Welcome to the webinar!

- The webinar will start the top of the hour.
- To type in a question, use the q and a box on your control panel. We'll read the questions aloud after the presentation for 30 minutes.
- A recording will be available in our archive (see below) and on the eOrganic YouTube channel within 1-2 weeks
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- Find out more about the NIFA OREI project on Participatory Breeding and Testing Networks: A Maize Based Case Study for Organic Systems at https://eorganic.info/CASH

Corn Breeding for Organic Markets

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aMaizing –
How to Harness the Tremendous Diversity of Corn?

Martin Bohn

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Crop Sciences
COLLEGE OF AGRICULTURAL, CONSUMER
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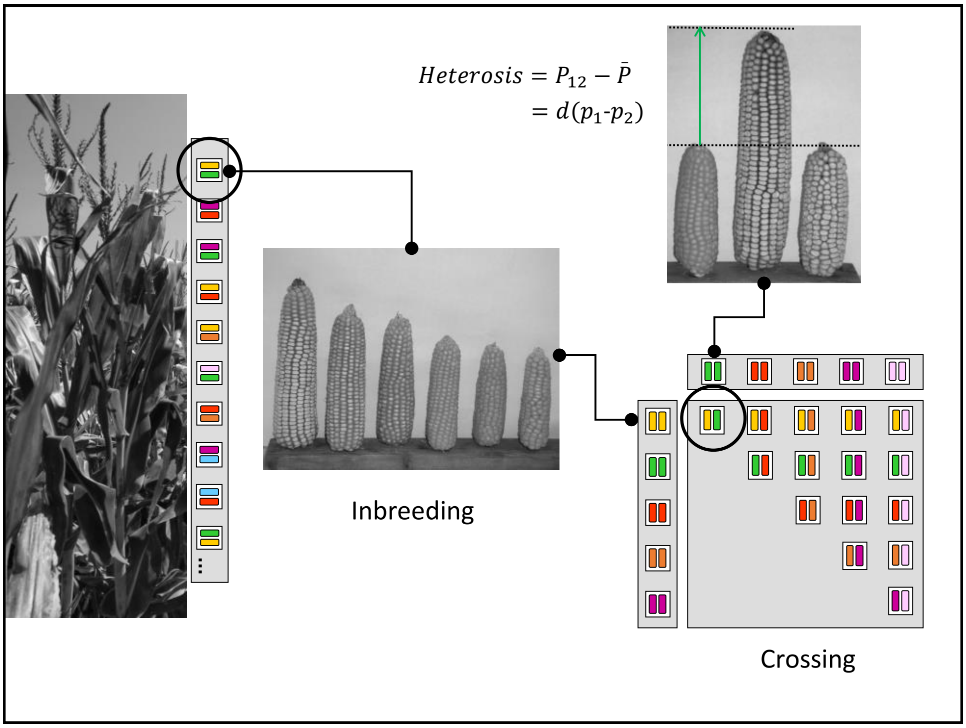
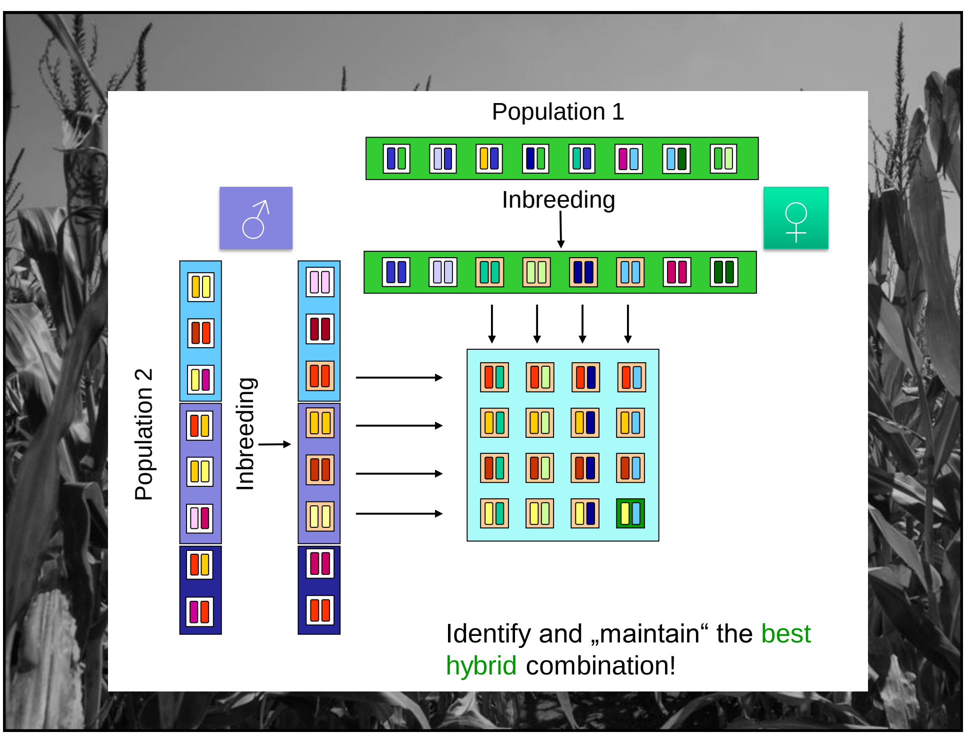
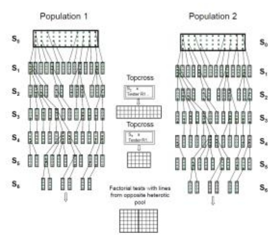
G.H. Shull (1908, 1909)

"Every field of corn is a mixture of hybrids with varying degree of heterozygosity..."

"The object of the corn breeder should not be to find the best pure line, but to find and maintain the best hybrid combination."

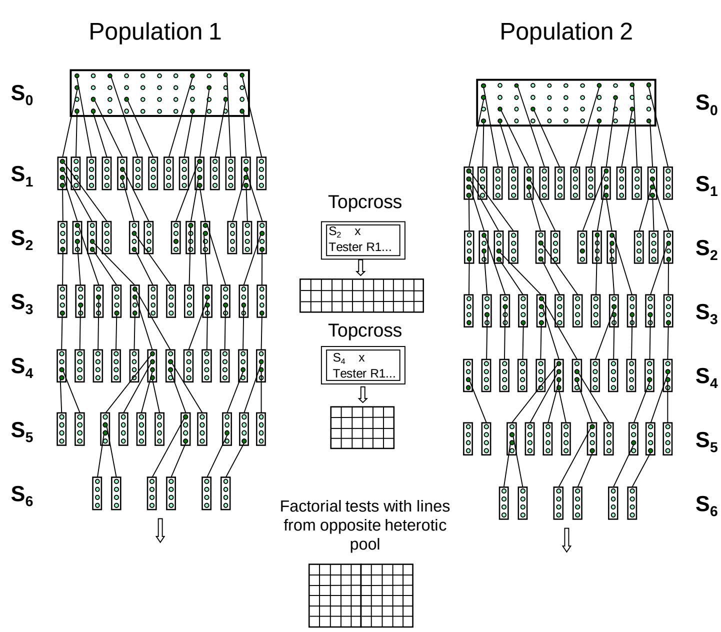

$Heterosis = P_{12} - \bar{P}$
$= d(p_1\text{-}p_2)$
Inbreeding
Crossing

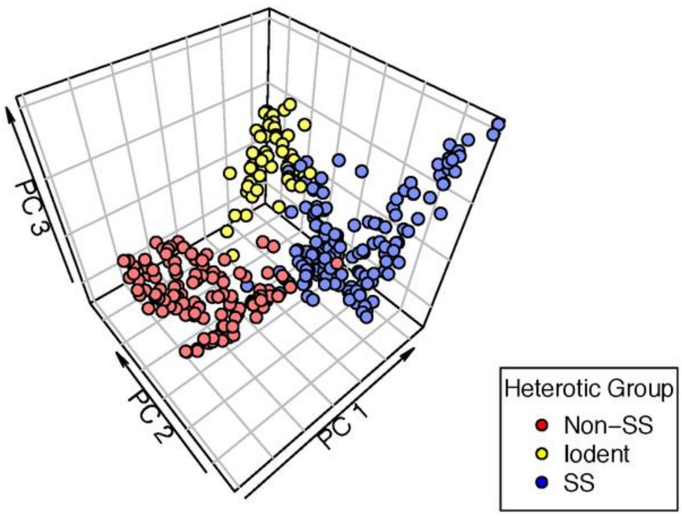

Population 1
Inbreeding
♂
♀
Population 2
Inbreeding
Identify and „maintain“ the best hybrid combination!



Breeding Phases

1. Procuring initial variation
2. Forming varietal parents
3. Testing experimental varieties

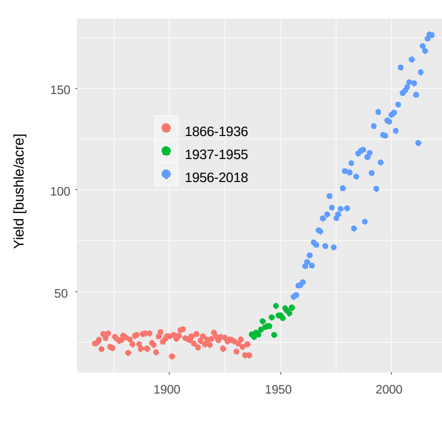


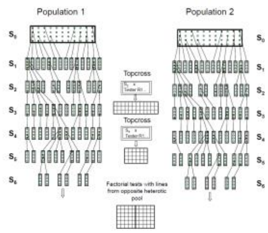


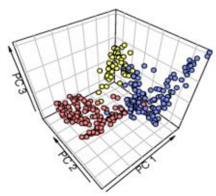
Beckett TJ, Morales AJ, Koehler KL, Rocheford TR (2017) Genetic relatedness of previously Plant-Variety-Protected commercial maize inbreds. PLOS ONE 12(12): e0189277. https://doi.org/10.1371/journal.pone.0189277
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0189277

PLOS | ONE

U.S. Corn Grain Yield 1866-2018
(Data source – USDA-NASS)







Issues

- Time
- Diversity
- Multiple Breeding Objectives
- Limited Resources

Solutions

- Doubled Haploids
- e.g., USDA – Germplasm Enhancement in Maize (GEM)
- Genomic Prediction

Mandaamin Institute

Partnerships with corn: environments elicit; plants/microbes create, and humans select.

- **Classical breeding is human driven: crossing makes more variation; inbreeding causes fixing of traits.**
- **Humans select the best, and reject unfit bodies.**
- **Emergence breeding is environmentally driven: Plants plus their microbial partners *do* soft *emergent* evolution towards fit bodies for specific environments.**
- **They generate variation and new possibilities through an active adaptation process that responds to the environment (for us, organic conditions and limited N).**
- **The shifts can be unpredictable and emergent!**
- **Breeder should choose environments, be attentive and develop a sense of balance.**

Culture Contrast on Inbred M632.

MF M632+B MF M632 USDA M632+B USDA M632

Culture contrast on breeding family GEMS29.

MF GEMS29+B MF GEMS29 USDA GEMS29+B USDA GEMS29

Emergent evolution:
Spontaneous increase in frequency of opaque kernels from 2005 to 2006.

	Original Crosses	
Parameter	FS8A.SS	AR21B
frequency of opaques in 2005	0.00005 to 0.00007	0.0009 to 0.0011
frequency of opaques in 2006	0.03 to 0.04	0.07 to 0.09 (0.05 to
increase in frequency	583 x	80 x (500 x)*

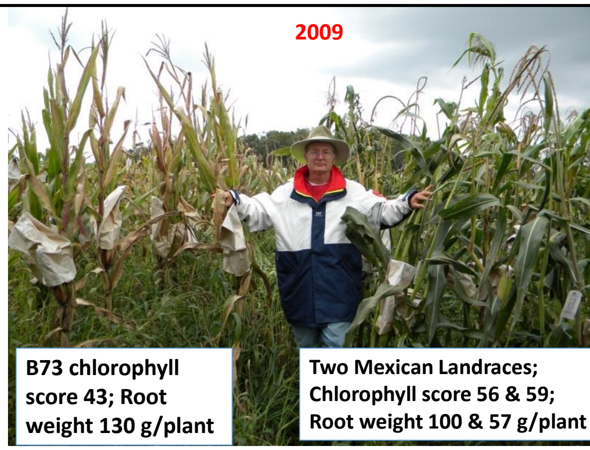
HPLC 2011 3 conventional hybrids, 6 Mandaamin hybrids.			
Parameter	**Conventional**	**Mandaamin**	**difference**
Protein	7.93	10.50	32
Lysine	0.290	0.331	14
Methionine	0.174	0.262	51
Cysteine	0.174	0.215	24
% Met in protein	2.15	2.46	14
NIRS samples from 2011 to 2016;			
149 conventional and 1250 Mandaamin hybrid samples.			
Parameter	**Conventional**	**Mandaamin**	**difference**
Protein	8.62	9.99	16
Methionine	0.21	0.274	30
% met in protein	2.46	2.76	12
% met @ same level			22

Piebald kernels in LH123Ht and LH185 probably caused by jumping genes.

Conventional inbreds LH206, LH123, S7, S5 grown on JR or Creek field (S5) in 2017 without fertilizer. LH206 and 123 were bred by Monsanto; S7 and S5 are commercial inbreds from a seed licensing company.

Nokomis Gold Seed Company inbreds C4-6, LAT-7, NG2-3-2, and C2-B bred at the Mandaamin Institute and grown on JR or Creek field (C2-B) in 2017 without fertilizer.

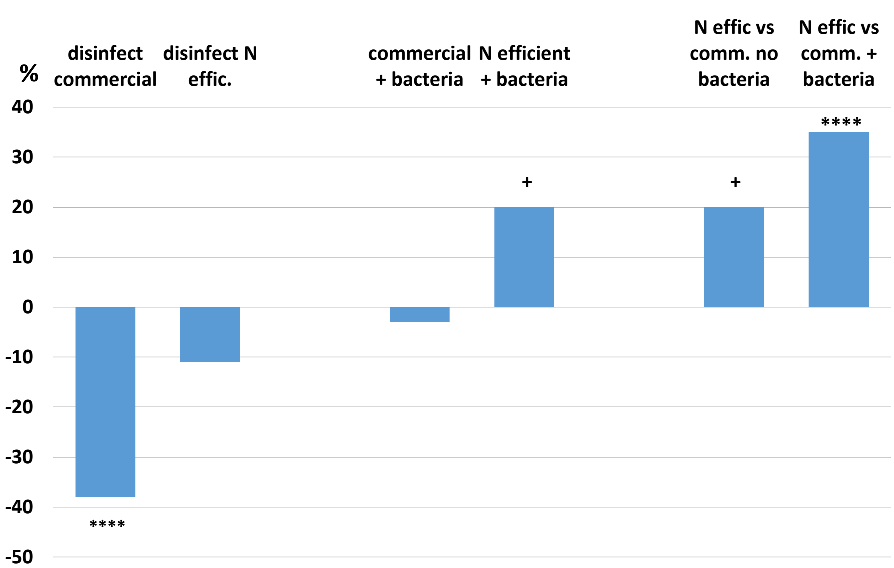
Nutrient efficiency: **select inbreds with broad, fibrous rooting systems adapted to extracting nutrients from soil**



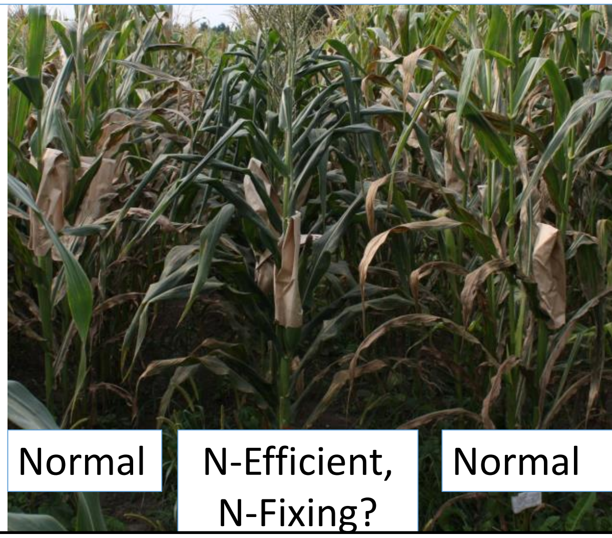
2009 Data Chlorophyll in leaves and N isotope distribution in grain.

Cultivar	No. of cultivars	Ave Chlorophyll score	ave % of plants score>50	No. of cultivars	range delta 15N	best % NDA
Old commercial inbreds	15	37	8	15	3.9 to 5.4	27
New commercial inbreds	23	40	8	9	3.9 to 5.8	32
Our breeding lines and inbreds	26	45	34	15	4.6 to 6.1	35
Landraces	13	54	65	10	3.2 to 6.1	48

Treatment effects on protein/acre from 4 commercial hybrids and 4 experimental N efficient hybrids.



Fixing the trait in an inbred:
Mex.6(2x)-1-B-4-sister lines 5,6,and 7, Elkhorn, Goldstein Farm, corn after grass & clover in 2015.



Normal

N-Efficient, N-Fixing?

Normal

Adjacent plots in 2018
Parent commercial inbred (left)
C-4-6 inbred (¾ that inbred and ¼ Mexican landrace) (right).

Results in 2016 on two low fertilility and low fertilizer organic sites. Near Elkhorn, Wisconsin.					
Site and Pedigree	grain yield	protein	lysine	methionine	Protein yield
	bu/acre	--percent total dry matter--			pounds/acre
JR3 site, low fertilization rate					
Mandaamin ave 5 hybrids	125	9.00	0.36	0.26	535
Conventional ave 4 hybrids	115	6.97	0.30	0.19	381
diff NGSC vs checks in %	9	29	18	35	40
BP site, low fertilization rate					
Mandaamin ave 5 hybrids	150	8.88	0.36	0.27	627
Conventional ave 1 hybrid	124	6.96	0.29	0.19	411
diff NGSC vs check in %	21	28	20	38	53
Zinniker site very heavily manured					
Mandaamin ave 10 hybrids	178	11.28	0.39	0.30	951
Conventional ave 6 hybrids	180	10.40	0.33	0.25	885
diff NGSC vs checks in %	-1	8	19	23	7

Overall yields 2018 Wisconsin, 2018, various trials.

all checks, strip + small plot			all checks, strip + small plot		
	checks	2.4)17xC2B2		checks	2.4)17xC46
sites	13	13	sites	8	8
reps	42	17	reps	37	8
bu/acre	136	160	bu/acre	128	151
moisture	22.1	25.8	moisture	21.6	21.9
% yld	100	118	% yld	100	111
FOS8507 Check strip plot			FOS8507 Check strip plot		
	FOS8507	2.4)17xC2B2		FOS8507	2.4)17xC46
sites	5	5	sites	6	6
reps	5	5	reps	6	6
bu/acre	198	175	bu/acre	195	156
moisture	26.3	27.6	moisture	21.6	21.0
% yld	100	88	% yld	100	79

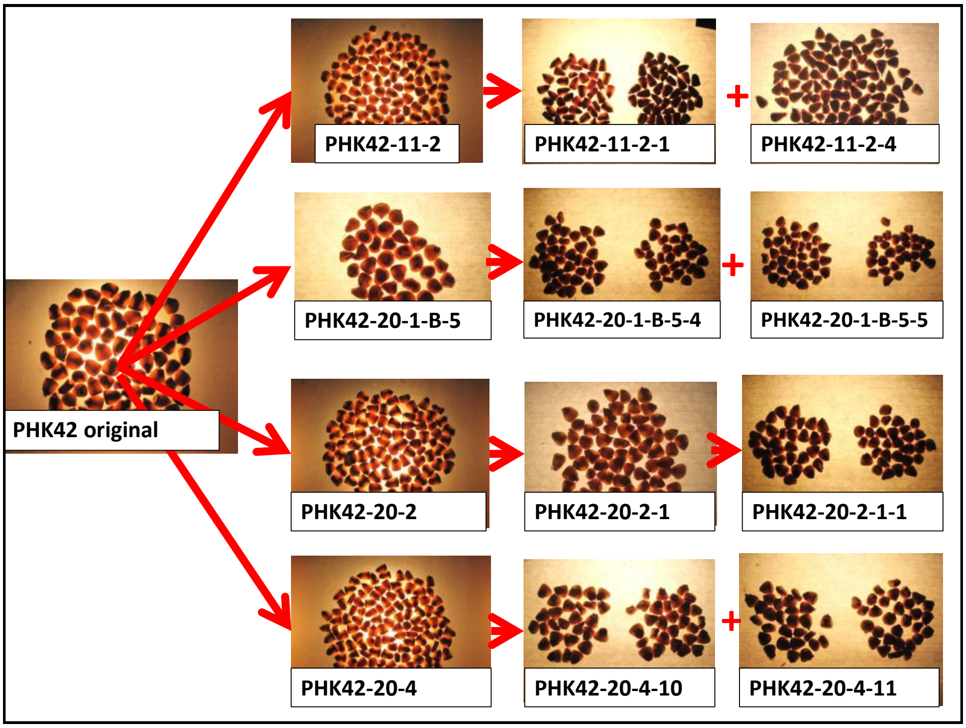
2014 isolation.

Detasseled putative Ga1 plants and let them be pollinated by a normal ga1 male plant.

Tested 1 row each of 39 inbreds, 5 hybrids, 1 check.

Results:
35 no pollinations,
6 had a few kernels pollinated in the row.
4 had whole ears pollinated.

Mandaamin Institute Certified. Naturally Bred for Quality Nutrition & Sustainability.



JR1 2015. Summary of 2 row plot data. Top 21 hybrids

Pedigree of Hybrid	grain yld @ 15.5% moist	grain moisture	reps	Protein	Oil	Starch	Density	Lysine	Met	Cys	Met + Cys	pro/acre	oil/acre	pro + oil/acre
	bu/a	%		-----------------------------%-----------------------------								-----lbs/acre-----		
Organic check Hybrid	**172**	**23.1**	**29**	**8.2**	**4.0**	**73.0**	**1.24**	**0.31**	**0.22**	**0.17**	**0.39**	**611**	**296**	907
NG10-6-3-1/S7	199	25.3	1	9.3	4.6	71.0	1.21	0.34	0.25	0.19	0.44	778	386	1164
N.L.-17/8-4-3	170	28.3	2	10.6	5.1	68.8	1.17	**0.41**	**0.30**	**0.20**	**0.50**	722	347	1070
8-4-1/S7	185	25.4	2	9.2	5.0	70.6	1.21	**0.38**	0.22	0.19	0.41	709	384	1093
S7/8-4-1	192	25.8	3	8.8	4.9	70.8	1.20	0.36	0.24	0.19	0.42	704	394	1098
8-4-2/NG10-3-1-1	166	26.4	1	10.2	4.9	69.9	1.19	0.36	**0.28**	**0.21**	**0.49**	698	335	1033
8-4-1/NG10-6-1-B	181	25.7	3	9.0	4.6	71.2	1.21	0.35	0.24	0.19	0.42	680	344	1025
NG9-32-7-2/B-6-B-tall 6	168	30.5	2	10.4	5.2	69.2	1.18	**0.38**	**0.28**	**0.21**	**0.49**	679	341	1020
M-5-4/FS.NL-2	167	23.6	1	9.5	5.7	69.2	1.17	**0.37**	**0.28**	**0.20**	**0.48**	678	409	1087
8-6/S7	191	27.7	3	8.7	4.6	71.3	1.19	0.35	0.24	0.19	0.43	673	357	1030
FS.NG/B-6-B-tall 5	152	26.8	3	10.8	4.8	69.8	1.26	0.35	**0.27**	0.21	**0.48**	673	299	972
6-B7/FS.NL	169	27	1	9.6	4.8	70.3	1.18	0.36	**0.28**	**0.20**	**0.48**	665	332	997
H-4/8-4-4	185	27.3	2	8.7	5.0	70.7	1.19	0.34	0.26	0.19	0.45	659	377	1036
M-5-B/H-2	149	26.2	3	10.5	5.4	69.2	1.24	0.35	**0.27**	**0.21**	**0.48**	645	330	975
M-8-6/NG10-6-1-B	148	27.9	2	10.7	5.3	68.8	1.19	**0.37**	**0.28**	**0.21**	**0.50**	641	320	961
NG9-51-4-3/B-6-3-4	153	29.7	3	10.6	4.6	69.9	1.23	0.36	**0.28**	**0.20**	**0.48**	636	274	910
NG9-35-5-B/6-B5	147	26	1	10.4	4.7	69.4	1.18	**0.40**	**0.28**	**0.21**	**0.49**	635	286	921
S7/8-6	173	26.8	3	8.9	4.4	71.3	1.20	0.35	0.24	0.19	0.43	633	315	949
NG9-45-2-5/B2-22-2-9	170	28	1	9.2	5.1	70.0	1.17	0.35	**0.28**	**0.20**	**0.48**	626	351	977
M-5-4/FS-14-8-3	135	22.3	2	10.6	4.9	69.6	1.22	**0.37**	**0.27**	**0.21**	**0.47**	626	288	914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- Thank you for coming!