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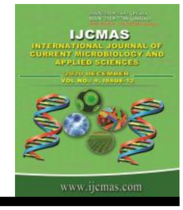

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Evaluation of Different Maize Hybrids for Morpho-physiological, Biochemical and Yield and Yield Components

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A field experiment was conducted during *Kharif* 2015-16 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad to find out the physiological basis of yield variation of different maize hybrids. The experiment consisted of twenty maize hybrids replicated thrice in randomized block design. Observations recorded were morpho-physiological, biochemical, and yield and yield attributes. The hybrids DMH-01, DMH-13 and GPMH-1101 exhibited superiority over rest of the hybrids with respect to higher morphological (plant height, more number of leaves and total dry matter) and physiological parameters (SPAD, Chlorophyll, total sugar and starch content).Significantly higher yield and yield parameters such as cob length, cob girth, number of seeds per cob, number of seed rows per cob, 100-kernel weight and harvest index were recorded by DMH-01, DMH-13 and GPMH-1101 which increased the yield of maize hybrids. Significant improvement in overall growth of the crop was due to its increased photosynthetic efficiency which resulted in greater availability of photosynthates, metabolites and increased dry matter accumulation for growth and development of reproductive structures which has contributed for higher productivity.

Introduction

Maize (*Zea mays* L.) is the world's leading crop and is widely cultivated as cereal grain that was domesticated in Central America. It is one of the most versatile emerging crops having wider adaptability. Globally, maize is known as queen of cereals because of its highest genetic yield potential. Maize is the only food cereal crop that can be grown in diverse seasons, ecologies and uses. Beside this maize have many types like normal yellow/ white grain, sweet corn, baby corn, popcorn, waxy corn, high amylase corn, high oil corn, quality protein maize, etc. Apart from this, maize is an important industrial raw material and provides large opportunity for value addition.

In India, maize is the third important food crop after rice and wheat.. Maize is primarily used for feed (60 %) followed by human food (24%), industrial (starch) products (14%) beverages and seed (1% each). Thus, maize has attained an important position as industrial crop because 75% of its produced is used in starch and feed industries. In India, maize is predominantly cultivated as rainfed crop but due to focused research on single cross hybrids. The projected growth rates suggest that maize demand is expected to increase from current level of 22 to 45 M. tonnes by 2030. Maize is truly a forward looking crop especially in the context of climate change. It is an annual, short day, cross pollinated, photosynthetically more active (C_4) and which is grown extensively in temperate, subtropical and tropical regions of the world.

In addition to staple crop for human being and quality feed for animals, maize serves as a basic raw material for production of starch, oil, protein, alcohol beverages, food sweeteners and more recently as a potential bio-fuel crop in India. Maize occupies important place as food (25%), animal feed (12%) poultry feed (49%), industrial products mainly starch (12%) and one per cent each in brewery and seed (Dass *et al.,* 2008). Maize has attained a commercial crop status due to easiness in cultivation, tolerance towards pest and diseases, high yield and better market price. It comes up well under a wide range of soil and climatic conditions. There is great variations occur in the yields of maize and these large differences in yield are not only be accounted by climate or soil variability alone, since areas with the same climate and rainfall pattern show markedly different average yields. The present study was conducted to evaluate the hybrid performance for the morpho-physiological, biochemical quality aspects such as starch and total sugars and yield and its components

Materials and Methods

The present study consisted of twenty maize hybrids viz., Arjun, GH-0727, GPMH-1101, GPMH-1111, GH-1018, GH-1043, GH-110145, GH-110204, DMH-01, DMH-03, DMH10, DMH-13, NAH-1137, NAH-2049, MAH-957, MAH-974 and were evaluated in randomized complete block design with three replications at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during kharif 2015-16. The quality attributes such as starch content, total sugar content and morpho-physiological parameters of these genotypes and their yield attributes were studied. The plant height was measured from base of the plant to tip of the leaf. Manual counting of leaf and assessment of dry matter was recorded during reproductive stage. Leaf area of all green leaves from five tagged plant was measured by adopting Stickler's linear measurement method and total chlorophyll content was determined by following DMSO method of Hiscox and Israeltam, 1979. The absorbance of the extract was measured at 645, 652 and 663 nm in a UV- VIS spectrophotometer (Elico, SL -159). The amount of starch and soluble sugars present in the maize kernels was estimated by Anthrone method.

Results and Discussion

Various morpho-physiological characters like plant height, number of leaves, leaf area and total dry matter production at reproductive stages were studied. Though the plant height is genetically controlled character, it is being influenced by environmental conditions and management practices. The results of the present investigation revealed the significant differences in plant height of maize at reproductive stages. Of the 20 genotypes tested, DMH-01 was recorded significantly higher plant height at harvest (193.43cm) as compared to other genotypes and the lowest plant height of 154.57 cm was noticed in DMH-08 (Table 1). The hybrids GPMH, DMH-03, DMH-10, DMH-13, NAH-13, NAH-1137, NAH-2049, MAH-957 and MAH974 were found to be on par with each other (192.79, 189.30, 193.66, 193.66, 191.16, 190.32, 191.32, 191.50 and 188.77 respectively). It was found that plant height was positively correlated with grain yield per unit area. (Saleem *et al.*, 2007) reported that, plant height showed positive and direct effect on grain yield. Increase in grain yield with an increase in plant height during later stages could be attributed to the better utilization of stem reserves and also to the canopy architecture i.e., increase in plant height alters the spatial arrangement of leaves leading to higher leaf area and better light distribution in the canopy The leaf number per plant differed significantly among the hybrids. Among the hybrids DMH-01 and DMH-13 recorded significantly higher leaf number per plant (13.24 and 13.24 respectively) compared to other hybrids. Hybrid Arjun recorded significantly lower leaf number (11.36). Such a variation in number of leaves was also reported by (Modarres *et al*., 1997) where they also observed the effect of genotype and ear and the interaction of the two were significant for leaf number results in greater yield. The data on leaf area was recorded at reproductive stages of maize genotypes are presented in table 1.

Leaf area differed significantly among the genotypes. In general, leaf area increased up to 60 days after sowing. DMH-01 recorded significantly higher leaf area (108.2 dm^2 $plant^{-1}$) followed by DHM-13 (100.5 dm^2 $plant^{-1}$). The lowest leaf area was recorded in hybrid DMH-04 (94.2 dm^2 $plant^{-1}$). Therefore formed useful indirect indicator for yield improvement in maize crop. These results are in conformity with the experiments conducted by (Hader, 2006) and (Banziger and Araus, 2007). The data on total dry weight presented in Table 1. In general, total dry weight increased with the age of the crop and maximum at harvest. At reproductive stage, there was significant differences were recorded among the hybrids, although numerically the maximum total dry matter accumulation (181.29 g $plant^{-1}$) was recorded with genotype DMH-01 followed by MAH-957 and DMH-13 (177.95 and 176.85 g $plant^{-1}$ respectively), while least (163.45 g $plant^{-1}$) total dry matter accumulation was recorded with DMH-04. The hybrids NAH-1137 and NAH-2049 were found to be on par with each other.

Long duration hybrids recorded more total dry weights compared to short duration hybrids at all the growth stages. This might be due to genotypic difference in the translocation of source-sink ratio. Further resulting in better uptake of nutrients, increased vegetative growth, PAR and RUE throughout the growth period leads to increased accumulation of dry matter in the different parts of the plant. These results are in conformity with the findings of (Manish kumar 1998). It was also noticed that, the higher dry matter in reproductive parts increased with an increase in total dry weight.

Crop yield is mainly dependent on the interplay of various physiological and biochemical functions of the plant in addition to the impact of environment. Chlorophyll is a natural pigment that traps light which is essential for the process of photosynthesis. A close relationship between leaf chlorophyll content and photosynthetic rate was observed. The data on SPAD values which are influenced by different maize genotypes recorded at reproductive stages presented in table 2. In general, SPAD values increased with the age of the crop from 45 to 60 days after sowing. At reproductive stage, the highest SPAD value (47.61) was recorded with DMH-01 which was superior over all maize genotypes except DMH-04, DMH-08 and DMH-17 and DMH-06 which were statistically significant with DMH-01.

However, lower SPAD value (34.09) was recorded with DMH-04 genotype. such results were also noticed by (Peng *et al.*, 1996), (Balasubramanian *et al.*, 1999) and (Pellizzaro *et al.*, 1998). In general, total chlorophyll content was increased with age of the crop from 30 DAS to 60 DAS and thereafter decreases till harvest. At reproductive stage, DMH-01 recorded significantly high chlorophyll content (2.81 mg g^{-1} fr. wt.) followed by DMH-13 (2.34 mg g^{-1} fr. wt.), GPMH-1101 (2.08 mg g^{-1} fr. wt.) and MAH-957 (2.03 mg g^{-1} fr. wt.). Results of present study indicated that total chlorophyll was maximum at silking period and among the maize genotypes, DMH-01 recorded higher total chlorophyll content during cob initiation period and the lowest chlorophyll content was recorded in low yielding DMH-04 genotype. Similar results were reported by (Yunfeng *et al.*, 2014). The data on starch content of different maize genotypes presented in (Table 2).

After the harvest of the crop starch content was measured in kernels, maximum starch content (61.7 mg g^{-1}) was recorded with DMH-01, which differ significantly superior with all other genotypes followed by DMH-13 (59.8mg g^{-1}), GPMH-1101 (58.6 mg g^{-1}) and MAH-957 (56.9 mg g^{-1}). Whereas, least starch content (32.5 mg g^{-1}) was recorded with DMH-04. The data on starch content was in agreement with the study by (Yunfeng *et al.*, 2014).

Table.1 Genotypic differences in plant height, number of leaves, leaf area and total dry matter at reproductive stages of maize

Genotypes	Plant height (cm)	Number of Leaves	Leaf area (dm^2 $plant^{-1}$)	Total dry of leaves matter (g $plant^{-1}$)
Arjun	178.99a-c	11.36f-g	90.5b-d	167.35
GH-0727	184.04ab	11.69d-f	82.1c-f	165.82
GPMH-1101	192.79a	13.13ab	94.2bc	171.72
GPMH-1111	185.16ab	12.02c-e	91.8b-d	169.18
GH-1018	187.86a	12.24cd	90.7b-d	170.25
GH-1043	171.56a-c	10.80gh	84.1 c-e	168.78
GH-110145	175.61a-c	10.91gh	87.1 b-e	166.40
GH-110204	178.03a-c	11.13f-h	81.7 c-f	169.54
DMH-01	193.43a	13.24a	108. 2 a	181.29
DMH-03	189.30a	12.35cd	79.5 d-f	173.15
DMH-10	189.96a	12.46bc	86.0 c-e	173.59
DMH-13	193.66 a	13.24a	100.5ab	176.75
NAH-1137	191.16 a	12.58a-c	86.6 b-e	175.17
NAH-2049	190.32 a	12.58a-c	81.4 c-f	174.88
MAH-957	191.50 a	13. 13ab	91.0 b-d	177.95
MAH-974	188.77 a	12.35cd	74.9ef	168.62
DMH-04	151.49 c	9.91i	68.4f	169.19
DMH-06	167.66 a-c	10.58hi	78.0d-f	163.45
DMH-08	156.02bc	10.47hi	73.5ef	170.56
DMH-17	164.00a-c	10.58hi	75.0ef	168.92
S.Em+	3.14	0.23	5.1	1.15
LSD (5%)	8.98	0.67	14.6	NS

Note: DMRT-values in the column followed by the same letter do not differ significantly
DAS – Days after sowing NS: Non significant

Table.2 Genotypic differences in SPAD values, chlorophyll content, starch content (mg g^{-1}) and total sugar content at reproductive stages of maize

SL No.	Genotypes	SPAD values	Chlorophyll content (mg g^{-1} fr.Wt.)	Starch content (mg g^{-1})	Total sugar content (mg g^{-1})	Photosynthetic rate (μ mol CO_2 m^{-2} s^{-1})
1.	Arjun	41.19a-d	1.76fg	41.2e	0.77g	21.49 f-h
2.	GH-0727	41.69a-d	1.82e-g	45.7cd	0.79g	21.58 f-h
3.	GPMH-1101	46.61ab	2.08c	58.6ab	1.19c	28.42ab
4.	GPMH-1111	42.79a-c	1.90c-f	47.3cd	0.80g	22.23e-h
5.	GH-1018	42.81a-c	1.91c-f	47.8cd	0.83fg	23.19d-g
6.	GH-1043	39.49a-d	1.89c-f	36.5f	0.52hi	18.01i
7.	GH-110145	39.76a-d	1.82e-g	35.2f	0.57hi	20.07h
8.	GH-110204	40.05a-d	1.77fg	35.1f	0.60h	21.12gh
9.	DMH-01	47.61a	2.81a	61.7a	2.92a	29.57a
10.	DMH-03	45.06a-c	1.89c-f	45.2c-e	0.92ef	23.96de
11.	DMH-10	45.81ab	1.98c-e	49.1c	0.95e	23.37d-g
12.	DMH-13	47.32a	2.34b	59.8ab	2.56b	28.76a
13.	NAH-1137	45.34ab	1.88d-f	56.2b	1.08cd	26.52bc
14.	NAH-2049	44.34a-c	1.91c-f	45.9cd	0.98de	24.56cd
15.	MAH-957	46.12ab	2.03cd	56.9b	1.10c	28.31ab
16.	MAH-974	43.21a-c	1.88d-f	43.2de	0.88e-g	23.65d-f
17.	DMH-04	34.09d	1.38h	32.5f	0.28j	10.97k
18.	DMH-06	38.38b-d	1.47h	33.2f	0.47i	16.91i
19.	DMH-08	36.37cd	1.45h	34.3f	0.35j	14.69j
20.	DMH-17	38.38b-d	1.65g	35.1f	0.46i	16.00ij
	S.Em+	0.39	0.06	1.4	0.04	0.70
	LSD (5%)	1.11	0.17	4.1	0.11	2.01

Note: DMRT-values in the column followed by the same letter do not differ significantly
DAS – Days after sowing

Table.3 Genotypic differences of cob weight (g), Cob girth (cm), cob length (cm), No. of seed rows cob^{-1} and No. of seeds cob^{-1}

SL No.	Genotype	Cob Weight (g)	Cob girth (cm)	Cob length (cm)	No. of seed rows cob^{-1}	No. of seeds cob^{-1}
1.	Arjun	161.33e -h	15.75ab	14.61d-g	14.27b-f	330.08 g-i
2.	GH-0727	167.33d- g	15.99ab	14.77d-g	14.27b-f	349.84f -i
3.	GPMH-1101	199.00bc	17.06ab	17.47a-c	16.13a-c	428.95 b-e
4.	GPMH-1111	170.67c -g	16.15ab	15.15c-f	14.40b-f	355.34f -i
5.	GH-1018	174.33c -g	16.19ab	15.24c-f	14.40b-f	399.55c -f
6.	GH-1043	147.33g- i	15.41ab	13.61f- h	13.60c-f	382.44e -h
7.	GH-110145	151.00f -i	15.65ab	14.05e- g	13.60c-f	390.50 d-g
8.	GH-110204	157.33f -i	15.71ab	14.31e- g	13.73b-f	517.00a
9.	DMH-01	234.00a	17.71a	18.12a	17.47a	520.77a
10.	DMH-03	179.00c -f	16.49ab	15.57b-f	14.67b-f	437.02 b-e
11.	DMH-10	183.67c -e	16.57ab	15.77a-f	14.93b-f	425.60 b-e

12.	DMH-13	220.00ab	17.14ab	17.87ab	16.27ab	432.91 b-e
13.	NAH-1137	191.33c d	16.84ab	16.59a-e	15.73a- d	458.40a -d
14.	NAH-2049	185.67c -e	16.69ab	16.27a-e	15.33a-e	470.92ab
15.	MAH-957	195.67b- d	16.90ab	17.07a- d	15.87a-c	482.41ab
16.	MAH-974	175.67c -g	16.31ab	15.39b-f	14.53b-f	461.79a -c
17.	DMH-04	119.00j	14.34b	11.54h	12.67f	327.37 g-i
18.	DMH-06	137.00h-j	15.34ab	13.38f- h	13.60c-f	431.82 b-e
19.	DMH-08	132.33ij	14.64ab	12.25gh	13.07ef	314.19 hi
20.	DMH-17	134.00h-j	15.06ab	13.21f- h	13.20d-f	295.16 i
	Mean	**170.78**	**16.10**	**15.11**	**14.59**	**410.60**
	S.Em+	6.655	0.17	14.99	0.25	33.01
	LSD(5%)	19.052	0.50	0.45	0.73	94.51

Note: DMRT-values in the column followed by the same letter do not differ significantly
DAS – Days after sowing

Table.4 Genotypic differences of test weight, yield plant^{-1}, yield (q ha^{-1}), shelling (%), harvest index (%)

SL No.	Genotype	Test weight (g)	Yield plant^{-1} (g)	Yield (q ha^{-1})	Shelling (%)	Harvest index (%)
1.	Arjun	43.3a	138.67f -j	77.65f-j	86.00	49.76a-c
2.	GH-0727	40.9a	141.33f -j	79.15f-j	84.53	46.30a-c
3.	GPMH-1101	41.5a	177.67a-c	99.49a-c	89.25	52.70ab
4.	GPMH-1111	41.7a	143.67e -j	80.45e-j	84.18	48.67a-c
5.	GH-1018	38.3ab	152.33d- i	85.31d-i	87.40	50.83ab
6.	GH-1043	33.8a- d	128.33i- k	71.87i- k	87.24	47.82a-c
7.	GH-110145	33.5a- d	130.33h-k	72.99h- k	86.38	46.50a-c
8.	GH-110204	26.3d	135.00g-k	75.60g- k	85.77	49.04a-c
9.	DMH-01	37.2a-c	192.33a	107.71a	82.21	52.39ab
10.	DMH-03	35.8a-c	155.33b-g	86.99b-g	86.77	48.78a-c
11.	DMH-10	38.3ab	159.67b-g	89.41b-g	86.88	50.27a-c
12.	DMH-13	42.0a	180.00ab	100.80ab	82.47	49.87a-c
13.	NAH-1137	36.8a-c	167.33b-e	93.71b-e	87.39	51.22ab
14.	NAH-2049	34.9a-c	163.33b-f	91.47b-f	87.93	50.51a-c
15.	MAH-957	35.6a-c	171.33a-d	95.95a- d	87.48	49.89a-c
16.	MAH-974	33.5a- d	154.67c-h	86.61c- h	88.07	53.79a
17.	DMH-04	31.3b- d	102.33l	57.31l	86.27	42.16c
18.	DMH-06	29.2cd	125.33j- l	70.19j-l	91.70	48.97a-c
19.	DMH-08	36.0a-c	112.67kl	63.09kl	85.24	44.38 bc
20.	DMH-17	40.8a	120.00j- l	67.20j-l	89.76	48.84a-c
	Mean	**36.54**	**147.58**	**82.65**	**86.65**	**49.13**
	S.Em+	2.5	5.934	3.32	2.66	1.75
	LSD(5%)	7.1	16.988	9.51	NS	5.01

Note: DMRT-values in the column followed by the same letter do not differ significantly
DAS – Days after sowing

Total soluble sugar content in corn is significantly varied with genotypes. Soluble sugar is main osmolytes in maize plants and they are used for osmotic adjustment. Increase in soluble sugar content in plant cells have been observed among the hybrids. The data on total soluble sugar content was presented in the (Table 2). The maximum total soluble sugar (2.92 mg g^{-1}) was recorded with DMH-01 and which was statistically significant with other genotypes followed by DMH-13 (2.56 mg g^{-1}), GPMH-1101 (1.19 mg g^{-1}) and MAH-957 (1.10 mg g^{-1}). Whereas, lower total soluble sugar was recorded (0.28 mg g^{-1}) with DMH-04 genotype. This is in agreement with the study by (Guanghua yin *et al.*, 2012) and a parameter suitable to screening for drought tolerance in maize varieties.

Yield is the ultimate manifestation of morphological, physiological, biochemical processes and growth parameters and is considered to result from trapping and the conversion of solar energy efficiency. Improvement in yield can be realized in two ways *i.e*. by adopting the existing varieties to grow better in their environment by altering the relative proportion of different plant parts so as to increase the yield of economically important parts (Humphries, 1969).

Maize grain yield was affected by numerous other plant traits, Grain yield could be improved by selecting for the increased plant height, cob length, and 100 grain weight as reported by (Khan *et al.*, 1999). Maize grain yield has high positive genetic association with ear length, kernel rows per ear, 1000kernel weight. Large variation in cob yield was noticed ranging from 57.31 to 107.71 quintals per hectare (Table 4). This indicates that the yield variability could be due to differential photosynthetic capacity or by differential dry matter production of respective genotypes. Ability of a genotype to produce reproductive apparatus is an important characteristic of a plant. Varietal difference for cob yield was due to variation in leaf carbon fixation (Jurgens *et al.*, 1978) and could also be due to variation in grain number, kernel weight and cob length (Hall *et al.*, 1981; Coasta *et al.*, 1988).

Significant improvement in overall growth of the crop was due to increased photosynthetic efficiency which resulted in greater availability of photosynthates, metabolites and increased dry matter accumulation for growth and development of reproductive structures which has resulted in increased cob girth, cob length and cob weight.

DMH-01 registered significantly maximum cob weight (234.00g) over all the hybrids followed by DMH-13.Whereas, lower cob weight (119.00g) was recorded with hybrid DMH-04. Cob girth was significantly higher (17.71 cm) in DMH-01 which was statistically on par with all other hybrids except DMH-04 (Table 3). While, DMH-04 recorded significantly lower cob girth (14.34 cm) among all the hybrids. In the present study, maximum cob girth and cob length was recorded in DMH-01, which is in accordance with (Younas *et al.*, 2002).

The maximum cob length (18.12 cm) was recorded with DMH-01 followed by DMH-13, GPMH-1101, MAH-957, NAH-1137, NAH-2049 and DMH-10 which were statistically on par with each other and the least (11.54 cm) was recorded with DMH-04.Number of seed rows per cob (17.47) was significantly higher in DMH-01followed by DMH-13, GPMH-1101, MAH-957, NAH-1137 and NAH-2049 which were statistically on par with each other and the least number of seed rows per cob (12.67) was recorded with DMH-04. The number of seeds per cob was significantly higher (520.77) in hybrid DMH-01 followed by GH-110204, MAH-957, NAH-2049, MAH-974 and NAH-1137 which were statistically on par with each other. While, DMH-17 recorded lower number of seeds (327.37) which was on par with DMH-08, DMH-04, Arjun, GH-0727 and GPMH-1111 hybrids.

Maximum test weight (43.3 g) was recorded with Arjun and which was statistically on par with each other in all maize hybrids and least (26.3g) was recorded with GH-110204. Significantly higher grain weight per plant (192.33g) was recorded with DMH-01 followed by DMH-13, GPMH-1101 and MAH-957, these hybrids recorded significantly superior over rest of hybrids. DMH-04 hybrid recorded lower yield per plant (102.33g). Yield per hectare was significantly higher (107.7 q ha^{-1}) in DMH-01 followed byDMH-13, GPMH-1101and MAH-957, which were statistically on par with each other and the least (57.31 q ha^{-1}) was recorded with DMH-04.

Shelling percentage was significantly higher (91.7%) in DMH-06 and which was recorded statistically on par with each other and the least shelling percentage (82.21%) was recorded with DMH-01.Harvest index varied significantly with hybrids. The highest harvest index (53.79%) in MAH-974, and which was on par with other hybrids except DMH-17 and DMH-08.Whereas, lowest harvest index was recorded with DMH-04 (42.16%).

Based on the results it was concluded that genotype DMH -01 recorded higher plant height, number of leaves, leaf area and TDM and recorded higher SPAD value, Chlorophyll content, photosynthetic rate starch and total sugar and also yield components like cob weight its length, number of seed rows and kernels per cob, shelling percentage, harvest index, yield and yield components compared to other genotypes.

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