Breeding Tomato for Pigments

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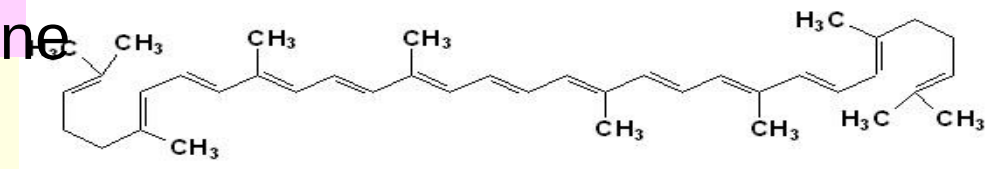
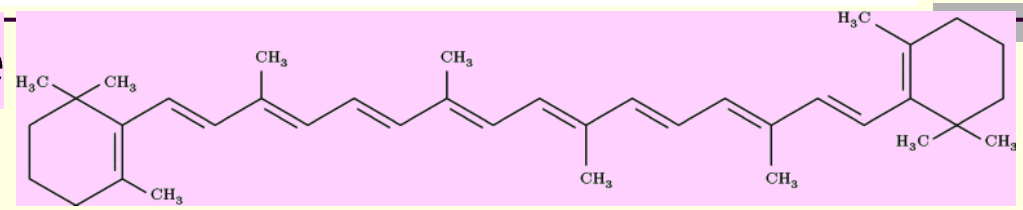
Pigments in tomato

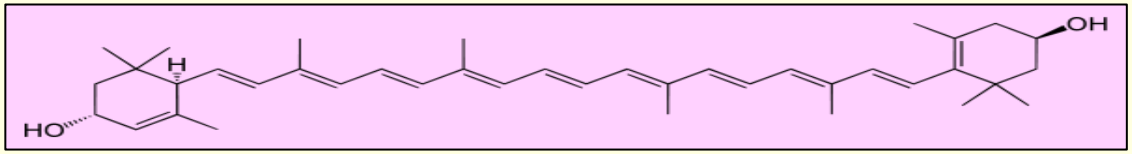
Lycopene



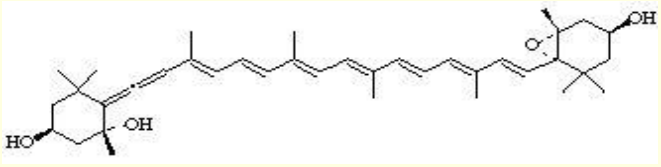
β-carotene



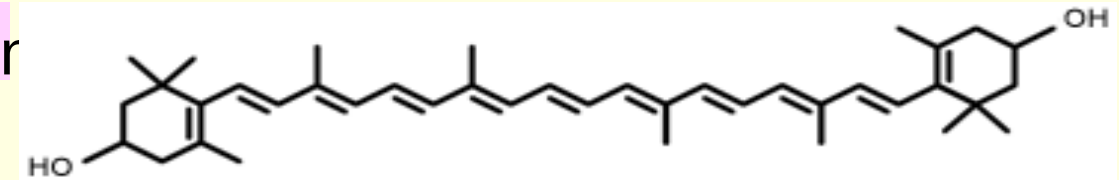
Lutein



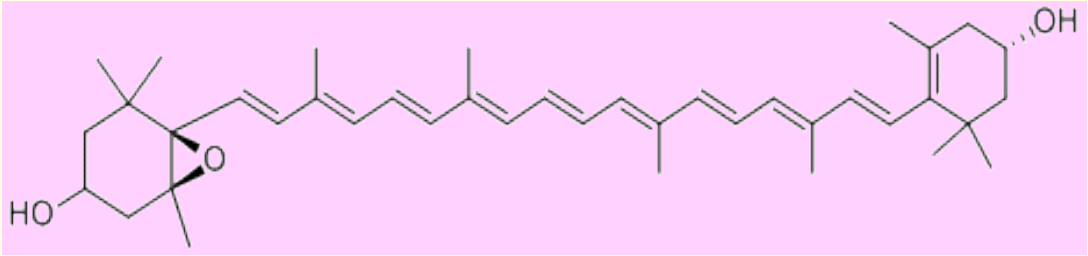
Neoxanthin



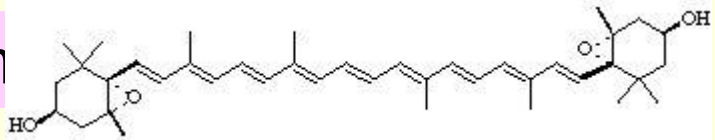
Zeaxanthin



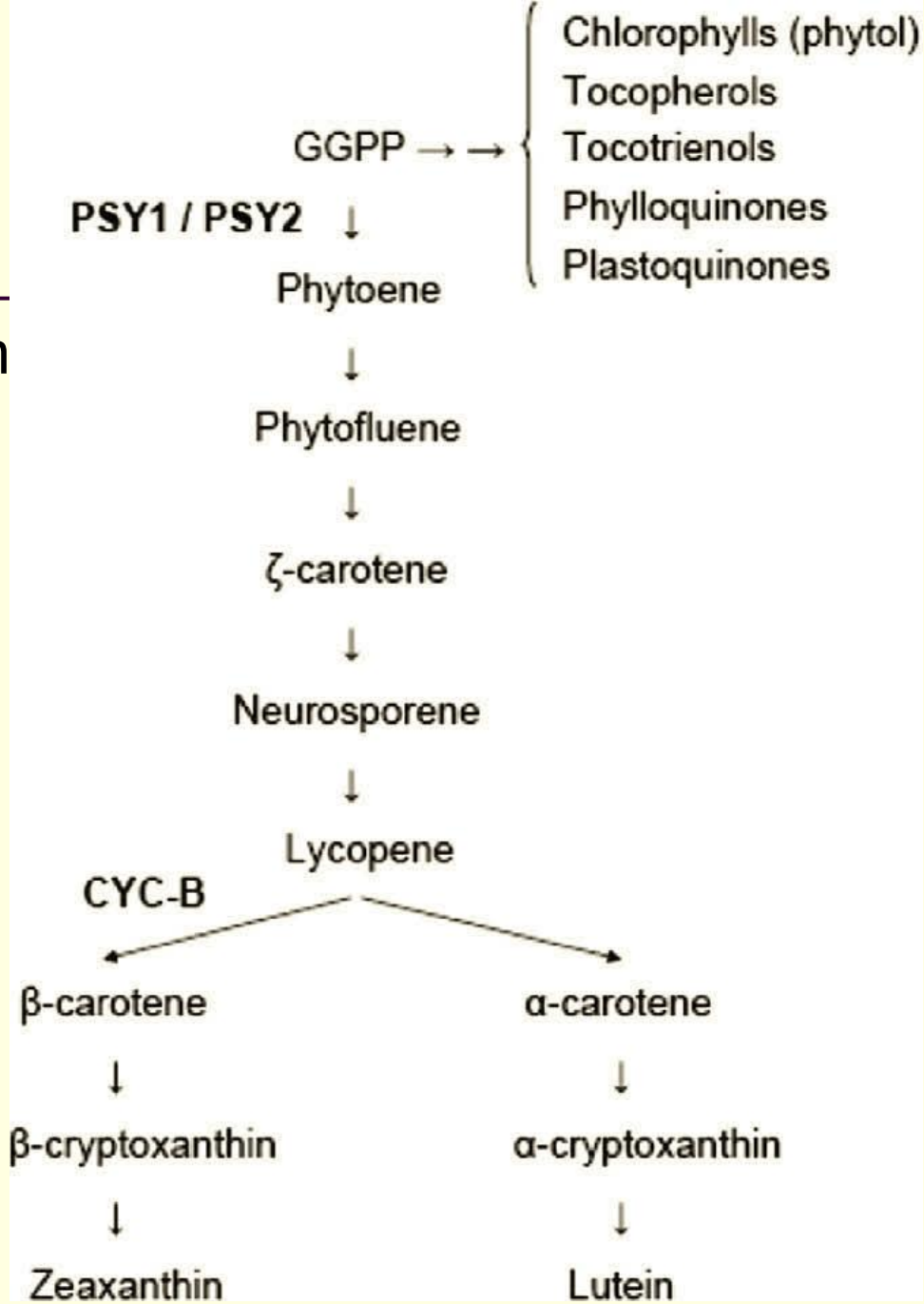
Antheraxanthi

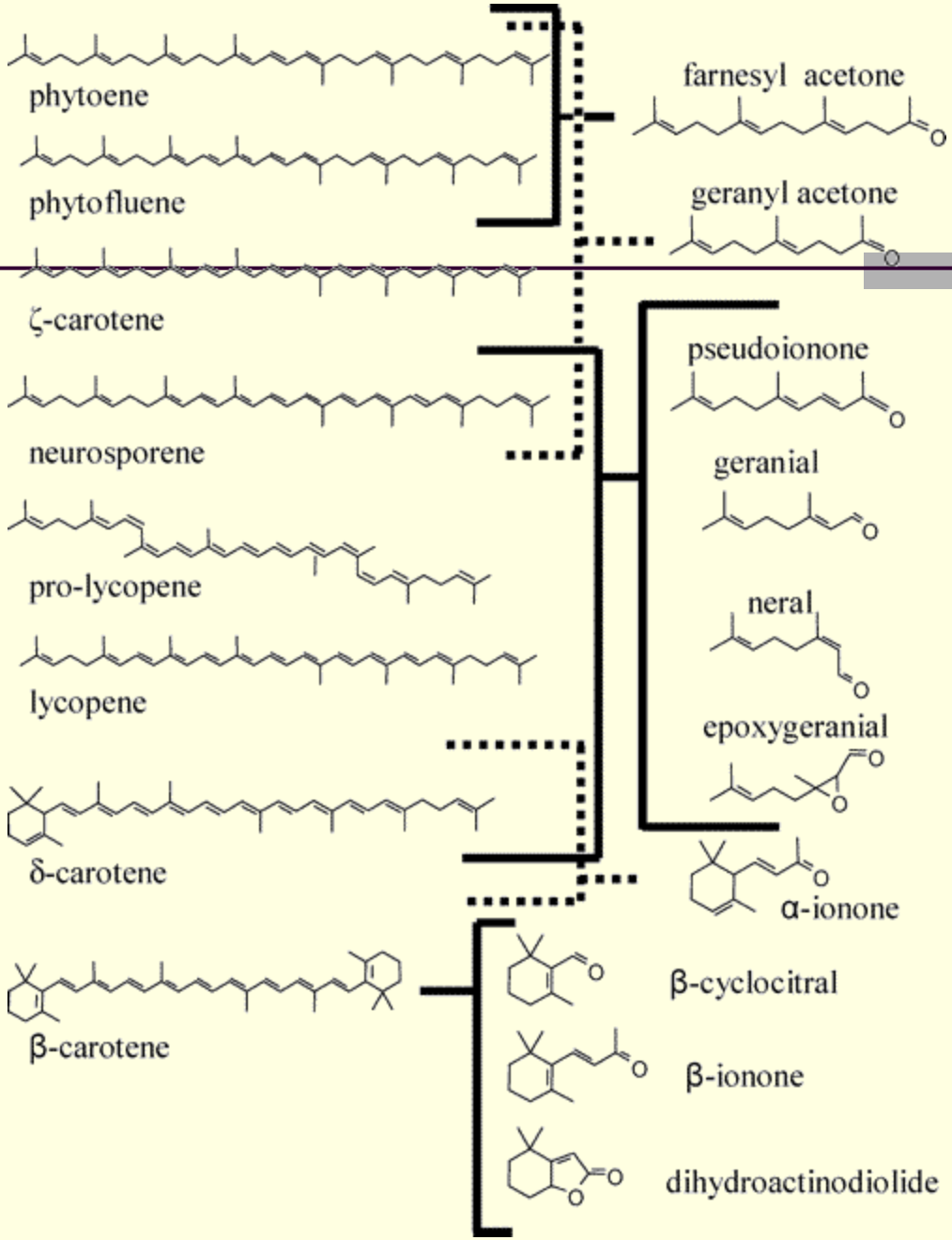


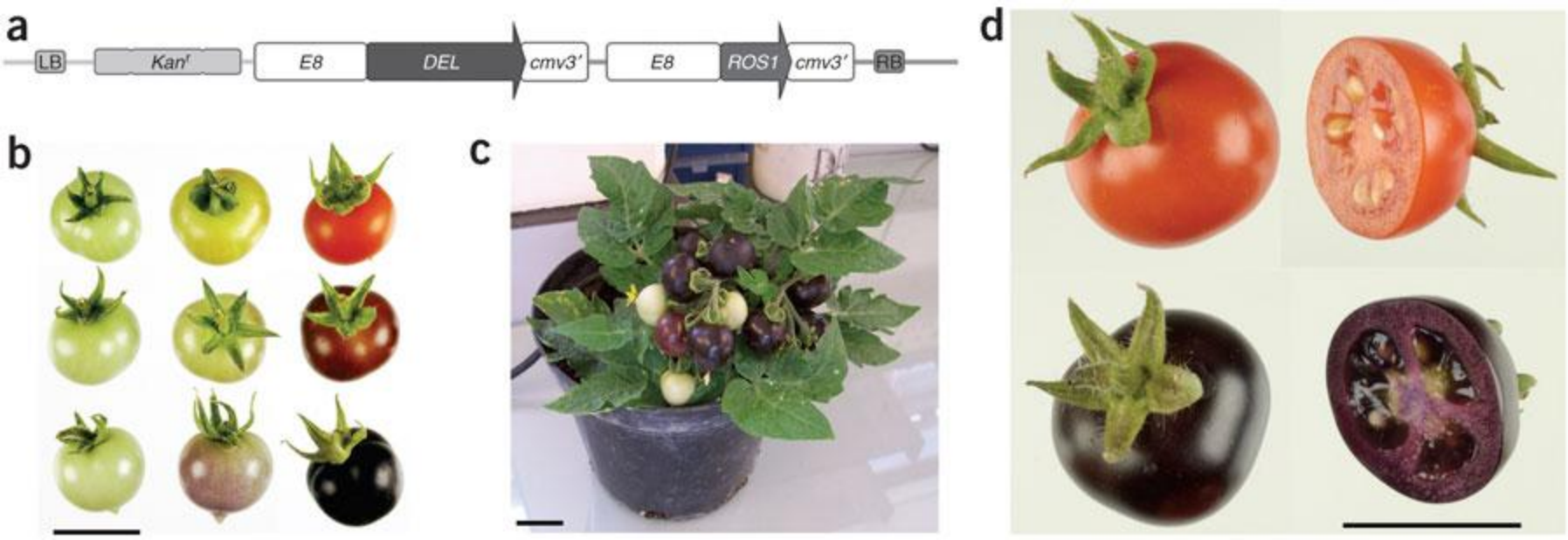
Violaxanthin



- Change in pigmentation is caused by accumulation of lycopene within the plastids and the disappearance of chlorophyll.
- The chloroplasts of the mature green fruit change into chromoplasts, which accumulate lycopene in membrane-bound crystals.




phytoene
phytofluene
ζ-carotene
neurosporene
pro-lycopene
lycopene
δ-carotene
β-carotene
farnesyl acetone
geranyl acetone
pseudoionone
geranial
neral
epoxygeranial
α-ionone
β-cyclocitral
β-ionone
dihydroactinodiolide

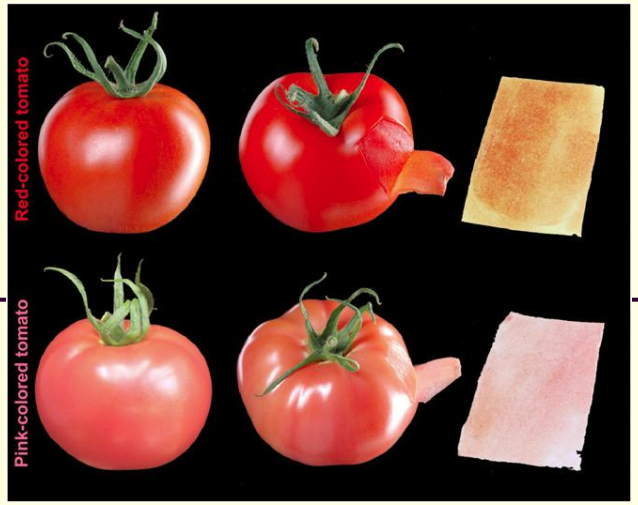


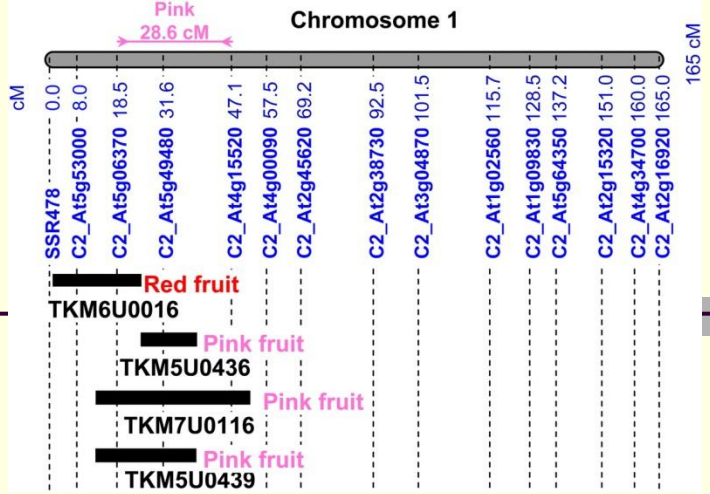
Eugenio Butelli et al (2008). Nature Biotechnology 26, 1301 – 1308

Anthocyanins offer protection against certain cancers, cardiovascular disease and age-related degenerative diseases.
Anthocyanins also have anti-inflammatory activity, promote visual acuity, and hinder obesity and diabetes.

Anti-cancer properties in transgenic tomato

- Anthocyanine concentrations comparable to the levels found in blackberries and blueberries.
- Expression of the transgenes enhanced the hydrophilic antioxidant capacity of tomato fruit three fold and resulted in fruit with intense purple coloration.
- In a study, cancer-susceptible mice fed a diet supplemented with the high-anthocyanin tomatoes showed a significant extension of life span.



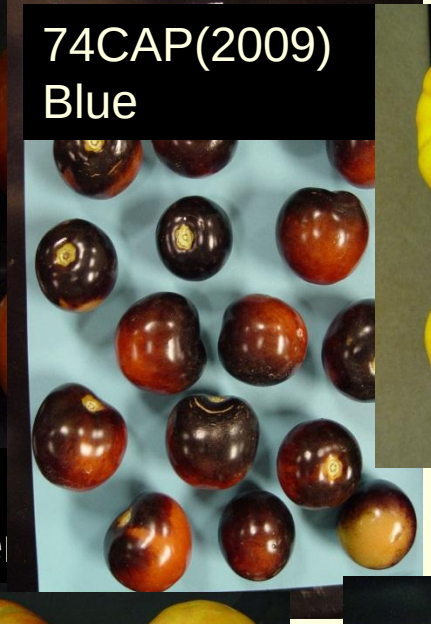


Metabolic analysis showed that pink fruit lack the ripening-dependent accumulation of the yellow-colored flavonoid **naringenin chalcone** in the fruit peel, while carotenoid levels are not affected.

Biochemical and molecular data, gene mapping, segregation analysis, and VIGS experiments demonstrate that the MYB12 transcription factor plays an important role in regulating the flavonoid pathway in tomato fruit and suggest strongly that *SlMYB12* is a likely candidate for the *y* mutation.

Ballester, A. et al. 2010. Plant Physiology; 71-84

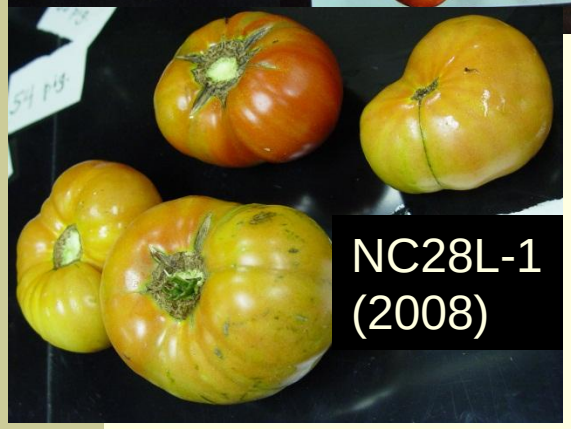
NC 1 CS
Crimson ge



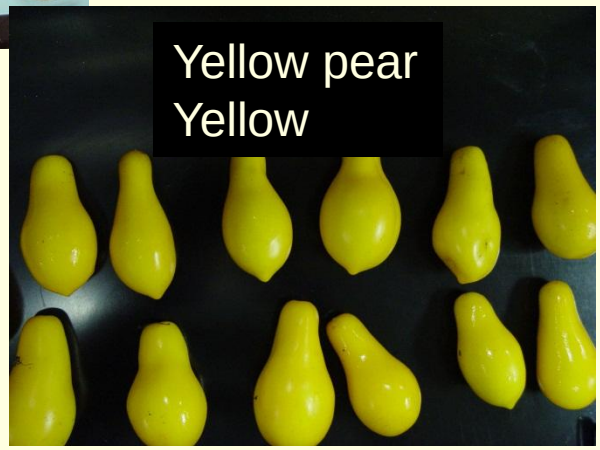
74CAP(2009)
Blue

194LB-1W(2000)
B-Gene- Orange

NC 08133-1(x)-7W



NC28L-1
(2008)



Yellow pear
Yellow

NC 1Y
Yellow

Chocolate
Stripe

Malachite Box
Green

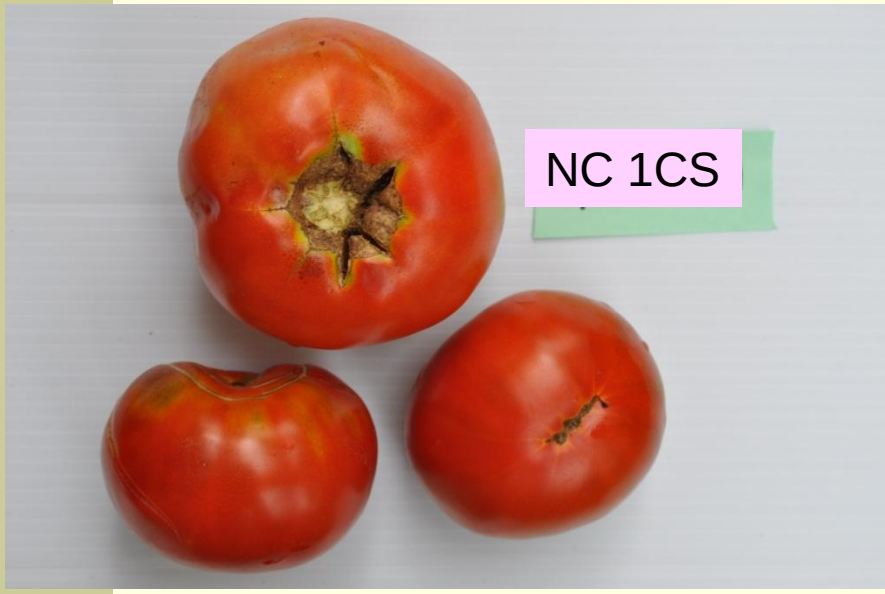
NC 161L-1W
(2007): Pink

No	Parent	Color
1	NC1CS	Red crimson
2	74CAP(2009)-Bk	Blue
3	72LYC(2009)-Bk	Beta gene
4	08133-1(x)-7W	Yellow red stripe
5	28L-1(2008)	Red
6	95LYC(2009)-Bk	Yellow
7	NC1Y	Tangarine
8	Chocolate Stripe	Brown-purple
9	Malachite Box	Green
10	161L-1W(2007)	Pink

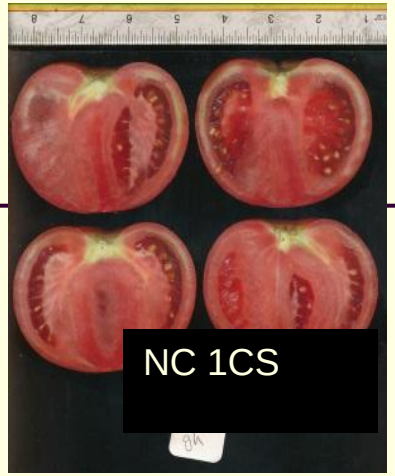
Phenotyping

Wet chemistry for lycopene

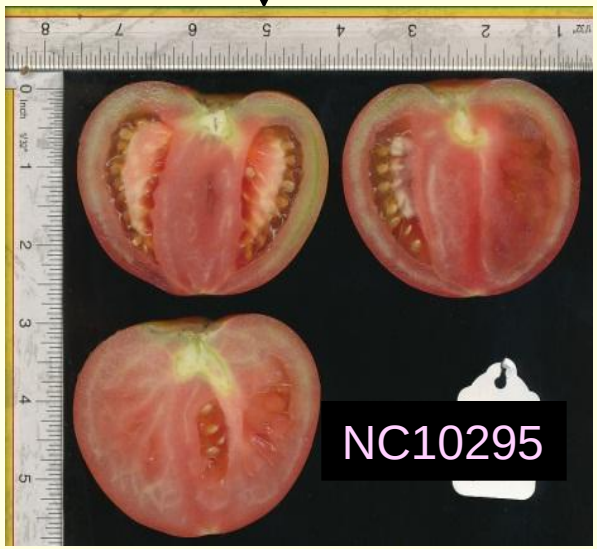
Subjective rating for flavor



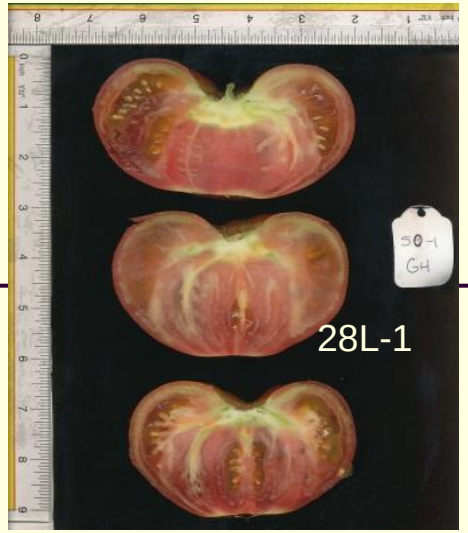
X



X



X

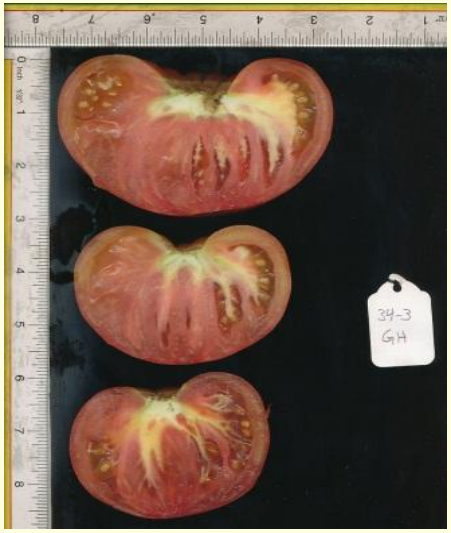


28L-1

X

M. Box

NC 10321



NC08133

×

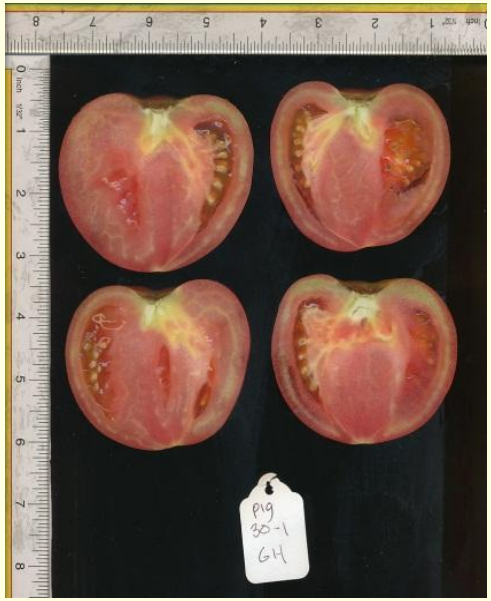
NC 161L-1W

↓

NC 10317

X

NC 10317



Lycopene content in different hybrids

	1	2	3	4	5	6	7	8	9	10
1	59.3	63.0	64.5	81.3	75.6	57.3	59.4	63.6	52.9	-
2		-	67.7	55.8	59.6	51.4	68.4	82.6	-	64.8
3			55.2	-	59.5	-	64.9	65.4	58.1	54.8
4					71.9	-	71.2	63.0	-	72.7
5						57.2	74.2	61.8	71.5	56.3
6							57.7	61.8	-	-
7								61.6	-	58.9
8								48.9	63.9	-
9									53.7	61.1
10										71.3

TSS content in different hybrids

	1	2	3	4	5	6	7	8	9	10
1	5.0	4.9	4.7	5.4	4.9	4.9	5.0	5.2	5.3	5.0
2		4.5	4.8	5.4	5.2	4.7	4.8	5.0	4.8	4.8
3			5.4	5.0	5.3	5.7	4.7	5.8	4.9	5.4
4				4.1	5.5	6.9	5.2	4.8	6.1	5.2
5					4.9	5.1	5.3	5.1	5.1	5.4
6						4.7	4.9	4.7	4.6	4.9
7							6.1	5.1	3.6	5.0
8								5.2	4.9	4.7
9									4.2	5.5
10										4.9

Flavor rating for different hybrids

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	**4.2**	2.3	2.3	3.0	3.7	2.3	3.3	3.7	**4.2**	3.5
2		1.5	3.2	1.3	2.7	1.5	2.7	2.3	3.2	2.0
3			**3.2**	1.5	2.3	3.8	2.7	3.5	3.2	2.3
4				2.7	2.8	3.5	2.5	3.5	3.3	**4.3**
5					**3.8**	2.2	2.7	3.3	**4.3**	3.3
6						**4.0**	2.7	2.5	3.3	2.7
7							2.5	3.3	3.8	2.8
8								2.2	3.7	3.0
9									1.2	3.7
10										2.8

Parent	Mean-lycopene	GCA-lycopene
NC1CS	64.1	1.3
74CAP(2009)-Bk	64.3	1.6
72LYC(2009)-Bk	59.6	-3.1
08133-1(x)-7W	69.7	6.9
28L-1(2008)	64.2	1.4
95LYC(2009)-Bk	59.8	-3.0
NC1Y	60.3	-2.5
Chocolate Stripe	56.4	-6.4
MalachiteBox	57.4	-5.4
161L-1W(2007)	71.3	8.6

Parent	Mean-TSS	GCA-TSS
NC1CS	5.0	-0.02
74CAP(2009)-Bk	4.9	-0.10
72LYC(2009)-Bk	5.3	0.22
08133-1(x)-7W	5.2	0.13
28L-1(2008)	5.2	0.16
95LYC(2009)-Bk	4.8	-0.26
NC1Y	5.0	0.00
ChocolateStripe	5.0	-0.02
MalachiteBox	4.9	-0.16
161L-1W(2007)	4.9	-0.11

Parent	Mean-flavor	GCA-flavor
NC1CS	3.2	0.5
74CAP(2009)-Bk	2.3	-0.5
72LYC(2009)-Bk	2.8	0.0
08133-1(x)-7W	3.2	0.4
28L-1(2008)	3.3	0.5
95LYC(2009)-Bk	3.0	0.3
NC1Y	3.1	0.4
ChocolateStripe	2.9	0.2
MalachiteBox	2.4	-0.4
161L-1W(2007)	2.8	0.1

Specific combining ability: Lycopene

Parent	2	3	4	5	6	7	8	9	10
1	0.27	1.74	**18.48**	**12.83**	-5.51	-3.37	0.85	-9.88	-
2		4.91	-6.97	-3.18	-11.42	5.65	**19.81**	-	2.02
3			-	-3.30	-	2.15	2.64	-4.72	-7.99
4				9.10	-	8.47	0.20	-	9.90
5					-	**11.44**	-1.01	8.78	-6.47
6						-5.03	-0.94	-	-
7							-1.16	-	-3.83
8								1.12	-
9									-1.69

Specific combining ability: TSS

Parent	2	3	4	5	6	7	8	9	10
1	-0.70	-0.70	-0.03	0.64	-0.70	0.22	0.64	**1.14**	0.47
2		0.14	-1.70	-0.36	-1.53	-0.36	-0.70	0.14	-1.03
3			-1.53	-0.78	0.80	-0.36	0.47	0.14	-0.70
4				-0.28	-3.03	-0.53	0.47	0.30	**1.22**
5					-0.86	-0.36	0.30	**1.30**	0.22
6						-0.36	-0.53	0.30	-0.36
7							0.30	0.80	-0.20
8								0.64	-0.03
9									0.64

Specific combining ability: Flavor

Parent	2	3	4	5	6	7	8	9	10
1	-0.70	-0.70	-0.03	0.64	-0.70	0.22	0.64	**1.14**	0.47
2		0.14	-1.70	-0.36	-1.53	-0.36	-0.70	0.14	-1.03
3			-1.53	-0.78	0.80	-0.36	0.47	0.14	-0.70
4				-0.28	-3.03	-0.53	0.47	0.30	**1.22**
5					-0.86	-0.36	0.30	**1.30**	0.22
6						-0.36	-0.53	0.30	-0.36
7							0.30	0.80	-0.20
8								0.64	-0.03
9									0.64

Mid-parent heterosis

$$MPH = 100x\left[\frac{F1 - \frac{(P1 + P2)}{2}}{\frac{(P1 + P2)}{2}}\right]$$

Heterosis (%) for Lycopene

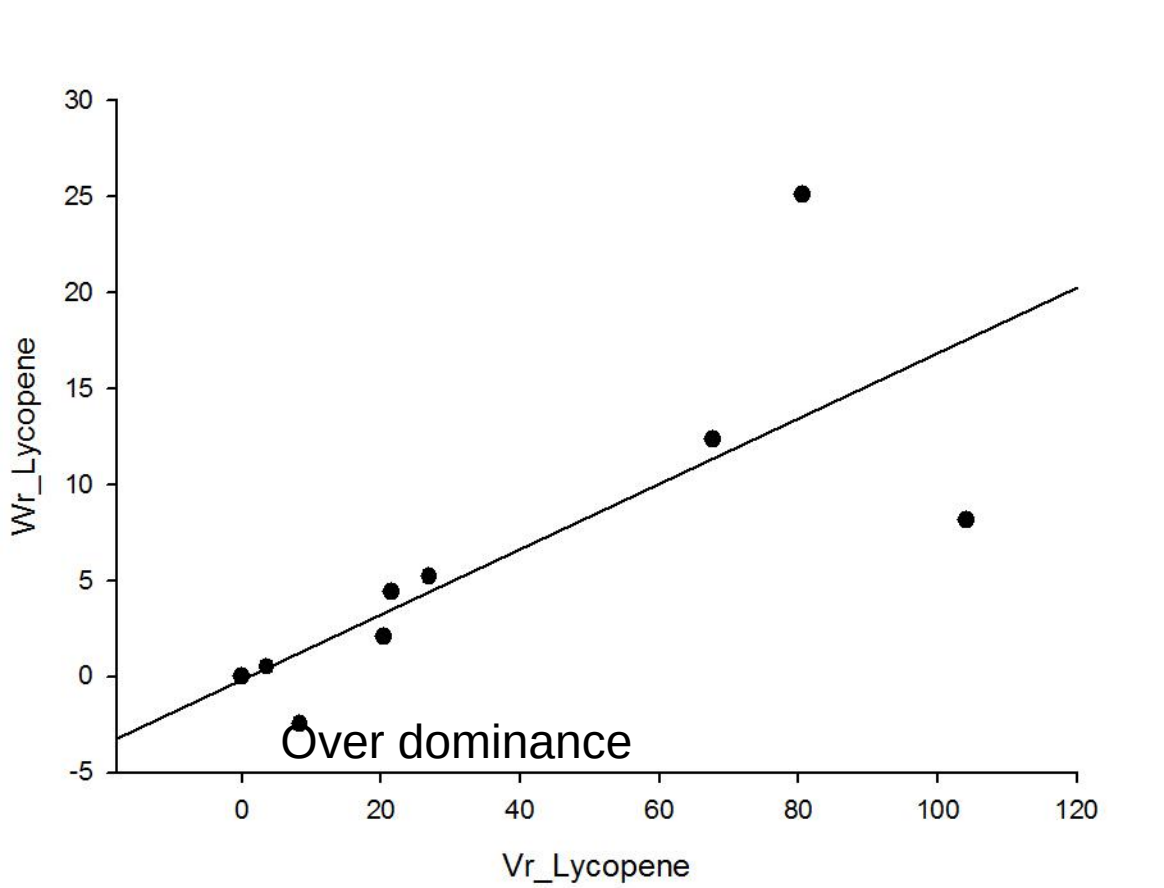
Parent	2	3	4	5	6	7	8	9	10
1	**112.5**	**133.9**	**194.6**	**110.4**	92.6	66.8	**160.4**	3.1	-
2		**145.4**	**102.3**	65.8	72.7	92.1	**238.0**	-	3.6
3			-	65.5	-	82.3	**167.7**	13.2	-12.4
4				**130.3**	-	**119.8**	**108.2**	-	19.7
5					-	**108.3**	**152.8**	39.5	-10.0
6							**153.1**	-	-
7							**152.2**	-	-5.8
8								24.5	-
9									-2.3

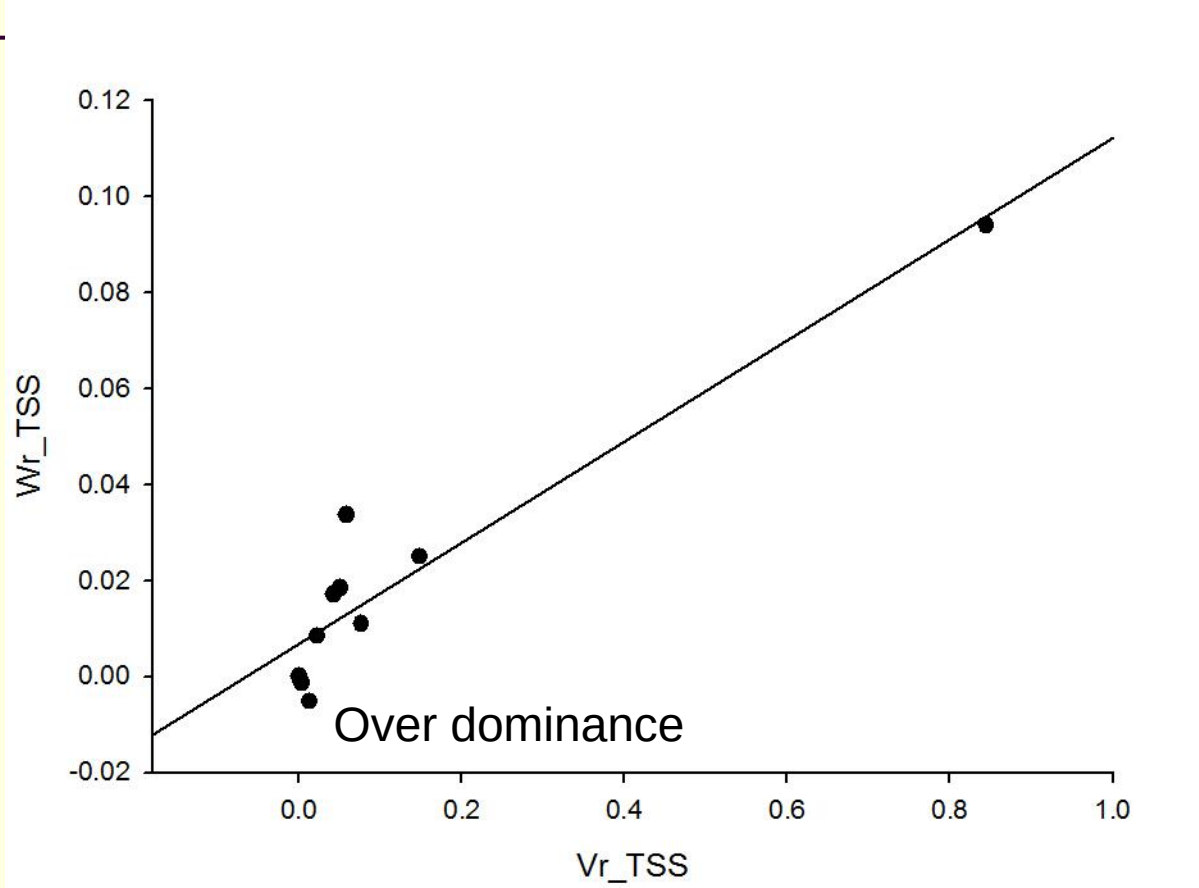
Heterosis (%) for TSS

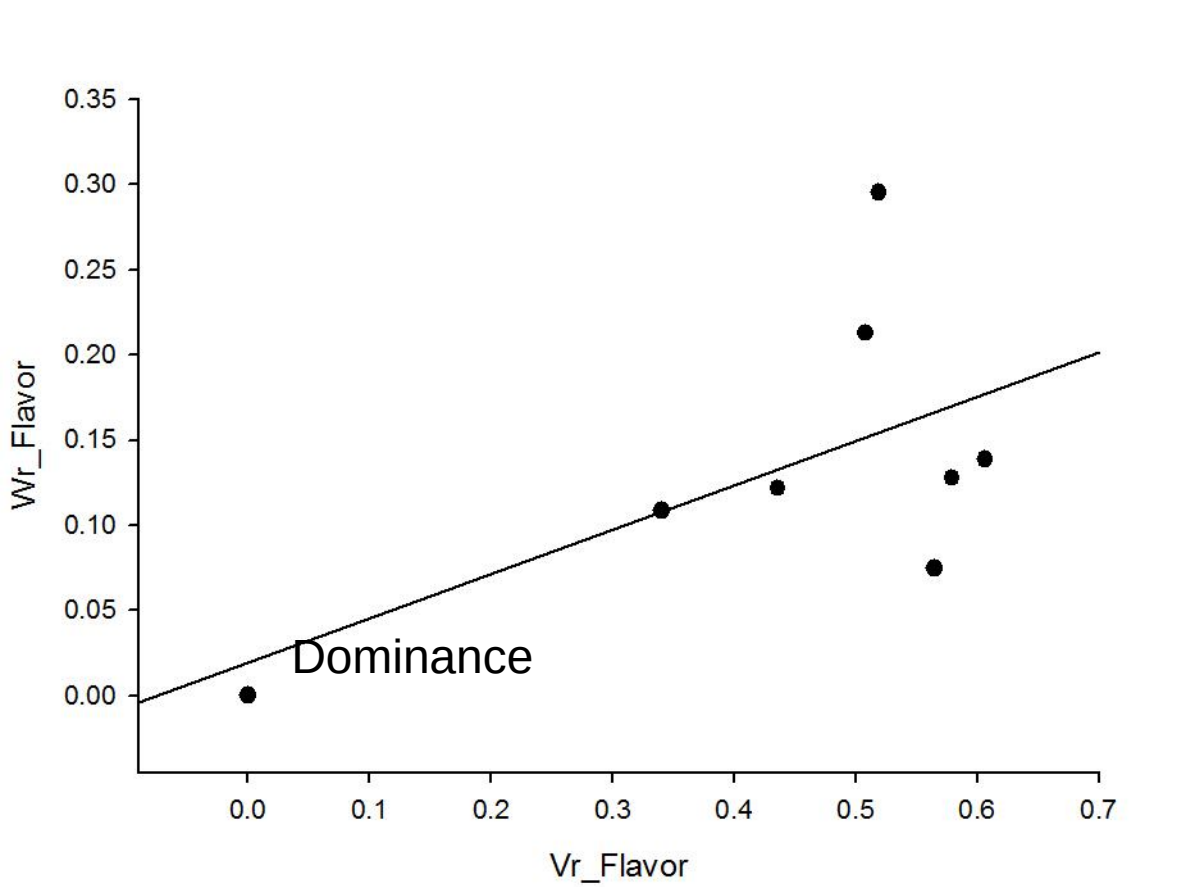
Parent	2	3	4	5	6	7	8	9	10
1	95.6	77.2	**102.6**	79.6	83.6	93.4	8.0	81.3	-1.0
2		77.9	100.4	87.7	76.5	86.4	4.1	44.2	-4.3
3			-100.0	93.4	-100.0	83.5	21.8	68.8	7.2
4				102.9	-96.7	97.1	1.6	-60.9	4.5
5					93.4	104.3	6.2	74.7	7.6
6						88.4	-1.6	-100.0	-100.0
7							6.3	-100.0	-1.0
8								66.9	-100.0
9									9.6

Heterosis (%) for flavor

Parent	2	3	4	5	6	7	8	9	10
1	-18	0	3	13	-40	0	57	**150**	75
2		36	-54	-18	-62	-18	0	90	0
3			-49	-31	-2	-18	50	90	17
4				-17	-121	-19	36	71	**135**
5					-45	-18	43	**160**	63
6						-18	7	100	33
7							43	**130**	42
8								**120**	50
9									83


30
25
20
15
10
5
0
-5
Wr_Lycopene
0
20
40
60
80
100
120
Vr_Lycopene
Over dominance


0.12
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
Wr_TSS
0.0
0.2
0.4
0.6
0.8
1.0
Vr_TSS
Over dominance

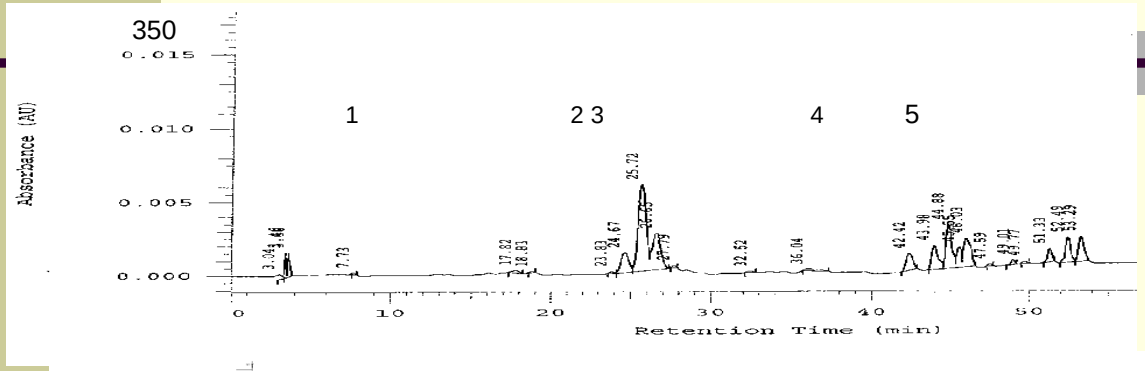

0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Wr_Flavor
Dominance
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Vr_Flavor

Correlations with color parameters

Parameter	Lycopene	Flavor
Red	-0.08	-0.17
Green	-0.38	-0.20
Blue	-0.16	-0.16
L*	-0.34	-0.20
a*	0.37	0.16
b*	-0.34	-0.14
Hue	-0.36	-0.13
Chroma	0.18	0.10
Lycopene		0.29

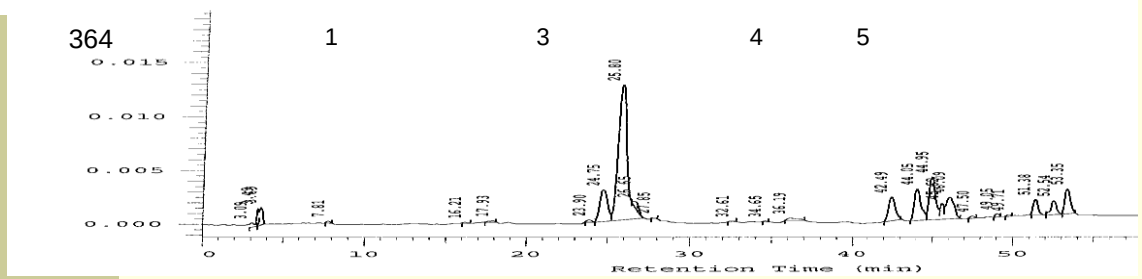
ORANGE TOMATO LINES

350



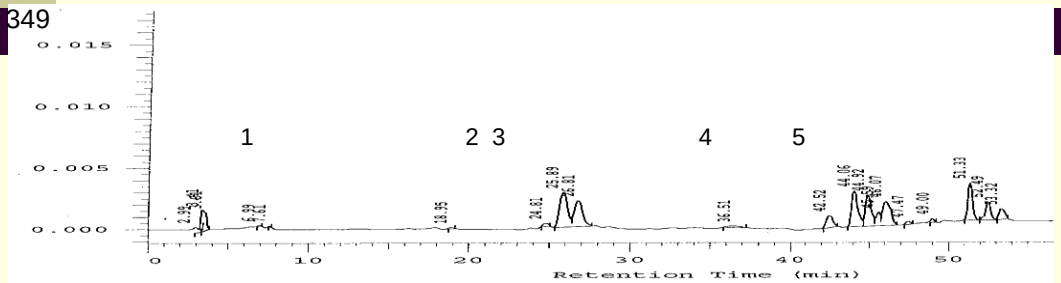
ave beta
ave prolycopene

364



low beta
high prolycopene

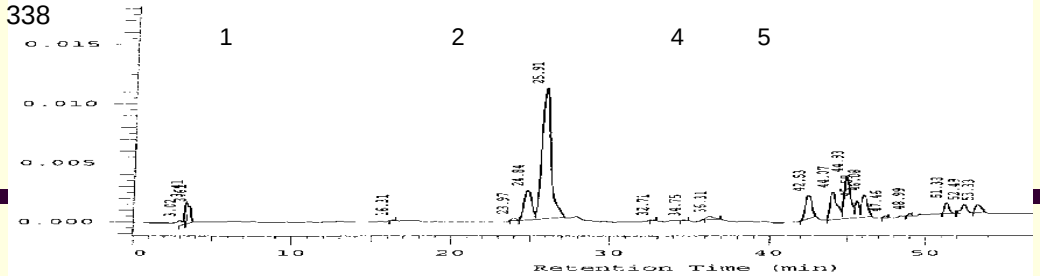
349



1=lutein (rt=7.7)
2=prolycopene cis (rt=25.7)
3=b-carotene (rt=26.7)
4=prolycopene trans (rt=44.9)
5=trans lycopene (rt=53.3)

No beta
Low prolycopene
Low lycopene

338



No beta
High prolycopene
Low lycopene

Potential hybrid: NC 10290 and NC 10291

Potential hybrid: NC 10294 and NC 10295

Potential hybrid: NC 10296

Summary

- Potential hybrids for differrent pigments in pipe-line.
- Interesting materials for the investigation of pigment regulation at molecular levels.
- Potential expansion to investigate the effect on human health and plant defense.

Questions?