Managing Quality in Tomatoes for Processing

David Francis, OSU/OARDC
Chris Gunter, Purdue
Tim Hartz, U.C. Davis
Steve Garrison, Rutgers
Majid Foolad, Penn State

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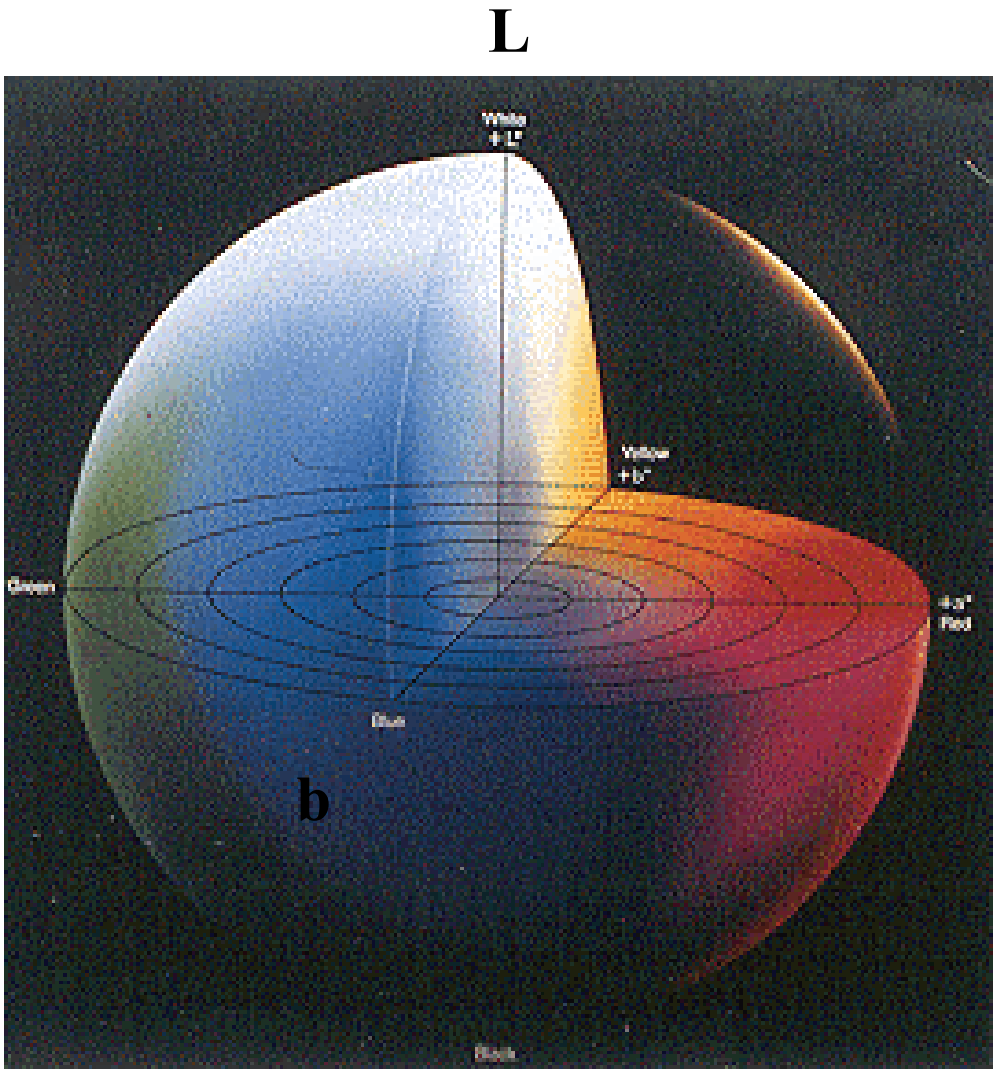
Color uniformity is among the most important quality attributes for our market

- What are the causes of blotchy ripening disorders?
  - biological, genetic, and environmental
- How many disorders are there?
  - Yellow shoulder, yellow eye, green shoulder, internal white tissue appear to be a single disorder
- Can we predict when and where disorders will appear?
- Can we manage for color quality?

Terminology: objective measurements of color



Terminology

- YSD = yellow shoulder disorder
- Hue = color
- Hue difference = a uniformity measurement. Large values indicate YSD
- L = light to dark
- L difference = a uniformity measurement. Large values indicate internal white tissue

Uniform varieties = varieties that are less susceptible to YSD
low Hue diff and L diff values

Non-uniform varieties = varieties that are susceptible to YSD
high Hue diff and L diff values

What kind of color variation can we measure?

- **Absolute color between genotypes**
- **Color uniformity between varieties**
- **color and uniformity between fruit, plots, locations, years**

Important factors

- Location
- Environment
- Variety

Location differences

- Soil structure
- Soil composition
- Nutrient balance
- Management
- More….

Environmental causes

- Heat
- Water
- Pathogens (virus)
- Insect feeding
- Nutrient balance

Variety differences

- Based on multiple years and locations
- Uniform varieties = varieties that are less susceptible to YSD low Hue diff and L diff values
- Non-uniform varieties = varieties that are susceptible to YSD high Hue diff and L diff values

We can estimate the importance of factors based on the observed variance:

Location **20-30%**

- Soil structure
- Soil nutrients

Weather **5-10%**

- Water
- Temperature

Variety **10-15%**

- Uniform (resistant)
- Non-uniform (susceptible)
- Nutrient uptake

Interactions **10-20%**

- Weather x Variety
- Weather x Location
- Variety x Location

Unexplained **25-50%**

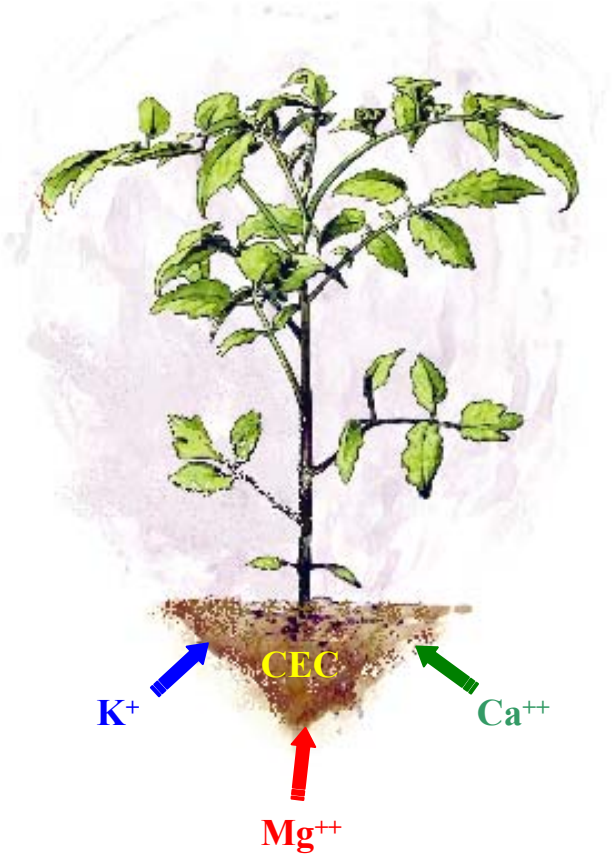
- unknown causes
- more complex interactions

Focus of efforts

- Identify important location specific parameters
  - Focus on soil characteristics and nutrients
  - Risk assessment
- Identify strategies that are effective at amending problem fields
  - Effective strategies may address both weather and nutrient causes
- Variety development

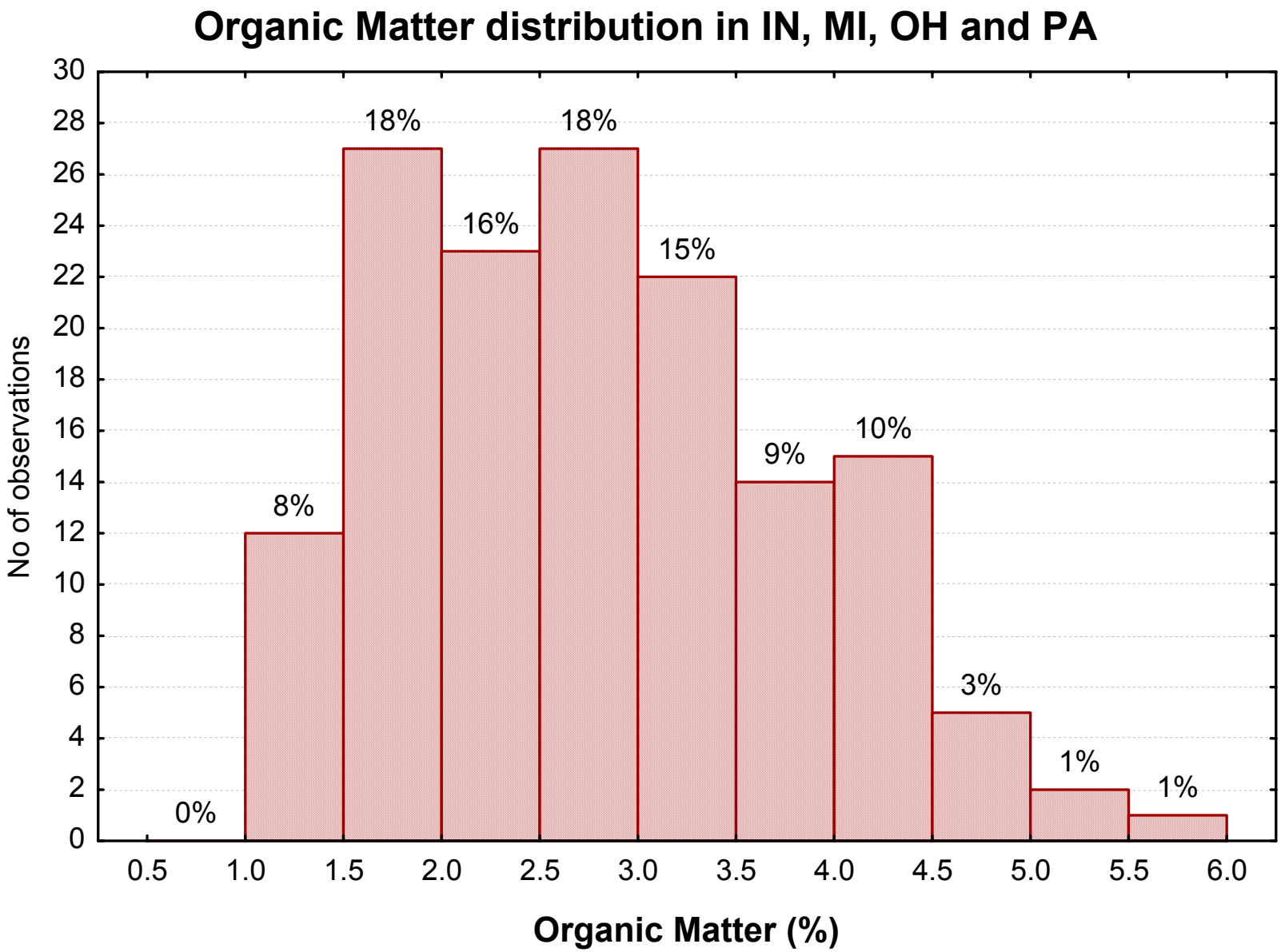
Can we predict location differences and within field differences?

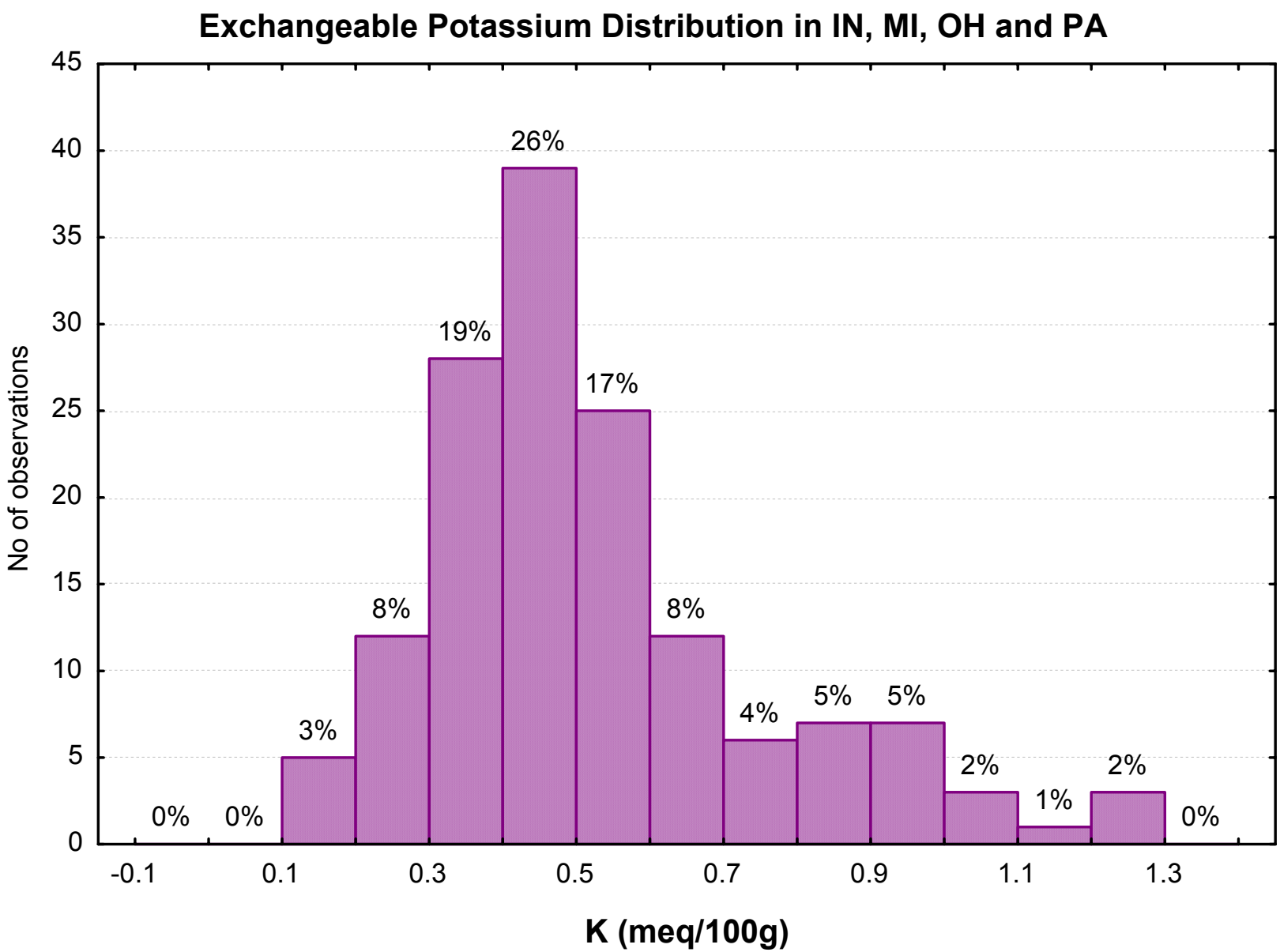
- K^+ (meq/100gm)/ Sqrt Mg^{2+} (meq/100gm)
  - Predictive equation
  - Hartz and Co.
- Units of predictive equation are important
  - meq/100 gm = cmol/Kg are units that take into account the charge and molecular wt.
  - For the plant, charge and molecular wt. are important
- Soil tests tend to give you ppm or T/A
  - Soil test data must be converted

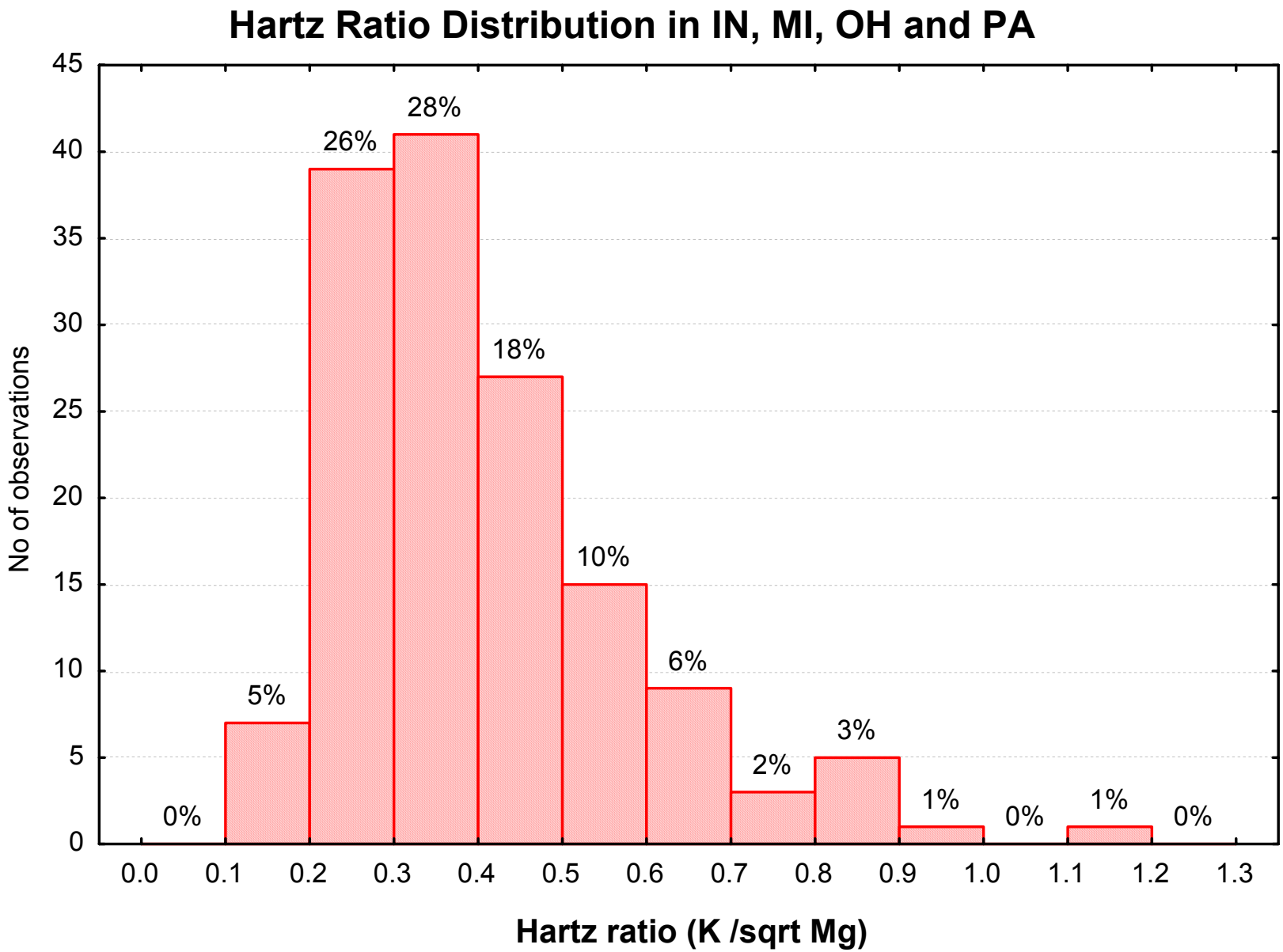


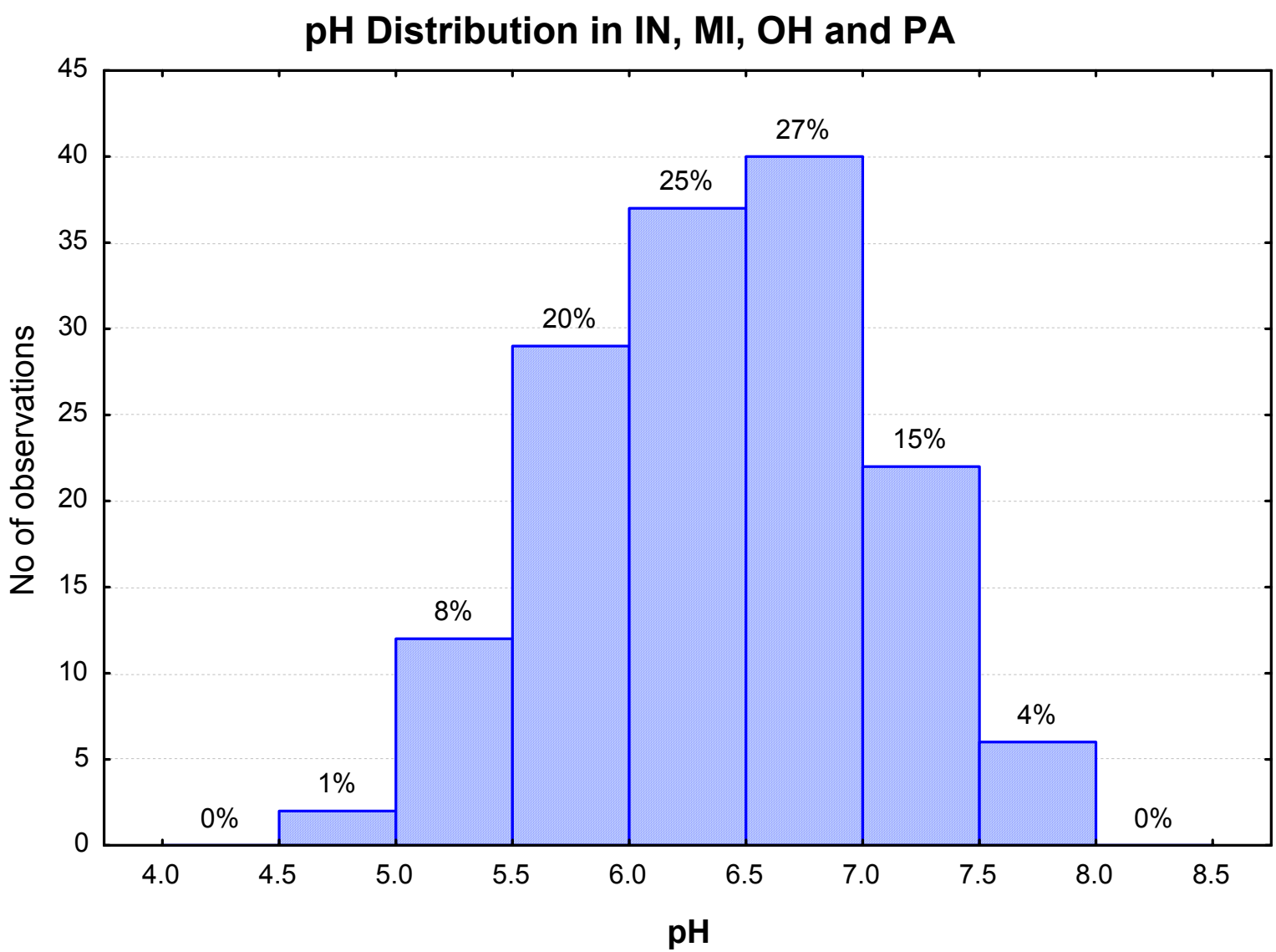
Field survey:

- Grower and processor data to establish a base
- ~70 fields
- multiple varieties per field
- collect soil samples
- collect fruit


Organic Matter distribution in IN, MI, OH and PA
No of observations
Organic Matter (%)
0%
8%
18%
16%
18%
15%
9%
10%
3%
1%
1%
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0


Exchangeable Potassium Distribution in IN, MI, OH and PA
No of observations
K (meq/100g)
45
40
35
30
25
20
15
10
5
0
-0.1
0.1
0.3
0.5
0.7
0.9
1.1
1.3
0%
0%
3%
8%
19%
26%
17%
8%
4%
5%
5%
2%
1%
2%
0%


Hartz Ratio Distribution in IN, MI, OH and PA
No of observations
Hartz ratio (K /sqrt Mg)
0
5
10
15
20
25
30
35
40
45
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
0%
5%
26%
28%
18%
10%
6%
2%
3%
1%
0%
1%
0%


pH Distribution in IN, MI, OH and PA
No of observations
pH
0
5
10
15
20
25
30
35
40
45
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
0%
1%
8%
20%
25%
27%
15%
4%
0%

Linear correlations between nutrients and color 2001

All varieties

Uniform varieties

Non-uniform varieties

Blue - marginally NS
Red - Significant

	K		Ca		Mg		K/sqrt(Mg)	
Trait	Significanc	r2	Significanc	r2	Significanc	r2	Significance	r2
L	0.5645	0.0076	0.4481	0.0131	0.3317	0.0214	0.3195	0.0225
a	0.5562	0.0079	0.3699	0.0183	**0.0067**	**0.1554**	0.1064	0.0582
b	**0.002**	**0.1972**	**0.0014**	**0.2093**	**0.0563**	**0.0803**	**0.0525**	**0.0828**
Hue	**0.0148**	**0.1276**	0.2921	0.0252	0.2849	0.0259	**0.0073**	**0.1526**
Ldiff	0.1628	0.0438	0.3628	0.0189	0.2523	0.0297	**0.0597**	**0.0783**
adiff	**0.0792**	**0.0684**	0.6055	0.0061	0.1218	0.0535	**0.0128**	**0.1327**
bdiff	0.1034	0.0591	0.1243	0.0529	0.7075	0.0032	**0.0847**	**0.066**
Huediff	0.1984	0.0373	0.3311	0.0215	0.3459	0.0202	**0.0838**	**0.0664**

	K		Ca		Mg		K/sqrt(Mg)	
Trait	Significanc	r2	Significanc	r2	Significanc	r2	Significance	r2
L	0.2258	0.085	0.856	0.002	0.9535	0.0002	0.3131	0.0598
a	0.1135	0.1408	0.813	0.0034	**0.0843**	**0.1651**	**0.0427**	**0.2201**
b	0.1396	0.1238	**0.0063**	**0.3634**	**0.0186**	**0.285**	0.8938	0.0011
Hue	**0.0012**	**0.4675**	**0.0207**	**0.2768**	0.9305	0.0005	**0.0185**	**0.2851**
Ldiff	**0.0036**	**0.4017**	0.7698	0.0052	**0.0123**	**0.3158**	**0.0001**	**0.5947**
adiff	**0.0181**	**0.2867**	0.8512	0.0021	**0.0148**	**0.3022**	**0.0018**	**0.4467**
bdiff	**0.0378**	**0.2298**	0.5639	0.02	0.1192	0.1367	**0.021**	**0.2756**
Huediff	**0.0288**	**0.2513**	0.8437	0.0024	**0.0137**	**0.3079**	**0.0036**	**0.4008**

	K		Ca		Mg		K/sqrt(Mg)	
Trait	Significanc	r2	Significanc	r2	Significanc	r2	Significance	r2
L	0.8356	0.0018	0.1154	0.0962	0.1852	0.0691	0.6982	0.0061
a	0.427	0.0254	**0.0194**	**0.1998**	**0.0341**	**0.1673**	0.8988	0.0007
b	**0.0214**	**0.1943**	0.318	0.0399	0.8543	0.0014	**0.0324**	**0.1702**
Hue	0.5598	0.0138	0.1853	0.0691	0.1163	0.0957	0.2051	0.0634
Ldiff	0.5815	0.0123	0.9693	0.0001	0.5627	0.0136	0.8213	0.0021
adiff	0.9152	0.0005	0.3528	0.0346	0.1872	0.0685	0.5268	0.0162
bdiff	0.9826	0	0.4655	0.0215	0.9731	0	0.9656	0.0001
Huediff	0.5082	0.0177	0.9677	0.0001	0.847	0.0015	0.7058	0.0058

2002

All Varieties

Uniform Varieties

Non-Uniform Varieties

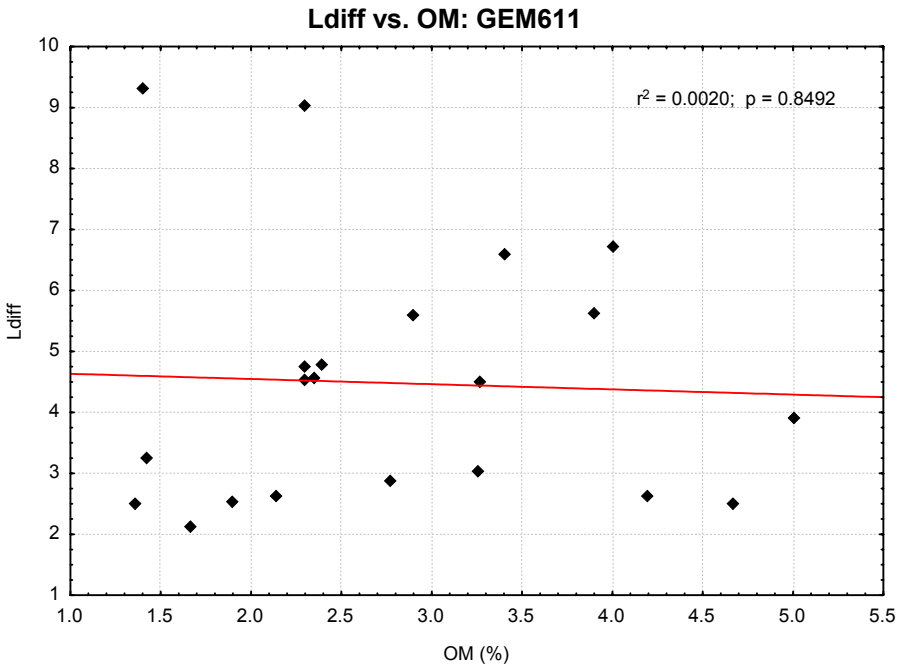
Blue - marginally NS
Red - Significant

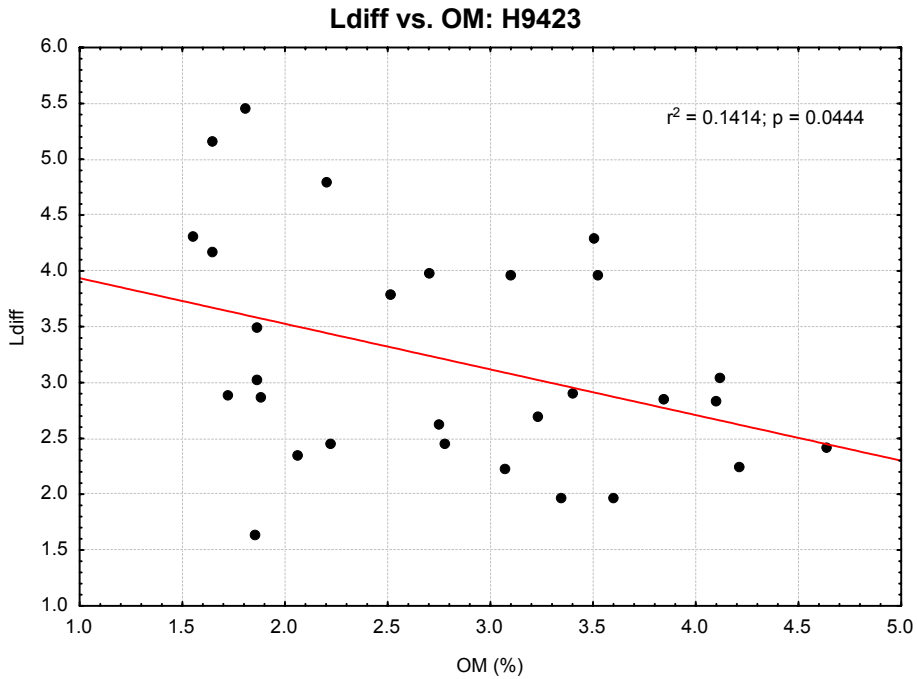
	K		Ca		Mg		K/sqrt(Mg)		pH		OM	
Trait	p	r2	p	r2	p	r2	p	r2	p	r2	p	r2
L	**0.000**	**0.100**	0.889	0.000	0.133	0.015	**0.029**	**0.032**	0.645	0.001	**0.001**	**0.077**
a	**0.040**	**0.028**	0.976	0.000	0.759	0.001	**0.008**	**0.047**	0.595	0.002	0.260	0.009
b	0.194	0.012	0.533	0.003	0.366	0.006	0.124	0.016	0.932	0.000	0.176	0.013
Hue	**0.032**	**0.031**	0.774	0.001	0.511	0.003	**0.009**	**0.045**	0.779	0.001	0.125	0.016
Ldiff	**0.002**	**0.061**	**0.073**	**0.022**	0.173	0.013	**0.042**	**0.028**	0.796	0.000	0.077	0.021
adiff	0.173	0.013	0.806	0.000	0.726	0.001	0.098	0.019	0.663	0.001	0.480	0.003
bdiff	0.158	0.014	0.130	0.016	0.805	0.000	**0.051**	**0.026**	0.574	0.002	0.836	0.000
Huediff	0.126	0.016	0.777	0.001	0.722	0.001	**0.084**	**0.020**	0.485	0.003	0.360	0.006

	K		Ca		Mg		K/sqrt(Mg)		pH		OM	
Trait	p	r2	p	r2	p	r2	p	r2	p	r2	p	r2
L	**0.020**	**0.095**	0.694	0.003	0.122	0.043	0.923	0.000	**0.027**	**0.086**	0.131	0.041
a	0.847	0.001	0.156	0.036	**0.031**	**0.082**	**0.045**	**0.071**	0.158	0.036	0.918	0.000
b	0.306	0.019	0.409	0.012	0.753	0.002	**0.032**	**0.081**	0.205	0.029	0.589	0.005
Hue	0.274	0.022	0.314	0.018	**0.041**	**0.074**	0.706	0.003	**0.046**	**0.071**	0.977	0.000
Ldiff	0.157	0.036	0.769	0.002	0.924	0.000	0.171	0.034	**0.035**	**0.079**	0.624	0.004
adiff	0.889	0.000	0.798	0.001	0.262	0.023	0.662	0.004	**0.072**	**0.072**	0.953	0.000
bdiff	0.715	0.002	0.566	0.006	0.234	0.026	**0.030**	**0.082**	0.266	0.022	0.508	0.008
Huediff	0.418	0.012	0.594	0.005	0.131	0.041	0.868	0.001	0.241	0.025	0.808	0.001

	K		Ca		Mg		K/sqrt(Mg)		pH		OM	
Trait	p	r2	p	r2	p	r2	p	r2	p	r2	p	r2
L	0.353	0.015	**0.047**	**0.065**	0.339	0.016	0.357	0.014	0.637	0.004	0.426	0.011
a	0.407	0.012	0.468	0.009	0.585	0.005	0.643	0.004	0.998	0.000	0.829	0.001
b	0.492	0.008	**0.002**	**0.148**	**0.001**	**0.167**	0.107	0.043	0.697	0.003	0.174	0.031
Hue	0.692	0.003	**0.071**	**0.054**	**0.081**	**0.051**	0.304	0.018	0.792	0.001	0.853	0.001
Ldiff	0.213	0.026	0.500	0.008	0.810	0.001	0.867	0.001	0.855	0.001	0.402	0.012
adiff	0.616	0.004	0.164	0.033	**0.068**	**0.056**	0.984	0.000	0.279	0.020	0.507	0.008
bdiff	0.799	0.001	0.469	0.009	0.587	0.005	0.995	0.000	0.884	0.000	0.570	0.006
Huediff	0.690	0.003	0.184	0.030	**0.073**	**0.054**	0.988	0.000	0.161	0.033	0.703	0.003

Organic matter vs uniformity of color for two varieties

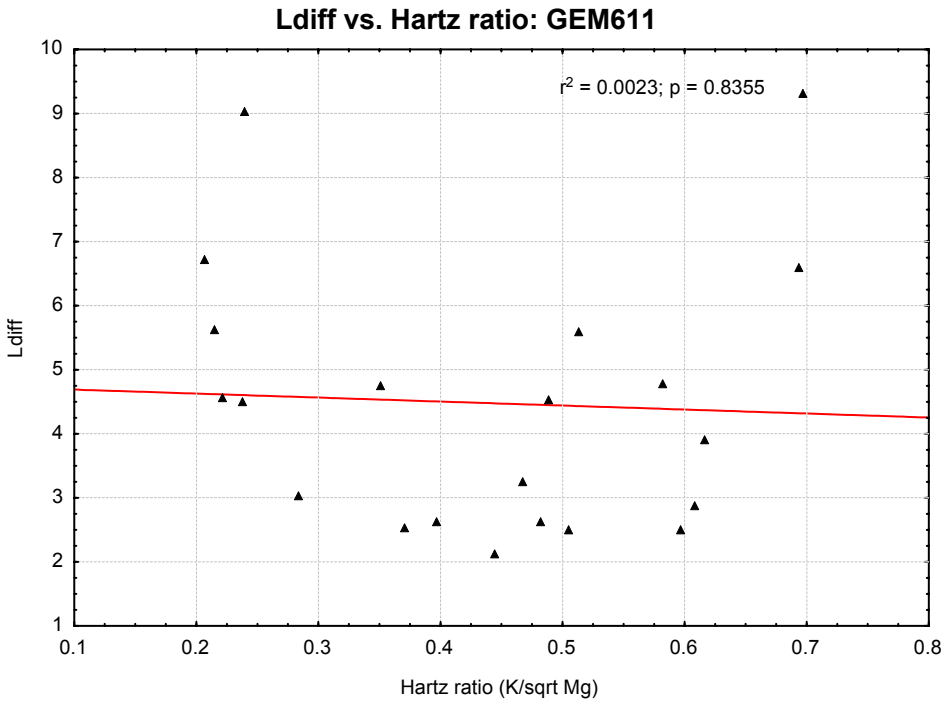


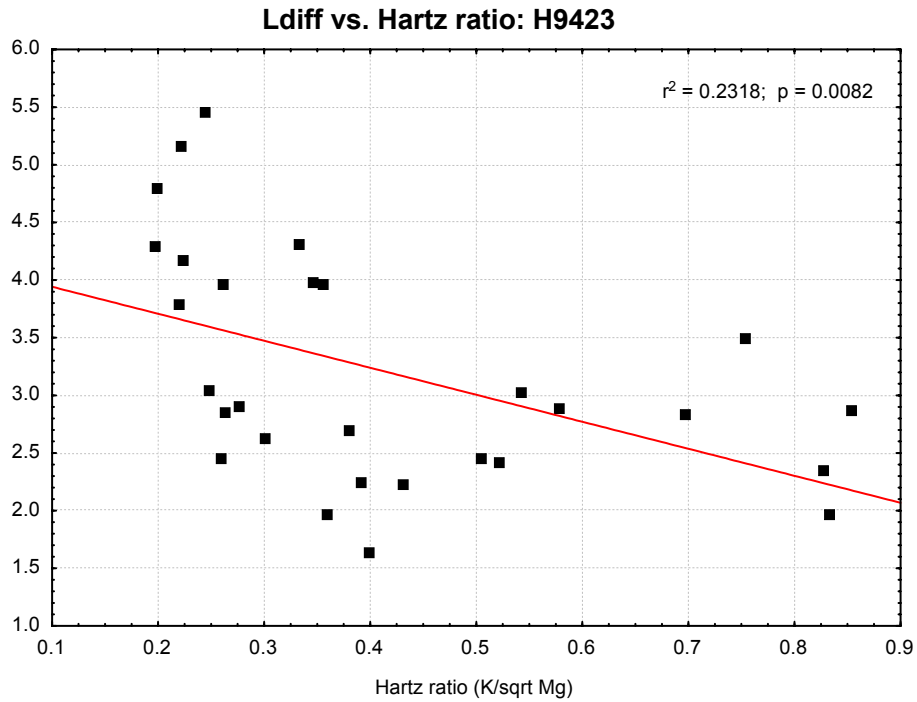


< 0.2% of variation

14 % of variation

Hartz Ratio vs uniformity of color for two varieties

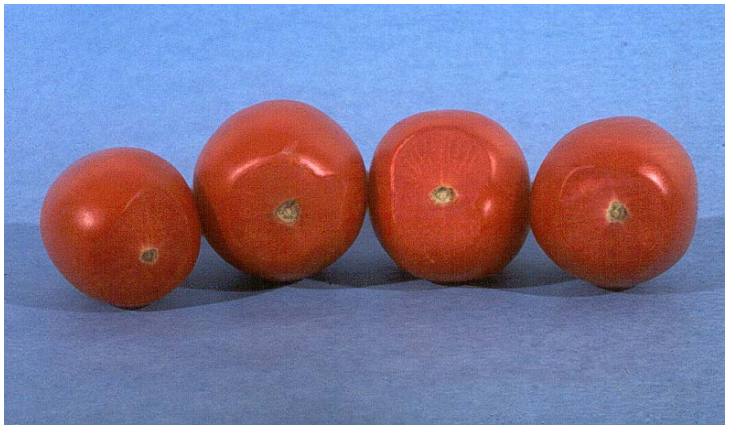




~ 0.2% of variation

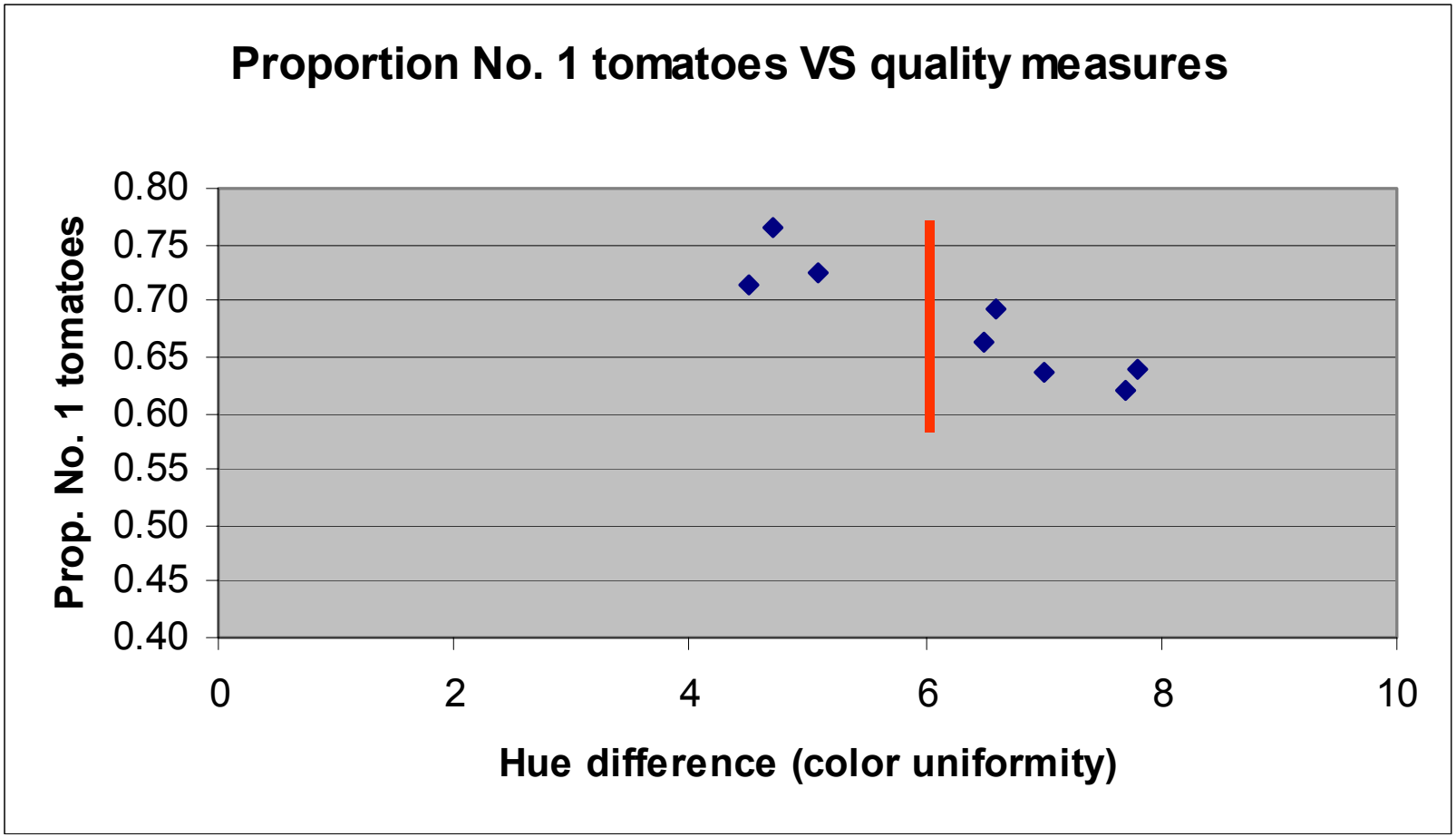
23 % of variation

Not all varieties demonstrate a linear correlation between color quality and soil nutrients or organic matter.



- “Uniform” varieties tend to show significant correlations.
- “Non-Uniform” varieties tend not to show correlations.

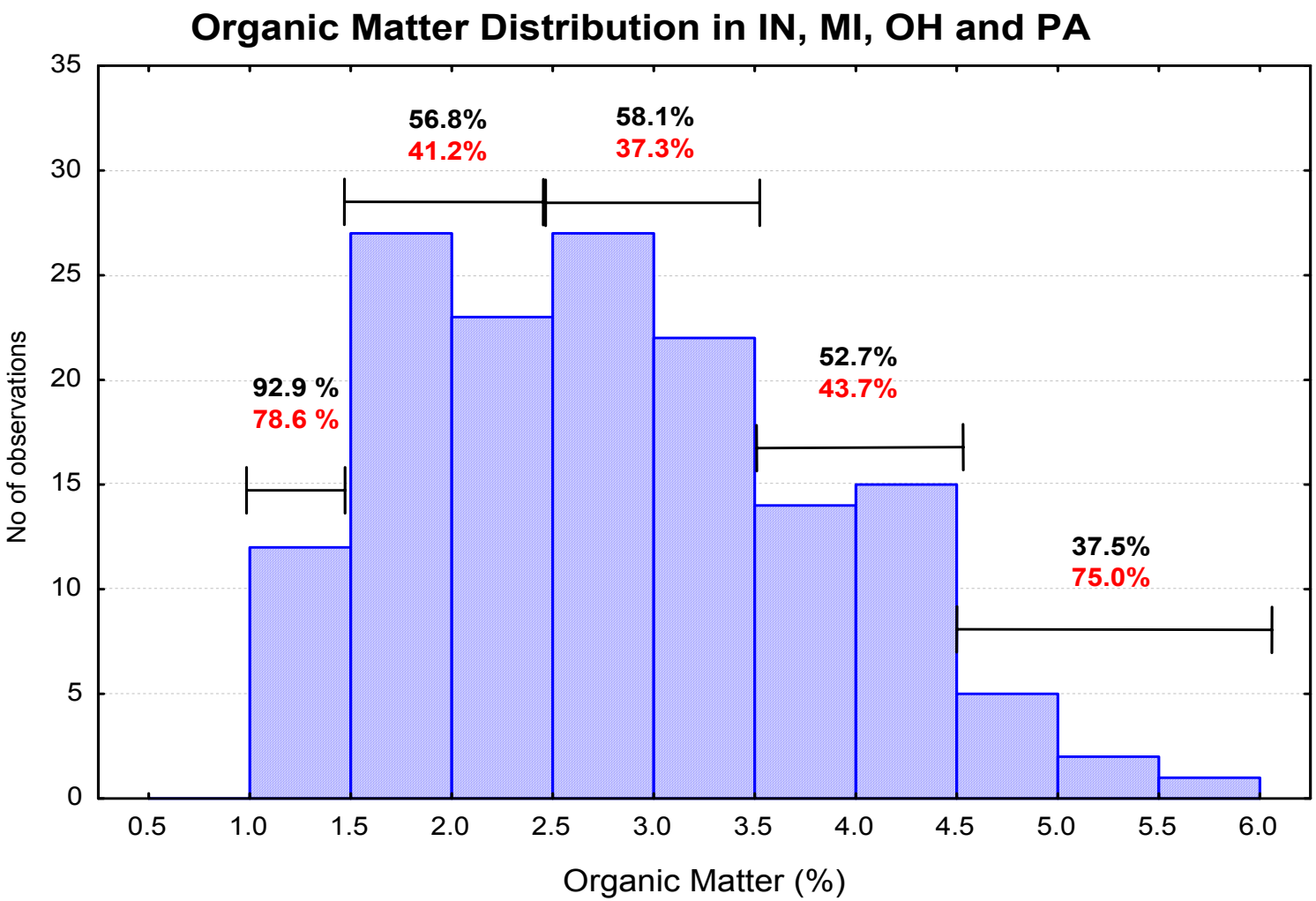
Objective measurements of color uniformity correlate with processor grades. This correlation helps us choose a cut-off.

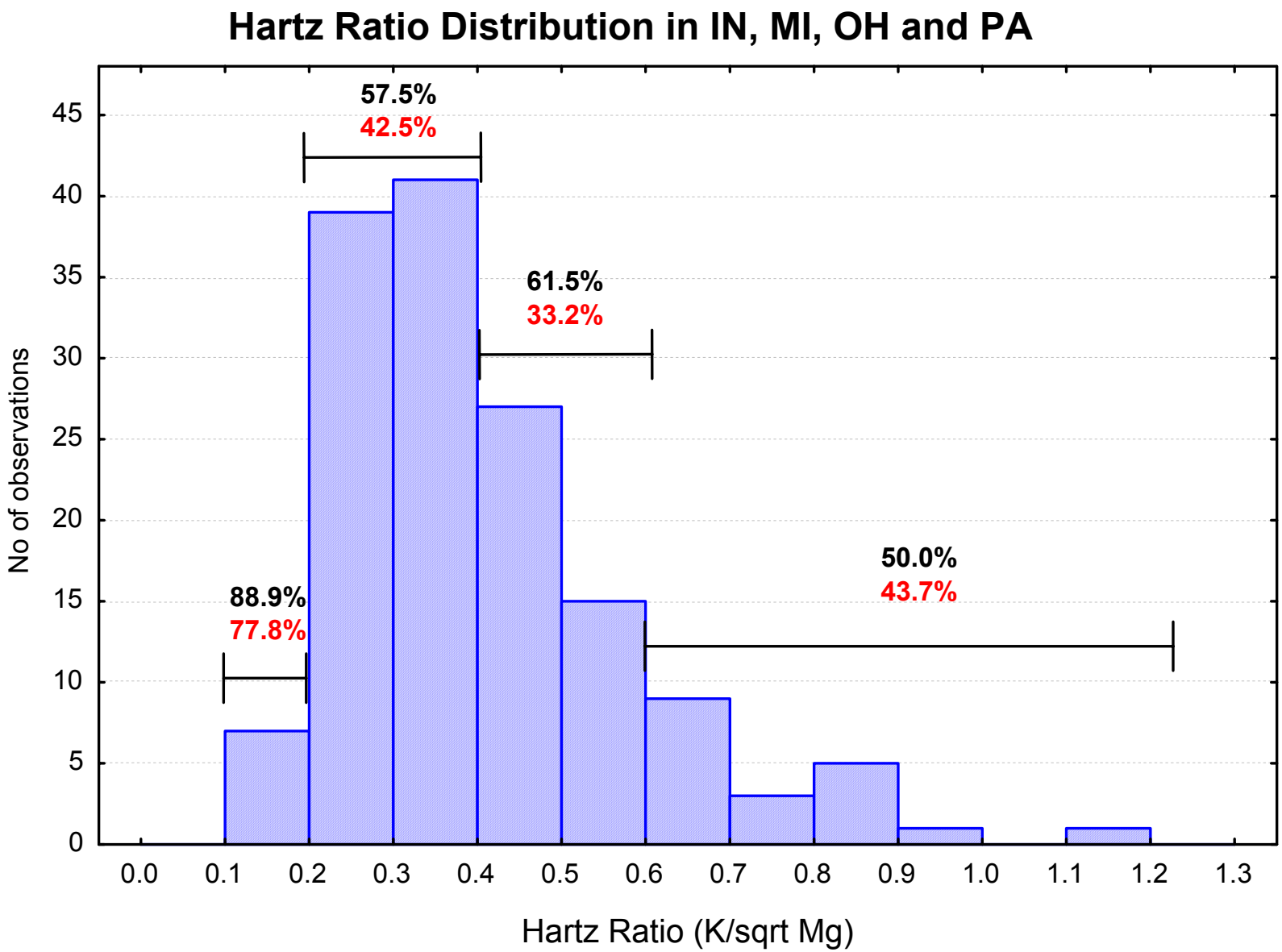


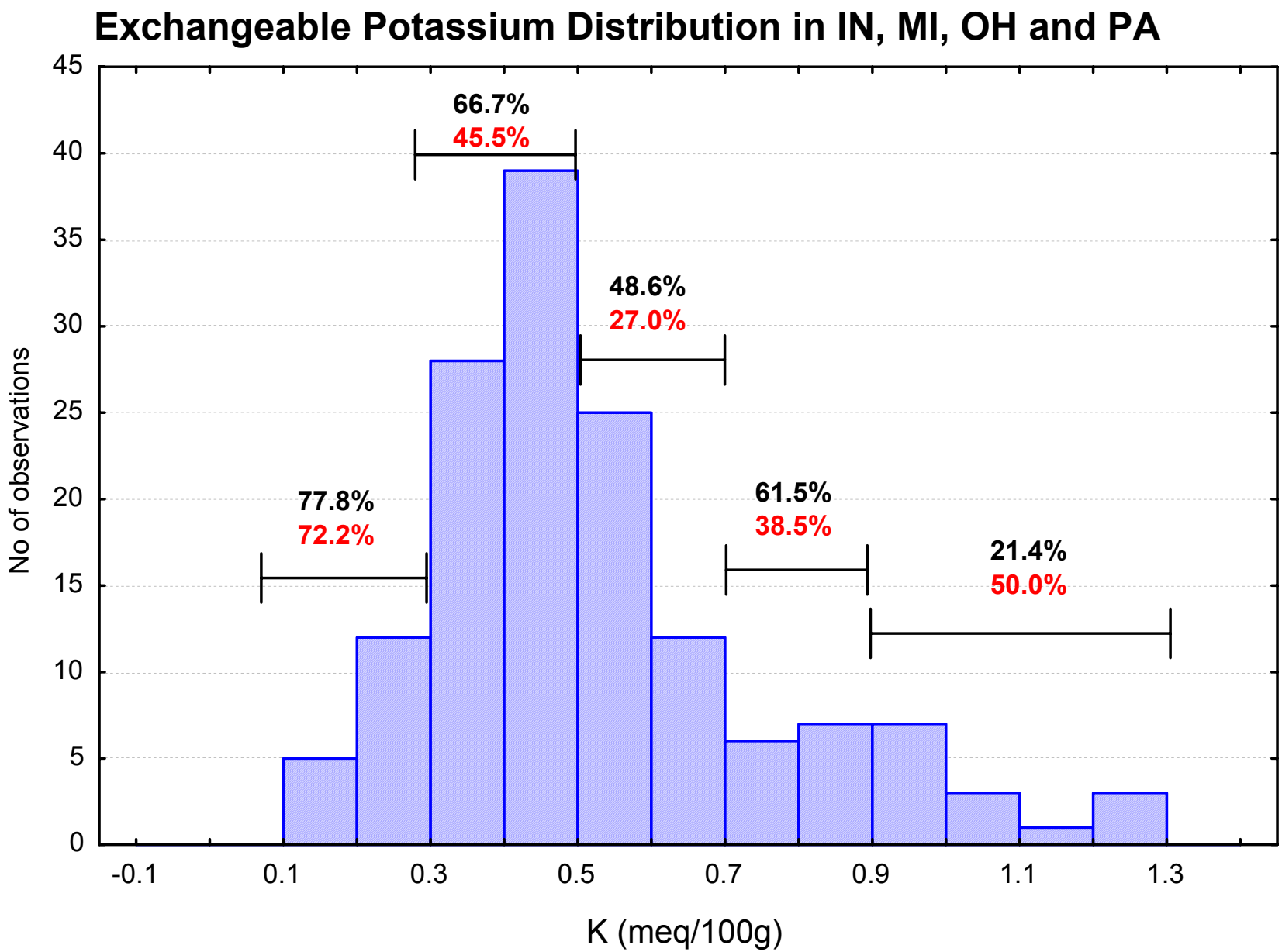
Data for 8 varieties, 2 years, >1,200 loads

Risk assessment: Black - Hue (YSD)

Red - L (IWT)




Hartz Ratio Distribution in IN, MI, OH and PA
57.5%
42.5%
61.5%
33.2%
50.0%
43.7%
88.9%
77.8%
No of observations
0
5
10
15
20
25
30
35
40
45
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
Hartz Ratio (K/sqrt Mg)


Exchangeable Potassium Distribution in IN, MI, OH and PA
No of observations
K (meq/100g)
0
5
10
15
20
25
30
35
40
45
-0.1
0.1
0.3
0.5
0.7
0.9
1.1
1.3
66.7%
45.5%
48.6%
27.0%
77.8%
72.2%
61.5%
38.5%
21.4%
50.0%

Recommendations:

- Uniform varieties
  - H9423, OX23, TR12, 401
- Non Uniform varieties
  - PS696, 611, Ohio8245, H9035
- Organic matter >1.5%
- K meq/100 gm >0.5
- Hartz ratio >0.3
- pH ~6.5

Can we “fix” a problem field?

		Yield Mg/ha					
Treatment	Total K (kg/ha)	Total	Red	Brix	% YS	L value	Hue value
100 mg liter-1 K contin.	400	134	123	4.69	8.8 d	40.9 d	39.6 cd
200 mg liter-1 K contin.	800	140	127	4.69	8.2 d	41.0 cd	40.5 cd
Early batch K injection	250	128	121	4.81	8.2 d	42.8 abc	43.5 abcd
Late batch K injection	250	120	110	4.81	8.2 d	40.7 d	38.8 d
Early foliar K2SO4	29	114	105	4.79	18.7 ab	43.6 ab	47.2 a
Late foliar K2SO4	36	121	111	4.76	20.0 a	43.9 a	47.9 a
Early K metalosate	6	108	105	4.89	10.9 cd	41.9 bcd	42.0 bcd
Late K metalosate	7	112	103	4.91	13.1bcd	42.8 ab	44.0 abc
Early foliar K2SO4 + ma	29	113	106	4.92	15.1 abc	42.3 abcd	43.4 abcd
Untreated control	0	118	109	4.84	17.3 ab	43.8 a	46.6 ab

Good news !?

Drip irrigation and K injection reduced yellow shoulder and improved color

		Yield Mg/ha					
Treatment	Total K (kg/ha)	Total	Red	Brix	% YS	L value	Hue value
100 mg liter-1 K contin.	400	134	123	4.69	8.8 d	40.9 d	39.6 cd
200 mg liter-1 K contin.	800	140	127	4.69	8.2 d	41.0 cd	40.5 cd
Early batch K injection	250	128	121	4.81	8.2 d	42.8 abc	43.5 abcd
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Early foliar K2SO4	29	114	105	4.79	18.7 ab	43.6 ab	47.2 a
Late foliar K2SO4	36	121	111	4.76	20.0 a	43.9 a	47.9 a
Early K metalosate	6	108	105	4.89	10.9 cd	41.9 bcd	42.0 bcd
Late K metalosate	7	112	103	4.91	13.1bcd	42.8 ab	44.0 abc
Early foliar K2SO4 + ma	29	113	106	4.92	15.1 abc	42.3 abcd	43.4 abcd
Untreated control	0	118	109	4.84	17.3 ab	43.8 a	46.6 ab

New varieties

- OX323 and OX325 approved for "branded" release
- Late season, high yielding, field storage varieties
- Color quality is excellent
- Seeking commercial partner

Variety	Tons per acre (ripe)	rank	% Cull	rank	Avg Fruit Weight (ounces)	rank	Folliear Disease Index (0-3)	rank	Fruit Rot Index (0-3)	rank	Blossom End Rot Index (0-3)		Solids	rank
OX331	44.0	1	5.4	10	2.2	5	1.3	4	1.3	15	0.0	1	4.71	15
OX328	44.0	2	6.9	16	2.0	18	1.4	13	0.9	3	0.0	1	4.54	19
OX325	**43.8**	**3**	**4.6**	**5**	**2.3**	**4**	**1.2**	**3**	**1.3**	**15**	**0.0**	**1**	**4.78**	**13**
981670.1	43.8	4	5.7	11	2.0	15	1.1	2	0.9	3	0.0	1	5.03	5
FG98-52	42.5	5	4.2	4	2.1	11	1.4	13	0.9	3	0.0	1	5.19	2
PS696	42.3	6	6.5	15	2.2	9	1.3	4	1.4	19	2.1	15	4.83	12
OX323	**39.8**	**7**	**4.0**	**3**	**2.1**	**12**	**1.4**	**13**	**1.0**	**10**	**0.0**	**1**	**4.85**	**11**
OX329	39.2	8	10.6	20	2.0	19	1.4	13	0.9	3	0.0	1	4.52	20
8245	39.0	9	6.1	12	2.2	10	1.3	4	1.2	13	1.0	12	4.96	8
OX327	38.7	10	5.1	8	2.2	5	1.3	4	1.0	10	0.1	11	4.89	9
OX324	38.7	11	3.9	2	2.4	3	1.0	1	1.2	13	0.0	1	4.97	7
OX23	38.6	12	6.3	13	2.0	17	1.5	18	0.9	3	5.3	20	5.01	6
OX150	38.4	13	5.3	9	2.1	13	1.5	18	0.9	3	2.3	16	4.58	17
987034-	37.9	14	11.9	21	2.0	14	1.3	4	1.3	15	0.0	1	4.63	16
OX264	36.0	15	7.5	17	1.8	21	1.4	13	0.4	1	1.1	13	4.58	17
E3259	33.7	16	7.7	18	2.2	5	1.7	20	1.4	19	0.0	1	4.25	21
OX52	33.2	17	2.3	1	1.9	20	1.3	4	0.8	2	2.3	16	4.72	14
TR12	32.9	18	5.0	7	2.0	15	1.3	4	0.9	3	3.5	19	5.11	4
9242	30.6	19	9.6	19	2.4	2	1.3	4	1.4	19	1.8	14	5.18	3
7983	28.7	20	4.7	6	2.2	5	1.3	4	1.0	10	5.3	20	5.32	1
H9423	27.7	21	6.4	14	2.4	1	1.8	21	1.3	15	2.9	18	4.89	9

Variety	L		Hue		Ldif		Hdif		Force	
		rank		rank		rank		rank		rank
H9423	43.0	19	40.3	2	3.1	1	4.0	1	6.0	1
OX23	41.4	12	42.5	9	3.3	3	4.6	2	5.2	8
9242	39.4	1	40.2	1	3.8	6	4.8	3	4.5	21
TR12	40.9	5	43.2	11	3.3	2	5.0	4	5.2	7
OX325	**40.8**	**4**	**41.0**	**5**	**4.0**	**9**	**5.5**	**5**	**4.9**	**11**
OX264	40.7	3	41.8	7	3.6	4	5.6	6	4.6	16
OX324	41.5	14	42.1	8	4.2	12	5.9	7	4.9	10
OX331	41.1	7	40.8	4	4.4	17	6.0	8	5.1	9
OX327	40.7	2	40.4	3	4.0	10	6.1	9	5.4	3
981670.1	41.3	9	44.4	18	4.0	11	6.1	10	4.8	13
OX329	40.9	6	42.9	10	4.4	17	6.3	11	4.6	19
OX323	**42.6**	**17**	**43.8**	**13**	**3.9**	**7**	**6.5**	**12**	**5.4**	**2**
7983	41.4	11	44.0	15	3.9	8	6.7	13	5.2	6
OX52	41.6	16	44.1	16	3.8	5	6.8	14	4.8	12
PS696	42.8	18	45.0	20	4.3	14	6.8	15	5.3	5
OX150	41.3	9	44.2	17	4.4	16	6.8	16	4.7	14
E3259	41.2	8	41.1	6	5.1	20	7.0	17	4.6	16
OX328	41.5	13	43.3	12	4.2	12	7.2	18	4.6	15
987034-	43.2	20	45.9	21	4.6	19	7.3	19	4.6	20
8245	43.4	21	44.0	14	5.1	21	7.4	20	5.4	3
FG98-52	41.6	15	44.5	19	4.3	15	7.4	21	4.6	16

- Conclusions
  - Manage risk
  - Use uniform varieties on high risk soils
  - Foliar sprays are not effective
  - Drip irrigation and K injection may help reduce risk associated with low Hartz ratio and water stress

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