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Jacob Gidale Kiyyo

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Jacob Gidale Kiyyo
Tanzania Agricultural Research Institute (TARI), Ilonga Center, Kilosa, Tanzania.

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Abstract

Purpose: The objective of this study is to validate the commonly recommended plant density in the target zone to maximize maize production and productivity. The commonly recommended plant density is 44,444 plants/ha for decades. However, there is no recent study done to validate this practice if it optimizes productivity under current climate and soil fertility variability. A blanket recommendation has been used for decades without validation for optimum productivity that farmer can realize.

Methodology: The factorial experiment was used with the total of 18 treatment combinations in a Randomized Complete Block Design (RCBD) with three replications according to Gomez, A and Gomez, K (1983). The open pollinated varieties (OPV) commonly grown by small scale farmers were planted in three different plant densities of 44,444, 53,333 and 66,666 plants per hector with inter and intra row spacings of 0.75mx0.3m, 0.75mx0.25m and 0.75mx0.2m respectively. Field management was done as usual following the recommended agronomic practices.

Findings: Analysis of variance (ANOVA) was done using GENSTAT (9th edition) statistical programme software and presented in a tabular form. The results indicated no significant difference in all parameters analysed except for 50% anthesis days (AD) and 50% Silking days (SD) both at 0.1% levels. The overall site mean for grain yield was found to be 6.43t/ha, 7.31t/ha and 6.11t/ha for the plant density of 44,444plants/ha, 53,333plants/ha and 66,666plants/ha respectively. Therefore, based on these findings the optimum plant density was found to be 53,333/ha unlike the commonly used plant density of 44,444 plants/ha.

Unique Contribution to Theory, Practice and Policy: This study contributes to existing experience and practice commonly recommended by extension officers in many parts of the country without performing a site-specific study to determine the optimum spacing for particular environment. This, study also open up an avenue for further research to validate various research technologies. Plant population, in addition to plant height, maturity class, and row spacings, affects the geometry of plant spacing and leaf distribution. All these factors may affect light and CO_2 penetration in the canopy, as well as water use rate (Tharp, B and Kells, J, 2001)

Keywords: *Plant Density, OPV, Grain Yield, Anthesis Days, Silking Days, MSV*

INTRODUCTION

Maize (*Zea mays L.*) is the essential staple food crop in sub-Saharan Africa (SSA) and Tanzania in particular whereby the crop accounts for over 30% of the food production, 20% of the agricultural gross domestic product (GDP) and over 75% of the cereal consumption. Maize is grown under a higher risk of failure due to the over-dependence on rain- fed farming system resulting in low income and food insecurity among maize-based farmers (Kadigi, I *et al*, 2020).

The increasing demand for maize in Tanzania for both human and commercial consumption has prompted the need for improved sustainable intensification. It has since been agreed that to improve maize intensification, a dynamic change on how maize is produced must be explored. These changes must consider making agronomic recommendations that deviate from the current generalized and blanket advice which do not recognize the wide variations in climatic and edaphic conditions (NAERLS and FDAE, 2017). Improving farming systems in resource-poor contexts is often difficult as farmers face multiple challenges to implement the innovations developed by researchers. However, like many other cereal sub-sectors in Tanzania, the maize sub-sector is grown under a higher risk of failure due to high dependence on a rain-fed farming system and low ability to adapt to climatic variability (URT, 2014). Plant density is one of the most important cultural practices affecting grain yield, as well as other important agronomic attributes of this crop (Workayehu, 2000; Sangoi, 2000; Abuzar *et al.*, 2011). Maize productivity is most affected by the variations in plant density (Vega *et al.*, 2001). Plant density affects maize yield through influencing yield components such as number of ears, number of kernels ears^{-1}and kernel weight (Sangoi, 2000). Many authors reported that maize yields significantly varied with plant density with the grain yield increasing with increasing plant density (Bozorgi *et al.*, 2011; Bakhtiar Gul *et al.*, 2011; Gobeze *et al.*, 2012; Chinyere, 2013). However, maize grains yield declines when the plant density increase beyond the optimum, primarily because of the decline in the harvest index and increased stem lodging (Sangoi, 2000). Optimum stand density (OSD) in annual crops is the intermediate seeding density that maximizes yield at harvest (Deng *et al.*, 2012). OSD selection is an agronomic practice that determines the growth and yield of maize, and its importance has long been established all over the world (Liu and Tollenaar, 2009; Duvick *et al.*, 2010; Casini, 2012; Al-Naggar *et al.*, 2015).

Low and mid altitude ecologies of Tanzania cover almost 51% of the maize growing area in the country. The crop is mainly grown as a staple food, main source of dietary calories and source of income (Kaliba., *et al*, 1998). Besides this fact, the production is hampered by number of biotic and abiotic stresses such as pest and disease, drought, heat stress, decline soil fertility and low soil water holding capacity. Thus, the rational and sustainable option among others is the choice of good agronomic packages including optimizing plant density.

In the recent years, the outbreak of Covid-19 pandemic has exacerbated the crop production failure including food crops in many countries. Food security was diminished as food availability on the market level was reduced due to mobility restrictions (Mugabe, P *et al.*, 2022). The impact of COVID-19 resulted in more than 85% of smallholder farmers experiencing an income reduction, thus also increasing the pre-existing vulnerability of these communities (Mugabe, P *et al.*, 2022). The pandemic has significant negative effects with many rural and urban areas across the globe effectively shut down for most commerce and transport. Border closures, quarantines and value chain disruptions are restricting access to food, low input supply and low purchasing power of those inputs among other factors threatening crop production capabilities (Mugabe, P *et al.*, 2022).

METHODOLOGY

The field trial was established during 2023 main cropping season at Tanzania Agricultural Research Institute (TARI), Ilonga Center farms. The factorial experiment was used with 18 treatment combinations laid down in a Randomized Complete Block Design according to Gomez, A and Gomez, K (1983). Experimental materials used were six adapted OPV maize varieties commonly grown in the low and mid altitude areas (**Table.1**). These varieties have generally a diverse characteristic in terms of yield and yield components, adaptability to adverse weather conditions and resistance to potential pest and diseases in the zone. The varieties were planted in three different plant densities of 44,444, 53,333 and 66,666 plants per hector at inter and intra row spacings of 0.75mx0.3m, 0.75mx0.25m and 0.75mx0.2m respectively. Field management was done as usual where Di-ammonium Phosphate (DAP) was applied at a recommended rate as a basal fertilizer. Urea fertilizer was applied as top dressing when the crop was at V5 and V12 growth stage respectively. Other operations such as hand weeding and insect control was done accordingly.

Table 1: Description of Varieties Used in the Trial

S/n	Commercial name	Maturity time (days)	Main characteristics	Average grain yield (t/ha)
1	TMV-1	100-110	MSV resistant, storage insect resistant, flint kernel	4.5
2	T104	100-110	Drought tolerant, MSV resistant	5.0
3	STAHA	110-120	Better yield advantage, tall stature, soft leaves and semi-dented	6.3
4	T105	110-110	Drought tolerant, MSV resistant, semi-dent	5.5
5	STUKAM-1	85-90	Drought tolerant, early maturity, dent kernel	3.8
6	BORA	90-100	MSV resistant, flint kernel,	4.5

Data Collection

Data collected includes grain yield (GY), days to 50% anthesis (AD), 50% silking days (SD), Maize streak virus count (MSV), ear height (EH), plant height (PH), ear position (EP), number of ears per plant (EPP) and days to physiological maturity (DPMAT).

Data Analysis

Analysis of variance (ANOVA) was done using GENSTAT (9th edition) statistical programme software and presented in a tabular form. The results indicated no significant difference in all parameters analysed except for 50% anthesis days (AD) and 50% Silking days (SD) both at 0.1% levels. The overall site mean for grain yield was found to be 6.43t/ha, 7.31t/ha and 6.11t/ha for the plant density of 44,444plants/ha, 53,333plants/ha and 66,666plants/ha respectively. Therefore, based on this finding the optimum plant density was found to be 53,333/ha unlike the commonly used plant density of 44,444 plants/ha

RESULTS AND DISCUSSIONS

Plant density of 44,444 per hector

The results showed no significant difference in all parameters analysed except for 50% anthesis days (AD) and 50% Silking days (SD) both at 0.1% levels. The overall site mean for grain yield was found to be 6.43t/ha at the spacing of 75cmx30 for all the entries used. However, for individual entry mean grain yield, TMV-1 showed higher performance with mean grain yield of 7.49t/ha followed by T105 with mean grain yield of 6.73t/ha on average as indicated in (Table 2).

Table 2: Plant Density of 44,444 Plants/ha with Row Spacing of 0.75x0.3m

Entry Name	GY	50%AD	50%SD	MSV	EH	PH	EP	EPP	PMAT
T104	6.39	55.33	57.67	0	76.7	211.7	0.36	0.918	106.57
STAHA	6.01	55.67	57.33	0	60	195	0.295	1	106.55
T105	6.73	54.33	56.67	0	93.3	221.7	0.409	1.035	106.2
BORA	5.76	54.33	61	0	76.7	210	0.362	1.03	106.52
TMV - 1	7.49	46.33	49	0	90	240.3	0.375	1.097	104.51
STUKAM-1	6.57	55.33	58.33	0	85	230	0.367	0.98	103.64
Site mean	**6.43**	53.56	56.67	0	80.3	218.1	0.361	1.01	105.66
LSD 0.05	2.731	5.185	7.03	0	48.58	64.54	0.1702	0.1989	6.664
%CV	2.5	0.9	2.1	0	16.6	8	11.1	3.3	0.6
Sign.	NS	**	**	NS	NS	NS	NS	NS	NS

*Statistical significance: *** and *** represent p-values of 1, 0.1 and 0.01 respectively, NS= Statistically not significant, LSD = Least Significant Difference, CV = Coefficient of Variation, GY=Grain Yield (t/ha), 50%AD= Anthesis Days. SD= Days to 50% Silk, MSV=Number of plants with Maize Streak Virus, PH=Plant height (cm), EH=Ear Height (cm), EPP=Ears per plant, PMAT=Days to Physiological Maturity*

Plant Density of 53,333 per Hector

When the plant density was increased to 53,333plants/ha with inter and intra row spacing of 0.75mx0.25m, there was a significant difference at 1% level for 50% anthesis days (AD), ear height (EH), ear position (EP) and number of days to physiological maturity (DPMAT). There was no significant difference for other parameters recorded. The mean grain yield was observed to be (7.31t/ha); however in terms of individual entries STAHA was found to be superior with the mean yield of 9.86t/ha followed by T105 with the mean grain yield of 8.27t/ha as indicated in (Table 3).

Table 3: Plant Density of 53,333 Plants/ha with Row Spacing 0.75mx0.25

Entry Name	GY	50%AD	50%SD	MSV	EH	PH	EP	EPP	PMAT
T104	6.42	52.67	55.33	0	75	196.7	0.382	0.883	106.57
STAHA	9.86	55.33	57.67	0	126.7	253.3	0.494	1.043	106.55
T105	8.27	53.67	56.33	0.67	83.3	211.3	0.395	1.056	106.2
BORA	5.28	49.33	52.67	0	75	191.7	0.38	0.834	106.52
TMV - 1	6.45	46.33	51	0	85	216.7	0.391	0.981	104.51
STUKAM-1	6.57	52	54.33	0.33	46.7	190	0.25	1.104	103.64
Site mean	**7.31**	51.61	54.56	0.17	81.9	209.9	0.382	0.983	105.66
LSD 0.05	3.659	5.023	4.091	0.879	41.01	56.63	0.1363	0.3059	6.664
%CV	5.1	1	2.3	173.2	11	3.8	7.2	10.1	0.6
Sign.	NS	**	NS	NS	**	NS	**	NS	NS

*Statistical significance: *** and *** represent p-values of 1, 0.1 and 0.01 respectively, NS= Statistically not significant, LSD = Least Significant Difference, CV = Coefficient of Variation, GY=Grain Yield (t/ha), 50%AD= Anthesis Days. SD= Days to 50% Silk, MSV=Number of plants with Maize Streak Virus, PH=Plant height (cm), EH=Ear Height (cm), EPP=Ears per plant, PMAT=Days to Physiological Maturity*

Plant Density of 66,666 per Hector

With the spacing of 75cmx20cm, there is highly significant difference in terms of 50% anthesis days **(50%AD***)** and 50% silking days **(50%SD***)** both at 0.1% level of confidence (CI).

Other parameters like ear height, plant height, ear per plant and plant maturity days are significantly different at 1% level of confidence. There is no significant difference for the rest of parameters recorded as indicated in (Table 4).

Table 4: Plant density of 66,666 plants/ha with row spacing of 0.75mx0.20

Entry Name	GY	50%AD	50%SD	MSV	EH	PH	EP	EPP
T104	6.89	51.33	54.33	142.6	210	0.312	0.943	104.8
STAHA	5.27	56.33	55.67	136.7	286.7	0.475	1.223	108.3
T105	4.83	52.33	55.33	88.3	231.7	0.379	1.032	105.66
BORA	6.70	50.67	53.33	108.3	253.3	0.427	1.029	103.55
TMV – 1	5.63	44.67	48	80	213.3	0.374	0.992	103.74
STUKA- M1	6.24	46.33	50	86.7	240	0.362	1.01	102.05
Site mean	**6.11**	50.28	52.78	94.4	239.2	0.388	1.038	104.69
LSD 0.05	1.275	2.433	2.692	33.78	42.11	0.1132	0.1472	3.323
%CV	5.3	1.8	2.2	7.1	5.5	3.3	6.6	0.5
Sign	NS	***	***	**	**	NS	**	**

*Statistical significance: *** and *** represent p-values of 1, 0.1 and 0.01 respectively, NS= Statistically not significant, LSD = Least Significant Difference, CV = Coefficient of Variation, GY=Grain Yield (t/ha), 50%AD= Anthesis Days. SD= Days to 50% Silk, MSV=Number of plants with Maize Streak Virus, PH=Plant height (cm), EH=Ear Height (cm), EPP=Ears per plant, PMAT=Days to Physiological Maturity*

CONCLUSION AND RECOMMENDATION

The purpose of this study is to contribute to the existing experience in the Tanzanian context in terms of optimum plant density for maize crop across different agroecological zones. The established recommendation for couple of years for maize crop has never been reviewed and validated, thus a blanket recommendation has been used countrywide. Therefore, optimizing plant density for various agroecological systems with current climate variability is a better farming decision for optimized productivity.

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