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Determination of yield, nutritional parameters and interrelationships among the pigmented and non-pigmented maize genotypes

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Abstract
Yield and yield-attributing traits are the main focus of maize improvement programs. Apart from the yield, emphasis on nutritional quality parameters is also seen owing to their health benefits. Pigmented maize has gained importance in recent years owing to its potential health benefits. With these objectives, a study was conducted at the Tamil Nadu Agricultural University, Coimbatore. Six genotypes comprising both yellow and pigmented maize were used for the study conducted during Rabi 2022–23. The experiment was carried out in a randomised block design (RBD) with four replications. Analysis of variance for yield, yield attributed traits, and nutritional traits showed significant differences, indicating the presence of variation among the studied genotypes. Correlation analysis showed a positive association of single plant yield with all the yield-attributed traits. Traits like number of kernel rows, number of kernels per row, kernel length, and hundred kernel weight showed a strong positive correlation with single plant yield. Results of the study showed that S8-2 showed high values for yield and yield-attributed traits, indicating its potential use as a parent in maize breeding programs. Studies on nutritional quality parameters revealed that VL21931 has the highest amylose, carbohydrate, and starch content among the studied genotypes, and this line can be used as a parent to improve nutritional parameters. The information obtained from this study can be used to improve the yield and nutritional parameters of maize improvement program.

Keywords: Maize, yield, yield attributing traits, nutritional quality, correlation

Introduction
Maize (*Zea mays* L.) is a C4 annual cereal crop that is majorly grown across the world and found its use as food, feed, and other industrial applications. Pigmented maize landraces such as purple, red, white, orange, blue, and black genotypes have been used for food and medicinal purposes but are limited to a limited area and have low productivity compared to the yellow genotypes due to a lack of wider usage for industrial food (Gogoi *et al*., 2023) [5]. In addition to their role as natural colouring agents, the pigments in these coloured genotypes possess health-promoting factors such as antioxidants, flavonoids, and polyphenols, which could reduce the risk of cancer, atherosclerosis, arthritis, neurodegenerative diseases, and cardiovascular diseases (Carocho *et al*., 2018) [3]. Many people prioritise natural foods in their daily diets due to the nutritional and curative perspective because they play a vital role in maintaining health, preventing nutrient deficiencies, and having health-associating properties (Yusuf *et al*., 2017) [15]. The nutritional quality of pigmented maize has not been extensively studied, and limited reports are available. Hence, the objective of the present study is to investigate the yield and yield-attributing traits, their interrelationships and the nutritional quality parameters of the pigmented and non-pigmented maize.

Materials and Methods
The experiment was conducted at the Department of Millets, TNAU, Coimbatore, during Rabi 2022-23. The experimental material comprised of six maize genotypes encompassing both pigmented and non-pigmented lines obtained from the Winter Nursery Centre, Indian Institute of Maize Research, Hyderabad, and Department of Millets, TNAU, Coimbatore. (Table 1). The experiment was carried out in a Randomized Block Design with four replications in a 3m row and adopted spacing of 60 x 25 cm. Recommended agronomical practices were followed till harvest.

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Studies on yield and yield attributing traits

The biometrical parameters were recorded for the yield and yield attributing traits namely cob length (cm), cob diameter (cm), number of kernels per row, number of kernel rows per cob, kernel length (mm), kernel width (mm), kernel thickness (mm), 100 kernel weight (g), shelling percentage and grain yield per plant (g).

Determination of Nutritional quality Parameters

Nutritional quality analysis was performed at the Department of Biochemistry, TNAU, Coimbatore. Total carbohydrate (mg/g), total starch (mg/g), total protein (mg/g), amylose (%) and amylopectin content (%) were estimated as per the methods outlined by Sadasivam and Manickam (2005) [13]. Crude fibre, fat and ash content were determined by adopting the Association of Official Analytical Chemists method (AOAC, 2000) [1]. Regression equations were obtained from standard curves using appropriate standards for each analysis (Fig.2). The analysis of variance (ANOVA) for the traits studied were calculated at a significance level of 5% (Panse and Sukhatme, 1964) [11]. Karl Pearson's outlined the correlation analysis to assess the relationship between the yield and yield contributing traits. Statistical analysis was carried out by using the GRAPES software version 1.1.0.

Results and Discussion

Analysis of variance revealed significant difference among the six genotypes for all the traits studied (Table 2), which shows considerable variation. The *Per se* performance of the pigment and non-pigmented maize genotypes are given in the Table 3. The results revealed that cob length ranged between 12.81cm – 15.43 cm with a mean value of 14.38 cm with 52099 (15.43 cm) having the longest cob among the studied genotypes. The cob diameter ranged between 3.93 cm – 5.33 cm with a mean of 4.57 cm with S8-2 (5.33 cm) showing the highest value. Basa *et al*., (2016) reported that cob length is an important characteristic to assess the size and shape of the maize cob and also plays a role in determining the yield. Cob diameter, along with cob length, influence the overall size of the ear and contributes to the yield potential of maize genotype. The No. of kernels per row varied between 22.0 – 30.0 with an average value of 26.16 and S8-2 having the highest kernel row number (30.0). The No. of kernel rows per cob ranged between 8.0 – 12.0 with a mean of 10.0 and the highest value observed in the genotype S8-2 (12.0). The No. of kernels and kernel rows per cob determines the yield and quality of maize grains, it can vary among different maize genotypes and is influenced by genetics and environmental factors (Ghimire *et al*., 2015) [4]. The kernel length varied between 8.03 mm – 10.05 mm with an average of 8.67 mm. The kernel width ranged from 4.94 mm – 7.98 mm with an average mean of 6.33 mm. Maximum kernel length (10.05 mm) and kernel width (7.98 mm) was observed for the genotype S8-2. The kernel thickness varied between 2.21 mm – 3.63 mm with a mean of 2.90 mm. The genotype 52099 (3.63 mm) recorded the highest kernel thickness Similar results were obtained for kernel length, width, and thickness by Sangamithra *et al*., (2016) [14]. Hundred kernel weight varied between 19.80 g – 29.20 g with an average of 23.28 g. S8-2 (29.20 g) has the highest kernel weight among the studied genotypes. Shelling percentage varied between 75.14% - 80.88% with an average of 78.34%, while 52099 (80.88%) recorded highest values for shelling percentage. Single plant yield ranged between 54.58 g – 71.72g with an average of 63.03g, with S8-2 (71.72 g) being the highest yield

among the genotypes.
Among the genotypes studied, S8-2 recorded the highest single plant yield (71.72 g), cob diameter (5.33 cm), No. of kernels per row (30 Nos.), No. of kernel rows per cob (12 Nos), kernel length (10.05 mm), kernel width (7.98 mm), hundred kernel weight (29.20 g). While, 52099 recorded the highest kernel thickness (3.63 mm) and shelling percentage (80.88%). These genotypes with good yield and yield attributing traits can be utilised as parental lines in the breeding programme.

Nutritional quality parameters

The analysis of variance (ANOVA) found to show significant difference ($p<0.05$) among the genotypes studied for all the nutritional quality traits. The performance of the genotype for various nutritional quality parameters are depicted in Table 4. The results revealed that total carbohydrate content of different genotypes varied between 65.95 mg/g – 73.56 mg/g with an average of 68.66 mg/g. The total starch content was found between 17.99 mg/g - 46.26 mg/g with the average of 31.27 mg/g. The genotype VL21931 had a high amount of carbohydrate (73.56 mg/g) and starch (46.26 mg/g) content. The total protein content of genotypes revealed a range of 9.84 mg/g – 10.97 mg/g with the average amount of 10.27 mg/g. Among the genotypes, highest protein content was found in the 52099 (10.97 mg/g) (Fig. 1). Gogoi *et al*., 2023 [5] reported that carbohydrates are digested by human enzyme and it provides energy to the body, and starch had a higher level of glycemic index for easily digestible and leading to increase the level of blood sugars, the maize protein serves as a balanced health diet. The amylose content of the genotypes varied between 12.08% - 16.88% with a mean of 13.47%. Highest amylose content was found to be recorded in white genotype VL21931 (16.88%) (Fig. 1). Similar findings were obtained by Ozdemir *et al*., (2022) [16] revealed that white genotype has highest amylose content than the coloured genotypes and high-amylose has been associated with several health benefits namely prevention of type II diabetes, colon cancer, obesity, and cardiovascular disease. The content of amylopectin values ranged from 83.0% - 87.53%. The content of crude fibre ranged between 2.67% - 3.35% with an average of 3.07%. Fat content of different genotypes varied between 3.83% - 4.93% with the mean of 4.27%. The ash content ranged between 1.06% - 1.60% with an average of 1.25%.

Results of the study for nutritional quality revealed that genotype VL21931 having the white kernels found to have the highest carbohydrate (73.56 mg/g), starch (46.26 mg/g) and amylose content (16.88 mg/g), followed by the yellow kernel genotypes S8-2, 52099, with yellow kernels. The genotypes with kernel pigmentation (IC 422880, 11583, IC 568293) had comparatively less carbohydrate, starch, protein and amylose content. The results interpreted that genotype VL21931 with white kernel having high carbohydrate, starch, amylose and the genotype 52099 having yellow kernels can be used as the parental lines in hybridization programme to improve the nutritional quality of maize.

Correlation analysis explores the degree and direction of the relationship between the traits which aid in crop improvement programme. (Table 5, Fig. 2) showed that single plant yield has strong and positive association with number of kernel rows, number of kernel rows per cob, cob length, cob diameter and hundred kernel weight. Though cob length, kernel width, kernel thickness and shelling percentage showed positive relationship with single plant yield, their magnitude was observed to be comparatively less significant compared

to other traits in affecting the plant yield. Similar findings have been reported by Priyanto *et al*., (2023) [12]. Shelling percentage was positively correlated with cob length, cob diameter, number of kernels per row, number of kernel rows per cob, kernel length, width, thickness, and hundred kernel weight. The number of kernel rows per cob was found to be highly significant and positively correlated with the number of kernels per row. Similar results were obtained for the shelling percentage and number of kernel rows per cob is reported by Pandey *et al*., (2017) [10]. Hundred kernel weight was found to be positive and highly significant with cob length, cob diameter, number of kernels per row, number of

kernel rows per cob, kernel length, kernel width and kernel thickness. Kernel thickness was found to be positive and significant correlated with kernel width. Kernel length showed a highly significant positive correlation with the cob diameter. This result for length, width and thickness of kernel is similar with the work carried out by Kumar *et al*., (2017) [8]. The number of kernels per row had positive correlated with the cob length and cob diameter. Similar findings were obtained by Jilo *et al*., 2019 [7]. These findings suggests that maize yield can be improved through direct positive selection for the cob and kernel yield attributing traits.

Table 1: Pigmented and Non-pigmented maize genotypes used for the study

S. No	Genotypes	Colour of seeds	Stereomicroscopic kernel images	Source
1.	IC 422880	Purple		Indian Institute of Maize Research, Hyderabad
2.	11583	Purple		Indian Institute of Maize Research, Hyderabad
3.	IC 568293	Dark Red		Indian Institute of Maize Research, Hyderabad
4.	S8-2	Yellow		Tamil Nadu Agricultural University, Coimbatore
5.	52099	Yellow		Tamil Nadu Agricultural University, Coimbatore
6.	VL21931	White		Indian Institute of Maize Research, Hyderabad

Table 2: Analysis of Variance (ANOVA) for yield and yield attributing traits of maize genotypes

Source of variation	Df	Cob length (cm)	Cob diameter (cm)	No. of kernels /row	No. of kernel rows / cob	Kernel length (mm)	Kernel width (mm)	Kernel thickness (mm)	Hundred Kernel weight (g)	Shelling%	Single plant yield (g)
Genotypes	5	36.49*	1.34*	87.57*	6.20*	2.58*	7.55*	1.55*	74.53*	18.89*	160.57*
Replication	3	0.06	0.02	0.18	0.01	0.02	0.03	1.40	0.52	2.74	1.79
Error	15	0.02	0.01	0.45	0.02	0.03	0.02	0.003	0.22	1.43	2.18

*Level of significance at 0.05

Table 3: *Per se* performance for yield and yield attributing traits of maize genotypes

Genotypes	Cob length (cm)	Cob diameter (cm)	No. of kernels / row	No. of kernel rows/ cob	Kernel length (mm)	Kernel width (mm)	Kernel thickness (mm)	Hundred Kernel Weight (g)	Shelling%	Single plant yield (g)
IC 422880	14.5	4.08	22	8	8.07	6.10	2.97	19.80	80.00	54.58
11583	15.0	4.40	24	10	8.03	6.0	2.77	21.95.	75.14	57.78
IC 568293	12.81	4.50	25	10	8.81	4.94	2.21	23.90	78.15	61.80
S8-2	14.62	5.33	30	12	10.05	7.98	3.57	29.20	79.41	71.72
52099	15.43	5.21	29	10	9.04	7.97	3.63	23.94	80.88	67.77
VL21931	13.94	3.93	27	10	8.04	4.95	2.22	20.92	76.25	64.53
Mean	14.38	4.57	26.16	10	8.67	6.33	2.90	23.28	78.34	63.03
Maximum	15.43	5.33	30	12	10.05	7.98	3.63	31.89	80.88	71.72
Minimum	12.81	3.93	22	8	8.03	4.94	2.21	19.80	75.14	54.58
SEd	0.10	0.08	0.47	0.09	0.13	0.09	0.04	0.33	0.84	1.04

Table 4: Mean performance for Nutritional quality parameters of the maize genotypes

| Genotypes	Carbohydrate (mg/g)	Starch (mg/g)	Protein (mg/g)	Crude fibre (%)	Fat (%)	Ash (%)	Amylose (%)	Amylopectin (%)
IC 422880	68.44	21.52	10.21	3.22	3.83	1.12	12.90	87.1
11583	66.64	27.79	9.94	3.35	4.93	1.06	12.08	87.9
IC 568293	67.60	17.99	9.84	2.71	4.50	1.37	12.28	87.7
S8-2	69.78	37.33	10.36	2.67	4.09	1.22	13.70	86.3
52099	65.95	36.72	10.97	3.23	4.06	1.14	13.00	87.0
VL21931	73.56	46.26	10.30	3.26	4.21	1.60	16.88	83.12
Grand mean	68.66	31.27	10.27	3.07	4.27	1.25	13.47	86.52
Maximum	73.56	46.26	10.97	3.35	4.93	1.60	16.88	87.9
Minimum	65.95	17.99	9.84	2.67	3.83	1.06	12.08	83.12
SEd	0.81	0.29	0.18	0.03	0.07	0.02	0.14	1.03

a)

b)

c)

d)
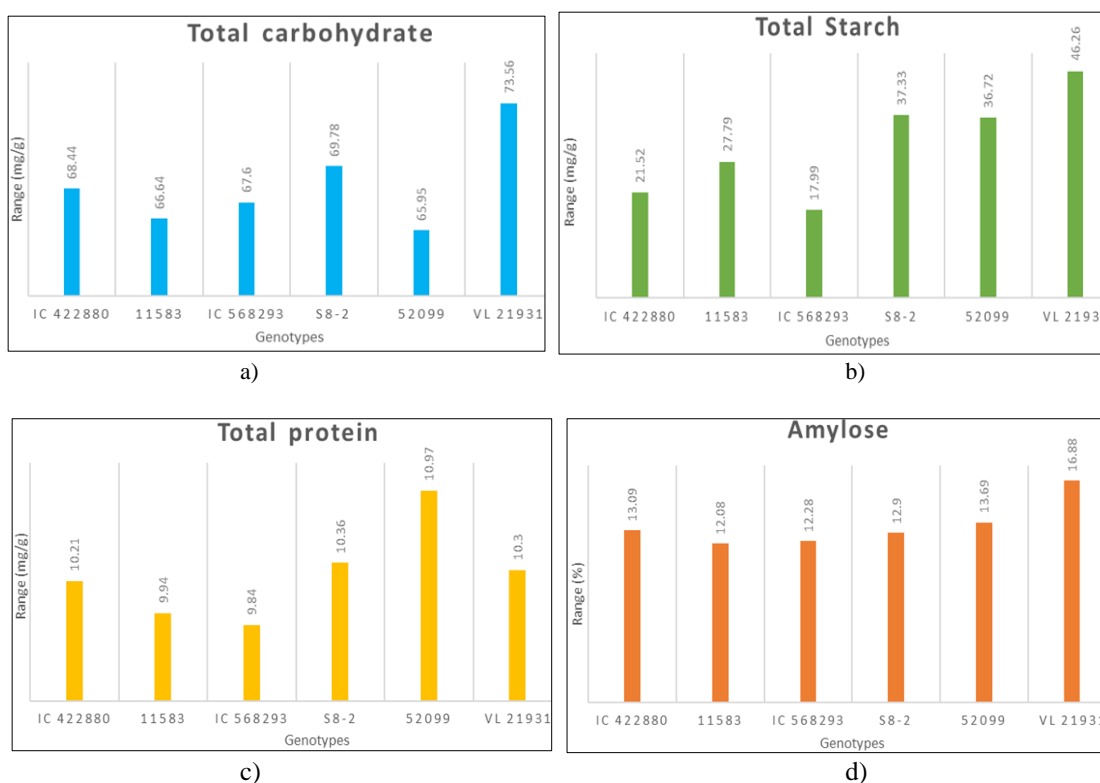
Fig 1: Bar diagram depicting the nutritional quality parameters of six maize distinct genotypes

Table 5: Correlation matrix for the yield and yield attributing traits

	CL	CD	NKR	KRC	KL	KW	KT	HKW	SP	SPY
CL	1	0.407	0.25	0.041	0.084	0.742	0.782	0.056	0.24	0.14
CD		1	0.756	0.684	0.897*	0.871*	0.804	0.868*	0.703	0.753
NKR			1	0.827*	0.776	0.625	0.51	0.773	0.478	0.99**
KRC				1	0.779	0.433	0.304	0.894*	0.235	0.855*
KL					1	0.709	0.626	0.967**	0.769	0.827*
KW						1	0.989**	0.634	0.76	0.585
KT							1	0.534	0.763	0.466
HKW								1	0.592	0.823*
SP									1	0.512
SPY										1

**Correlation is significant at 0.01 level, *Correlation is significant at 0.05 level

Fig 2: Pearson's correlation coefficient Where, CL= cob length, CD= Cob diameter, NKR= number of kernels per row, KRC=number of kernel rows per cob, KL=Kernel length, KW=Kernel width, KT=Kernel thickness, HKW= hundred kernel weight, SP=Shelling percentage, SPY=Single plant yield.

Conclusion

A successful maize breeding programme mainly focuses on increasing the yield potential of the hybrids. Yield is a complex trait that is influenced by multiple traits. Improvement in yield can be brought about by improving or selecting for traits that indirectly improve the yield. The study revealed that genotype S8-2 highest values for the single plant yield, cob diameter, No. of kernels per row, No. of kernel rows per cob, Kernel length, Kernel width and hundred kernel weight and 52099 having the highest value for kernel thickness and shelling percentage. This indicates the use of these lines as a potential parent in maize breeding programme. Apart from yield, present breeding programme also focus on improving the nutritional quality of the hybrids, as the potential health benefits are being emphasized. Improving nutritional parameters such as carbohydrate, starch, amylose

and protein leads to an improvement in the nutritional quality of the genotypes. The genotype VL21931 showed high values for, carbohydrate, starch, amylose, and genotype 52099 having high protein content and can be used in breeding programmes to improve the nutritional quality of the hybrids. Correlation analysis shows the degree and direction of how improving one trait affects the expression of another trait. The result of the study revealed that single plant yield had positive association with number of kernel rows, number of kernel rows per cob, cob length, cob diameter, hundred kernel weight, cob length, kernel width, kernel thickness and shelling percentage. Hence, selection for the traits can be done accordingly to achieve increased yields.

Reference
1. AOAC (Association of Official Analytical Chemists

International). 2000. Official methods of analysis, 17th edition. AOAC International, Gaithersburg, Maryland, USA. (17th ed.); c2000.

2. Băşa AG, Ion V, Dumbravă M, Temocico G, Epure LI, Ştefan D. Grain yield and yield components at maize under different preceding crops and nitrogen fertilization conditions. Agriculture and Agricultural Science Procedia. 2016;10:104-111.

3. Carocho M, Morales P, Ferreira IC. Antioxidants: Reviewing the chemistry, food applications, legislation and role as preservatives. Trends in Food Science & Technology. 2018;71:107-120.

4. Ghimire B, Timsina D. Analysis of yield and yield attributing traits of maize genotypes in Chitwan, Nepal. World Journal of Agricultural Research. 2015;3(5):153-162.

5. Gogoi P, Sharma P, Mahajan A, Goudar G, Chandragiri AK, Sreedhar M, *et al*. Exploring the nutritional potential, anti-nutritional components and carbohydrate fractions of Indian pigmented maize. Food Chemistry Advances. 2023;2:100176.

6. Gopinath P, Parsad R, Joseph BS, A. grapesAgri1: Collection of Shiny Apps for Data Analysis in Agriculture. Journal of Open Source Software. 2021;6(63):3437.

7. Jilo T, Tulu L. Association and path coefficient analysis among grain yield and related traits in Ethiopian maize (*Zea mays* L.) inbred lines. African Journal of Plant Science. 2019;13(9):264-272.

8. Kumar R, Dubey RB, Ameta KD, Kunwar R, Verma R, Bisen P. Correlation and path coefficient analysis for yield contributing and quality traits in quality protein maize (*Zea mays* L.). International Journal of Current Microbiology and Applied Sciences. 2017;6(10):2139-2146.

9. Özdemir E, Cengiz R, Bayram SADE. Characterization of white, yellow, red, and purple colored corns (*Zea mays indentation* L.) according to bio-active compounds and quality traits. Anadolu Tarım Bilimleri Dergisi. 2023;38(1):131-144.

10. Pandey Y, Vyas RP, Kumar J, Singh L, Singh HC, Yadav PC. Heritability, correlation and path coefficient analysis for determining interrelationships among grain yield and related characters in maize (*Zea mays* L.). Int. J Pure App. Biosci. 2017;5(2):595-603.

11. Panse VG, Sukhatme PV. Statistical methods for agricultural research workers. ICAR, New Delhi, 1964, 381.

12. Priyanto SB, Prayitno OD, Efendi R. Correlation and path analysis maize hybrid yield. Journal Lahan Suboptimal: Journal of Suboptimal Lands. 2023;12(1):80-87.

13. Sadasivam S, Manickam A. Biochemical Methods Revised. New Age International Publishers, New Delhi; c2005. p. 17-18.

14. Sangamithra A, Gabriela JS, Prema RS, Nandini K, Kannan K, Sasikala S, *et al*. Moisture dependent physical properties of maize kernels. International Food Research Journal. 2016;23(1):109.

15. Yusuf M, Shabbir M, Mohammad F. Natural colorants: Historical, processing and sustainable prospects. Natural products and bioprospecting. 2017;7:123-145.

16. Ozdemir D, Sharma M, Dhir A, Daim T. Supply chain resilience during the COVID-19 pandemic. Technology in Society. 2022 Feb 1;68:101847.