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RESEARCH PAPER

Standardization of Agro-techniques for Enhancing Growth and Yield in Pre-released Maize Hybrids

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ABSTRACT

Maize is a staple crop of significant importance in global food systems, contributing to both food security and economic stability. Optimizing agronomical practices for hybrid maize varieties is essential to enhance productivity, and to standardize agro-techniques for pre-released maize hybrids to maximize yield and profitability the following field experiment was conducted at M block, Agroforestry unit, GKVK, UAS, Bangalore during *kharif*-2023. The experiment was laid out in factorial randomized complete block design consisting of three factors *viz.,* two hybrids (MAH 14-5 and MAH 15-84), two spacings (45 cm × 30 cm and 60 cm × 30 cm) and three nutrient levels (100 % RDF, 125 % RDF and 150 % RDF) with 12 treatment combinations replicated thrice. Among hybrids, MAH 15-84 recorded significantly higher plant height (220.7 cm), total dry matter production (253.6 g plant^{-1}), kernel yield (7738 kg ha^{-1}) and stover yield (10290 kg ha^{-1}). Wider spacing of 60 cm × 30 cm recorded significantly higher plant height (221.6 cm), total dry matter production (253.6 g plant^{-1}), kernel yield (8354 kg ha^{-1}) and stover yield (11110 kg ha^{-1}). Application of 150 per cent RDF recorded significantly higher plant height (220.4 cm), total dry matter production (254.9 g plant^{-1}), kernel yield (8259 kg ha^{-1}) and stover yield (10984 kg ha^{-1}). Higher gross returns (₹ 216744 ha^{-1}), net returns (₹ 163547 ha^{-1}) and B:C ratio (4.07) was observed in MAH 15-84 hybrid with spacing of 60 cm × 30 cm under 150 per cent RDF.

HIGHLIGHTS

- Impact of hybrid and spacing on key growth parameters and yields in maize.
- Benefits if optimized nutrient management **for** increased plant growth, higher yields, and better economic returns.

Keywords: Hybrid, Spacing, Planting Geometry, Fertilizer level, Growth, Yield

Maize (*Zea mays* L.) is a globally renewed crop, ranking third in importance after wheat and rice. Originally domesticated in Mexico from its wild relative teosinte (Cruz-Cárdenas *et al.* 2019), maize has earned the title "Queen of Cereals" due to its high genetic yield potential and adaptability to various climatic zones, including tropical, subtropical, and temperate regions (Patel *et al.* 2024). It plays a crucial role in human and animal diets by providing essential nutrients such as protein, fibre, carbohydrates, amino acids, and minerals (Nuss and Tanumihardjo, 2010). Moreover, maize is highly valued for its industrial uses, including the production of ethanol, biofuels, and corn-based products (Maitra *et al.* 2021). In India maize is

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cultivated in 9.8 million hectares with a production of 33.18 million tonnes and with a productivity of 3199 kg ha^{-1} (Anonymous 2022a). The different maize-producing states are Karnataka, Andhra Pradesh, Maharashtra, Rajasthan, Uttar Pradesh and Madhya Pradesh. In Karnataka maize is cultivated in an area of 17.26 lakh hectares with a production of 53.6 lakh tonnes and with the average productivity of 3298.5 kg ha^{-1} (Anonymous, 2022b).

Modern management practices are essential to increase maize production, particularly using chemical fertilizers in combination with high yielding varieties (HYVs) (Maiangwa and Ogungbile, 2008; Santosh *et al*. 2023; Ray and Sairam, 2024). The response of maize to fertilizers varies based on soil fertility, environmental conditions, and genotype, making nutrient management crucial for maximizing yield (Santosh *et al*. 2024). In recent years, exotic maize hybrids have become popular due to their high yield potential, uniform growth, and adaptability (Yadav *et al*. 2015; Maitra *et al*. 2024). However, achieving optimum yields in maize is dependent on proper plant density and fertilizer application, especially during the *kharif* season (Nduwimana *et al*. 2020; Hulmani, 2022; Sairam *et al*. 2024). Optimum plant population and spacing are key to maximizing light interception and dry matter production (Manasa *et al*. 2021; Chapepa *et al*. 2020; Cheptoek *et al*. 2022; Santosh *et al*. 2022). Proper hybrid selection, based on specific agro-climatic conditions, is vital to ensure stable and high yields, as hybrids that perform well in one region may not perform as effectively in another (Abakemal *et al*. 2016).

MATERIALS AND METHODS

The experiment was conducted at 'M' block, Agro-forestry unit, University of Agricultural Sciences, GKVK, Bengaluru. The experimental site is located at a Latitude of 13°05'21" North, a Longitude of 77°34'02" East, and an Altitude of 989 m above Mean Sea Level under Eastern Dry Zone (ACZ- V) of Karnataka. As per the modified Troll's climatic classification acknowledged by ICRISAT, the experimental site falls within the semi-arid tropics. The crop was sown in the month of September and rainfall (941.4 mm) received during the crop period was adequate for growth. The soil of experimental site is red sandy clay loam in texture comes under *Alfisols* order with slightly acidic in pH (6.20), electric conductivity of 0.19 dS m^{-1} and organic carbon content was 0.41 per cent. The soil with 258.26 kg ha^{-1} available nitrogen, 34.58 kg ha^{-1} available phosphorus and 230.52 kg ha^{-1} potassium availability. The experiment was laid in Randomized complete block design with factorial concept comprising of three factors *viz.*, hybrids at two levels, spacing at two levels and fertilizers at three levels. All recommended package of practices followed during experimentation were as per package (PoP) of practice followed by the University of Agricultural Sciences, Bangalore (UASB). The recommended spacing is 60 cm × 30 cm and the dose of fertilizer (RDF) was 100:50:25 kg N, P_2O_5 and K_2O ha^{-1}. Hybrid levels comprised of H_1: MAH 14-5 and H_2: MAH 15-84. Spacing levels comprised of S_1: 45 cm × 30 cm and S_2: 60 cm × 30 cm. Fertilizer levels comprised of F_1:100 % RDF, F_2: 125 % RDF and F_3: 150 % RDF. Hybrids used was MAH 14-5 and MAH 15-84 which are high-yielding hybrids, suitable for both irrigated and rainfed conditions and stays lush green on the fields till the harvest. The required quantity of seeds for each treatment were sown based on the spacing and the recommended seed rate is 15 kg ha^{-1} for 60 cm x 30 cm as per UASB PoP. Recommended FYM 10 t ha^{-1} was applied to all the plots and incorporated well into soil two weeks before sowing. Pre- calculated quantities of fertilizer doses in the form of urea, di-ammonium phosphate, and muriate of potash were applied to each treatment plot. Half the dose of the recommended nitrogen and, a full dose of P and K were applied as basal and the remaining half dose of nitrogen was split into two doses. One dose was applied at the knee height stage of the crop and another dose during the tassel initiation.

Growth parameters like plant height, number of leaves per plant, leaf area per plant, leaf area index, leaf area duration and total dry matter production per plant at the harvest stage were recorded from five randomly selected plants in each treatment plot. Further, yield parameters such as cob length, number of kernel rows per cob, number of kernels per row, number of kernels per cob, kernel weight per cob, 100 seed weight, kernel yield and stover yield were recorded at harvest from five randomly selected plants in each plot.

RESULTS AND DISCUSSION

The growth parameters, yield attributes, and yield of maize hybrids as influenced by spacing and various nutrient levels, are presented in Table 1, Table 2 and Table 3, respectively.

Plant height showed significant differences between the two maize hybrids at the harvest stage. Hybrid MAH 15-84 recorded a significantly taller height (220.7 cm) compared to MAH 14-5 (202.7 cm), likely due to genetic differences in growth rates and maturity periods. Similar findings were reported by Nand (2015), Scaria *et al*. (2016) and Singh *et al*. (2015). Plant spacing also significantly affected plant height, with wider spacing of 60 cm × 30 cm resulting in taller plants (221.6 cm) compared to the closer spacing of 45 cm × 30 cm (201.9 cm). The increased height in wider spacing is attributed

Table 1: Growth parameters of maize hybrids as influenced by spacing and different nutrient levels

Treatments	Plant height (cm)	Number of leaves plant^{-1}	Leaf area (cm^2 plant^{-1})	Leaf area index	Leaf area duration (days)	Total dry matter production (g plant^{-1})
Hybrids (H)						
H_1: MAH 14-5	202.7	8.00	6429	3.70	119.1	235.1
H_2: MAH 15-84	220.7	8.45	7096	4.18	134.4	253.6
F-test	*	*	*	*	*	*
S.Em.±	4.32	0.15	137.1	0.15	4.46	4.45
CD at 5%	12.68	0.44	401.9	0.43	13.08	13.04
Spacing (S)						
S_1: 45 × 30 cm	201.9	7.89	6494	4.15	133.4	235.1
S_2: 60 × 30 cm	221.6	8.56	7031	3.73	120.0	253.6
F-test	*	*	*	*	*	*
S.Em.±	4.32	0.15	137.1	0.15	4.46	4.45
CD at 5%	12.68	0.44	401.9	0.43	13.08	13.04
Nutrient levels (F)						
F_1: 100 % RDF	199.6	7.70	6346	2.79	100.5	231.1
F_2: 125 % RDF	215.2	8.30	6868	4.28	133.4	247.1
F_3: 150 % RDF	220.4	8.68	7073	4.74	146.2	254.9
F-test	*	*	*	*	*	*
S.Em.±	5.29	0.18	167.9	0.18	5.46	5.45
CD at 5%	15.53	0.54	492.3	0.52	16.02	15.97
H × F × S						
$H_1F_1S_1$	183.0	7.23	5895	2.92	106.6	216.9
$H_1F_1S_2$	193.6	7.91	6108	3.80	112.8	229.4
$H_1F_2S_1$	204.0	7.99	6542	4.91	155.4	239.1
$H_1F_2S_2$	196.8	7.76	6198	2.47	85.49	230.1
$H_1F_3S_1$	218.9	8.56	6917	4.18	136.9	244.6
$H_1F_3S_2$	219.8	8.57	6916	3.90	117.2	250.4
$H_2F_1S_1$	201.2	7.57	6334	3.07	114.8	231.5
$H_2F_1S_2$	211.2	8.25	6896	4.55	131.8	242.3
$H_2F_2S_1$	218.1	8.39	7190	5.68	179.1	251.6
$H_2F_2S_2$	217.4	8.24	6958	2.71	95.23	245.9
$H_2F_3S_1$	237.0	8.47	7550	4.62	152.2	272.2
$H_2F_3S_2$	239.5	9.77	7646	4.48	133.2	278.4
F-test	NS	NS	NS	NS	NS	NS
S.Em.±	10.59	0.37	335.7	0.36	10.93	10.89
CD at 5%	—	—	—	—	—	—

DAS: *Days after sowing* **NS:** *Non-significant '*' indicates significant at 5% C.D. value.*

Table 2: Yield attributes of maize hybrids as influenced by spacing and different nutrient levels

Treatments	Cob length (cm)	No. of kernel rows cob^{-1}	No. of kernels row^{-1}	No. of kernels cob^{-1}	Kernel weight cob^{-1}	100 seed weight (g)
			Hybrids (H)			
H_1: MAH 14-5	17.25	13.90	31.19	397.2	195.0	28.57
H_2: MAH 15-84	18.77	15.38	33.41	433.4	212.1	30.15
F-test	*	*	*	*	*	NS
S.Em.±	0.33	0.29	0.60	8.58	4.37	0.76
CD at 5%	0.96	0.84	1.76	25.17	12.81	-
			Spacing (S)			
S_1: 45 × 30 cm	17.09	13.30	30.35	330.3	186.0	27.75
S_2: 60 × 30 cm	18.93	15.98	34.26	500.3	221.1	30.97
F-test	*	*	*	*	*	NS
S.Em.±	0.33	0.29	0.60	8.58	4.37	0.76
CD at 5%	0.96	0.84	1.76	25.17	12.81	-
			Nutrient levels (F)			
F_1: 100 % RDF	16.58	13.37	29.74	343.7	181.5	28.04
F_2: 125 % RDF	18.34	15.00	32.49	438.3	209.3	29.92
F_3: 150 % RDF	19.12	15.55	34.67	463.9	219.8	30.13
F-test	*	*	*	*	*	NS
S.Em.±	0.40	0.35	0.74	10.51	5.35	0.93
CD at 5%	1.17	1.03	2.16	30.83	15.69	-
			H × F × S			
$H_1F_1S_1$	15.23	11.55	27.13	272.3	124.4	23.02
$H_1F_1S_2$	16.54	12.82	29.75	334.4	197.8	28.00
$H_1F_2S_1$	17.61	13.48	31.90	362.4	205.1	27.36
$H_1F_2S_2$	16.68	13.73	30.67	410.4	207.3	29.85
$H_1F_3S_1$	18.47	15.54	33.44	471.8	216.4	29.94
$H_1F_3S_2$	18.98	16.28	34.26	532.1	219.3	29.13
$H_2F_1S_1$	16.39	13.60	28.86	283.9	181.3	27.02
$H_2F_1S_2$	17.90	14.09	30.96	349.4	199.9	30.48
$H_2F_2S_1$	18.89	14.29	33.47	379.9	207.7	30.47
$H_2F_2S_2$	18.02	14.60	32.31	408.2	213.2	32.10
$H_2F_3S_1$	20.43	17.55	35.82	582.1	223.1	32.09
$H_2F_3S_2$	21.01	18.16	39.06	597.4	247.2	32.72
F-test	NS	NS	NS	NS	NS	NS
S.Em.±	0.80	0.70	1.47	21.03	10.70	1.86
CD at 5%	—	—	—	—	—	—

DAS: *Days after sowing* **NS:** *Non-significant '*' indicates significant at 5% C.D. value.*

to better resource availability and less competition for light, nutrients, and water. These results align with the findings of Dutta *et al*. (2015), Biswas *et al*. (2014) and Niveditha and Nagvani (2016). Different nutrient levels also influenced plant height, with 150% RDF resulting in the higher plant height (220.4 cm), which was statistically on par with 125 % RDF (215.2 cm) but significantly higher than 100 % RDF (199.6 cm). This increase in plant height is likely due to balanced nutrient application promoting better growth and photosynthesis. Similar results were reported by Jogdand *et al*. (2008) and Mohamed *et al*. (2010). The interaction effects between hybrids, spacing and nutrient levels were non-significant, although numerically higher plant height (239.5 cm) was observed in hybrid MAH 15-84 with 60 cm × 30 cm spacing and 150 % RDF. Conversely, the lower plant height (183.0 cm) was observed in hybrid MAH 14-5 with 45 cm × 30 cm spacing and 100 % RDF.

Table 3: Yield of maize hybrids as influenced by spacing and different nutrient level

Treatments	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})
Hybrids (H)		
H_1: MAH 14-5	7068	9400
H_2: MAH 15-84	7738	10290
F-test	*	*
S.Em.±	148.8	197.9
CD at 5%	436.5	580.3
Spacing (S)		
S_1: 45 × 30 cm	6452	8581
S_2: 60 × 30 cm	8354	11110
F-test	*	*
S.Em.±	148.8	197.9
CD at 5%	436.5	580.3
Nutrient levels (F)		
F_1: 100 % RDF	6223	8276
F_2: 125 % RDF	7726	10276
F_3: 150 % RDF	8259	10984
F-test	*	*
S.Em.±	182.3	242.4
CD at 5%	534.6	710.8
H × F × S		
$H_1F_1S_1$	5418	7205
$H_1F_1S_2$	6790	9030
$H_1F_2S_1$	6920	9203
$H_1F_2S_2$	6206	8253
$H_1F_3S_1$	8432	11214
$H_1F_3S_2$	8644	11496
$H_2F_1S_1$	5436	7229
$H_2F_1S_2$	6528	8682
$H_2F_2S_1$	7620	10134
$H_2F_2S_2$	7832	10416
$H_2F_3S_1$	9156	12177
$H_2F_3S_2$	9852	13103
F-test	NS	NS
S.Em.±	364.5	484.7
CD at 5%	—	—

NS: *Non-significant '*' indicates significant at 5% C.D. value.*

Among the hybrids, MAH 15-84 produced significantly more leaves per plant at harvest (8.45) compared to MAH 14-5 (8.00), likely due to inherent genetic differences. Similar varietal differences in growth were reported by Patil *et al.* (2000), Ahmad *et al.* (2010) and Jemal (2010). Plant spacing also significantly affected leaf count, with wider spacing of 60 cm × 30 cm resulting in more leaves per plant (8.56) than the closer spacing of 45 cm × 30 cm (7.89). This is attributed to better access to light and moisture, enhancing plant growth. In contrast, closer spacing led to fewer leaves due to increased competition for resources. These results align with the findings of Sabo *et al.* (2016). Regarding nutrient levels, 150 % RDF resulted in the higher number of leaves per plant (8.68), statistically on par with 125 % RDF (8.30) but significantly higher than 100 % RDF (7.70). The increased leaf count can be attributed to optimal nutrient levels promoting better photosynthesis with nitrogen, phosphorus, and potassium contributing to vegetative growth and efficient nutrient use. These findings are consistent with those of Paramasivan *et al*. (2011), Ahmad *et al*. (2010) and Mohamed *et al*. (2010). The interaction effects between hybrids, spacing, and nutrient levels were non-significant. However, the superior number of leaves (9.77) was recorded in hybrid MAH 15-84 with 60 cm × 30 cm spacing and 150 % RDF, while the lower (7.23) was observed in hybrid MAH 14-5 with 45 cm × 30 cm spacing and 100 % RDF at harvest.

Among the hybrids, MAH 15-84 recorded significantly higher leaf area (7096 cm² plant⁻¹) compared to MAH 14-5 (6494 cm² plant⁻¹) at harvest, likely due to its superior genetic traits that contributed to the production of more and larger leaves. Similar findings were reported by Nwogboduhu (2016), Devkota *et al*. (2016) and Sivamurugan *et al*. (2015). Spacing also had a significant effect, with wider spacing of 60 cm × 30 cm resulting in more leaf area (7031 cm² plant⁻¹) compared to narrower spacing of 45 cm × 30 cm (6494 cm² plant⁻¹). This was attributed to better access to nutrients, light, and moisture, leading to broader leaves and higher leaf area per plant. These findings are consistent with Gollar and Patil (2000) and Chandankar *et al*. (2005). Nutrient levels influenced leaf area significantly. Application of 150 % RDF produced the higher leaf area (7073 cm² plant^{-1}), on par with 125 % RDF (6868 cm^2 plant^{-1}), while 100 % RDF resulted in the lower leaf area (6346 cm^2 plant^{-1}). The enhanced leaf area is due to better nutrient utilization promoting an efficient photosynthetic system, as noted by Ashwini *et al.* (2019). Although the interaction effects between hybrids, spacing, and nutrient levels were not significant, numerically higher leaf area (7646 cm^2 plant^{-1}) was recorded in MAH 15-84 with 60 cm × 30 cm spacing and 150 % RDF, while the lower leaf area (5895 cm^2 plant^{-1}) was observed in MAH 14-5 with 45 cm × 30 cm spacing and 100 % RDF.

A significant difference in leaf area index (LAI) was observed between the two maize hybrids, with MAH 15-84 exhibiting a higher LAI (4.18) compared to MAH 14-5 (3.70) at harvest. Similar findings were reported by Ahmad *et al*. (2010), Enujeke (2013) and Hargilas *et al*. (2014). Leaf area index was significantly influenced by different plant spacings, as the narrow spacing of 45 cm × 30 cm resulted in a higher LAI (4.15) than the wider spacing of 60 cm × 30 cm (3.73) at harvest. These results align with the findings of Chauhan and Opena (2013). Nutrient levels also significantly impacted the average LAI at harvest. Application of 150 % RDF led to a significantly higher LAI (4.74), which was on par with 125 % RDF (4.28), while 100 % RDF resulted in a significantly lower LAI (2.79). Fertilizer application notably influenced growth parameters, enhancing nutrient uptake and increasing the photosynthetic area, which contributed to a higher LAI compared to plants receiving lower fertilizer levels. This is consistent with the results of Tolessa *et al*. (2001) and Shivay *et al*. (2002). Although the interaction effects among different hybrids, spacing, and nutrient levels were non-significant at harvest, numerically higher LAI (5.68) was recorded in hybrid MAH 15-84 with 45 cm × 30 cm spacing and application of 125 % RDF, while lower LAI (2.47) was observed in hybrid MAH 14-5 with 60 cm × 30 cm spacing under 125 % RDF at harvest.

A significant difference in leaf area duration (LAD) was observed between the two maize hybrids at harvest, with hybrid MAH 15-84 recording a higher LAD (134.4 days) compared to MAH 14-5 (119.1 days) at harvest-90 DAS. Similar results were noted by Prasanna *et al*. (2007) and Ahmad *et al*. (2010). Spacing significantly affected LAD at harvest. The narrow spacing of 45 cm × 30 cm resulted in a greater LAD (133.4 days) than the wider spacing of 60 cm × 30 cm (120.0 days) at harvest-90 DAS. These findings align with Nwogboduhu (2016) and Nand (2015). Different nutrient levels significantly influenced the average LAD at harvest. The application of 150 % RDF yielded a significantly higher LAD (146.2 days), which was on par with 125 % RDF (133.4 days). In contrast, 100 % RDF recorded a significantly lower LAD (100.5 days) at harvest-90 DAS. Leaf area duration varied significantly over the growth stages among the treatments, as the production and translocation of photosynthates depend on the availability of mineral nutrients. Most photosynthetic pathways rely on enzymes and co-enzymes synthesized from mineral nutrients such as nitrogen, phosphorus, and potassium. The differences in growth parameters could be attributed to rapid cell division and elongation facilitated by nitrogen. These results are consistent with the findings of Roopashree (2013), Tolessa *et al.* (2001) and Kumar *et al*. (2010). Interaction effects among different hybrids, spacing, and nutrient levels were non-significant at harvest-90 DAS. However, numerically higher leaf area duration (179.1 days) was observed in hybrid MAH 15-84 with a spacing of 45 cm × 30 cm along with the application of 125% RDF, while lower LAD (85.49 days) was recorded in hybrid MAH 14-5 with 60 cm × 30 cm spacing under 125 % RDF at harvest-90 DAS of maize.

A significant difference was observed among maize hybrids regarding total dry matter production at all growth phases. Hybrid MAH 15-84 produced significantly greater dry matter (253.6 g plant^{-1}) compared to MAH 14-5 (235.1 g plant^{-1}) at harvest. The differences in dry biomass production at harvest can be attributed to the higher number of functional leaves, reflecting the genetic constitution of the hybrids. Similar findings were reported by Ibeawuchi *et al*. (2008), Scaria *et al*. (2016) and Singh *et al*. (2015). Spacing also had a significant effect on dry matter production, with wider spacing of 60 cm × 30 cm resulting in higher dry matter production (253.6 g plant^{-1}) compared to the narrow spacing of 45 cm × 30 cm (235.1 g plant^{-1}) at harvest. Increased total dry matter per plant under wider spacing is associated with a larger leaf area, which leads to a greater accumulation of photosynthates. The wider spacing allows better availability of light, nutrients, and moisture, facilitating individual plants to produce more leaves and a larger leaf area, thereby enhancing photosynthesis and total dry matter accumulation. These results align with those of Niveditha and Nagvani (2016). Nutrient levels significantly influenced total dry matter production per plant at different growth stages. The application of 150 % RDF resulted in the maximum dry matter production (254.9 g plant^{-1}), which was on par with 125 % RDF (247.1 g plant^{-1}). In contrast, 100 % RDF produced significantly lower dry matter (231.1 g plant^{-1}) at harvest. These results are linked to the greater number of leaves and increased solar radiation absorption, enhancing the rate of photosynthesis and resulting in higher dry matter production. Total dry matter production depends on the accumulation in plant parts and the uptake of nutrients like N, P, and K. The increase in dry matter was primarily due to the higher number of leaves produced and improved nutrient uptake. Similar findings were reported by Jogdand *et al*. (2008) and Shivay *et al*. (2002). Interaction effects among different hybrids, spacing, and nutrient levels were non-significant at harvest. However, numerically higher total dry matter production (278.4 g plant^{-1}) was observed in hybrid MAH 15-84 with spacing of 60 cm × 30 cm and application of 150 % RDF, while lower dry matter production (216.9 g plant^{-1}) was recorded in hybrid MAH 14-5 with 45 cm × 30 cm spacing under 100 % RDF at maize harvest.

A significant difference in cob length was observed among maize hybrids at harvest. Hybrid MAH 15-84 produced a longer cob (18.77 cm) compared to MAH 14-5 (17.25 cm). This variation can be attributed to the inherent genetic traits of the hybrids, as well as management practices that influenced cob length through enhanced vegetative growth and better partitioning of assimilates, consistent with findings by Nand (2015). Spacing significantly affected cob length, with wider spacing (60 cm × 30 cm) resulting in a greater cob length (18.93 cm) compared to closer spacing (45 cm × 30 cm), which measured 17.09 cm. The increased cob length in wider spacing is likely due to better resource availability, including light, nutrients, and moisture, which improved the translocation of photosynthates to the sink, corroborating results by Kandil *et al*. (2017), Nand (2015), and Singh *et al*. (2015). Nutrient levels had a significant impact on cob length as well. The application of 150 % RDF yielded the longer cob length (19.12 cm), which was statistically comparable to 125 % RDF (18.34 cm). In contrast, 100 % RDF resulted in the shortest cob length (16.58 cm). This effect is attributed to the adequate supply of essential nutrients at critical growth stages, as reported by Singh *et al.* (2003). The interaction effects of different hybrids, spacing, and nutrient levels on cob length were found to be non-significant. However, the highest numerical cob length (21.01 cm) was recorded in hybrid MAH 15-84 with a spacing of 60 cm × 30 cm and 150 % RDF, while the lower cob length (15.23 cm) was observed in hybrid MAH 14-5 with 45 cm × 30 cm spacing and 100 % RDF.

There was a significant difference among hybrids pertaining to number of kernel rows cob^{-1} at harvest. Significantly higher number of kernel rows cob^{-1} (15.38) was resulted in hybrid MAH 15-84 at harvest compared to MAH 14-5 (13.90). The results are in accordance with the results of Mangal *et al.* (2017). Spacing had a significant effect on number of kernel rows cob^{-1} at harvest. The wider spacing of 60 cm × 30 cm significantly recorded higher number of kernel rows cob^{-1} (15.98) over closer spacing of 45 cm × 30 cm (13.30). The results are in accordance with the results of Biswas *et al.* (2014). Nutrient levels had a significant effect on number of kernel rows cob^{-1} at harvest. The crop applied with nutrient level of 150 per cent RDF recorded significantly higher number of kernel rows cob^{-1} (15.55) and it was found to be on par with 125 per cent RDF (15.00). Whereas, 100 per cent RDF recorded significantly lower number of kernel rows cob^{-1} (13.37) at harvest. Similar results were reported by Jayaprakash *et al.* (2006). The interaction effect due to different maize hybrids, planting geometry and nutrient levels for number of kernel rows cob^{-1} at harvest was found non-significant. However, it was numerically higher number of kernel rows cob^{-1} (18.16) in hybrid MAH 15-84 with spacing of 60 cm × 30 cm along with application of 150 per cent RDF and lower number of kernel rows cob^{-1} (11.55) was recorded in hybrid MAH 14-5 with spacing of 45 cm × 30 cm along with application of 100 per cent RDF.

There was a significant difference among hybrids pertaining to number of kernels per row at harvest. Significantly higher number of kernels row^{-1} (33.41) was resulted in hybrid MAH 15-84 at harvest compared to MAH 14-5 (31.19). The results are in accordance with the results of Jithendra *et al.* (2013). Spacing had a significant effect on number of kernels row^{-1} at harvest. The wider spacing of 60 cm × 30 cm significantly recorded higher number of kernels row^{-1} (34.26) over closer spacing of 45 cm × 30 cm (30.35) might be nutrient competition due to less space per plot in the experiment. Besides, the variation in number of kernels row^{-1} at harvest among different crop geometries treatment might be attributed to variation observed in cob length. The results are in accordance with the results of Biswas *et al.* (2014). Nutrient levels had a significant effect on number of kernels row^{-1} at harvest. The crop applied with nutrient level of 150 per cent RDF recorded significantly higher number of kernels row^{-1} (34.67) and it was found to be on par with 125 per cent RDF (32.49). Whereas, 100 per cent RDF recorded significantly lower number of kernels row^{-1} (29.74) at harvest. Similar results were reported by Muhammad *et al.* (2010) and Hafiz *et al.* (2011). The interaction effect due to different maize hybrids, planting geometry and nutrient levels for number of kernels row^{-1} at harvest was found non-significant. However, it was numerically higher number of kernels row^{-1} (39.06) in hybrid MAH 15-84 with spacing of 60 cm × 30 cm along with application of 150 per cent RDF and lower number of kernels row^{-1} (27.13) was recorded in hybrid MAH 14-5 with spacing of 45 cm × 30 cm along with application of 100 per cent RDF.

There was a significant difference among hybrids pertaining to number of kernels per cob at harvest. Significantly higher number of kernels cob^{-1} (433.4) was resulted in hybrid MAH 15-84 at harvest compared to MAH 14-5 (397.2). The results are in accordance with the results of Sivamurugan *et al.* (2015) and Nwogboduhu (2016). Spacing had a significant effect on number of kernels cob^{-1} at harvest. The wider spacing of 60 cm × 30 cm significantly recorded higher number of kernels cob^{-1} (500.3) over closer spacing of 45 cm × 30 cm (330.3). The results are in accordance with the results of Jithendra *et al.* (2013). Nutrient levels had a significant effect on number of kernels cob^{-1} at harvest. The crop applied with nutrient level of 150 per cent RDF recorded significantly higher number of kernels cob^{-1} (463.9) and it was found to be on par with 125 per cent RDF (438.3). Whereas, 100 per cent RDF recorded significantly lower number of kernels cob^{-1} (343.7) at harvest. Similar results were reported by Singh *et al.* (2021). The interaction effect due to different maize hybrids, planting geometry and nutrient levels for number of kernels cob^{-1} at harvest was found non-significant. However, it was numerically higher number of kernels cob^{-1} (597.4) in hybrid MAH 15-84 with spacing of 60 cm × 30 cm along with application of 150 per cent RDF and lower number of kernels cob^{-1} (272.3) was recorded in hybrid MAH 14-5 with spacing of 45 cm × 30 cm along with application of 100 per cent RDF.

There was a significant difference among hybrids pertaining to kernel weight cob^{-1} at harvest. Significantly higher kernel weight cob^{-1} (212.1) was resulted in hybrid MAH 15-84 at harvest compared to MAH 14-5 (195.0). The results are in accordance with the results of Scaria *et al.* (2016). Spacing had a significant effect on kernel weight cob^{-1} at harvest. The wider spacing of 60 cm x 30 cm significantly recorded higher kernel weight cob^{-1} (221.1) over closer spacing of 45 cm x 30 cm (186.0). The results are in accordance with the results of Thavaprakash *et al.* (2005). Nutrient levels had a significant effect on kernel weight cob^{-1} at harvest. The crop applied with nutrient level of 150 per cent RDF recorded significantly higher kernel weight cob^{-1} (219.8) and it was found to be on par with 125 per cent RDF (209.3). Whereas, 100 per cent RDF recorded significantly lower kernel weight cob^{-1} (181.5) at harvest. Similar results were reported by Singh *et al.* (2021) and Nwogboduhu (2016). The interaction effect due to different maize hybrids, planting geometry and nutrient levels for kernel weight cob^{-1} at harvest was found non-significant. However, it was numerically higher kernel weight cob^{-1} (247.2) in hybrid MAH 15-84 with spacing of 60 cm × 30 cm along with application of 150 per cent RDF and lower kernel weight cob^{-1} (124.4) was recorded in hybrid MAH 14-5 with spacing of 45 cm × 30 cm along with application of 100 per cent RDF.

100 seed weight of maize was found non-significant among the different maize hybrids. However, hybrid MAH 15-84 recorded numerically higher 100 seed weight (30.15 g) and lowest (28.57 g) in hybrid MAH 14-5. The results of different planting geometry on 100 seed weight of maize was found non-significant. However, numerically it had higher for 60 cm x 30 cm spacing (30.97 g) and lowest (27.75 g) in 45 cm x 30 cm spacing level. Neither row nor

plant spacing affected the 100 seed weight of maize seed. Different levels of nutrients showed non-significant in 100 seed weight of maize. However, numerically higher 100 seed weight of maize was recorded under 150 per cent RDF (30.13 g), over 125 per cent RDF (29.92 g) and 100 per cent RDF (28.04 g). The combination result of different maize hybrids, planting geometry and RDF levels found non-significant. Among the different combinations hybrid MAH 15-84 with spacing of 60 cm × 30 cm under 150 per cent RDF (32.72 g) gave higher 100 seed weight whereas, the lower 100 seed weight was recorded in hybrid MAH 14-5 with spacing of 45 cm × 30 cm under 100 per cent RDF (23.02 g).

Among the different maize hybrids, MAH 15-84 has recorded a significantly higher kernel yield (7738 kg ha^{-1}) compared to MAH 14-5 (7068 kg ha^{-1}). This increase in kernel yield of hybrid MAH 15-84 might be due to higher production efficiency which was reflected through improvement in different yield contributing characters and genetical efficiency of the hybrid to convert biological yield into economic yield. Differential yield potential of different maize hybrids was reported by Nand (2015), Sabo *et al.* (2016), Jemal (2010) and Mukhtar *et al.* (2011). Results revealed that significantly, higher kernel yield was recorded with the spacing of 60 cm × 30 cm (8354 kg ha^{-1}) than compared to 45 cm × 30 cm (6452 kg ha^{-1}). Plants grown with wider spacing consume more nutrients and absorb more solar radiation for efficient photosynthesis and hence, perform better at individual basis. These results are in conformity with results obtained by Singh *et al.* (2008), Niveditha and Nagavani (2015) and Scaria *et al.* (2016). Application of 150 per cent RDF had recorded significantly higher kernel yield (8259 kg ha^{-1}) and it was found to be on par with application of 125 per cent RDF (7726 kg ha^{-1}). Significantly lower kernel yield was produced with the application of 125 per cent RDF (6223 kg ha^{-1}) at harvest. Improvement in kernel yield of maize with higher nutrient levels was due to more vegetative growth and increased plant metabolic activities and higher nitrogen, phosphorus and potassium fertilization contributed to better carbohydrates assimilation improved yield attributing characters viz., number of seed cob^{-1}, cob $length^{-1}$ and seed index under sufficient supply of nutrients. Similar findings were reported by Paramasivan *et al.* (2011), Singh *et al.* (2009) and Sivamurugan *et al.* (2015). For different maize hybrids, planting geometry and nutrient levels interaction effect was found non-significant for kernel yield of maize. Combination of hybrid MAH 15-84 with spacing of 60 cm × 30 cm under 150 per cent RDF recorded numerically higher kernel yield (9852 kg ha^{-1}). The lower kernel yield (5418 kg ha^{-1}) was recorded in hybrid MAH 14-5 with spacing of 45 cm × 30 cm under 100 per cent RDF.

Among the different maize hybrids, MAH 15-84 has recorded significantly higher stover yield (10290 kg ha^{-1}) compared to MAH 14-5 (9400 kg ha^{-1}). This increase in stover yield of hybrid MAH 15-84 may be due to fact that amount of dry weight deposition may have been decided by the extent of growth before silking stage and furthermore, the high dry matter accumulation of cob during reproductive stage may also be supported by larger vegetative organs, especially by the profuse root system. Similar line of result was also reported by Jogdand *et al.* (2008) and Muhammad *et al.* (2010). Results revealed that significantly higher stover yield was recorded with the spacing of 60 cm × 30 cm (11110 kg ha^{-1}) compared to 45 cm × 30 cm spacing (8581 kg ha^{-1}). Wider row spacing produced higher straw yield which was significantly superior over narrow spacing because of better growth and development of crop. Straw yield was an augmenting effect of increased vegetative growth through plant height, number of leaves per plant and space available for plant growth and hence more number of leaves, highest plant height and maximum dry matter as a result of these highest straw yield was obtained. These results are in conformity with results obtained by Singh *et al.* (2021), Mangal *et al.* (2017) and Dutta *et al.* (2015). Application of 150 per cent RDF had recorded significantly higher stover yield (10984 kg ha^{-1}) and it was found to be on par with application of 125 per cent RDF (10276 kg ha^{-1}). Significantly lower kernel yield was produced with the application of 100 per cent RDF (8276 kg ha^{-1}) at harvest. Improvement in stover yield of maize with higher nutrient levels is due to increase in height, number of leaves and dry matter production per plant due to increasing fertility levels might have prolonged the vegetative period and resulted in higher straw yields. These results are in conformity with results obtained by

Singh *et al.* (2003), Jayaprakash *et al.* (2006) and Hafiz *et al.* (2011). For different maize hybrids, planting geometry and nutrient levels interaction effect was found non-significant for stover yield of maize. Combination of hybrid MAH 15-84 with spacing of 60 cm × 30 cm under 150 per cent RDF recorded numerically higher stover yield (13103 kg ha^{-1}). The lower stover yield (7205 kg ha^{-1}) was recorded in hybrid MAH 14-5 with spacing of 45 cm × 30 cm under 100 per cent RDF.

CONCLUSION

The study revealed that combination of hybrid, spacing and fertilizer levels significantly influenced the growth and yield parameters of maize. Hybrid MAH 15-84 performed better as evidenced with higher growth, yield attributes and economic returns due to superior genetic traits of the hybrids. Wider spacing (60 cm × 30 cm) is found ideal for maize hybrid MAH 15-84 as evidenced with higher kernel yield, stover yield and higher economic return due to reduced competition. Higher fertilizer application (150 % RDF) consistently enhanced plant growth, yield and yield attributes. The combination of hybrid maize MAH 15-84 with a spacing of 60 cm × 30 cm under the application of 150 per cent RDF is found ideal for higher kernel yield (9852 kg ha^{-1}), stover yield (13103 kg ha^{-1}) and economic returns (4.07).

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