fruit yield of okra in maize/okra intercrop in Kilifi

Treatment	Number of fruits per plant	Okra fruit weight (g)	Fruit diameter (cm)	Fruit length (cm)	Yield tons/Ha	LER
Sol okra	10.8a	19.9a	1.9a	13.4a	3.2a	
1maize:2okra	7.7b	16.4b	1.8a	11.3b	3.4a	1.71a
2maize:2okra	8b	20.5a	1.9a	11.4b	1.6a	1.47a
Mean	8.3	18.9	1.9	12	2.7	1.59
P- Value ≤ 0.05	0.039	0.009	0.500	0.034	0.504	0.682
CV (%)	20.60	11.72	3.03	9.87	36.54	10.67

4.0 DISCUSSION

Intercropping maize and okra produced a smaller number of fruits per plant in okra. This could be due to the fact that, intercropping has the effect of introducing competition for growth resources especially for space, light, and heat. Since intercropping resulted in reduced number of branches, and fruits are born on the branches, it therefore, follows that reducing branching in okra resulted in reduced number of branches and few fruits per plant. Similar observation was made by Ijoyah et al. (2010) who observed that, the number of okra fruits depends on the growth characteristics of the plant. In addition, the greater leaf surface area produced by the sole crop might have enhanced its higher yield (Tareq et al., 2020). The sole planted okra crop and that under 2:2 maize/okra intercrop had significantly ($P \leq 0.05$) higher fruit weight compared to okra crop in the 1:2 maize/okra intercrop. This could perhaps be explained by the fact that, under sole cropping, the okra plants experienced intra-species competition, which had less competition effects compared to inter-species competition occasioned by maize plants. In the 2:2 arrangement, the low population density of both okra and maize, as are results of two rows of maize taking more spaces, reduced both intra and inter-species competition. Similar observations were reported by Choudhuri and Jana (2016) who observed that okra fruit yield was highest in sole cropping compared to intercropped okra with Amaranthus, or with cow peas. In addition, Samsuri et al. (2022) reported that the weight of okra fruit was substantially reduced in an intercropping system of okra and sweet corn. The high fruit weight in 2:2 maize/okra spatial arrangements could have resulted from low population of okra leading to less intra specific competition for growth resources. Agba et al. (2011) observed that high population density of okra reduces the fruit weight.

Intercropping maize and okra resulted in significant shorter okra fruits. This could have been due to the level of competition for growth resources such as water, nutrients and light, the okra plants curtailed fruit elongation. Competition from maize plants could have reduced availability of nitrogen and phosphorus to okra plants, which affected fruit elongation (Ramos and Da Rocha, 2014). Muoneke and Mbah (2007) reported similar findings – that when okra is intercropped with cassava, okra fruit length is significantly reduced due to stiff competition for growth resources.

5. CONCLUSION

Total grain yield of maize is not significantly affected when maize and okra crops are grown together. While intercropping maize and okra affects yield parameters such as number of fruits per plant, fruit weight, and fruit length, fruit dimeter and total fruit yields are not significantly affected. Intercropping maize and okra can enable farmers get their staple food while at the same time have okra vegetable to meet their dietary requirements, and increase land utilization. Farmers in Kilifi County in the Coastal lowland Agro ecological zone three (CL-3) can combine maize and okra as intercrop in the ratio 1:2 and 2:2.

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.

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