

Research Article**Estimates of genetic parameters and quantification of β carotene in Pearl Millet (*Pennisetum glaucum* L.) segregating population****P. Sowmiya, P. Sumathi* and S. Revathi**Department of Millets, Centre for Plant Breeding and Genetics,
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Abstract

An attempt was made to study the genetic variability and inter-relationship analysis in F_3 and F_4 generations for ten quantitative characters. The phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) for all the characters studied in both F_3 and F_4 generation, indicating environmental influence on expression of all characters. High heritability combined with high genetic advance for the trait ear head girth and moderate heritability with high genetic advance noticed in single ear head grain weight and grain yield per plant indicated that these characters were governed largely through additive effects of genes and improvement in these traits may be achieved through phenotypic selection. Association studies revealed that, selection based on the traits, single ear head grain weight, ear head girth, single ear head weight, number of productive tillers per plant, plant height and grain yield per plant will be effective. In path coefficient analysis, single ear head grain weight and total number of productive tillers showed direct effect to account for yield. The effect through ear head girth, single ear head weight and 1000 grain weight was high in F_3 and F_4 generations indirectly. These revealed that the true relationship of these characters with grain yield. Selection based on these characters may be helpful in planning efficient breeding programme. Total carotenoids and β carotene content was estimated in parents and ten F_4 progenies. Among them, five progenies viz., TNBG-06-81-9-13 (1.698 $\mu\text{g/g}$), TNBG-06-81-10-9 (1.624 $\mu\text{g/g}$), TNBG-06-127-3-3 (1.585 $\mu\text{g/g}$), TNBG-06-53-6-6 (1.460 $\mu\text{g/g}$) and TNBG-06-81-7-10 (1.420 $\mu\text{g/g}$) were identified for high β carotene and these lines were used for future breeding programme for producing high yield with β carotene rich pearl millet inbreds.

Key wordsPearl millet, β carotene, Genetic variability, Correlation and Path analysis**Introduction**

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is a cross pollinating, diploid ($2n=2x=14$) annual crop and belongs to section Paniceae of family Poaceae. It is world's sixth and India's fourth important cereal crop and one of the most suitable dual purpose, drought resistant fodder crop; its cultivation extends widely from well irrigated area to the most arid regions of the world in Asia and Africa (Kapila *et al.*, 2008). Pearl millet grain has higher levels of nutritional value and it has high protein content with balanced amino acids, carbohydrate and fat which are important in the human diet, and its nutritive value is considered to be comparable to rice and wheat. It is also rich in B vitamins, potassium, phosphorus, magnesium, iron, zinc, copper and manganese. Besides, Pearl millet contain sufficient amount of β carotene which is the precursor of vitamin A (Curtis *et al.*, 1966). Vitamin A deficiency (VAD) causes about 70 percent of childhood deaths worldwide and blindness in 0.25-0.50 million children every year. Vitamin A is an important micronutrient that plays vital role in vision, growth and development of humans. Vitamin A Deficiency, widely prevalent worldwide, affects people predominantly dependent on cereals diet that are mostly deficient in β carotene (Vignesh *et al.*, 2014). A stable food with rich β carotene would be the easiest way to alleviate vitamin A deficiency which is one of the most important nutritional problems in developing

countries. Grain yield as a character is quantitative in nature and is polygenetically controlled. Selection on the basis of grain yield character alone is usually not very effective and efficient. The nature and magnitude of variability, genetic variations among yield attributes, inter relationship of different characters are required to initiate an effective breeding programme (Izge *et al.*, 2006).

Correlation and path analysis aid in the selection of superior genotypes from the breeding population. The correlation between yield and other component traits should therefore be given importance in the selection of genotypes for more yield in pearl millet. The partitioning of correlation coefficient into the measure of direct and indirect effects determines their contribution towards yield.

The present investigation was conducted with the objectives to study the genetic parameters in the F_4 population which was developed involving beta carotene lines and to identify agronomically superior progeny with rich β carotene for developing β carotene rich inbreds in biofortification breeding.

Materials and methods

Two hundred F_3 progenies were chosen for the present studies which were derived from a cross between PT 6029 \times PT 6129 to develop RIL

population for β carotene. The parent PT 6129 (yellow grain type) contained a high amount of β -carotene content of 1.71 $\mu\text{g/g}$ and PT 6029 (grey grain type) contained low β -carotene content of 0.61 $\mu\text{g/g}$. The 200 F_3 progenies were raised during summer 2011 and were forwarded to F_4 generation during *kharif* 2011 at Department of Millets, Centre for Plant Breeding and Genetics, TamilNadu Agricultural University, Coimbatore, which lies between 11° North latitude and 77° East longitude. All the recommended package of practices was carried out to grow a healthy crop. Each selfed ear head was raised in a single progeny row with spacing of 45 cm between rows and 15 cm between plants. Ten plants were selected randomly in each row for recording observation in both the F_3 and F_4 generations. Data were recorded on ten quantitative characters *viz.*, days to 50 per cent flowering (days), days to maturity (days), plant height (cm), number of productive tillers per plant (nos.), ear head length (cm), ear head girth (cm), single ear head weight (g), single ear head grain weight (g), 1000 grain weight (g) and grain yield per plant (g). The various variability parameters were worked out as per Burton (1952). The broad sense heritability and genetic advance was estimated according to Johnson *et al.* (1955), correlation and Path analysis (Dewey and Lu, 1959) were calculated as per statistical method.

In F_4 generation, ten plants were selected based on grain colour and ear head compactness to β carotene analysis. Three qualitative characters *viz.*, grain colour, total carotenoid content and β carotene were recorded in these selected progenies. Total carotenoid and β carotene estimation was done in triplicate to minimize handling error.

Extraction of carotenoid and quantification of β -carotene content: Representative samples of pearl millet grains were homogenized into powder and 3 g of ground representative samples were used for the assay. Since β -carotene is sensitive to light, oxygen and temperature, the extraction was done in dark at low temperature to prevent oxidation of carotenoids. The extraction was done as per the Harvest plus method (Rodriguez Amaya and Kimura 2004). Estimation of total carotenoid content was done with a spectrophotometer (450 nm) and quantification of β -carotene content was done using RP-HPLC (Shimadzu HPLC Analytical C18G 120A column 250 x 4.6 mm). Samples were eluted through YMC Carotenoid C18 column and detected with a photodiode array detector. The mobile phase consisted of Acetonitrile: Methanol: Ethyl acetate (80:10:10) at high pressure through the column, and the flow rate was 1 ml/min. The standard for β -carotene was purchased from M/s. Sigma Aldrich India, reconstituted in acetone to five different concentrations (0.1 $\mu\text{g/g}$; 1 $\mu\text{g/g}$; 10 $\mu\text{g/g}$; 50 $\mu\text{g/g}$; 100 $\mu\text{g/g}$) (Kurilich and Juvik 1999) and were used to make the standard curve

for β -carotene. The concentration of β carotene in each inbred was measured by standard regression with external standards. Absorbance was measured at 453 nm to maximize the detection of β -carotene. The chromatogram was compared with that of the standards in order to calculate the amount of β -carotene in the samples.

Result and discussion

A wide range of variation was observed for all the traits studied (Table 1). In general, the mean value for almost all the traits in F_4 progenies was higher than the F_3 progenies in desirable direction. This shows the improvement of the traits in the advanced generation. The phenotypic and genotypic coefficients of variation are the measures of phenotypic and genotypic variances, respectively. In general, phenotypic coefficient of variation was found to be higher than genotypic coefficient of variation for all characters.

The phenotypic, genotypic variances, GCV and PCV were higher in F_3 generation than in the F_4 generation for all the traits studied except days to 50 per cent flowering. The PCV was higher than GCV for all the ten quantitative characters in F_3 and F_4 generations indicating higher environmental influence on expression of all the traits. The highest value of genotypic coefficients of variation was noted for single ear head grain weight (22.34 g and 19.85 g) and grain yield per plant (30.82 g and 24.51g) in F_3 and F_4 generation respectively. This revealed that the variation for these characters contributed markedly to the total variability. Similar result was reported by Kale *et al.*, 2011. Similarly moderate PCV and GCV was observed for the traits number of productive tillers per plant, ear head girth, 1000 grain weight, single ear head weight and plant height in F_3 and F_4 generations. Selection will be effective based on the heritable nature of these traits. Moderate PCV and Low GCV were observed for the trait ear head length in F_3 and F_4 generations. Low PCV and GCV were observed for the trait, days to maturity and days to 50 per cent flowering in F_3 and F_4 generations and hence selection based on these traits may not be rewarding. This was in accordance with the results of Meenakumari and Nagarajan, 2008 for days to 50 per cent flowering.

The estimate of heritability of a character provides a measure of the effectiveness of selection for that character. The high heritability was observed for plant height (67.99 and 62.81) and ear head girth (65.55 and 62.95) in both the populations (F_3 and F_4) whereas the remaining characters showed moderate heritability. Heritability alone will mislead the selection; hence, genetic advance should also be taken into consideration along with heritability during selection programme. High heritability combined with high genetic advance was observed for the trait earhead girth and

moderate heritability with high genetic advance was noticed in single ear head grain weight and grain yield per plant. This indicates that these characters were governed largely through additive effects of genes and improvement in these traits may be achieved through phenotypic selection. A high estimate of genetic advance for grain yield was reported by Solanki *et al.* (2002). Days to 50 % flowering and days to maturity showed moderate heritability with low genetic advance. Such a situation may be caused by non-additive gene action *i.e.* dominance and epistasis. Hence considering the GCV, PCV, heritability and genetic advance as percent of mean, plant height and grain yield per plant were found to be better performing traits in both F₃ and F₄ generation with less environmental influence and selection based on these traits would be effective for future pearl millet breeding.

In association study grain yield showed significant and positive association with plant height (0.476 and 0.254), number of productive tillers per plant (0.568 and 0.480), ear head length (0.195 and 0.234), ear head girth (0.759 and 0.707), single ear head weight (0.740 and 0.682), single ear head grain weight (0.854 and 0.812) and 1000 seed weight (0.570 and 0.458) in both the F₃ and F₄ generations (Table 2). This confirmed that these characters were mostly responsible for determining the yield. Hence, selection based on these characters will help in improving the yield in pearl millet. The present findings were in conformity with the results of Govindaraj and Selvi (2012) for plant height, number of productive tillers per plant.

Association of yield and its components alone are not adequate in any selection programme. The inter relationship existing between the individual characters which ultimately influence the yield component showed the following relationship. Days to 50 per cent flowering showed highly significant positive correlation with days to maturity in F₃ and F₄ generations.

Ear head length and ear head girth was positively associated with single ear head grain weight, single ear head weight and 1000 grain weight in F₃ and F₄ generations. Positive correlation of ear head length was reported by Yadav *et al.* (2012) for single ear head weight. Single ear head weight, single ear head grain weight and 1000 grain weight was positive and significantly inter correlated with each other. Similar results were reported by Vagadiya *et al.* (2010) for single ear head grain weight with single ear head weight, Meenakumari and Nagarajan (2008) for single ear head grain weight with 1000 grain weight. Number of productive tillers per plant showed significant positive association with single ear head grain weight in F₃ generation, whereas, it showed negative

association with single ear head weight F₄ generation.

Path coefficient analysis was worked out to determine the direct and indirect contributions of different traits towards grain yield per plant. Hence, path coefficient analysis is the best method to evaluate the cause and effect relationship between the yield and yield components. Path coefficient provides a clear cut picture about the direct and indirect effect of component character on yield.

Positive direct effect on grain yield per plant was observed by the traits, days to 50 % flowering, plant height, productive tillers, ear head girth and single ear head weight and single ear head grain weight in F₃ and F₄ generations. The trait, single ear head grain weight (0.761 and 0.687) recorded highest positive direct effect on grain yield per plant followed by number of productive tillers per plant (0.400 and 0.401) in F₃ and F₄ generations (Table 3). This was in corroborate of the findings of Govindaraj and Selvi (2012) for number of productive tillers per plant; Vagadiya *et al.* (2010) for ear head girth; Kale *et al.* (2011) for single ear head weight Ibrahim *et al.* (2012) for single ear head grain weight.

Single ear head grain weight showed positive indirect effect towards grain yield per plant through days to maturity, plant height, number of productive tillers, ear head girth, single ear head weight and single ear head grain weight in F₃ and F₄ generations. Similar results were reported by Meenakumari and Nagarajan (2008) for ear head length, ear head girth, 1000 grain weight and plant height.

The residual effect of 0.284 and 0.400 was observed in F₃ and F₄ generations respectively. This minimum value of residual effect indicates that most of the characters contributing towards grain yield per plant are reliable and realistic. Though, about 28.4 percent and 40 percent of variability was unaccounted and there might be a few more componential characters other than those studied in the present investigation, which might have been accountable for manipulating the grain yield of pearl millet. Association studies revealed that, selection based on the traits, single ear head grain weight, ear head girth, single ear head weight, number of productive tillers per plant, plant height and grain yield per plant will be effective. Therefore selection on the basis of direct and indirect effects is much more useful than selection for yield *per se* alone.

β carotene estimation in F₄ progenies: Pearl millet grains containing a substantial amount of pro-vitamin A would be acceptable to farmers if this higher nutritional value can be delivered to locally

adapted, pest and disease resistant cultivars that have reasonable yield potential. This emanated the thought that enhancing the β carotene content in pearl millet is feasible (Kimura *et al.*, 2007). So, distinct levels of β carotene having genotypes were used as parents in this study. The results exhibited considerable variations was observed in total carotenoid (1.706-9.013 $\mu\text{g/g}$) and β carotene content (0.120-1.698 $\mu\text{g/g}$) among the parents and the selected progenies (Fig.1a and 1b). The parent PT 6129 showed high total carotenoid (9.013 $\mu\text{g/g}$) and β carotene content (1.639 $\mu\text{g/g}$), whereas, PT 6029 showed low total carotenoid (2.986 $\mu\text{g/g}$) and β carotene content (0.712 $\mu\text{g/g}$) (Table 4).

The parent PT 6129 was recorded as yellow grain colour, while, the parent PT 6029 recorded grey colour grain. It indicated that yellow colour grain may contribute to β carotene content. The selected progenies in F_4 generation showed variations for grain colour *viz.*, grey brown, cream, yellow and yellow brown grain colour. The progeny, TNBG-06-81-9-13 registered high total carotenoids (8.106 $\mu\text{g/g}$) and β carotene (1.698 $\mu\text{g/g}$) which showed yellow brown grain colour followed by TNBG-06-81-10-9 (yellow grain colour), TNBG-06-127-3-3 (yellow brown grain colour), TNBG-06-53-6-6 9 (yellow brown grain colour), TNBG-06-81-7-10 and β carotene content was ranged between 0.120 to 1.698 $\mu\text{g/g}$ among these progenies. Sathya *et al.*, 2014 reported the β carotene range from 0.46 to 2.83 $\mu\text{g/g}$ in pearl millet and Tura *et al.*, 2010 in maize the range of 0.122 to 4.74 $\mu\text{g/g}$. These variations provide a valuable basis for increasing β carotene through conventional breeding. The progenies in F_4 generation *viz.*, TNBG-06-81-9-13 (1.698 $\mu\text{g/g}$), TNBG-06-81-10-9 (1.624 $\mu\text{g/g}$), TNBG-06-127-3-3 (1.585 $\mu\text{g/g}$), TNBG-06-53-6-6 (1.460 $\mu\text{g/g}$) and TNBG-06-81-7-10 (1.420 $\mu\text{g/g}$) had high β carotene and good agronomic value. Hence these lines can be utilized after attained the stability in β carotene biofortification programme to develop β carotene rich variety/ hybrids.

References

- Burton, G.W. 1952. Quantitative inheritance in grasses. *Proc. 6th Int. Grassland Cong.*, 1: 277-283.
- Curtis, D.L. Burton, G.W. and Webster, O.J. 1966. Carotenoids in pearl millet seed. *Crop Sci.*, 6: 300-301.
- Dewey, D.R. and Lu, K.M. 1959. Correlation and path coefficient analysis of crested wheat grass seed production. *Agron. J.*, 51: 515-516.
- Govindaraj. M. and Selvi, B. 2012. Path coefficient analysis in local pearl millet germplasm for grain minerals and agronomic characters. *Agric. Sci. Digest.*, 32(2): 128.
- Ibrahim, A.A., Abdelmulla, A.A and Idris, A.E. 2012. Character Association and Path Analysis in Pearl Millet (*Pennisetum glaucum*L.). *Am. J. Exp. Agric.*, 2(3): 370-381.
- Izge, A.U., Kadam, A. Mand Gungla, D.T. 2006. Studies on character association and path analysis of certain quantitative character among parental lines of pearl millet (*Pennisetum glaucum* L.) and their F_1 hybrids in a diallel cross. *African. J.*, 5: 194-198.
- Johnson, H.W., Robinson, H.F and Comstock, R.E. 1955. Estimation of genetic variability and Environmental variability in Soyabean. *Agron. J.*, 47: 314-318.
- Kale, B.H., Jadeja, G.C. and Patel, K.K. 2011. Genetic variability, correlation and path coefficient in segregating generation of Pearl millet [*Pennisetum glaucum* (L.)]. *Int. J. Agric. Sci.*, 7(2): 373-377.
- Kapila R.K, Yadav,R.S., Plaha,P., Rai, K.N., Yadav, O.P., Hash, C.T. and Howarth, C.J. 2008. Analysis of genetic diversity in pearl millet inbreds using microsatellite markers. *Plant breed.*, 127: 33-37.
- Kimura, M., Cintia, N., Kobori, Delia, B., Amaya, R., Nestel, P. 2007. Screening and HPLC methods for carotenoids in sweet potato, cassava and maize for plant breeding trials. *Food Chem.*, 100: 1734-1746.
- Kurilich, A. and Juvik, J. 1999. Quantification of carotenoid and tocopherol antioxidants in *Zea mays*. *J. Agric. Food Chem.*, 47: 1948-1955.
- Meenakumari, B. and Nagarajan, P. 2008. Variability and heritability analysis in pearl millet (*Pennisetum glaucum* (L.) R. Br.). *Madras Agric. J.*, 95: 190-192.
- Rodriguez-Amaya, D.B. and Kimura, M. 2004. Carotenoids in foods. In HarvestPlus Handbook for Carotenoid Analysis; International Food Policy Research Institute and International Center for Tropical Agriculture: Washington DC 2-8.
- Sathya, M., Sumathi, P. and John Joel. A. 2014. A simple and rapid screening technique for grain β carotene content in pearl millet through spectrophotometric method. *J. Agric. Res.*, 9(5): 572-576.
- Solanki, Y.P.S., Khairwal, I.S. and Bidinger, F.R. 2002. Genetic variability, heritability and genetic advance in three pearl millet composites. *Forage Res.*, 28(3): 174
- Tura, S., Senthil, N., Raveendran, M., Vellaikumar, S., Ganesan, K.N., Nallathambi, G., Saranya, Shobhana, V.G., Abirami, B. and VijayaGowri, E. 2010. Exploitation of natural variability in maize for β - carotene content using HPLC and gene specific markers. *Elect. J. Plant Breed.*, 1(4): 548-555.
- Vagadiya, K.J., Dhedhi, K.K., Joshi, H.J., Bhadelia, A.S. and Vekariya, H.B. 2010. Correlation and path co-efficient analysis in pearl millet (*Pennisetum glaucum*(L.)). *Intl. J. Agric. Sci.*, 6: 216-219.
- Vignesh, M., Hossain, F., Thirunavukkarasu, N., Choudhary, M., Saha, S., Jayant, S.B., Prasanna, M. and Gupta, S.H. 2014. Development of b-Carotene Rich Maize Hybrids through Marker-Assisted Introgression of b-carotene hydroxylase Allele. *PLoS ONE*, 9(12): e113583.
- Yadav, A.K., M.S. Narwal and R.K. Arya. 2012. Study of genetic architecture for maturity traits in relation to supra-optimal emperature tolerance in pearl millet (*Pennisetum glaucum* (L.) R. Br.). *Intl. J. Pl. Breeding and Genet.*, 6(3): 115-128.



Table 1. Genetic Variability parameters for ten biometrical traits in F₃ and F₄ generations of pearl millet

Characters	Generation	Mean	PV	GV	PCV (%)	GCV (%)	Heritability (%)	GA	GA as % of Mean
Days to 50% flowering	F ₃	48.56	9.36	4.86	6.30	4.54	51.94	3.26	6.71
	F ₄	47.24	10.98	6.48	7.01	5.39	59.01	4.01	8.48
Days to maturity	F ₃	87.53	10.50	6.00	3.70	2.79	57.15	3.80	4.34
	F ₄	87.34	9.52	5.02	3.53	2.57	52.74	3.34	3.82
Plant height	F ₃	163.23	563.83	383.33	14.55	11.99	67.99	33.09	20.27
	F ₄	169.47	485.39	304.89	13.00	10.30	62.81	28.37	16.74
No of productive tillers / plant	F ₃	2.99	0.32	0.19	19.05	14.71	59.59	0.70	23.27
	F ₄	3.26	0.29	0.16	16.54	12.30	55.30	0.61	18.75
Ear Head Length	F ₃	25.31	9.84	5.80	12.40	9.52	59.01	3.79	15.00
	F ₄	24.07	8.90	4.86	12.39	9.16	54.67	3.34	13.89
Ear Head Girth	F ₃	8.95	2.30	1.51	16.95	13.73	65.55	2.04	22.78
	F ₄	9.04	2.14	1.35	16.18	12.84	62.95	1.89	20.88
Single ear head weight	F ₃	39.52	42.18	23.51	16.43	12.27	55.74	7.42	18.78
	F ₄	41.33	41.45	22.78	15.58	11.55	54.97	7.25	17.55
Single ear head grain weight	F ₃	20.53	37.52	21.02	29.84	22.34	56.04	7.04	34.28
	F ₄	21.78	35.18	18.69	27.24	19.85	53.13	6.46	29.66
1000 grain weight	F ₃	9.14	2.37	1.42	16.84	13.04	59.98	1.89	20.70
	F ₄	9.32	2.18	1.23	15.86	11.92	56.54	1.71	18.38
Grain yield per plant	F ₃	66.30	699.37	417.51	39.89	30.82	59.70	32.36	48.82
	F ₄	75.50	624.28	342.41	33.09	24.51	54.85	28.09	37.21

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Table 2. Simple correlation coefficient between yield and yield components in F₃ and F₄ generations

Characters	Generation	Days to 50% flowering	Days to maturity	Plant height	No of productive tillers / plant	Ear head length	Ear head girth	Single ear head weight	Single ear head grain weight	1000 grain weight	Grain yield / plant
Days to 50% flowering	F ₃	1.000	0.936**	-0.058	0.073	-0.118	-0.100	-0.030	-0.044	0.014	-0.016
	F ₄	1.000	0.922**	-0.009	0.007	-0.027	-0.116	-0.117	-0.087	-0.060	-0.054
Days to maturity	F ₃		1.000	-0.043	0.033	-0.101	-0.088	-0.023	-0.038	0.026	-0.033
	F ₄		1.000	-0.008	-0.028	-0.026	-0.100	-0.072	-0.051	0.007	-0.053
Plant height	F ₃			1.000	0.505**	0.438**	0.243**	0.181*	0.269**	0.231**	0.476**
	F ₄			1.000	0.153	0.346**	0.248**	0.192*	0.216**	0.109	0.254**
No of productive tillers/ plant	F ₃				1.000	0.152	0.113	0.099	0.167*	0.075	0.568**
	F ₄				1.000	0.010	0.057	0.224**	0.077	-0.027	0.480**
Ear head length	F ₃					1.000	0.122	0.179*	0.183*	0.242**	0.195*
	F ₄					1.000	0.254**	0.238**	0.248**	0.235**	0.234**
Ear head girth	F ₃						1.000	0.804**	0.899**	0.590**	0.759**
	F ₄						1.000	0.604**	0.859**	0.556**	0.707**
Single ear head weight	F ₃							1.000	0.893**	0.606**	0.740**
	F ₄							1.000	0.705**	0.515**	0.682**
Single ear head grain weight	F ₃								1.000	0.707**	0.854**
	F ₄								1.000	0.598**	0.812**
1000 grain weight	F ₃									1.000	0.570**
	F ₄									1.000	0.458**
Grain yield / plant	F ₃										1.000
	F ₄										1.000

*, ** Significance at 5 and 1 per cent level, respectively

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Table 3. Path coefficient analysis showing direct and indirect effects on grain yield per plant in F₃ and F₄ generations

Characters	Generation	Days to 50% flowering	Days to maturity	Plant height (cm)	No of tillers / plant	Ear head length (cm)	Ear head girth (cm)	Single ear head weight (g)	Single ear head grain weight (g)	1000 grain weight (g)	Grain yield / plant (g)
Days to 50% flowering	F ₃	0.045	-0.053	-0.005	0.030	0.005	-0.002	-0.0005	-0.034	-0.0004	-0.016
	F ₄	0.070	-0.072	0.0001	0.003	-0.0008	-0.005	-0.010	-0.060	0.0006	-0.054
Days to maturity	F ₃	0.042	-0.057	-0.004	0.013	0.004	-0.002	-0.0004	-0.030	-0.0007	-0.033
	F ₄	0.083	-0.078	-0.0001	-0.011	-0.0008	-0.004	-0.006	-0.035	-0.0001	-0.053
Plant height	F ₃	-0.002	0.002	0.087	0.202	-0.019	0.004	0.003	0.205	-0.006	0.476**
	F ₄	0.0009	0.0006	0.006	0.062	0.010	0.010	0.016	0.149	-0.001	0.254**
No of productive tillers/ plant	F ₃	0.003	-0.002	0.0440	0.400	-0.006	0.002	0.002	0.128	-0.002	0.568**
	F ₄	0.0007	0.002	0.001	0.401	0.0003	0.002	0.019	0.053	0.0003	0.480**
Ear head length	F ₃	-0.005	0.006	0.038	0.061	-0.042	0.002	0.003	0.139	-0.007	0.195*
	F ₄	-0.003	0.002	0.002	0.004	0.029	0.011	0.020	0.171	-0.003	0.234**
Ear head girth	F ₃	-0.005	0.005	0.021	0.045	-0.005	0.017	0.013	0.684	-0.016	0.759**
	F ₄	-0.016	0.008	0.002	0.023	0.007	0.0423	0.051	0.590	-0.006	0.707**
Single ear head weight	F ₃	-0.005	0.001	0.016	0.040	-0.008	0.013	0.016	0.680	-0.017	0.740**
	F ₄	-0.016	0.006	0.001	0.090	0.007	0.026	0.084	0.485	-0.006	0.682**
Single ear head grain weight	F ₃	-0.005	0.002	0.023	0.067	-0.008	0.015	0.015	0.761	-0.020	0.854**
	F ₄	-0.005	0.004	0.001	0.031	0.007	0.036	0.059	0.687	-0.006	0.812**
1000 grain weight	F ₃	0.000	-0.002	0.020	0.030	-0.010	0.010	0.010	0.539	-0.028	0.570**
	F ₄	0.001	-0.0006	0.0007	-0.011	0.007	0.024	0.043	0.411	-0.011	0.458**

Residual effect (F₃) = 0.2839, Residual Effect (F₄) = 0.400



Table 4. Total carotenoid and β carotene content ($\mu\text{g/g}$) of parents and selected progenies in F_4 generation

Entry	Colour	Grain colour score	Total carotenoids ($\mu\text{g/g}$)	β Carotene content ($\mu\text{g/g}$)
PT 6129 (P)	Yellow	3	9.013	1.639
PT 6029 (P)	Grey	4	2.986	0.712
TN BG-06-3-3-4	Grey brown	6	1.706	0.360
TN BG-06-3-12-2	Grey brown	6	1.866	0.120
TN BG-06-53-6-1	Cream	2	4.000	0.440
TN BG-06-53-6-6	Yellow brown	7	5.653	1.460
TN BG-06-53-8-2	Cream	2	4.298	0.663
TN BG-06-81-7-10	Yellow	3	5.226	1.420
TN BG-06-81-9-13	Yellow brown	7	8.106	1.698
TN BG-06-81-10-9	Yellow	3	5.653	1.624
TN BG-06-127-1-9	Cream	2	4.949	0.760
TN BG-06-127-3-3	Yellow brown	7	4.56	1.585

(P) - Parents; Grain colour score: 1- Whitish 2- Cream 3- Yellow 4- Gray 5- Deep gray 6- Gray brown 7- Yellow brown 8- Purple 9- Purplish black

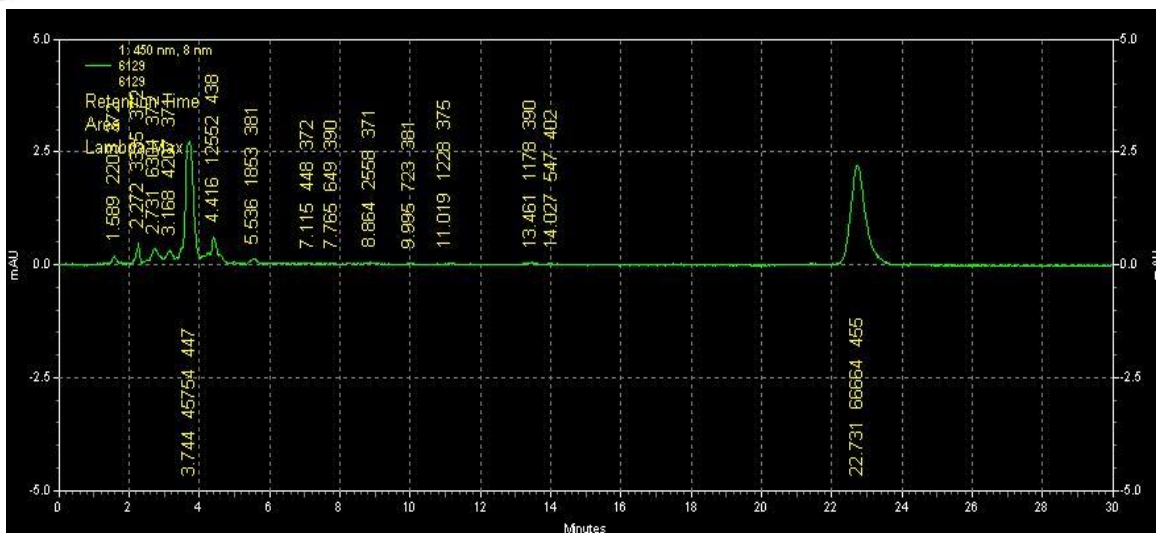


Fig. 1a HPLC chromatogram for β carotene content in parent PT 6129 (yellow colour grain and rich β carotene content)

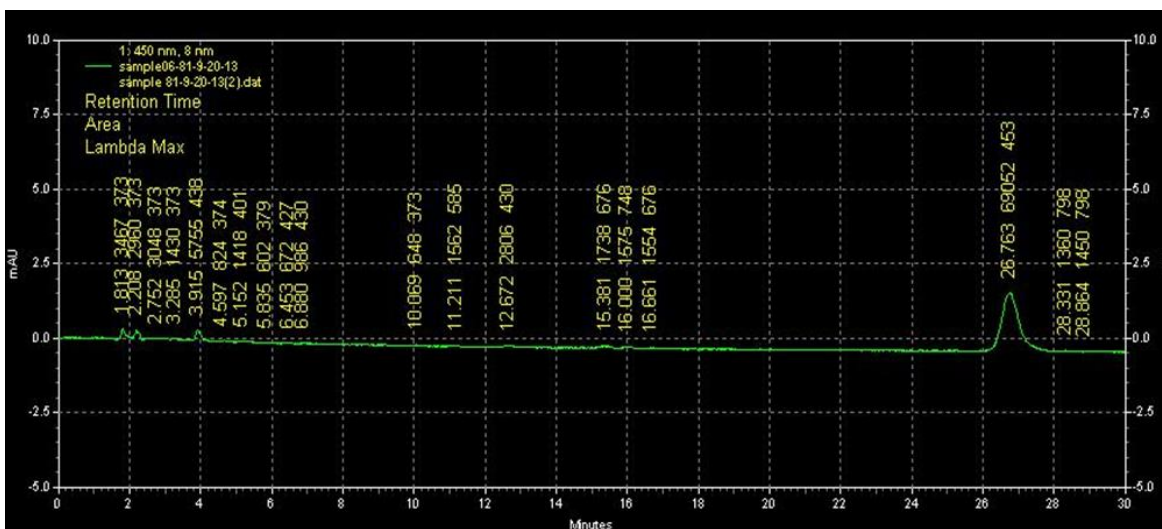


Fig. 1b HPLC chromatogram for β carotene content in TNBG-06-81-9-13 line