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Effect of spacing and number of plants per hill on growth and yield of Sc duma 43 in the coastal lowlands

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Abstract
Maize (*zea mays L)* is an important cereal grain globally as feed, and food for human and livestock respectively, rated third after wheat and rice in terms of production. The per capita consumption is 103 kg per person annually in Kenya, at the coastal lowlands it is rated first ahead of cassava and sweet potatoes. Maize is a rich source of carbohydrates, proteins, fats and minerals for the inhabitants of sub-Saharan Africa. Maize production at coast is constrained by inadequate knowledge of agronomic practices such as spacing plants per hill, crop management, limited arable land and choice of suitable cultivar choice and climate change. This study was conducted at Sugar Research Institute farm, Kikambala sub-county, Kilifi County between May and November 2015 cropping season, to evaluate the effect of four inter row spacing S1 (60 cm), S2 (70 cm), S3 (80 cm) and S4 (90 cm) and the number of plants per hill of 1, 2 and 4 as a second factor tested for effect on the growth and yields of the hybrid maize variety SC DUMA 43. Randomized complete block design (RCBD) in a split – plot arrangement was used with 3 replicates**.** The parameters investigated were plant height, stem diameter, cob length, weight of 1000 seeds, and grain yields per hectare. The data was summarized in MS Excel and analyzed using SPSS version 20 for ANOVA and LSD. Spacing and interaction between spacing and number of plants per hill did not show a significant effect on plant height, plant diameter and cob length. However, an inter – row spacing of 70 cm gave a significantly lower mean weight of 1000 seeds (312.48 g) against a highest mean value of 342.60 g for 80 cm which was however, not significantly different from the means obtained with 60 and 90 cm. The number of plants per hill significantly affected all growth and yield parameters with the highest grain yield recorded for 2 plants per hill (6543 kgha^{-1}) against a lowest mean value of 4575.4 kgha^{-1} obtained with 4 plants per hill. Stem diameter, cob length, weight of 1000 seeds decreased significantly as the number of plants per hill increased. Based on the findings of this study, it was concluded that for higher grain yields with the variety SC DUMA 43, planting should be done at 2 plants per hill and a spacing 80 × 30 cm.

Keywords: coastal lowlands, maize, plants per hill, row spacing

1. Introduction

Maize (*Zea mays L.*) is the third most important cereal crop after wheat and rice in terms of production globally, highly adaptable and productive cereal crop (Enujeke, 2013) [3]. It is grown under a wide range of environmental conditions. However, it yields well under moderate temperatures provided there is sufficient moisture. Essentially a tropical crop but currently it is grown across temperate, tropical and sub-tropical regions of world. It is a staple food for the majority of inhabitants of sub Saharan Africa and it is a major component of livestock feed and source of raw materials for industrial products in developed countries.

Globally, maize production is approximated at 116 million tons, of which Africa produces about 7.5% (75million bags) cultivated on 24% of land in Africa. Nigeria is the leading producer with 33 million bags followed by South Africa and Ethiopia in Eastern Africa (FAOSTAT, 2018; Belay, 2019) [4, 2]. In Kenya, maize is a staple food, source of income and employment for the majority of rural households and forms a larger percentage of national food security strategic grain reserve. It accounts for 25% of agricultural employment and more than 20% of all agricultural production in Kenya (Ouma & De Groote, 2011) [14]. It is cultivated across diverse agro ecological conditions from the central highlands to the coastal lowlands of Kenya, and it is largely cultivated under rain fed conditions. Small scale farmers produce approximately over 70% of the country's maize, while large-scale farmers and commercial farms contribute 30% (MOALF, ERA report, 2015). Approximately 2.1 million hectares of land is dedicated to maize production, with an average annual total production of 34 million 90 kg bags against requirement of 37 million 90 kg bags leaving a deficit of 3-4 million bags, which are met through imports (Government of Kenya (GOK), 2014).Yields average is about 1.8 t/ha, but a yield potential of over 6 t/ha is possible especially in the country's high potential areas (Schroeder *et al*., 2013) and this is low still compared to other leading maize producing countries such as Italy at 9.6, USA 8.6 and China 5.6 t/ha respectively (Zamir *et al*., 2011) [19].

In the coastal lowland of Kenya maize is equally an important food crop, ranked first ahead of cassava and sweet potatoes particularly in Kilifi and Kwale counties of Kenyan coast (KCDP, 2015). It is cultivated in almost all ecological zones of the coastal lowlands including in the arid and semi-arid areas (Wekesa *et al*., 2003) [18]. The total area of Kenya's Coast Province is estimated at 83,466 km^2 of which only 4,750 km^2 (approximately 6%) fall under crop production, (Shuma, *et al*., 2007). The region produces approximately 149,000 metric tons against a demand of 460,900 metric tons leaving a deficit of over 315,000 (Farm Concern International (FCI), 2015). Under current production and agronomic management systems, yields range between 1.02 -1.5 tons per hectare which are far below the potential for the region 2 – 3 tons per hectare and the low production levels create serious food deficits. The main challenges of maize production are poor agronomic practices such as row spacing and number of plants per hill among small holder farmers, especially in Kikambala Sub County of Kilifi County. Farmers are used to planting maize at varied inter row spacing of 60-100 cm and sowing of 3-6 plants per hill regardless of maize cultivar and this results in inadequate or overcrowded plant population that affect yields negatively. While in the earlier years this practice gave satisfactory yields, land fragmentation and population increase coupled with monocropping of maize has seen yield decline and stagnate over couple of years. There exists an opportunity to improve maize grain yields through choice of suitable hybrid variety at right spacing and number of plants per hill. Therefore, this study was done to determine the suitable row spacing and number of plans per hill that give appropriate plant population per unit area for optimum maize production for hybrid variety, SC DUMA 43 for the coastal lowlands of Kenya.

2. Materials and Methods

2.1 Site Description

The study was conducted at sugarcane breeding station farm of the Sugar Research Institute in Mtwapa - Kilifi County, Kikambala Sub County from May to November 2015. The site is located at latitude 3°5´ South, 39°44´ East, at an altitude of 15 meters above the sea level. The climatic conditions are generally hot and humid with mean temperatures 23°C and maximum 30°C, mean relative humidity of 80%. Rainy season is experienced between April – December, with annual mean rainfall 1200 mm. The distribution is bimodal in nature with peaks in May and November respectively with low rainfall in August (Mtwapa Agromet weather station, 2015). Soils are predominantly sandy loam, pH range 5.8-6.2, while chemical elements such as nitrogen % and organic carbon are low and low respectively. The site is in coastal lowland zone Cl_3area predominantly occupied by coconut and cassava crops but capable also of supporting production of maize, sugarcane, pulses and vegetables (Jaetzold & Schmidt, 1983).

2.2 Cultivar Choice

The selected maize variety for this trial was SC DUMA 43 (table 1) is classified as early maturating (4 - 5 months) white maize, with yield potential of 6 - 7 tons per hectare, tolerant to drought, maize mosaic virus (MSV), maize blight, has wider environmental adaptability and compares favorably to other popular hybrids such as Pwani hybrid 4 (PH4) and Pwani hybrid 1 (PH1).

Table 1: Hybrid maize varieties cultivated at the Kenyan coast

No	Variety	Year of release	Maturity (months)	Yield potential (tons/ha)	Special features
1	Pwani Hybrid 1	1989	3 – 4	5 – 7	Tolerant to drought and lodging
2	Pwani Hybrid 4	1995	4 – 5	6 – 8	Heat tolerant and tolerant maize streak virus (MSV)
3	DH 02	1995	3 – 4	4 – 6	Early and stay green
4	DH 04	2001	3 – 5	4 – 6	Early and short
5	SC DUMA 43	2004	4 – 5	6 – 7	Early, drought resilient, ear rot MSV and blight, wide adaptability scope

***Source*:** County government of Kilifi, Department of Agriculture, 2015 Annual Report.

2.3 Treatment and Treatment Combinations

Two factors were investigated inter row spacing: 60 × 30 cm (S1), 70 × 30 cm (S2), 80 × 30 cm (S3), 90 × 30 cm (S4) and number of plants per hill**:** 1 plant per hill (PH1), 2 plants per hill (PH2) and 4 plants per hill (PH3).

Table 2: Treatment and treatment combinations

Spacing	Number of plants per hill		
	PH1	PH2	PH3
S1	S1PH1	S1PH2	S1PH3
S2	S2PH1	S2PH2	S2PH3
S3	S3PH1	S3PH2	S3PH3
S4	S4PH1	S4PH2	S4PH3

The experimental design used was a randomized complete block (RCBD) in split-plot arrangement, with three replicates. Inter - row spacing was assigned to main plots and number of plants per hill to sub - plot treatments.

2.4 Crop Establishment and Management

The land was bush cleared, ploughed and harrowed, then demarcated into three blocks of dimensions 60 m long × 4 m wide, separated by paths of 2 meter from each other. Each block divided into 4 main plots measuring 15m × 3 meters, further demarcated to 3 sub plots within main plot each measuring 4 × 3 meters separated with paths of 1.5 meters so as to have 12 subplots per block and a total of 36 plots for the entire experiment. Certified maize seeds were sown in the experimental plots at a depth of 2 - 3 cm. The hills were sown with 3-6 seeds and thinned out at 10 days after sowing to obtain desired number of plants per treatments. Basal Double ammonium phosphate (DAP) fertilizer was applied at rate of 80 kg P_2O_5 ha^{-1} at planting and the crop was top dressed at 6 - 8 leaf stage with calcium ammonium nitrate (CAN - 26% N) at rate of 100 kg N ha^{-1}. The crop was weeded twice, at 4 - 5 leaf stage (3 weeks after sowing) and at 8 - 10 leaf using a hand hoe. An insecticide was applied to twice at 3 - 4 leaf stage and repeat done at 6 - 8 leaf stage at rate 10 kg per hectare, to prevent the attack of maize by maize stalk borer.

2.5 Data Collection

Data was collected on five randomly selected plants in the middle rows for plant height and girth at 14 days interval from date of sowing up to 84 days. The plant heights were measured using meter rule from the base of plant to tip of the panicle. The stem diameter (girth) was determined using vernier calipers across middle point of the stem of the maize plant. After harvest, cob length was measured from the tip to the bottom the cob using ruler, grain weight, and above ground biomass were also measured and harvest index at harvest was calculated. For grain yield**,** the harvested cobs were threshed manually, sun dried to moisture content of 12 - 13.5% and yield recorded per plot and converted into kgha-

[1].

2.6 Data Analysis

The data obtained was summarized in MS Excel and subjected to analysis of variance using SPSS version 20 and means were separated by least significance difference (LSD) post hoc test at 5% level of significance.

3. Results and Discussions

3.1 Effect of Spacing and Number of plants per hill on Growth

3.1.1 Plant height

There were gradual increases in plant heights of maize throughout growth period until tasseling. The results on plant heights showed that the highest mean plant height was 173.4 cm (60 × 30 cm) followed by 169.9 (90 × 30 cm) and the lowest mean height was noted for plants spaced at 70 × 30 cm. In addition, 2 plants per hill gave highest plant height 171.16 cm, while lowest was 165.9 cm was recorded on 4 plants per hill. However, the analysis of variance (see table 3) revealed that spacing and number of plants per hill had no significant effect on plant height ($p > 0.05$). Even though short stature plants were observed on four plants per hill, the fact that there was no significant difference did not allow us to corroborate the findings of Mashiqa *et al*. (2011) [12] who observed that plant heights were significantly affected at high plant populations due to increased competition for sunlight and nutrients.

Table 3: ANOVA summary for the effect of spacing and number of plants per hill on plant height

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Spacing	1166.041	3	388.680	.082	.970
Num. of plants per hill	1136.563	2	568.281	.119	.887
Spacing * Num. Plans/hill	1185.629	6	197.605	.042	1.000
Error	1999053.337	420	4759.651		
Total	2002541.569	431			
a. R Squared = .002 (Adjusted R Squared = -.024)					

3.1.2 Stem diameter

Stalk diameters were recorded at two weeks interval up to 84 days after sowing. Analysis of variance revealed that number of plants per hill significantly affected stem diameter, but row spacing and interaction of spacing and number of plants per hill did not have a significant effect on plant girth. LSD test results (see table 4) revealed that the highest mean stem diameter was recorded on single plant per hill (1.99 cm), followed by on two plants per hill (1.8 cm), while the lowest mean plant diameter was 4 plants per hill (1.60 cm). The results indicated that stem thickness decreased with increase in number of plants per hill from one to four and it decreased as inter-row spacing reduced from 90 cm to 60 cm, though with no significant difference.

Table 4: Mean stem diameter for different spacing levels and number of plants per hill

Parameter	Stem Diameter (cm)
Inter - row Spacing	
90 cm	1.82a
80 cm	1.79a
70 cm	1.80a
60 cm	1.77a
Number of plants per hill	
1	1.99a
2	1.80b
4	1.60c

Means the same parameter with the different letters are significantly different at the 0.05 level

The thin stem diameter at 4 plants per hill could be associated with crowding effect of plants, enhanced inter plant competition for available resources and mutual shading that may have inhibited lateral growth and favored dominance of apical growth. These results are in agreement with the findings of Gozubenli (2010); and Lashkari *et al*. (2011) [11] who found a significant decrease in stem diameter with increasing plant population.

3.2 Effect of Spacing and Number of plans per hill on Yield Components

3.2.1 Cob length

Cob length in maize is a dominant trait that affects seed size, seed weight and grain yield. Mean cob lengths of 17.89 cm and 16.17 cm were recorded for one and two plants per hill respectively, while four plants per hill gave smallest cob length of 13.5cm. The response of cob length to variation in inter row spacing revealed that 90 cm inter-row spacing posted cob length of 16.24 cm while the lowest mean cob length was 15.58 cm was given by 60 cm. Analysis of variance showed that cob length differed significantly due to number of plans per hill, but not due to spacing or interaction effect between spacing and number of plants per hill. As can be seen from the results in Table 6, LSD test revealed significant differences one plant per hill yielded significantly longer cobs, followed by 2 plants per hill, while the smallest cobs were recorded for 4 plants per hill. The reduced cob length at 4 plants per hill could be attributed to a limited photosynthesis activity of leaves because of crowding effect and leaf shading.

Table 6: Mean cob length for different spacing levels and number of plants per hill

Parameter	Cob length (cm)
Inter - row Spacing	
90 cm	16.1a
80 cm	16.0a
70 cm	15.7a
60 cm	15.6a
Number of plants per hill	
1	17.89a
2	16.12b
4	13.50c

Means the same parameter with the different letters are significantly different at the 0.05 level

The results in Table 6 indicate that four plants per hill probably exposed the crop to intense competition for available growth resources impacting negatively on growth and development of the cobs. These findings are in line with those reported by Zamir *et al*., 2011 [19] and Violeta *et al*., 2016 [17] who found that a significant reduction in ear length was associated with increased in plant population in maize. The results also concur with the findings of (Ukonze *et al*., 2016; Enujeke, 2013; and Lashkari *et al*., 2011 [15, 3, 11] who suggested that cob length decreased with increase in plant population because wider spaced crops encountered less competition for resources per unit area of land.

3.2.2 Weight of 1000 seeds

Seed weight is also a yield contributing factor, which plays an important role in indicating the potential grain yield of a variety. Mean weight of thousand seeds were determined at harvest and the results show that single plant per hill posted the highest mass of a thousand seeds (343.28 g), while 4 plants per hill recorded lowest mass (315.29 g). Based on inter-row spacing 80 cm had the highest mass of 342.6 g against a lowest mean of 312.48 g for 70 cm. Analysis of variance revealed that 1000 seed weight differed significantly ($p < 0.05$) due to variations in spacing and number of plants per hill. The result of Post hoc test as also given in table 7 show that there was no significant difference between 1 and 2 plants per hill yielded while the mean weight of 1000 seeds was significantly lower for 4 plants per hill compared to either 1 or 2 plants per hill. Similarly, spacing significantly influenced weight of a thousand seeds, with row spacings 60 cm, 80 cm, and 90 cm giving significantly higher mass weights compared to 70 cm as shown in the LSD test results in table 7.

Table 7: Mean weight of 1000 seeds for different spacings and number of plants per hill

Parameter	Weight of 1000 seeds (g)
Inter - row Spacing	
90 cm	333.32a
80 cm	342.60a
70 cm	312.48b
60 cm	335.29a
Number of plants per hill	
1	343.28a
2	334.20b
4	315.29c

Means the same parameter with the different letters are significantly different at the 0.05 level

The weight of 1000 seeds declined with increase in number of plants per hill from one to four. On the other hand, there was a significant response due to row spacing with the lowest value being recorded at an inter-row spacing of 70 cm and the seed weight increasing at 80 cm and 90 cm. Low seed weight at four plants per hill could be associated to limited products of photosynthesis for grain development due to high inter plant competition and mutual shading. This same trend if found with the number of plants per hill where 2 plants per hill gave significantly heavier seeds than 4 plants per hill and 1 plant per hill produced significantly heavier seeds than 2 plants per hill. These results are in line with the findings of Abuzar *et al*. (2011) [1] and Zamir *et al*. (2011) [19] who observed lower plant populations yielded heavier kernel mass compared to planting at higher populations due to unfavorable growing conditions such as reduced aeration and available solar radiation for photosynthesis and environmental resources. Kandil *et al*. (2017) [10] and Belay (2019) [2] also reported that because of a relatively lower number of plants, wide row spacing produced heavy kernel mass due to abundance of resources (nutrients, light, water) which they used to produce heavy kernels.

3.3 Grain Yield

Grain yield is a result of many complex morphological and physiological processes occurring during the growth and development of a crop. Mean grain yields per plot were measured after grains were dried and they were used to estimate the yields per hectare and the results are shown in figure 1.

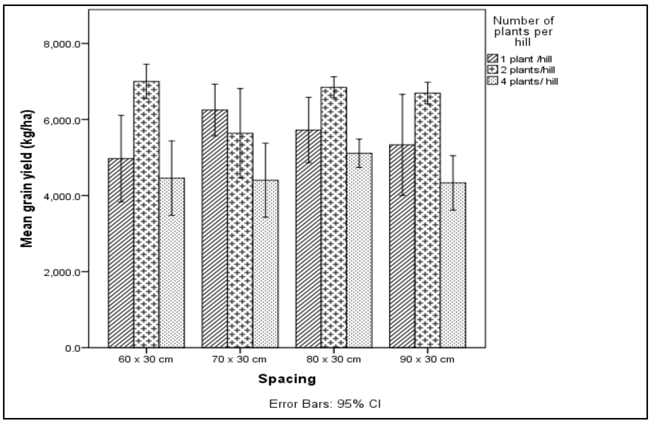

Fig 1: Effect of spacing and plants per hill on grain yield.

It can be seen from figure 1 that the highest mean grain yield per hectare was recorded for 2 plants per hill followed by one plant per hill. The lowest mean grain yield was recorded with maize planted at 4 plants per hill. Inter-row spacing also seems to have affected grain yields but the means do not seem to show any significant difference. ANOVA was carried out (see Table 8), it confirmed that grain yields were significantly affected by the number of plants per hill, but not by spacing.

Table 8: ANOVA summary for the effect of spacing and number of plants per hill on Grain Yield

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Spacing	2630473.772	3	876824.591	1.353	.266
Number of plants per hill	46512136.500	2	23256068.250	35.882	.000
Spacing * Num. of plants per hill	11947862.581	6	1991310.430	3.072	.011
Error	38887354.673	60	648122.578		
Total	99977827.526	71			
a. R Squared = .611 (Adjusted R Squared = .540)					

LSD test (table 9) revealed that 2 plants per hill had the highest yield (6543.1 kgha^{-1}) and it was significantly higher than the mean for 1 plant per hill (5569.4 kgha^{-1}) which was also significantly higher than the mean yield for 4 plants per hill (4575.0 kgha^{-1}).

Table 9: LSD test results for the effect of number of plants per hill on yield (kg/ha^{-1})

Number of plants per hill	Yield (kgha^{-1})
1	5569.4b
2	6543.1a
4	4575.0c

Means with the different letters are significantly different at the 0.05 level

Higher grain yield at 2 plants per hill compared to 1 plant per hill could be attributed to a greater number of cobs due to more plants per unit area of land, while the low grain yield at 4 plants per hill may be associated with low weight of individual grains which impacted negatively on grain yield. These results confirm the findings of Violeta *et al*. (2016) [17] and Mashiqa *et al*. (2011) [12] who recorded low grain yield for treatments with high plant population per unit area.

4. Conclusions and Recommendations

4.1 Conclusion

This study aimed at investigating the effect of inter row spacing and number of plants per hill on growth and yield parameters of hybrid maize variety SC DUMA 43 under coastal lowlands conditions. In conclusion, no significant differences were detected on growth and yield parameters measured due to inter-row spacing with exception of weight of 1000 seeds. On the other hand, the number of plants per hill had a significant effect on growth and yield parameters of SC DUMA 43 at $p < 0.05$, with effects observed on plant length, stem diameter, cob length, weight of 1000 seeds and grain yield per hectare. A spacing of 80 × 30 cm gave the highest grain yield, though not significantly higher than the other spacing levels, while two plants per hill gave the highest grain yield 6545 kgha^{-1} and it was significantly higher than all the other numbers of plants per hill.

4.2 Recommendation

Based on the results of this study, sowing at 2 plants per hill at spacing of 80 × 30 cm is recommended for improved maize yields of the maize variety SC DUMA 43 in the agro-climatic condition of the area of study.

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