Application of Decision Support System for Agro Technology Transfer (DSSAT) to Simulate Agronomic Practices for Cultivation of Maize in Southern Highland of Tanzania

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Abstract

The southern highlands zone of Tanzania is the one of the most potential area for agriculture contributes up to 46% of the total country's maize production. However, the rate of maize production tends to decrease with time due of poor agronomic practices. The aim of this study was to simulate the effect of nitrogen dose and plant spacing on grain yields from five selected maize varieties. Decision Support System for Agrotechnology transfer crop model was used for this purpose. Based on the agroecological zones, six sites were selected which includes Ihumbu farm, Mwazye and Nyera Estate Mbozi, Lupa Tinga Tinga, Santilya and Mbinga. Maize varieties H614, Kitumani Composite I, H511, H626 and H612; Spacing (90 × 30 cm and 60 × 30 cm) and nitrogen dose (0, 50, 100, 150 and 200 kg/ha) were simulated. It was found that only H614 (4610.9 kg/ha) and Kitumani Composite I (3998.7 kg/ha) maize varieties performed well at the spacing of 60 × 30 cm and up to the nitrogen dose of 150 kg/ha. Therefore the two maize varieties H614 and Kitumani Composite I could be recommended for cultivation at the spacing of 60 × 30 cm and nitrogen dose of 150 kg/ha for improving production of maize in southern highland of Tanzania.

Keywords

Southern Highlands (Tanzania), DSSAT, Nitrogen Dose, Plant Spacing and Maize Varieties

1. Introduction

The economy of Tanzania is highly dependent on agriculture which provides the

source of livelihood for over 80% of the population. The agricultural sector constitutes nearly 24% of the value of the national income (GDP) [1]. To a large extent the sector is characterized by traditional production systems which rely on indigenous varieties whose overall productivity is generally low.

The southern highlands zone of Tanzania contributes about 46% of national maize production and it accounts for nearly 90% of the maize purchased for the National Food Security Granary [2]. This zone comprises of four regions viz. Iringa, Mbeya, Rukwa, and Ruvuma. Over 80% of the maize produced in this region is grown by smallholders under a wide range of agronomic practices, climatic conditions, and socioeconomic conditions. Beside the contribution of the zone to the country maize production, still there is a large gap between national average yield (1.4 t/ha) and potential yields (7.0 t/ha) [3]. Among the agronomic factors responsible for low yield of the region which are plant population in the field, application of inappropriate amount of inorganic fertilizers and use of low yielding varieties/cultivars are of prime importance [4]. Crop row spacing is another important agronomic management strategy used by farmers to optimize the husbandry of the soil and plant ecosystem from sowing to harvest with the goal of increasing the production of crops [5]. Row spacing has a special significance since it is ultimately related with plant population, root development, plant growth and fruiting [6]. Maize is well known for its high demand of nutrients. In addition to other agronomic practices, fertilization may be the most important way to maintain high crop productivity and soil fertility [7]. The fact that nitrogen has a good effect on plant productivity is universally accepted. Nevertheless, it also has a pollutant effect on the environment when dissolved and leach down to ground water/aquifer zones when applied irrationally. When nitrogen is rapidly leached down to ground water, they affect human and animal health [8]. Therefore, judicious use of mineral nitrogen fertilizer should be promoted on improvement maize productivity [9], without reduction in yields and much adverse impact on environment (soil and ground water quality). The development of appropriate management practices can be achieved by employing crop models like DSSAT in simulation studies.

The decision support system for agro technology transfer (DSSAT) crop model has been used for different applications in various countries around the world. It was originally developed by an international network of scientists, cooperating in the International Benchmark Sites Network for Agrotechnology Transfer project [10], to facilitate the application of crop system models such as Crop Environment Resource Synthesis (CERES) maize model in a systems approach to agronomic research. Its initial development was motivated by a need to integrate knowledge about soil, climate, crops, and management for making better decisions about transferring production technology from one location to others where soils and climate differed [11]. The DSSAT helps decision-makers by reducing the time and human resources required for analyzing complex alternative decisions [12]. It also provides a framework for scientific cooperation through

research to integrate new knowledge and apply it to research questions. The objective of this study is to simulate the effect of nitrogen dose, spacing and suitability of varieties on increasing grain yield of maize grown in southern highland zone of Tanzania by application of CERES-maize model of DSSAT.

2. Materials and Methods

2.1. Description of the Study Area

The southern highlands zone found on the latitude of 7° and 11.5°S and longitudes of 30° and 38°E (Figure 1). The zone occupies an area of 250,000 km^2 which is about 28% of the mainland area of Tanzania. The elevation from the sea level ranges from 400 and 3000 m. The region experience semi-arid condition in some parts of Iringa region to high rainfall in highland areas (more than 2500 mm of rain per year) with cool temperatures. The rainfall pattern is unimodal with a long rainy season (700 mm to over 2600 mm) from November to May with a dry and cool spell between June and September [13]. The soil has low fertility, highly weathered and frequently acidic. Normally, maize is planted between the ends of November and early of December and harvested between April and July, depending on the weather and the variety grown [14]. For the purposes of the study six (6) sites were bee selected, Ihumbu farm (−7.88, 35.8), Mwazye (−8.43, 31.71), Nyera Estate Mbozi (−9.16, 33.11), Santilya (−9.08, 33), Lupa Tinga Tinga (−8.01, 33.26) and Mbinga (−10.91, 35.0).

2.2. Model Input Data

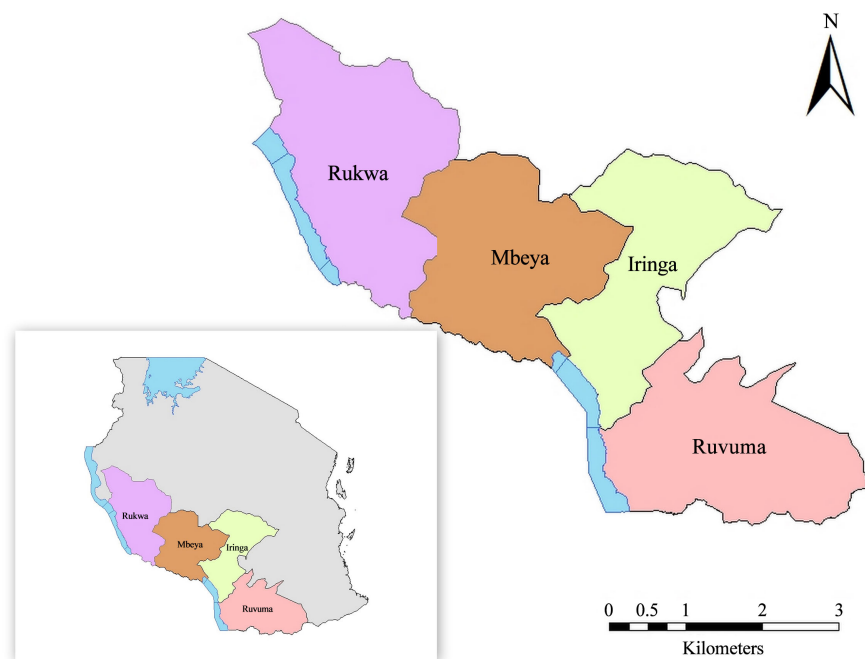DSSAT crop simulation models in generally predict crop yield as a function of

Figure 1. Map of Tanzania showing the location of Southern Highland zone.

weather conditions, soil conditions and crop management practices. The minimum daily weather data required running the DSSAT models which includes maximum and minimum temperature (°C), rainfall (mm), and sunshine hours (hours/day) which were downloaded from the New_LocClim of Food and Agriculture Organisation. The New_locClim (an abbreviation for "Local Climate"), a software program and database, provides estimates of average climatic conditions at locations for which no observations are available. The sunshine hours (hours/day) were converted into solar radiation (MJm^{-2} day^{-1}) by using Weatherman tool of DSSAT.

Soil characteristics data which includes clay fraction (%), silt fraction (%), stones fraction (%), organic carbon (%), CEC (Cation Exchange Capacity) (cmol/kg), pH (in water), horizon thickness (depth), surface characteristics such as soil color, Land slope, permeability, drainage class, and soil series name. These data were obtained from HWSD (Harmonized World Soil Database) which was created by the Food and Agriculture Organization of the United Nations and the International Institute for Applied Systems Analysis (IIASA) [15]. These organizations took the initiative of combining the recently collected vast volumes of regional and national updates of soil information with the information already contained within the 1:5,000,000 scales FAO-UNESCO Digital Soil Map of the World, into a new comprehensive HWSD.

The crop management data were obtained from the survey report, documented by [14]. These data includes crop cultivar, planting date, seedling rate (plant/hill), plant spacing (cm), row spacing (cm), and planting depth (cm). Others include fertilizer application (dates, amounts, type of material, and method of application), tillage/intercultural operations (dates, depth equipment used), organic fertilizer amendments (date, amount, type and method of application). The collected soil and weather data were for running the model were compiled and presented as shown in Table 1 and Figure 2 respectively.

2.3. Simulation Processing

The CERES-Maize model incorporated in DSSAT v4.5 was used for simulation. Simulation was done separately for each selected sites in all treatment combination (cultivar, spacing and nitrogen dose) making 75 runs. Cultivars more or less cultivated/available in that region are used in the simulation to determine their suitability to that particular region. For this purpose five varieties of maize were selected Kitumani Composite 1 (V1), H614 (V2), H626 (V3) H612 (V4) and H511 (V5). Planting date was set on 20 November where by Dry seed of Maize at the depth of 5 cm where planted at seed rate of 2 plants/hill. Spacing treatments used in the simulation are S1 (90 × 30 cm), S2 (60 × 30 cm) and S3 (90 × 50 cm). The number of plants at seedling and emergency by calculation was set 8 plants per m^2 and 7 plants per m^2 respectively at spacing one (S1) making the population of 70,000 plants per hectare. At spacing two (S2) and the same seed rate, the number plants at seedling was 12 plants per m^2 and at emergency was 11 plants
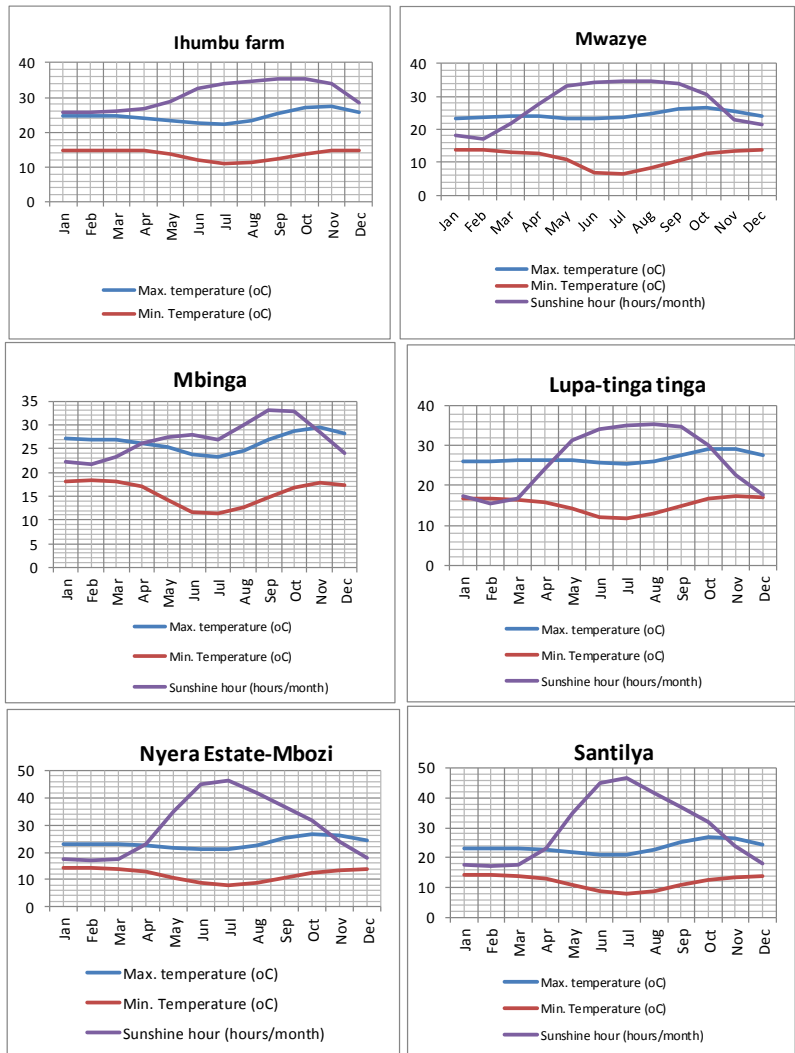
(a)
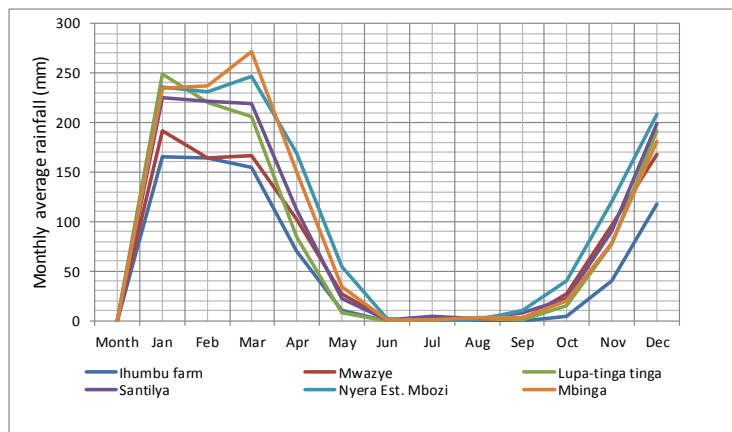
(b)

Figure 2. (a) A graph of average monthly minimum and maximum temperature and sunshine hours at the selected sites of Southern Highlands of Tanzania; (b) A graph of average monthly minimum and maximum temperature and sunshine hours at the selected sites of Southern Highlands of Tanzania.

Table 1. Soil characteristics of different locations of Southern Highlands of Tanzania.

Ihumbu farm							
Soil classification: Clay, Colour: Red, Drainage: Moderately well							
Land slope: 0.15 Fertility factor (0 - 1): 1, Runoff potential: Moderately low							
Depth	Horizon	Percentage				pH in	*CEC	Total
(bottom), (cm)	Master	Clay	Silt	Stones	*OC	water	(cmol/kg)	Nitrogen (%)
0 - 10	A	49	27	2	2.45	5.3	20	0.22
10 - 30	A1	55	24	3	1.67	5.3	20	0.21
30 - 60	B	61	21	4	0.96	5.4	20	0.2
60 - 100	B1	67	18	5	0.81	5.4	20	0.19
Mwazye							
Soil classification: Clay loam, Colour: Brown, Drainage: Moderately well							
Land slope: 0.16 Fertility factor (0 - 1): 1, Runoff potential: Moderately low							
Depth	Horizon	Percentage				pH in	*CEC	Total
(bottom), (cm)	Master	Clay	Silt	Stones	*OC	water	(cmol/kg)	Nitrogen (%)
0 - 10	A	21	15	2	1.2	5.4	5	0.22
10 - 30	A1	26	18	3	0.78	5.4	4	0.21
30 - 60	B	30	21	4	0.35	5.4	3	0.2
60 - 100	B1	36	24	5	0.18	5.4	2	0.19
Nyera Estate Mbozi							
Soil classification: Sandy clay loam, Colour: Red, Drainage: Moderately well							
Land slope: 0.17 Fertility factor (0 - 1): 1, Runoff potential: Moderately low							
Depth	Horizon	Percentage				pH in	*CEC	Total
(bottom), (cm)	Master	Clay	Silt	Stones	*OC	water	(cmol/kg)	Nitrogen (%)
0 - 10	A	31	3	2	0.63	5.8	5	0.22
10 - 30	A1	40	3	3	0.47	5.4	5	0.21
30 - 60	B	49	3	4	0.31	5.2	5	0.2
60 - 100	B1	58	3	5	0.15	4.6	5	0.19
Santilya							
Soil classification: Sandy loam, Colour: Brown, Drainage: Moderately well							
Land slope: 0.16 Fertility factor (0 - 1): 1, Runoff potential: Moderately low							
Depth	Horizon	Percentage				pH in	*CEC	Total
(bottom), (cm)	Master	Clay	Silt	Stones	*OC	water	(cmol/kg)	Nitrogen (%)
0 - 10	A	7	32	1	2.43	5.8	17	0.23
10 - 30	A1	6.5	29	2	2.94	5.9	16	0.22
30 - 60	B	6	26	4	1.48	6.1	10	0.21
60 - 100	B1	5.5	22	5	0.12	6.3	10	0.2
Lupa Tinga Tinga							

Continued

Soil classification: Sandy clay, Colour: Brown, Drainage: Moderately well								
Land slope: 0.16 Fertility factor (0 - 1): 1, Runoff potential: Moderately low								
Depth	Horizon		Percentage			pH in	*CEC	Total
(bottom), (cm)	Master	Clay	Silt	Stones	*OC	water	(cmol/kg)	Nitrogen (%)
0 - 10	A	39	10	2	1.73	5.3	12	0.22
10 - 30	A1	42	9	3	1.26	5.4	10	0.21
30 - 60	B	44	8	4	0.78	5.6	9	0.2
60 - 100	B1	46	6	5	0.31	5.8	7	0.19
Mbinga								
Soil classification: Sandy loam, Colour: Red, Drainage: Moderately well								
Land slope: 0.16 Fertility factor (0 - 1): 1, Runoff potential: Moderately low								
Depth	Horizon		Percentage			pH in	*CEC	Total
(bottom), (cm)	Master	Clay	Silt	Stones	*OC	water	(cmol/kg)	Nitrogen (%)
0 - 10	A	19	19	2	1.38	6.4	9	0.22
10 - 30	A1	26	18	3	0.91	5.7	8	0.21
30 - 60	B	34	17	4	0.41	5	7	0.2
60 - 100	B1	41	15	5	0.21	4.3	6	0.19

*CEC: Cation Exchange Capacity; *OC: Organic Carbon.

per m^2 which make the population of 110,000 plants per hectare. At spacing three (S3) and the same seed rate, the number plants at seedling was 4 plants per m^2 and at emergency was 4 plants per m^2 which make the population of 40,000 plants per hectare.

Varying nitrogen application from no nitrogen to 200 kg of nitrogen per hectare was used as treatments to study the effect of nitrogen on grain yields of maize for different cultivars. The nitrogen treatments used for yield simulation studies were N1 (0 kg/ha), N2 (50 kg/ha), N3 (100 kg/ha), N4 (150 kg/ha) and N5 (200 kg/ha). Half of the total nitrogen is applied at the time of sowing; the remaining amount is given just before the juvenile stage of the crop. Urea is used as nitrogen supplement in this simulation study and the depth of placement is 5 cm during basal application and banded on the surface during the second application. Genetic coefficients of the maize varieties used in the simulation pre-existed within the model hence the model generated the data on the growth and developmental parameters without specifying it in the input data. The harvesting date is simulated for the crop when 50% of the plants reach harvest maturity (GS006).

3. Results and Discussion

The results of DSSAT simulated yield of maize obtained for six sites (Ihumbu

farm, Mwazye and Nyera Estate Mbozi, Lupa Tinga Tinga, Santilya and Mbinga), five varieties (H614, Kitumani Composite I, H511, H626 and H612), five nitrogen doses (0, 50, 100, 150 and 200 kg N/ha) and three spacings (90 × 30 cm, 60 × 30 cm and 90 × 50 cm) are presented in Table 2 and discussed in the forthcoming paragraphs.

3.1. Response of Maize Varieties to Nitrogen with Respect to Grain Yield

[16] explains that, an increase in grain yield of maize after application of Nitrogen is due to an increase in the number of ears per plant, increase in total dry matter distributed to the grain and increase in average ear weight. These plant characteristics tend to vary from one variety to another. The results from Table 2 show that, grain yield of all varieties tend to increase with the increasing rate of nitrogen, where by H614 variety followed by Kitumani composite I (KC I) respond faster than the other varieties (H612, H511 and H626). The overall mean grain yield in bracket of all varieties at spacing one (Sp 1) was H614 (4610.9 kg/ha), Kitumani Composite I (3998.7 kg/ha), H612 (2835.7 kg/ha), H511 (2231.6 kg/ha), and H626 (1673.3 kg/ha). The results are in agreement with [17] who found out positive response of different maize varieties on supply of nitrogen in increasing grain yield.

3.2. Suitability of Maize Variety to Different Location

Grain yield is the results of genetic potential and environmental interaction. From the results (Table 2), grain yield differ from one location to another at a given maize variety. An example of maize cultivar H614 at spacing one (S1) and 0 kg N/ha, maximum yield was observed at Santilya (2684 kg/ha) and the minimum grain yield of 395 kg/ha at Mbinga. The results are supported by [18] who report that maize varieties significantly differed in yield at different locations. [19] also reports the same on response to maize variety to different environmental condition. Overall results show that highest yield was obtained from H614 (4610.9 kg/ha) followed by Kitumani Composite I (3998.7 kg/ha), H612 (2835.7 kg/ha), H511 (2231.6 kg/ha) and H626 (1673.3 kg/ha) at spacing one (S1) and H614 (4724.5 kg/ha) followed by Kitumani Composite I (3465.3 kg/ha), H612 (2288.7 kg/ha), H511 (2151.6 kg/ha) and H626 (1626.9 kg/ha) at spacing 2 (S2).

3.3. Effect of Plant Spacing on Grain Yield

The effects of plant spacing on grain yield are also shown on Table 2. [20] has documented that, yield and yield component of corn are significantly affected by planting patterns, plant densities and maize hybrids. Corn hybrids respond differently to high plant density [21]. Plant density is a function of plant spacing on the field, the larger spacing results into low plant density per unit area. The overall results shows that the mean grain yield of all varieties was 3428.0 kg/ha in spacing one (S1) and 3169.2 kg/ha at spacing two (S2). Taking an example of

Table 2. DSSAT forecasted grain yields of Maize (*Zea mays L.*) as affected by locations, variety, spacing and nitrogen dose in Southern Highlands of Tanzania.

No.	Treatments	Location															
		Ihumbu				Mwazye				Nyera Estate Mbozi				Santilya			
		S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
1	V1N1	1887.0	2058.0	1914.0	**1953.0**	634.0	576.0	793.0	**667.7**	459.0	449.0	491.0	**466.3**	2733.0	2976.0	2708.0	**2805.7**
2	V1N2	5089.0	3836.0	4393.0	**4439.3**	2864.0	2679.0	3041.0	**2861.3**	2113.0	2175.0	2652.0	**2313.3**	4698.0	4410.0	4438.0	**4515.3**
3	V1N3	6200.0	7465.0	4412.0	**6025.7**	3769.0	4329.0	2286.0	**3461.3**	5140.0	4201.0	4309.0	**4550.0**	6080.0	6447.0	4504.0	**5677.0**
4	V1N4	6206.0	8114.0	4413.0	**6244.3**	2893.0	4959.0	2240.0	**3364.0**	6181.0	7229.0	4504.0	**5971.3**	6366.0	7642.0	4504.0	**6170.7**
5	V1N5	6207.0	8117.0	4413.0	**6245.7**	2876.0	4092.0	2248.0	**3072.0**	6367.0	8216.0	4504.0	**6362.3**	6367.0	8199.0	4504.0	**6356.7**
	Mean	5117.8	5918.0	3909.0	4981.6	2607.2	3327.0	2121.6	2685.3	4052.0	4454.0	3292.0	3932.7	5248.8	5934.8	4131.6	5105.1
1	V2N1	1784.0	1567.0	2039.0	**1796.7**	462.0	426.0	582.0	**490.0**	409.0	406.0	443.0	**419.3**	3053.0	2684.0	3285.0	**3007.3**
2	V2N2	3295.0	2388.0	4669.0	**3450.7**	1907.0	1738.0	2105.0	**1916.7**	1643.0	1362.0	2067.0	**1690.7**	4885.0	4845.0	4939.0	**4889.7**
3	V2N3	6590.0	4941.0	6134.0	**5888.3**	2846.0	2630.0	2930.0	**2802.0**	3935.0	3468.0	4665.0	**4022.7**	6437.0	6643.0	6235.0	**6438.3**
4	V2N4	8538.0	8416.0	7504.0	**8152.7**	3091.0	3361.0	3117.0	**3189.7**	6585.0	5236.0	6336.0	**6052.3**	7727.0	8177.0	7075.0	**7659.7**
5	V2N5	9565.0	10284.0	7500.0	**9116.3**	3320.0	3562.0	3182.0	**3354.7**	8353.0	7892.0	7339.0	**7861.3**	8805.0	9481.0	7552.0	**8612.7**
	Mean	5954.4	5519.2	5569.2	5680.9	2325.2	2343.4	2383.2	2350.6	4185.0	3672.8	4170.0	4009.3	6181.4	6366.0	5817.2	6121.5
1	V3N1	929.0	1069.0	851.0	**949.7**	467.0	443.0	457.0	**455.7**	405.0	415.0	436.0	**418.7**	1762.0	2008.0	1483.0	**1751.0**
2	V3N2	1066.0	1250.0	1580.0	**1298.7**	742.0	829.0	709.0	**760.0**	963.0	1095.0	905.0	**987.7**	2290.0	2429.0	2171.0	**2296.7**
3	V3N3	2262.0	1611.0	2643.0	**2172.0**	1106.0	1090.0	928.0	**1041.3**	1556.0	1552.0	1888.0	**1665.3**	2922.0	3064.0	2687.0	**2891.0**
4	V3N4	3075.0	2913.0	2845.0	**2944.3**	1225.0	1347.0	1201.0	**1257.7**	2441.0	2173.0	3061.0	**2558.3**	3316.0	3686.0	3101.0	**3367.7**
5	V3N5	3425.0	3489.0	2810.0	**3241.3**	1446.0	1469.0	1257.0	**1390.7**	3542.0	3079.0	3530.0	**3383.7**	3626.0	4181.0	3392.0	**3733.0**
	Mean	2151.4	2066.4	2145.8	2121.2	997.2	1035.6	910.4	981.1	1781.4	1662.8	1964.0	1802.7	2783.2	3073.6	2566.8	2807.9
1	V4N1	1072.0	1123.0	1081.0	**1092.0**	455.0	382.0	464.0	**433.7**	375.0	377.0	407.0	**386.3**	1644.0	1725.0	1593.0	**1654.0**
2	V4N2	2447.0	1943.0	3109.0	**2499.7**	1337.0	1247.0	1416.0	**1333.3**	1042.0	1060.0	1303.0	**1135.0**	2511.0	2422.0	2672.0	**2535.0**
3	V4N3	4186.0	3736.0	3468.0	**3796.7**	2030.0	1937.0	1864.0	**1943.7**	2478.0	2020.0	3099.0	**2532.3**	3502.0	3361.0	3370.0	**3411.0**
4	V4N4	4515.0	5032.0	3468.0	**4338.3**	2262.0	2551.0	1540.0	**2117.7**	3970.0	3418.0	3535.0	**3641.0**	4065.0	4364.0	3528.0	**3985.7**
5	V4N5	4495.0	5396.0	3468.0	**4453.0**	2130.0	2715.0	1445.0	**2096.7**	4602.0	4793.0	3535.0	**4310.0**	4404.0	4800.0	3536.0	**4246.7**
	Mean	3343.0	3446.0	2918.8	3235.9	1642.8	1766.4	1345.8	1585.0	2493.4	2333.6	2375.8	2400.9	3225.2	3334.4	2939.8	3166.5
1	V5N1	1061.0	906.0	1793.0	**1253.3**	264.0	224.0	283.0	**257.0**	204.0	198.0	198.0	**200.0**	1854.0	1481.0	2342.0	**1892.3**
2	V5N2	4070.0	4430.0	2681.0	**3727.0**	1894.0	2868.0	1417.0	**2059.7**	2455.0	1516.0	2328.0	**2099.7**	3390.0	4258.0	2496.0	**3381.3**
3	V5N3	4078.0	5476.0	2655.0	**4069.7**	1798.0	2486.0	1394.0	**1892.7**	3591.0	4157.0	2567.0	**3438.3**	3594.0	4574.0	2567.0	**3578.3**
4	V5N4	4079.0	5478.0	2649.0	**4068.7**	1809.0	2496.0	1400.0	**1901.7**	3697.0	4998.0	2567.0	**3754.0**	3597.0	4722.0	2567.0	**3628.7**
5	V5N5	4079.0	5479.0	2648.0	**4068.7**	1813.0	2500.0	1400.0	**1904.3**	3697.0	4998.0	2567.0	**3754.0**	3697.0	4861.0	2567.0	**3708.3**
	Mean	3473.4	4353.8	2485.2	3437.5	1515.6	2114.8	1178.8	1603.1	2728.8	3173.4	2045.4	2649.2	3226.4	3979.2	2507.8	3237.8
1	N1	1346.6	1344.6	1535.6	1408.9	456.4	410.2	515.8	460.8	370.4	369.0	395.0	378.1	2209.2	2174.8	2282.2	2222.1
2	N2	3193.4	2769.4	3286.4	3083.1	1748.8	1872.2	1737.6	1786.2	1643.2	1441.6	1851.0	1645.3	3554.8	3672.8	3343.2	3523.6

Continued

3	N3	4663.2	4645.8	3862.4	4390.5	2309.8	2494.4	1880.4	2228.2	3340.0	3079.6	3305.6	3241.7	4507.0	4817.8	3872.6	4399.1
4	N4	5282.6	5990.6	4175.8	5149.7	2256.0	2942.8	1899.6	2366.1	4574.8	4610.8	4000.6	4395.4	5014.2	5718.2	4155.0	4962.5
5	N5	5554.2	6553.0	4167.8	5425.0	2317.0	2867.6	1906.4	2363.7	5312.2	5795.6	4295.0	5134.3	5379.8	6304.4	4310.2	5331.5
Overall Mean		4008.0	4260.7	3405.6	3891.4	1817.6	2117.4	1588.0	1841.0	3048.1	3059.3	2769.4	2959.0	4133.0	4537.6	3592.6	4087.7

No.	Treatments	Locations											Overall Mean
		Lupa Tinga Tinga				Mbinga				Mean			
		S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	
1	V1N1	1347.0	1564.0	1273.0	**1394.7**	471.0	440.0	503.0	**471.3**	1255.2	1343.8	1280.3	1293.1
2	V1N2	3529.0	3026.0	3667.0	**3407.3**	2329.0	1969.0	2488.0	**2262.0**	3437.0	3015.8	3446.5	3299.8
3	V1N3	5086.0	5703.0	3688.0	**4825.7**	4167.0	4240.0	2997.0	**3801.3**	5073.7	5397.5	3699.3	4723.5
4	V1N4	5086.0	6492.0	3688.0	**5088.7**	4495.0	5845.0	3162.0	**4500.7**	5204.5	6713.5	3751.8	5223.3
5	V1N5	5086.0	6508.0	3688.0	**5094.0**	4559.0	5999.0	3209.0	**4589.0**	5243.7	6855.2	3761.0	5286.6
	Mean	4026.8	4658.6	3200.8	3962.1	3204.2	3698.6	2471.8	3124.9	4042.8	4665.2	3187.8	3965.3
1	V2N1	1279.0	1213.0	1421.0	**1304.3**	414.0	395.0	456.0	**421.7**	1233.5	1115.2	1371.0	1239.9
2	V2N2	3243.0	2861.0	4308.0	**3470.7**	2038.0	1817.0	2688.0	**2181.0**	2835.2	2501.8	3462.7	2933.2
3	V2N3	6608.0	5270.0	6193.0	**6023.7**	4985.0	4982.0	4377.0	**4781.3**	5233.5	4655.7	5089.0	4992.7
4	V2N4	8143.0	8018.0	6855.0	**7672.0**	6206.0	7060.0	5581.0	**6282.3**	6715.0	6711.3	6078.0	6501.4
5	V2N5	8357.0	8939.0	6855.0	**8050.3**	7231.0	8266.0	5742.0	**7079.7**	7605.2	8070.7	6361.7	7345.8
	Mean	5526.0	5260.2	5126.4	5304.2	4174.8	4504.0	3768.8	4149.2	4724.5	4610.9	4472.5	4602.6
1	V3N1	706.0	871.0	627.0	**734.7**	339.0	351.0	291.0	**327.0**	768.0	859.5	690.8	772.8
2	V3N2	1241.0	1223.0	1456.0	**1306.7**	888.0	900.0	1284.0	**1024.0**	1198.3	1287.7	1350.8	1278.9
3	V3N3	2169.0	2001.0	2259.0	**2143.0**	2139.0	2137.0	1732.0	**2002.7**	2025.7	1909.2	2022.8	1985.9
4	V3N4	2690.0	2787.0	2390.0	**2622.3**	2557.0	3013.0	2066.0	**2545.3**	2550.7	2653.2	2444.0	2549.3
5	V3N5	2865.0	3084.0	2390.0	**2779.7**	2782.0	3308.0	2092.0	**2727.3**	2947.7	3101.7	2578.5	2875.9
	Mean	1934.2	1993.2	1824.4	1917.3	1741.0	1941.8	1493.0	1725.3	1898.1	1962.2	1817.4	1892.6
1	V4N1	766.0	835.0	733.0	**778.0**	250.0	233.0	277.0	**253.3**	760.3	779.2	759.2	766.2
2	V4N2	1797.0	1580.0	2153.0	**1843.3**	1114.0	1039.0	1629.0	**1260.7**	1708.0	1548.5	2047.0	1767.8
3	V4N3	3013.0	2946.0	2599.0	**2852.7**	2657.0	2519.0	2210.0	**2462.0**	2977.7	2753.2	2768.3	2833.1
4	V4N4	3323.0	3688.0	2599.0	**3203.3**	2973.0	3596.0	2315.0	**2961.3**	3518.0	3774.8	2830.8	3374.6
5	V4N5	3323.0	3929.0	2599.0	**3283.7**	3110.0	3810.0	2334.0	**3084.7**	3677.3	4240.5	2819.5	3579.1
	Mean	2444.4	2595.6	2136.6	2392.2	2020.8	2239.4	1753.0	2004.4	2528.3	2619.2	2245.0	2464.2
1	V5N1	827.0	653.0	917.0	**799.0**	213.0	204.0	208.0	**208.3**	737.2	611.0	956.8	768.3
2	V5N2	3330.0	3702.0	2358.0	**3130.0**	2142.0	1769.0	1815.0	**1908.7**	2880.2	3090.5	2182.5	2717.7
3	V5N3	3330.0	4390.0	2358.0	**3359.3**	2961.0	3877.0	2119.0	**2985.7**	3225.3	4160.0	2276.7	3220.7

Continued

4	V5N4	3330.0	4390.0	2358.0	3359.3	2961.0	3884.0	2119.0	2988.0	3245.5	4328.0	2276.7	3283.4
5	V5N5	3330.0	4390.0	2358.0	3359.3	2961.0	3884.0	2119.0	2988.0	3262.8	4352.0	2276.5	3297.1
	Mean	2829.4	3505.0	2069.8	2801.4	2247.6	2723.6	1676.0	2215.7	2670.2	3308.3	1993.8	2657.4
1	N1	985.0	1027.2	994.2	1002.1	337.4	324.6	347.0	336.3	950.8	941.7	1011.6	968.1
2	N2	2628.0	2478.4	2788.4	2631.6	1702.2	1498.8	1980.8	1727.3	2411.7	2288.9	2497.9	2399.5
3	N3	4041.2	4062.0	3419.4	3840.9	3381.8	3551.0	2687.0	3206.6	3707.2	3775.1	3171.2	3551.2
4	N4	4514.4	5075.0	3578.0	4389.1	3838.4	4679.6	3048.6	3855.5	4246.7	4836.2	3476.3	4186.4
5	N5	4592.2	5370.0	3578.0	4513.4	4128.6	5053.4	3099.2	4093.7	4547.3	5324.0	3559.4	4476.9
Overall Mean		3352.2	3602.5	2871.6	3275.4	2677.7	3021.5	2232.5	2643.9	3172.8	3433.2	2743.3	3116.4

Kitumani composite I at 150 kg N/ha in Santilya, grain yield increase from 6366 kg/ha at Spacing two (S2) to 7642 kg/ha at spacing one (S1). The results are in accordance with [22] who reported that grain yield increase linearly with increasing plant density provided that there is no limitation of other production factors. [23] reports that grain yield increases until plant densities reach the optimum plant population per unit area.

3.4. Effect of Nitrogen on Grain yields

The optimum N rate (needed to achieve maximum yield) is influenced by factors including soil type, tillage, irrigation, fertilizer timing and method, and crop yield potential. These factors, as well as the interaction of these factors, will vary greatly from one location to another in a given geographic region [24]. The effects of different rates of nitrogen on grain yield of different maize varieties are shown on Table 2. Generally the increasing of the rate of nitrogen application has positive effect on the grain yield of maize in all sites. The grain yield increases until reach the maximum and no further increase in addition of nitrogen. This may be attributed to the significant effect of nitrogen on chlorophyll formation, photosynthesis and assimilate production that resulted in optimum production of yield components which have direct bearing on the final grain yield. This is supported by [25] on the study of the effect of nitrogen in increasing grain yield. In an example of results from Ihumbu farm and Mwazye, for Kitumani Composite I variety at a spacing one (Sp1), the Grain yield increases significantly from 0 kg N/ha up to the rate of 150 kg N/ha. The following grain yield was obtained at Ihumbu farm, 2058, 3836, 7465 and 8117 kg/ha at the rate of 0, 50, 100 and 150 kg N/ha respectively. At Mwazye, 576, 2679, 4329 and 4959 kg/ha at the rate of 0, 50, 100 and 150 kg N/ha respectively was obtained. At further application of 200 kg N/ha the increase in Grain yield was insignificantly, 8117 kg/ha and 4092 kg/ha for Ihumbu farm and Mwazye respectively. This is supported by [26] who reported that the grain yield level off when the supply of nitrogen is beyond the optimum requirement.

4. Conclusion

A different maize variety has been found to vary in grain yielding with respect to nitrogen application and weather condition and soil type. In this study, Maize variety H614 and Kitumani composite I have been found to respond positively to all factors of production compared to H511, H612 and H626 varieties. The increase in nitrogen application results in increasing grain yield. The optimum amount required differs from one location to another depending on soil type. In most area under the study the rate of 150 kg N /ha was found to be appropriate in increasing grain yield. Spacing has effect on plant population per unit area, reducing spacing from (90 cm × 30 cm) and leading to (60 cm × 30 cm) an increase plant population and hence an increasing in grain yield. For the purposes of improving maize production Maize varieties H614 and Kitumani Composite I, Spacing 1 (60 cm × 30 cm) and application of nitrogen up to 150 kg/ha can be recommended.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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