Testing N efficient, high methionine corn hybrids with organic farmers[1].

Photo Collages, Tables, Diagrams for SARE project LNC-389.

Photo Collage 1.

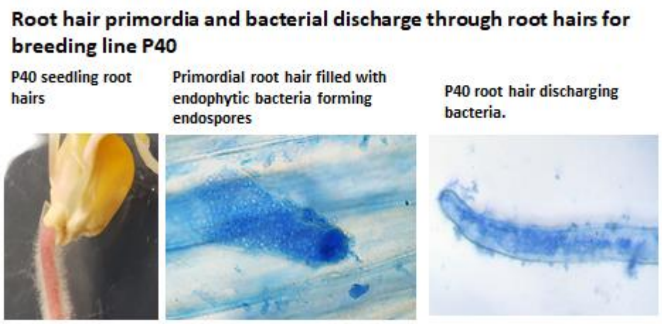


Photo collage 2. Bacterial aggregates in the roots of the C4-6 inbred (left) and spore forming bacteria in C2B2.

[1]This research was made possible by the cooperation and assistance of numerous people, institutions, and farms. We acknowledge their part in this work and in formulating data with great thanks. First, the work would not have been possible without the help of many organic and biodynamic farmers who participated in the thinking behind the project and the work with it on their farms. The Corn and Soil Health project, centered at the University of Illinois, with OREI funds, accomplished basic soil analyses, worked up data on soils and farms, and helped in formulating experimental designs for the farm trials. This included graduate students E. Gulkirpik, M. Toc, C. Mujjabi, M. Nunez, data coordinator Emily Marriot, and Professors: C. Ugarte, M. Wander, M. Bohn, and J. Andrade. USDA-ARS, Morris, Minnesota (A.A. Jaradat, Chris Wente, and Jane Johnson), did tissue analysis of corn for minerals and helped prepare samples for isotope analysis. Foundation Organic Seed (S. Mohr) contributed seed and advice to the project. Rutgers University (J. White., A. Lotfi, K. Kingsley, and others) contributed rhizophagy research on maize seedlings, advice on interpreting our results, and continuous inspiration based on their research findings. University of Wisconsin Extension (Mike Travis) and Pepin County Conservation (Chase Cummings) helped organize farmers and events and meetings around the issue of N_2 fixing corn and helped carry out on farm research in the NW part of Wisconsin. Wood Ends Soil Testing Lab and Cornell University assisted with extra soil quality tests. At the Mandaamin Institute, J.Karnes, V. Thomas, A. Lanser, J. Mayfield and others contributed to getting the field research done. Any errors in interpretation of results are due to the author and not to any of the people mentioned above. Finally we would like to acknowledge funding from USDA-NIFA-OREI, SARE and the Ceres Trust, without which this work could not have been accomplished.

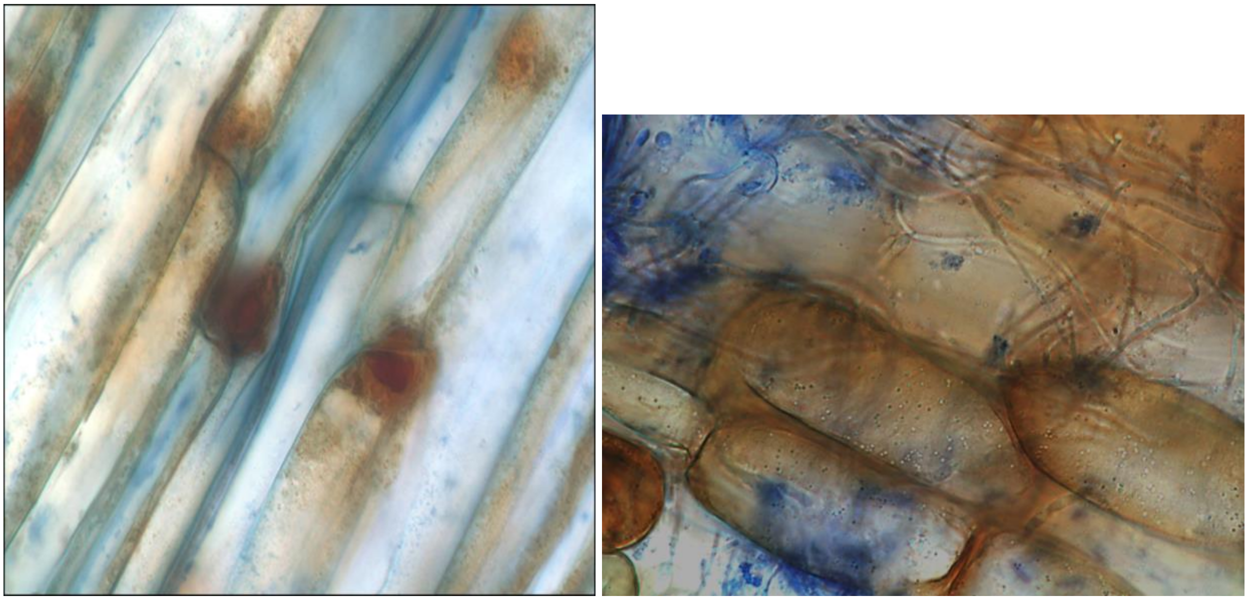


Photo collage 3. Roots of LH206 on left and of Novartis 942 on right.

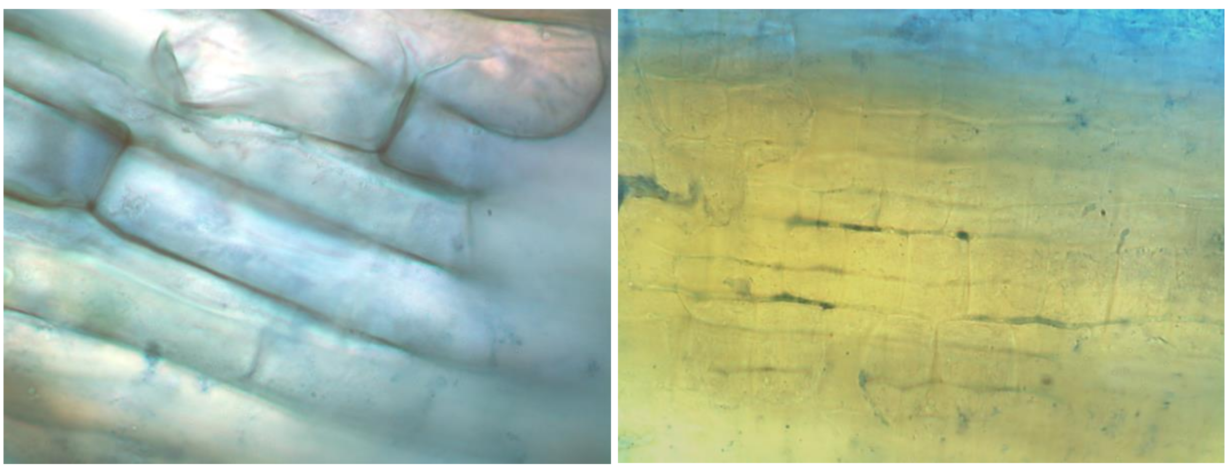
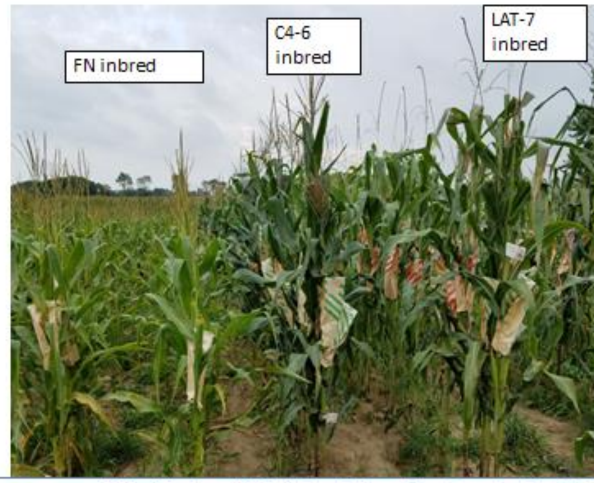


Photo collage 4 shows hairy stalks of C4-6 on left and foliage color of C4-6 when grown beside a normal inbred on left (FN) and LAT-7, an inbred derived from root weeping landrace Mixeno.



Phenotype of N efficient/N2 fixing inbreds. Results in 2019 with corn inbreds following after a winter rye disk down crop. FN is a typical inbred. The pedigree of LAT-7 is 1/4th Mixeno.

Photo collage 5 shows rooting systems of multiple commercial or Mandaamin inbreds grown on N limited sites in 2017 without fertilization.

Photo collage 5 shows rooting systems of multiple commercial or Mandaamin inbreds grown on N limited sites in 2017 without fertilization.

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.

NokomisGold 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.

Photo collage 6. Roots extracted in September from Mandaamin nursery show root health of putative N2 fixing inbred C4-6 (left) and conventional inbred LH206 (right). The two hybrids possess the same relative maturity.

Table 1 describes sites used for varietal trials in 2019.

Farm	**Year**	**Crop rotation (past 4-5 years)**	**Soil fertility in corn phase**	**Soil fertility time**	**Soil texture**	**manure rate**
Clark	**2018**	**alfalfa-corn**	**+/- cow manure**			**10 tons/acre**
Stoltzfus	2018	Wheat-Hay (alfalfa+clover+timothy)-Corn	CC	Preplant	Silty clay loam	0
Adsit	2019	Alfalfa (3 years)-Wheat-Corn	Chicken manure	Preplant	Clay loam	3 tons/acre
Doudlah	2019	Soybean-Corn-Kidney bean	CC	Preplant	Silty clay loam	0
Zinniker1	2019	Hay (grass+alfalfa for 5 years)-Corn	Compost	Preplant	Silty clay loam	15 tons/acre
Anibas	2019	Alfalfa (3 years)-Corn	Cattle manure	Preplant	Silty clay loam	6000 gal/acre
Beiler1	2019	Oat-Corn-Pumpkin-Corn	Chicken manure	Preplant	Silty clay	10 tons/acre
Stoltzfus1	2019	Hay-Hay (alfalfa+clover+timothy)-Corn	Cow manure slurry + box stall manure	Preplant	Silty clay	4800 gal/acre + 660 bu/acre
Stoltzfus2	2019	Hay-Hay (alfalfa+clover+timothy)-Corn	Cow manure slurry	Preplant	Silty clay	7000 gal/acre
Weiss/Bauer	2019	inoculation trial continuous corn	N starter +/- slurry	Preplant	sandy loam	75 lbs N starter, +/-unspecified slurry
C.C. means cover crop.						

Photo 1. C2B2.C46 growing on the Zinniker Farm in 2017.

Table 2 describes sites used for varietal trials in 2020 and provides notes on weeds and animal damage.

Farmer	Plot dimensions			Preceding crop				Tillage				biology			notes
	no rows	row width inches	row length (feet)	2019	2018	2017	2016	planting date	primary tillage	secondary tillage	weed control	weeds	weed control	manure	
Moses Beiler	2	30	100	alfalfa&grass	alfalfa&grass	alfalfa&grass	corn	ca. May 15	spring plow	disk 3x	drag 1x; cultivate 2x	foxtail, quackgrass	fairly good	with and without ca 10t/a BYM	Good stands and yields.
Daniel Esch	2	34	60	strawberries	strawberries	strawberries	pasture	end May	spring plow	harrow cultimulch 3x	cultivate 3x	fairly clean	good	12-15 t/acre composted dairy pack	Good stands and yields.
James Lengacher	2	30	30	legume grass hayfield	legume grass hayfield	legume grass hayfield	soybeans	June 8th	deep rip 8 inch tine	disk 2x; field cultivator	cultivate 2x	practically no weeds	excellent	2019 hay got 4-5 t/a manure/compost	Population density not determined.
Dale Clark	3	30	42	fallow & weeds	fallow & weeds	fallow & weeds	fallow & weeds	22-May	offset heavy disk	not necessary	rotary hoe 1x cultivate 1x	mostly foxtail	good	unmanured	spatial variation, erratic stands, poor growth in very low fertility spots; variable moisture; erratic yields, not usable.
Jim Egre	2	36	50	soybeans	grass	grass	grass	June 5th	plowed	rotary tiller 3x	cultivator + hand weed	foxtail, creeping charlie, morning glory	good	unmanured	Plano silt loam B soil. Deer severely damaged plots so a yield determination was not feasible.
Gold/Mandaamin/MFAI	2	30	40	alfalfa&grass	alfalfa&grass	alfalfa&grass	alfalfa&grass	June 16th	offset disk 3x		rotary hoe 1x cultivate 2x	Canada thistle patch	poor	not manured	Severe Canada thistle infestation held in check by cultivation.
Gary Bauer/Don Weiss	3	30	90	corn	corn	corn	corn	6-May	vertical till		herbicide	some velvetleaf	good	not manured	

Table 3. The yields of corn on 14 sites comparing yields of FOS8500 and 17.461.

year	farm	system	manuring	hybrid	Grain yield bu/acre	%
2019	Doudlah	arable	none	FOS8500	59	100
2019	Bauer/Weiss	cattle	none	FOS8500	177	100
2020	Bauer/Weiss	cattle	none	FOS8500	145	100
2020	Lengacher	arable	none	FOS8500	113	100
2020	Beiler	arable	none	FOS8500	94	100
2019	Doudlah	arable	none	17.461	98	166
2019	Bauer/Weiss	cattle	none	17.461	180	102
2020	Bauer/Weiss	cattle	none	17.461	131	90
2020	Lengacher	arable	none	17.461	124	110
2020	Beiler	arable	none	17.461	128	136
2019	Zinniker	cattle	manured	FOS8500	200	100
2019	Anibas	cattle	manured	FOS8500	150	100
2019	Anon1	cattle	manured	FOS8500	253	100
2019	Anon2	cattle	manured	FOS8500	228	100
2019	Beiler	arable	manured	FOS8500	173	100
2019	Adsit	arable	manured	FOS8500	81	100
2020	Beiler	arable	manured	FOS8500	117	100
2020	Esch	arable	manured	FOS8500	228	100
2020	MFAI	cattle	manured	FOS8500	50	100
2019	Zinniker	cattle	manured	17.461	207	104
2019	Anibas	cattle	manured	17.461	132	88
2019	Anon1	cattle	manured	17.461	227	90
2019	Anon2	cattle	manured	17.461	164	72
2019	Beiler	arable	manured	17.461	122	71
2019	Adsit	arable	manured	17.461	79	98
2020	Beiler	arable	manured	17.461	94	80
2020	Esch	arable	manured	17.461	207	91
2020	MFAI	cattle	manured	17.461	53	106

Table 4. Analysis of variance for yield trials on 14 sites comparing 17.461 and FOS8500.

		bushels/acre			**yield as % of FOS8500**		
Source	**DF**	**SS**	**F Ratio**	**Prob > F**	**SS**	**F Ratio**	**Prob > F**
system	1	11110	3.1427	0.0915	459	3.2371	**0.0871**
hybrid	1	179	0.0506	0.8243	39	0.2728	0.6072
manuring	1	2906	0.822	0.3754	1255	8.859	**0.0075**
manuring*hybrid	1	1719	0.4864	0.4936	1255	8.859	**0.0075**
system*hybrid	1	326	0.0922	0.7645	459	3.2371	**0.0871**
system*manuring	1	1119	0.3167	0.5799	910	6.4231	**0.0197**
manuring*hybrid*system	1	565	0.1597	0.6936	910	6.4231	**0.0197**

Diagram 1. Yields of 17.461 and FOS8500 across 14 sites over two years.

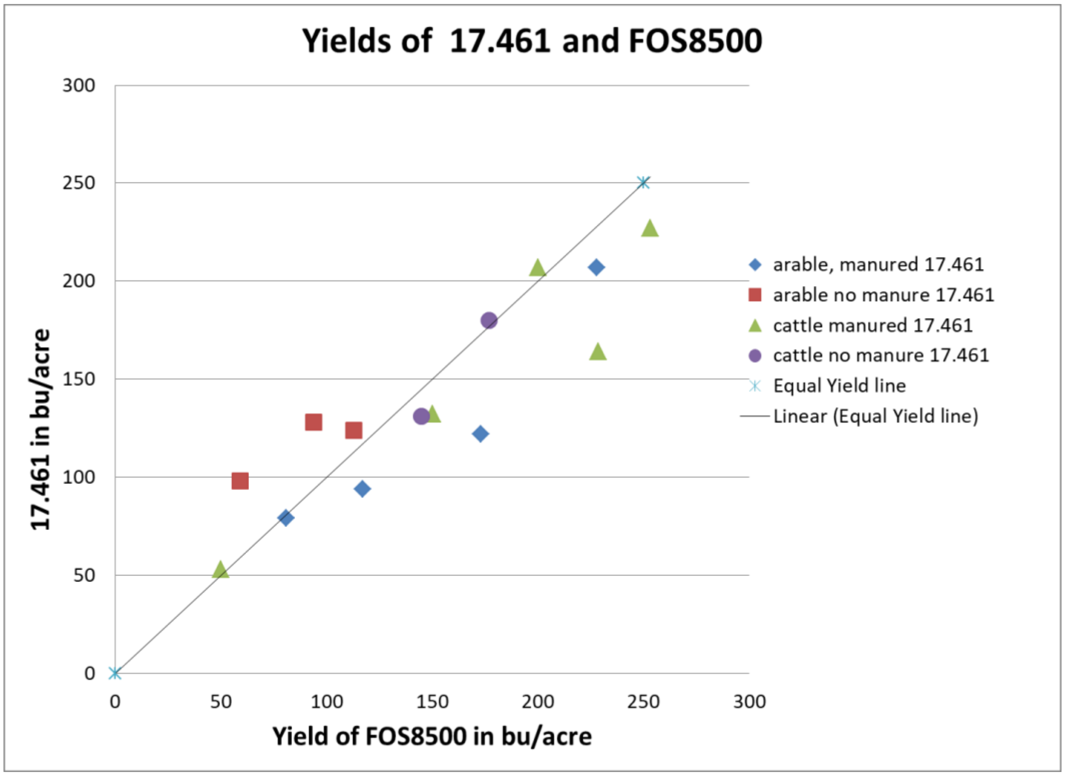


Table 5. Yields of 17.461 and FOS8500 from 14 sites.

Level	no sites	% of FOS check		bu/acre	
system effect					
arable	14	106	a	120	a
cattle	14	97	a	162	a
hybrid effect					
17.461	14	102	a	139	a
FOS8500	14	100	a	144	a
manure effect					
none	10	**108**	a	130	a
manured	18	**94**	b	152	a
system x hybrid interaction					
arable, 17.461	7	**111**	**a**	121	a
arable,FOS8500	7	**100**	**b**	119	a
cattle,17.461	7	**94**	**b**	156	a
cattle,FOS8500	7	**100**	**b**	169	a
manure x hybrid interaction					
none,17.461	5	**117**	a	136	a
none,FOS8500	5	**100**	b	125	a
manured,17.461	9	88	b	141	a
manured,FOS8500	9	100	b	163	a
manure x hybrid x system interaction					
none,17.461,arable	3	**137**	a	117	a
none,FOS8500,arable	3	**100**	b	89	a
none,17.461,cattle	2	96	b	156	a
none,FOS8500,cattle	2	100	b	161	a
manured,17.461,arable	4	85	b	126	a
manured,FOS8500,arable	4	100	b	150	a
manured,17.461,cattle	5	92	b	157	a
manured,FOS8500,cattle	5	100	b	176	a

Table 6. Analysis of variance for five different experiments comparing FOS8500, NG10, and C46 based hybrids.

Source	DF	SS	F Ratio	Prob > F
hybrid	2	2816	1.1162	0.3492
system	1	5610	4.4481	0.0492
manuring	1	363	0.2877	0.5982
system*manuring	1	114	0.0903	0.7673
hybrid*system	2	2553	1.0121	0.3832
hybrid*manuring	2	1022	0.4053	0.6727
hybrid*system*manuring	2	3	0.0012	0.9988

Diagram 2. Interaction between manuring and hybrids on five sites.

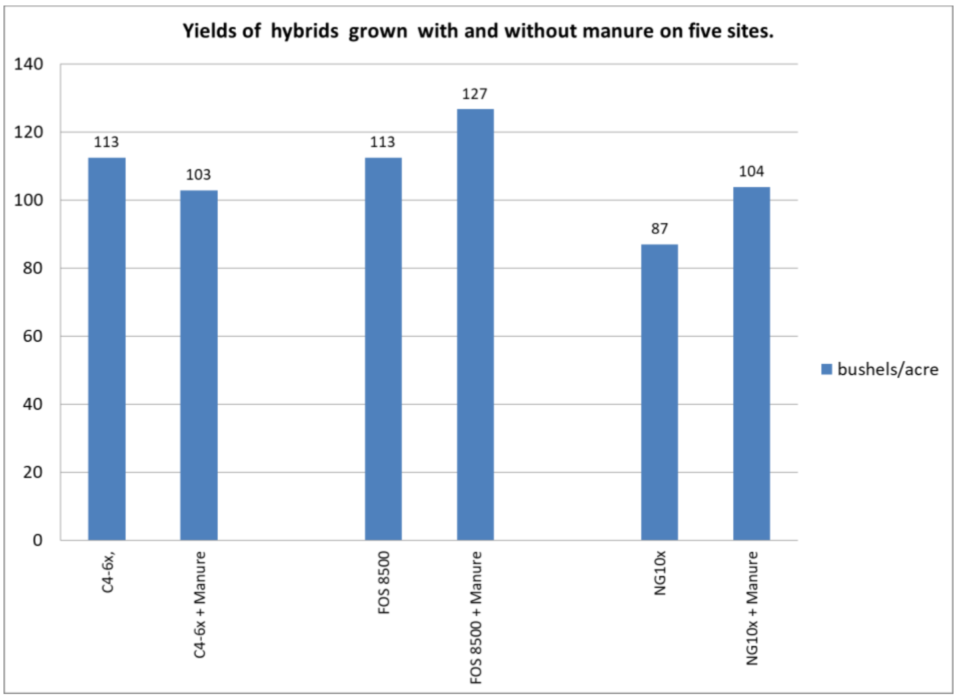


Table 7. Strip trial on the Beiler farm, 2020, showing response to manure for different hybrids. –M and +M indicate not manured and manured plots.

	Grain yield in bushels/acre			total Nitrogen uptake lbs/acre			K + Mg + Ca lbs/acre			P + S in lbs/acre			Cu + Fe + Mn + Zn in lbs/acre		
Hybrids with a positive manure response.															
hybrid	-M	+M	%dif.	-M	+M	%dif.	-M	+M	dif.	-M	+M	%dif.	-M	+M	%dif.
FOS 8500	83	117	41	67	67	0	108	91	-16	46	44	-4	3.75	2.42	-35
924.NG10	68	105	54	72	93	29	66	87	31	36	50	38	1.05	1.09	0
K5N.NG10	53	77	45	110	71	-36	78	59	-24	45	39	-14	2.27	0.80	-65
15.461	65	94	45	58	66	13	68	104	52	35	53	53	1.65	1.24	-25
17.2B24	118	121	3	95	101	6	124	121	-2	50	55	9	2.07	2.67	29
average	77	103	38	81	80	3	89	92	8	42	48	16	2.16	1.64	-19
Hybrids with a negative manure response.															
hybrid	-M	+M	%dif.	-M	+M	%dif.	-M	+M	dif.	-M	+M	%dif.	-M	+M	%dif.
9215.461	100	98	-2	92	68	-26	99	57	-42	48	36	-26	2.27	0.58	-74
9211.461	90	71	-21	75	58	-23	99	76	-23	47	36	-23	2.02	1.13	-44
17.461	128	94	-27	118	78	-34	161	164	2	66	66	0	3.50	3.13	-10
UR65.461	127	91	-28	137	77	-44	161	119	-26	81	55	-32	3.98	1.87	-53
Average	111	89	-20	106	70	-32	130	104	-22	61	48	-20	2.94	1.68	-46

Table 8. Strip trial on the Weiss/Bauer farm, 2019, showing response to manure for different hybrids. –M and +M indicate not manured and manured plots.

	Soil Protein mg/kg			Grain yield in bushels/acre			total Nitrogen uptake lbs/acre			K + Mg + Ca lbs/acre			P + S in lbs/acre			Cu + Fe + Mn + Zn in lbs/acre		
Hybrid	-M	+M	%dif.	-M	+M	%dif.	-M	+M	%dif.	-M	+M	%dif.	-M	+M	%dif.	-M	+M	%dif.
FOS 8500	9.25	10.7	15	177	214	21	196	239	22	300	189	-37	73	67	-9	3.51	4.71	34
17.2B24	10.3	11.4	11	167	172	3	213	280	31	279	285	2	66	86	30	4.18	5.04	21
C2B21.461	9.4	10.4	10	181	169	-7	223	241	8	323	244	-25	72	78	8	3.60	5.00	39
17.461	10.2	11.9	16	180	145	-19	237	222	-6	290	319	10	69	98	42	4.27	5.32	25

Table 9. Soil analysis results for 2019 varietal trials.

Soil	Arable Cropping poultry manure						dairy/beef-based farming with arable cropping								ave. Cash	ave. cow
Parameter	Adsit		Beiler		Doudlah		Anon1		Anon2		Zinniker		Anibas			
	ave.	s.e.	ave.	s.e.	ave.	s.e.	ave.	s.e.	ave.	s.e.	ave.	s.e.	ave.	s.e.		
NH4+ (mg/kg)	**3.0**	0.2	**2.8**	0.1	**1.8**	0.4	**3.1**	0.2	**4.0**	0.3	**5.5**	1.8	**4.1**	1.2	2.5	4.2
NO3- (mg/kg)	**22.3**	0.8	**20.9**	0.4	**22.1**	1.4	**20.2**	0.4	**20.8**	0.6	**21.2**	1.2	**24.5**	1.7	21.8	21.7
Inorganic N (mg/kg)	**25.2**	0.8	**23.7**	0.5	**23.9**	1.4	**23.3**	0.5	**24.8**	0.8	**26.7**	2.6	**28.5**	2.4	24.3	25.8
PMN (mg/kg)	**13.6**	2.8	**35.8**	3.9	**27.0**	2.1	**52.6**	2.2	**54.7**	2.7	**55.4**	2.6	**49.8**	1.8	25.5	53.1
pH	**6.2**	0.1	**7.2**	0.0	**6.9**	0.1	**6.7**	0.1	**6.6**	0.1	**6.7**	0.1	**7.2**	0.0	6.8	6.8
Bray I P (ppm)	**12**	1	**71**	5	**102**	9	**36**	11	**16**	3	**13**	3	**34**	3	61.9	24.5
K* (mg/kg)	**163**	6	**265**	26	**251**	9	**187**	19	**178**	15	**131**	17	**104**	4	226	150
Ca* (mg/kg)	**2755**	59	**3213**	51	**1568**	49	**3138**	87	**2976**	103	**1816**	73	**1835**	33	2512	2441
Mg* (mg/kg)	**792**	26	**1126**	13	**337**	13	**864**	32	**872**	41	**519**	26	**424**	10	752	670
TON (g/kg soil)	**1.2**	0.0	**1.3**	0.0	**0.9**	0.1	**2.0**	0.1	**2.0**	0.1	**1.4**	0.1	**1.4**	0.0	1.2	1.7
TOC (g/kg soil)	**10.4**	0.4	**12.4**	0.5	**8.8**	0.7	**21.1**	0.6	**21.5**	0.7	**14.0**	0.9	**14.4**	0.5	10.5	17.7
C/N ratio	**8.6**	0.2	**9.2**	0.1	**9.7**	0.3	**10.7**	0.1	**11.0**	0.1	**10.1**	0.2	**10.2**	0.1	9.2	10.5
POM-C (g/kg soil)	**1.3**	0.1	**2.3**	0.2	**1.5**	0.1	**2.9**	0.3	**3.1**	0.3	**2.8**	0.2	**3.3**	0.2	1.7	3.0

PMN means potentially mineralizable N. TOC and TON mean total organic carbon and N.

POM-C means particulate organic matter carbon.

Table 10. Comparison of arable organic and cattle organic systems in 2019 varietal trials.

Parameter	scale	Arable Organic	Cattle Organic	p level	Arable/ cattle as %
NH_4^+	mg/kg	2.5	4.4	0.05	57
NO_3^-	mg/kg	21.8	22.1	0.84	99
total inorganic N	mg/kg	24.3	26.4	0.20	92
pH		6.8	6.9	0.83	99
Bray I P	ppm	61.9	24.1	0.24	257
K^+	mg/kg	226.5	139.2	0.09	163
Ca^{2+}	mg/kg	2511.8	2235.8	0.69	112
Mg^{2+}	mg/kg	751.7	603.4	0.61	125
total organic N	g/kg	1.2	1.6	0.13	73
total organic C	g/kg	10.5	16.6	0.08	64
C/N		9.2	10.4	0.04	89
particulate organic matter-C	g/kg	1.7	3.1	0.01	54
potentially mineralizable N	mg/kg	25.5	53.0	0.01	48

Table 11. Relationship between farming systems and September soil test values in 2019.

Parameter	scale	Arable Organic	Cattle Organic	Cattle Conv. Monoc.	differences p level	Arable/cattle as %
Protein	mg/kg	5.0c	7.3b	10.4a	0.0001	68
Protein Score	mg/kg	32.0c	58.8b	87.1a	0.0001	54
CO2 corr. BD	mg/kg	72.2b	89.3a	65.5b	0.0053	81
SLAN	ppm	82.0b	129.0a	119.7a	0.0001	64
Aggregate Stability	%	24.1b	29.0a	6.4c	0.0001	83
NO_3^- N	ppm	14.5c	30.6a	21.7b	0.0001	48
Bulk density	g/cm3	1.11b	1.00c	1.19a	0.0001	110

Table 12. Relationships between spring and fall soil tests in 2019.

	Protein		Protein score		SLAN		Nitrate		Aggregate Stability		Bulk Density		CO2 Respiration	
Parameter & variance	% of total SS	P level	% of total SS	P level	% of total SS	P level	% of total SS	P level	% of total SS	P level	% of total SS	P level	% of total SS	P level
PMN	0.0	0.9144	0.1	0.7664	4.0	0.4496	17.6	0.0052	48.0	0.0896	29.5	<.0001	15.1	0.2442
TON	35.3	<.0001	35.4	<.0001	39.5	0.0198	27.6	0.0006	1.2	0.7882	5.3	0.0663	35.1	0.0784
TOC	33.7	<.0001	33.8	<.0001	31.5	0.0363	27.4	0.0006	0.5	0.8626	3.9	0.1163	35.8	0.0753
C/N	30.6	<.0001	30.5	<.0001	24.8	0.0623	20.2	0.0029	2.4	0.6975	2.9	0.1695	13.8	0.2641
POM	0.3	0.4816	0.2	0.5517	0.2	0.8498	7.1	0.0702	48.0	0.0896	58.3	<.0001	0.2	0.9052
%N,C,C/N	99.6		99.7		95.8		75.3		4.1		12.1		84.8	
R2 Model%	85	<.0001	86	<.0001	77	<.0001	67	<.0001	39	<.0001	73	<.0001	23	0.0211

Table 13. Effects of hybrids on soil characteristics in 2019 varietal trials.

hybrid averages	SLAN	Nitrate	Aggregate Stability
	mg/l	ppm	Vol%
17.C2B2-4	106.7	18.8	22.0
17.461	109.0	20.0	21.1
C2B2-2.461	108.6	24.5	18.1
FOS8500	116.7	25.7	18.1
Contrasts	level of p		
17.C2B24:FOS8500	0.1010	0.0178	0.0363
17.461:FOS8500	0.2070	0.0475	0.1092
C2B2.C46:FOS8500	0.1828	0.6633	0.9819
both 17's:FOS8500	0.0956	0.0129	0.0340

Table 14. Overall yields from varietal trials in 2019

Hybrid Combination 2019 strip trials.										
Farm	system	**FOS8500**	**15.C4-6**	**17.461**	**17.2B24**	**C2B2-1.4-6**	**C2B24-7.C46**	**C46.9.2)-11**	**NG10-2-3-2.Md1**	**average yield**
		bushels/acre								
Adsit	cash	81	60	79	112	70	65	16	11	**62**
Beiler	cash	173	112	122	103	139	148	154	152	**138**
Doudlah	cash	59	141	98	122	95	105	148	102	**109**
Anibas	dairy	150	154	132	131	123	115	105	127	**130**
Anon1	dairy	253	194	227	215	185	204	140	169	**198**
Anon2	dairy	228	161	164	188	151	209	92	191	**173**
Weiss/Bauer	dairy	214	161	145	172	169	124	144	170	**162**
Weiss/Bauer	dairy	177	204	180	167	181	130	138	116	**162**
Zinniker	beef	200	177	207	171	172	180	158		**181**
ave		**170**	**152**	**151**	**153**	**143**	**142**	**122**	**130**	**145**
Plots in blue were not fertilized (Doudlah), or fertilized with lower level of nutrients (Weiss/Bauer).										

Table 15. Yield results for manured and not manured trials and for arable cash and cattle based trials in 2019.

Hybrid Combination 2019 strip trials.										
Farm		FOS8500	15.C4-6	17.461	17.2B24	C2B2-1.4-6	C2B24-7.C46	C46.9.2)-11	NG10-2-3-2.Md1	average yield
		bushels/acre								
Ave with manure		185	146	154	156	144	149	116	137	**149**
Ave. without manure		118	172	139	145	138	118	143	109	**135**
Ave cash		104	104	100	112	101	106	106	89	**103**
Ave cow		203	175	176	174	164	160	130	155	**168**

Table 16. Grain yield and mineral uptake as affected by hybrid and farming systems in 2019.

Farming System	Hybrid	Grain DM	Grain N	Stalk N	Root N	Total N	Micronutrient uptake	Macronutrient uptake
		values as % of FOS8500						
arable crop organic	17.461	**95**	**94**	**166**	**42**	**107**	**97**	**109**
arable crop organic	17.2B24	**97**	**97**	**187**	**67**	**115**	**115**	**108**
arable crop organic	C2B2-1.C46	**101**	**101**	**174**	**83**	**116**	**123**	**107**
arable crop organic	FOS8500	**100**	**100**	**100**	**100**	**100**	**100**	**100**
cattle based organic	17.461	**91**	**105**	**143**	**110**	**112**	**134**	**123**
cattle based organic	17.2B24	**85**	**86**	**150**	**98**	**98**	**136**	**114**
cattle based organic	C2B2-1.C46	**77**	**80**	**103**	**94**	**85**	**112**	**96**
cattle based organic	FOS8500	**100**	**100**	**100**	**100**	**100**	**100**	**100**
cattle mono corn conv	17.461	**83**	**98**	**126**	**97**	**106**	**115**	**126**
cattle mono corn conv	17.2B24	**87**	**92**	**122**	**241**	**114**	**110**	**125**
cattle mono corn conv	C2B2-1.C46	**90**	**106**	**82**	**203**	**107**	**107**	**110**
cattle mono corn conv	FOS8500	**100**	**100**	**100**	**100**	**100**	**100**	**100**
average across systems	17.461	**90**	**99**	**145**	**83**	**108**	**115**	**119**
average across systems	17.2B24	**89**	**92**	**153**	**135**	**109**	**120**	**116**
average across systems	C2B2-1.C46	**89**	**96**	**120**	**127**	**103**	**114**	**105**
average across systems	FOS8500	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 17. Grain, stalk (stover) and root yields, harvest index (HI), total N, and the percentage of total N in grain for hybrid variety trials in 2019.

	grain	grain	stalks	roots	total dm	HI	total N	N in grain
Farming System	bu/acre	lbs dm/a				%	lbs/a	%
Arable organic/poultry	114c	5,388c	4,072c	830.4c	10,291c	56b	92c	62b
Organic cattle based	195a	9,202a	4,646b	985b	14,833b	67a	173b	73a
Conv. Mono. Cattle	176b	8,303b	6,143a	2597a	17,054a	57b	231a	58b
Hybrid	bu/a	lbs dm/a				HI	lbs/a	%
17.2B24	156 b	7,384b	5,268a	1,759a	14,411a	58b	172a	60b
17.461	158b	7,471b	5,491a	1,118b	14,080a	57b	172a	63ab
C2B2.C46	156b	7,290b	4,626b	1,759a	13,675a	61a	159a	65ab
FOS8500	177a	8,389a	4,430b	1,248b	14,057a	64a	159a	69a
Mandaamin vs FOS in %	89	89	112	124	100	92	105	91
Contrast	level of p							
two 17's and FOS8500	**0.0038**	**0.0038**	**0.0001**	0.2667	0.72	**0.0001**	0.3914	**0.0219**

Table 18 shows results of analysis of variance examining effects of covariates on nutrient uptake per acre.

		N	C	Al 237	Ca	Cu	Fe	K	Mg	Mn	P 177	S 180	Si	Sr	Ti	Zn
Source	DF	Prob > F														
Pedigree	3	0.7375	0.9183	0.7177	**0.0087**	0.9319	0.1455	0.5503	0.3698	0.4522	0.712	0.5128	**0.0476**	**0.0353**	**0.0162**	0.5401
system	2	**0.0109**	**0.0225**	0.2842	0.577	0.4194	**0.0623**	**0.0005**	0.8198	**0.0043**	**0.0091**	**0.007**	0.905	**0.012**	**0.0052**	0.531
system*Pedigre	6	0.7671	0.7579	0.9935	0.7088	0.7465	0.1905	0.667	0.8929	0.1653	0.9026	0.3857	0.3805	0.5669	0.2993	0.9583
δ15N grain (‰)	1	**0.06**	**0.0357**	0.1092	0.2515	0.4025	**0.001**	**0.0938**	0.3084	**0.0357**	0.1577	**0.0133**	0.1135	**0.0222**	**0.0002**	0.4578
δ15N root (‰)	1	0.7931	0.7978	0.6029	0.7694	0.7803	0.1252	0.4409	0.9514	0.4639	0.5586	0.7645	0.4974	0.3458	0.9799	0.5521
δ15N stalk (‰)	1	0.9101	0.9442	0.4	0.3283	0.4564	0.2935	0.6238	0.4699	0.9791	0.2557	0.7935	0.8493	0.4679	0.8714	0.6717
plants/acre	1	0.8399	0.1616	0.4334	0.4341	0.8369	0.1317	**0.0824**	0.434	**0.0926**	0.7906	**0.0974**	0.1937	0.1688	0.1474	0.9188
%SS Pedigree		5	2	14	74	6	12	4	42	6	5	6	48	30	21	37
%SS system		64	50	30	4	27	14	75	5	47	70	45	1	34	23	22
%SS Sys x Ped		12	13	6	12	47	20	7	24	25	8	17	29	11	9	21
%SS δ15N grain		18	25	33	5	11	43	6	14	13	9	23	12	17	44	10
%SS δ15N stalk		0	0	3	0	1	5	1	0	1	1	0	2	2	0	6
%SS δ15N root		0	0	8	3	8	2	0	7	0	6	0	0	1	0	3
%SS plants/a		0	9	7	2	1	5	7	8	7	0	8	8	5	3	0

Diagram 3. Relationship between δN^{15} and uptake of nutrients.

Relationship between the $\delta^{15}N$ isotope ratio in the grain and the total uptake of different minerals/acre.

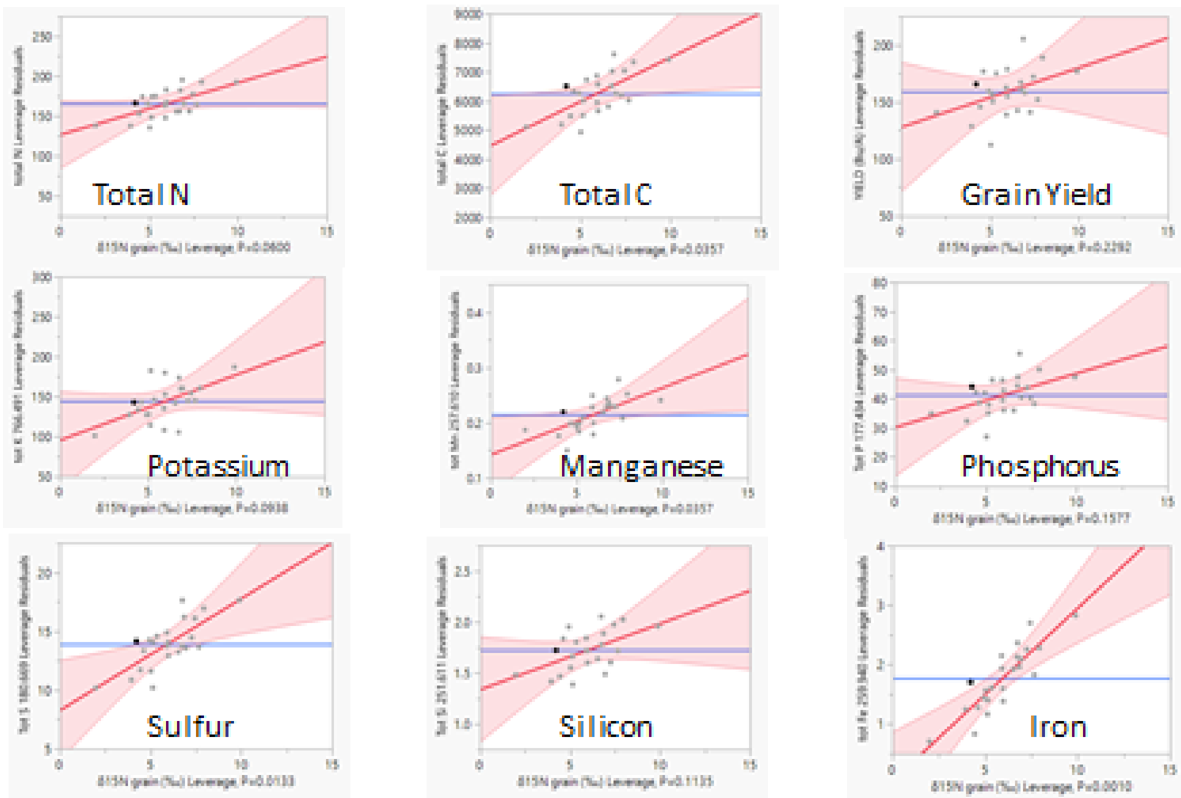


Table 19. Relationship between soil tests and crop performance for variety trials in 2019.

	grain yld	stlk yld	root yld	N yld	C yld	%N	delta15N	
	level of p							
protein	**0.06**	1.00	**0.05**	**0.10**	**0.01**	0.69	0.46	
protein score	**0.01**	0.27	0.21	**0.00**	**0.00**	0.17	0.21	
CO2 corr to BD	0.86	0.54	0.57	0.30	0.46	0.93	0.40	
SLAN ppm	0.23	0.87	0.93	0.29	0.47	0.66	0.86	
Aggregate Stability	0.77	0.07	0.16	**0.06**	**0.02**	0.52	**0.01**	
Nitrate N	0.47	**0.00**	0.86	0.83	0.35	0.94	0.52	
BD g/cc	**0.01**	**0.01**	0.90	**0.05**	**0.00**	0.64	**0.07**	
	grain yld	stlk yld	root yld	N yld	C yld	%N	delta15N	Average
	% of total SS							
protein	19	0	50	12	18	5	4	16
protein score	33	6	20	46	35	66	12	31
CO2 corr to BD	0	2	4	5	1	0	6	3
SLAN ppm	7	0	0	5	1	7	0	3
Aggregate Stability	0	16	25	16	17	14	49	20
Nitrate N	3	45	0	0	2	0	3	8
BD g/cc	37	32	0	16	25	7	25	20
R2 Model	0.75	0.72	0.57	0.90	0.83	0.73	0.40	
p level model	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0027	

Diagram 4. The $\delta^{15}N$ values for hybrids and their plant parts.

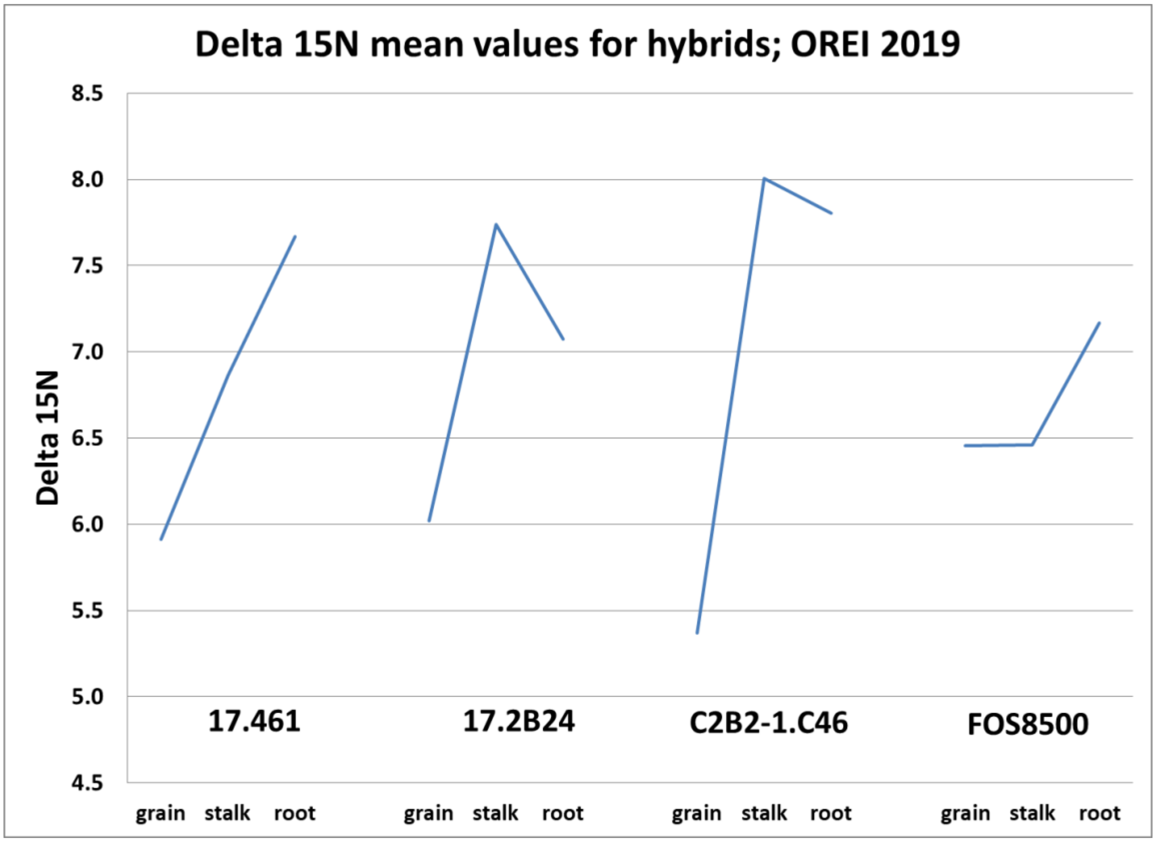


Table 20. Data for %N and δ[15]N levels of hybrids grown in 2019.

		%N			delta 15N		
hybrid	Part	mean	stdev	cv	mean	stdev	cv
17.461	grain	1.44	0.29	0.20	5.94	1.99	0.33
17.461	stalk	0.91	0.21	0.23	6.75	2.58	0.38
17.461	root	0.71	0.22	0.31	8.00	2.16	0.27
17.2B24	grain	1.32	0.25	0.19	6.08	4.01	0.66
17.2B24	stalk	0.99	0.23	0.23	7.79	2.36	0.30
17.2B24	root	0.76	0.31	0.41	7.08	3.28	0.46
C2B2-1.C46	grain	1.36	0.30	0.22	5.28	2.88	**0.54**
C2B2-1.C46	stalk	0.83	0.09	0.11	7.89	3.74	0.47
C2B2-1.C46	root	0.72	0.35	0.49	7.32	4.89	0.67
FOS8500	grain	1.27	0.18	0.14	6.27	2.66	0.42
FOS8500	stalk	0.83	0.27	0.33	5.41	0.98	0.18
FOS8500	root	0.74	0.23	0.32	6.38	1.58	0.25

Diagram 5. The δ[15]N values for hybrids and their plant parts grown in different farming systems.

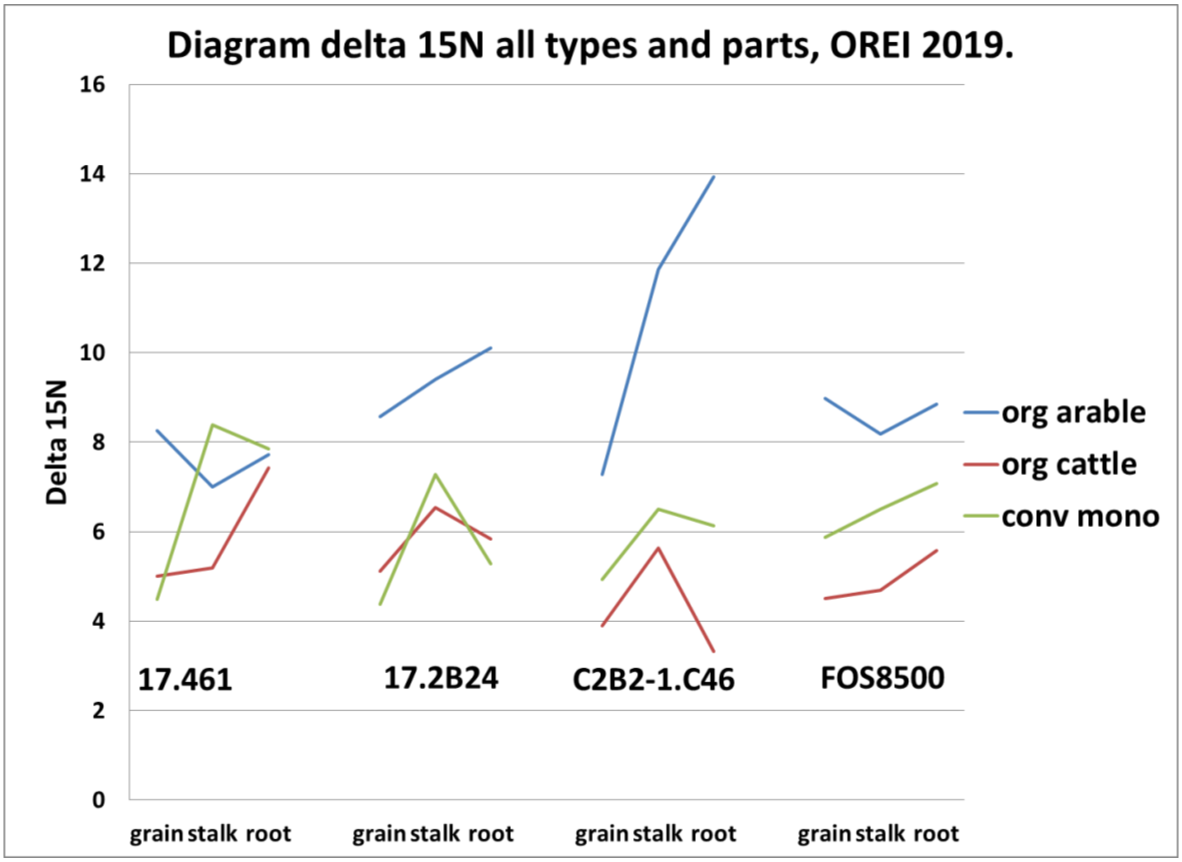


Table 21. Estimates of nitrogen derived from air (NDFA) and microbial biomass in 2019.

Hybrid	arable organic	cattle based organic	conv cattle mono	average
	best estimate %NDFA			
17.2B24	15	22	**40**	26
17.461	8	33	**47**	29
C2B2C46	**48**	31	24	34
FOS8500	-1	19	17	12
average	17	26	32	

	arable organic	cattle based organic	conv cattle mono	average
Hybrid	N from microbial biomass, available OM			
17.2B24	-15	-39	-12	-22
17.461	13	-33	-29	-16
C2B2C46	-58	-20	0	-26
FOS8500	0	0	0	0
ave Mand	-20	-31	-14	

Diagram 6. Relationship between %N and $\delta^{15}N$ in grain for different farming systems.

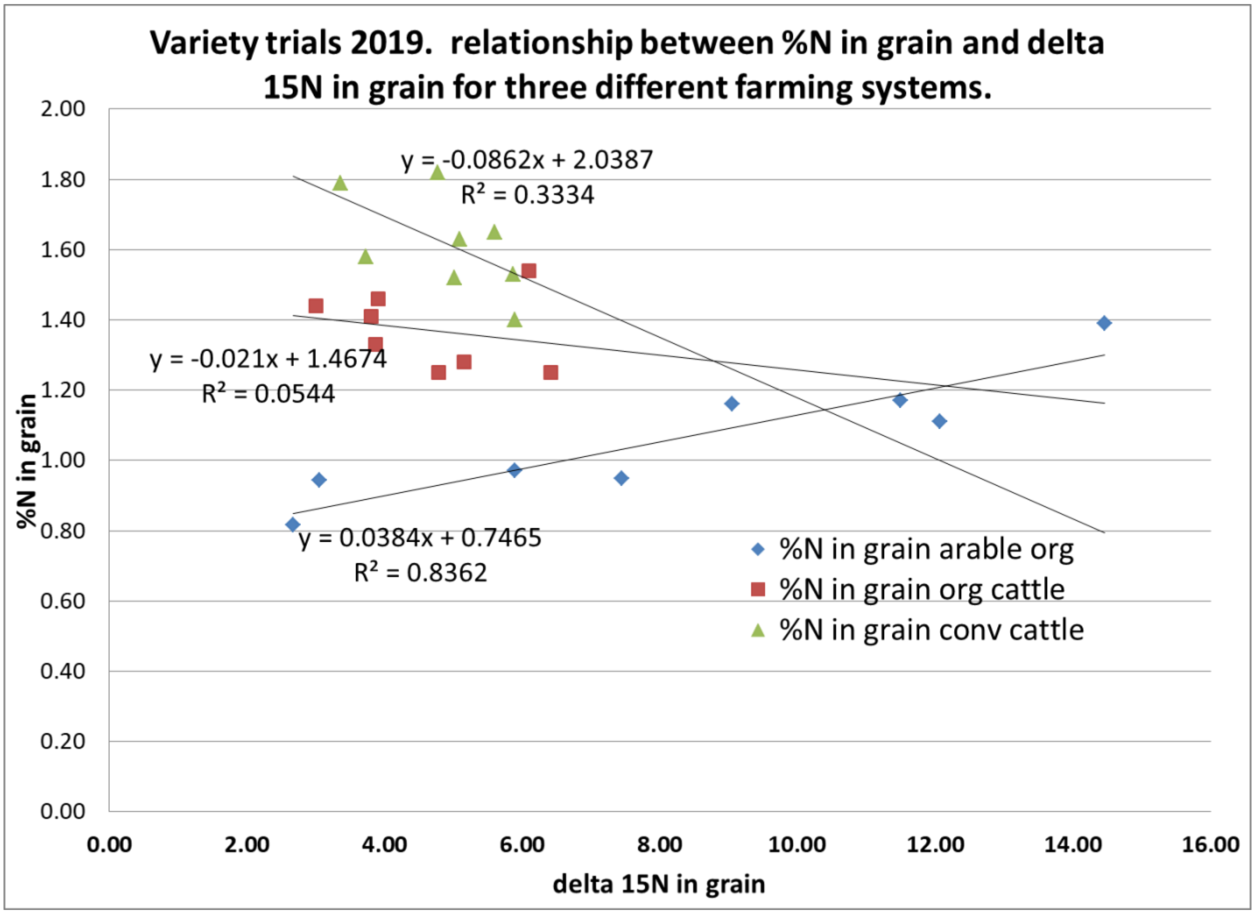


Table 22. Analysis of variance for different macronutrients in plant tissues in 2019 hybrid trials.

Significance of analysis of variance factor for the concentration of different macronutrients							
		%N	Ca	K	Mg	P	S
Source of variation	Df	Prob > F	Prob > F	Prob > F	Prob > F	Prob > F	Prob > F
system	2	**<.0001**	**0.03**	**<.0001**	**0.00**	**<.0001**	**0.07**
plant part	2	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**
Pedigree	3	0.44	**0.04**	0.34	0.69	0.47	0.91
system x plant part	4	**0.10**	0.25	**0.00**	**0.00**	**0.00**	**0.07**
System x Pedigree	6	0.91	0.87	0.97	0.96	0.98	0.79
plant part x pedigree	6	0.64	**0.01**	0.31	0.88	**0.05**	0.39
system x plant part x pedigree	12	0.76	0.99	0.99	0.98	0.25	0.71
% variation associated with pedigree		5	5	6	6	13	28

Significance of analysis of variance factor for the concentration of different micronutrients									
		Al 237	Cu	Fe	Mn	Si	Sr	Ti	Zn
Source of variation	Df	Prob > F	Prob > F	Prob > F	Prob > F	Prob > F	Prob > F	Prob > F	Prob > F
system	2	**0.01**	**0.08**	**0.02**	**<.0001**	**0.01**	0.14	**0.01**	0.56
plant part	2	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**0.00**
Pedigree	3	0.27	**0.04**	0.37	0.17	0.83	**0.01**	0.48	**0.00**
system x plant part	4	**0.00**	**0.00**	**0.00**	**<.0001**	**0.02**	0.57	**0.00**	0.25
System x Pedigree	6	0.93	**0.00**	0.73	0.12	0.88	0.86	0.77	**0.01**
plant part x pedigree	6	0.24	**0.00**	0.45	**0.10**	0.86	**0.00**	0.63	**0.00**
system x plant part x pedigree	12	0.96	**<.0001**	0.85	0.37	0.99	0.94	0.87	**0.00**
% variation associated with pedigree		18	64	24	11	2	3	13	83

Table 23. Concentration of minerals in hybrid tissue parts, hybrid trials 2019.

Part x hybrid	N	Ca	K	Mg	P 177	S 180	relative to FOS
	%	average in µg/g					%
Corn,17.2B24	1.33	37	4172	1122	3062	1038	106
Corn,17.461	1.43	42	4114	1244	3382	1082	114
Corn,C2B2-1.C46	1.38	36	4072	1233	3343	1192	112
Corn,FOS8500	1.27	35	3911	1073	2828	980	100
Stalk,17.2B24	1.00	3804	16168	2587	2872	954	112
Stalk,17.461	0.93	3614	17715	2649	3241	960	113
Stalk,C2B2-1.C46	0.85	2867	17146	2362	2442	800	97
Stalk,FOS8500	0.89	2715	16034	2249	3104	867	100
Root,17.2B24	0.77	1183	13610	1266	1089	718	91
Root,17.461	0.71	1136	18038	1199	1260	740	94
Root,C2B2-1.C46	0.75	1318	15279	1101	1784	737	100
Root,FOS8500	0.70	1134	20025	1263	1483	795	100
std error	0.06	169	1556	195	224	80	

Part x Hybrid	Al237	Cu	Fe	Mn	Si	Sr	Ti	Zn	relative to FOS
	average in µg/g								%
Corn,17.2B24	50	1.94	41	4.4	6	0.07	0.16	16.9	106
Corn,17.461	59	3.91	61	5.7	6	0.08	0.15	26.3	130
Corn,C2B2-1.C46	51	2.21	46	4.3	5	0.07	0.16	20.9	106
Corn,FOS8500	39	3.90	45	4.2	3	0.08	0.15	20.2	100
Stalk,17.2B24	88	7.88	193	35.6	334	7.18	2.06	29.0	104
Stalk,17.461	88	7.15	171	30.0	319	6.50	1.68	29.9	95
Stalk,C2B2-1.C46	80	7.07	196	31.0	290	5.73	1.84	26.2	93
Stalk,FOS8500	84	8.74	184	35.6	316	5.49	1.64	40.2	100
Root,17.2B24	294	3.81	405	17.5	124	2.56	7.18	5.2	101
Root,17.461	245	10.46	241	10.5	99	2.49	5.62	38.8	137
Root,C2B2-1.C46	490	9.09	608	24.0	128	2.89	9.52	25.0	167
Root,FOS8500	234	4.36	339	18.2	113	2.38	6.31	11.5	100
std error	58	1.07	89	2.6	21	0.21	1.13	4.0	

Table 24. Concentration of mineral macronutrients in hybrids grown in variety trials in 2019.

system x pedigree	N	Ca	K	Mg	P 177	S 180	relative to FOS
	%			µg/g			%
arable organic,17.2B24	0.80	1518	11526	1479	2440	793	100
arable organic,17.461	0.74	1413	12525	1568	2756	902	104
arable organic,C2B2-1.C	0.80	1477	12145	1538	2561	850	103
arable organic,FOS8500	0.73	1281	13470	1565	2516	829	100
cattle organic,17.2B24	1.00	1926	8664	1948	1760	883	107
cattle organic,17.461	1.03	1837	10147	1984	1816	851	109
cattle organic,C2B2-1.C4	0.92	1554	8195	1876	1862	928	101
cattle organic,FOS8500	0.92	1424	9509	1790	1776	918	100
conv mono,17.2B24	1.30	1579	13760	1548	2823	1034	109
conv mono,17.461	1.30	1542	17195	1540	3312	1030	114
conv mono,C2B2-1.C46	1.26	1189	16157	1283	3146	951	102
conv mono,FOS8500	1.21	1180	16990	1228	3123	895	100
std error	0.06	169	1556	195	224	80	

system x pedigree	Al 237	Cu	Fe	Mn	Si	Sr	Ti	Zn	relative to FOS
				µg/g					%
arable organic,17.2B24	190	3.2	305	19.2	172	3.29	4.39	16.4	106
arable organic,17.461	171	10.0	177	16.4	126	3.02	2.37	42.3	119
arable organic,C2B2-1.C46	266	3.3	487	27.9	152	3.03	5.95	18.9	131
arable organic,FOS8500	143	4.1	252	23.7	152	2.91	3.31	22.6	100
cattle organic,17.2B24	177	6.1	228	26.3	171	3.17	3.62	17.8	114
cattle organic,17.461	139	6.1	191	18.0	166	2.79	3.46	20.7	102
cattle organic,C2B2-1.C46	273	9.9	245	21.1	161	2.80	3.95	31.6	136
cattle organic,FOS8500	143	5.5	199	21.7	166	2.40	3.27	19.4	100
conv mono,17.2B24	66	4.3	107	11.9	120	3.35	1.39	16.9	90
conv mono,17.461	82	5.4	103	11.7	131	3.27	1.62	32.0	103
conv mono,C2B2-1.C46	82	5.2	118	10.4	109	2.86	1.62	21.6	94
conv mono,FOS8500	71	7.4	117	12.7	115	2.65	1.52	29.9	100
std error	58	1.1	89	2.6	21	0.21	1.13	4.0	

Table 25. Total uptake of macro nutrients in hybrid corn grown in different farming systems in 2019.

		Total C	total N	Ca	K	Mg	P177	S180
system	hybrid	lbs/acre						
arable crop organic	17.461	4500	90	5.0	34.1	5.8	10.8	3.1
arable crop organic	17.2B24	4645	97	5.4	34.1	5.5	9.4	2.9
arable crop organic	C2B2-1.C46	4592	98	4.3	34.7	5.6	10.1	3.3
arable crop organic	FOS8500	4500	84	3.9	33.6	5.6	10.3	2.9
cattle-based organic	17.461	7120	196	7.8	35.6	9.6	12.6	5.0
cattle-based organic	17.2B24	6609	172	7.5	34.1	8.6	11.7	4.6
cattle-based organic	C2B2-1.C46	5913	149	5.1	27.9	7.9	10.9	4.5
cattle-based organic	FOS8500	6872	175	4.3	33.0	7.3	11.8	5.1
cattle mono corn conv	17.461	7227	230	8.7	83.4	9.4	21.5	6.3
cattle mono corn conv	17.2B24	8025	247	9.1	75.4	9.6	18.8	6.6
cattle mono corn conv	C2B2-1.C46	7823	233	6.0	80.8	7.8	19.0	6.1
cattle mono corn conv	FOS8500	7392	217	5.5	68.9	7.1	18.0	5.3
average	17.461	6282	172	7.2	51.0	8.3	15.0	4.8
average	17.2B24	6426	172	7.3	47.9	7.9	13.3	4.7
average	C2B2-1.C46	6109	160	5.1	47.8	7.1	13.3	4.6
average	FOS8500	6254	159	4.5	45.2	6.7	13.4	4.4

Table 26. Total uptake of nutrients relative to the commercial check FOS8500 when grown in different farming systems in 2019.

		total C	total N	Ca	K	Mg	P177	S180	Average w/o C
system	hybrid	lbs/acre of macronutrients as % of FOS8500							
arable crop organic	17.461	100	**107**	**130**	102	104	**105**	**106**	**109**
arable crop organic	17.2B24	103	**115**	**141**	102	98	**91**	101	**108**
arable crop organic	C2B2-1.C46	102	**116**	**112**	103	100	98	**112**	**107**
arable crop organic	FOS8500	100	100	100	100	100	100	100	100
cattle-based organic	17.461	104	**112**	**183**	**108**	**131**	**107**	98	**123**
cattle-based organic	17.2B24	96	98	**175**	103	**118**	99	**91**	**114**
cattle-based organic	C2B2-1.C46	**86**	**85**	**119**	**84**	**108**	**92**	**90**	**96**
cattle-based organic	FOS8500	100	100	100	100	100	100	100	100
cattle mono corn conv	17.461	98	**106**	**158**	**121**	**132**	**119**	**119**	**126**
cattle mono corn conv	17.2B24	**109**	**114**	**166**	**109**	**134**	104	**124**	**125**
cattle mono corn conv	C2B2-1.C46	**106**	**107**	**110**	**117**	**109**	**105**	**114**	**110**
cattle mono corn conv	FOS8500	100	100	100	100	100	100	100	100
average	17.461	100	**108**	**157**	**110**	**122**	**110**	**108**	**119**
average	17.2B24	103	**109**	**161**	**105**	**117**	98	**105**	**116**
average	C2B2-1.C46	98	103	**113**	102	**106**	98	**105**	**105**
average	FOS8500	100	100	100	100	100	100	100	100
average Mandaamin		100	**107**	**144**	**106**	**115**	102	**106**	**113**

Table 27. Total uptake of micromineras in hybrid corn grown in different farming systems in 2019.

		Al237	Cu	Fe	Mn	Si	Sr	Ti	Zn
arable crop organic	hybrid	lbs/acre							
arable crop organic	17.461	0.228	0.015	0.346	0.057	0.417	0.010	0.003	0.088
arable crop organic	17.2B24	0.293	0.012	0.544	0.053	0.548	0.011	0.007	0.074
arable crop organic	C2B2-1.C46	0.373	0.010	0.767	0.064	0.421	0.009	0.008	0.075
arable crop organic	FOS8500	0.223	0.013	0.467	0.060	0.445	0.009	0.004	0.099
cattle-based organic	17.461	0.454	0.032	0.775	0.085	0.732	0.011	0.007	0.124
cattle-based organic	17.2B24	0.521	0.024	0.700	0.115	0.665	0.013	0.009	0.097
cattle-based organic	C2B2-1.C46	0.452	0.023	0.595	0.073	0.547	0.009	0.007	0.105
cattle-based organic	FOS8500	0.326	0.021	0.525	0.079	0.512	0.007	0.007	0.101
cattle mono corn conv	17.461	0.445	0.032	0.543	0.072	0.762	0.018	0.006	0.190
cattle mono corn conv	17.2B24	0.414	0.026	0.609	0.073	0.715	0.019	0.006	0.113
cattle mono corn conv	C2B2-1.C46	0.518	0.029	0.641	0.059	0.577	0.014	0.007	0.127
cattle mono corn conv	FOS8500	0.401	0.046	0.555	0.067	0.541	0.012	0.004	0.161
average	17.461	0.38	0.03	0.55	0.07	0.64	0.01	0.01	0.13
average	17.2B24	0.41	0.02	0.62	0.08	0.64	0.01	0.01	0.09
average	C2B2-1.C46	0.45	0.02	0.67	0.07	0.52	0.01	0.01	0.10
average	FOS8500	0.32	0.03	0.52	0.07	0.50	0.01	0.01	0.12

Table 28. Total uptake of microelements relative to commercial check when grown in different systems in 2019.

		Al237	Cu	Fe	Mn	Si	Sr	Ti	Zn	average
system	hybrid	lbs/acre of micronutrients as % of FOS8500								
arable crop organic	17.461	102	120	**74**	**95**	94	121	78	89	97
arable crop organic	17.2B24	131	**90**	116	**88**	123	132	163	**74**	115
arable crop organic	C2B2-1.C46	167	**81**	164	108	**95**	102	188	**76**	123
arable crop organic	FOS8500	100	100	100	100	100	100	100	100	100
cattle-based organic	17.461	139	151	148	109	143	153	109	123	134
cattle-based organic	17.2B24	160	116	133	146	130	176	127	96	136
cattle-based organic	C2B2-1.C46	139	112	113	**93**	107	121	110	104	112
cattle-based organic	FOS8500	100	100	100	100	100	100	100	100	100
cattle mono corn conv	17.461	111	**71**	98	107	141	148	126	118	115
cattle mono corn conv	17.2B24	103	**57**	110	110	132	159	139	**70**	110
cattle mono corn conv	C2B2-1.C46	129	**64**	115	**88**	107	120	153	**78**	107
cattle mono corn conv	FOS8500	100	100	100	100	100	100	100	100	100
average	17.461	**118**	**114**	**106**	**104**	**126**	**141**	**104**	**110**	**115**
average	17.2B24	**131**	**88**	**120**	**115**	**128**	**156**	**143**	**80**	**120**
average	C2B2-1.C46	**145**	**86**	**131**	96	**103**	**114**	**150**	**86**	**114**
average	FOS8500	100	100	100	100	100	100	100	100	100
average Mandaamin		**131**	96	**119**	**105**	**119**	**137**	**132**	92	**116**

Table 29. Analysis of variance for total mineral uptake in the varietal trials of 2019 that evaluated the pedigree x mineral interaction.

Source	DF	Sum of Sq	F Ratio	Prob > F
system	2	1734	0.76	0.47
hybrid	3	30034	8.73	<.0001
system*hybrid	6	7375	1.07	0.38
mineral	14	34055	2.12	0.01
system*mineral	28	29297	0.91	0.60
hybrid*mineral	42	41798	0.87	0.70
system*hybrid*mineral	84	26225	0.27	1.00

Table 30. LS mean values for the relative uptake of nutrients by hybrids based on FOS8500 as a standard for the varietal trials in 2019.

	hybrid				
Element	FOS8500	17.461	17.2B24	C2B2-1.C46	Ave. Mandaamin
	uptake/acre in % relative to FOS8500				
Al	100	136	125	145	135
C	100	106	108	101	105
Ca	100	162	163	116	147
Cu	100	129	93	92	104
Fe	100	118	117	128	121
K	100	119	112	106	112
Mg	100	130	123	111	121
Mn	100	106	114	98	106
N	100	114	111	105	110
P	100	122	107	105	111
S	100	114	111	109	111
Si	100	125	128	102	118
Sr	100	145	155	117	139
Ti	100	106	135	149	130
Zn	100	130	94	100	108
Average	100	124	120	112	

Table 31. Yield and grain quality of nine hybrids grown on five sites in the varietal trials of 2020.

RM	Hybrid	Grain Yield				Stover Yield		Harvest Index		Grain Protein		Grain Oil		Grain Starch		Grain Density		Ethanol Yield		Lysine		Methionine		Cysteine	
days		bu/acre		lbs dm/acre				%								g/cm^3		gal/bu		% in whole grain					
105	FOS 8500	130	a	6,173	a	7,908	bcd	47.2	a	5.88	c	4.07	d	61.2	a	1.172	b	2.84	a	0.275	d	0.197	c	0.157	d
108	17.2B24	96	ab	4,558	ab	7,987	bc	39.8	a	6.65	bc	4.33	abcd	59.9	b	1.176	b	2.77	b	0.305	bc	0.239	ab	0.180	abc
105	17.461	128	a	6,033	a	11,077	a	37.0	a	6.72	bc	4.40	abc	59.9	b	1.191	ab	2.77	b	0.304	bc	0.239	ab	0.177	abc
105	UR65.461	93	ab	4,400	ab	8,218	bc	38.3	a	6.36	bc	4.58	a	59.8	bc	1.167	b	2.77	b	0.317	abc	0.228	b	0.169	cd
103	15.461	90	ab	4,241	ab	7,941	bcd	37.7	a	7.16	ab	4.15	cd	59.5	bc	1.209	a	2.74	bc	0.316	abc	0.259	a	0.187	a
97	9215.461	79	b	3,759	b	5,613	cd	45.0	a	7.19	ab	4.55	ab	59.0	cd	1.178	ab	2.73	bc	0.325	ab	0.246	ab	0.181	abc
96	924.461	83	b	3,928	b	7,410	bcd	38.7	a	6.29	bc	4.50	ab	59.9	b	1.179	ab	2.78	b	0.303	c	0.235	ab	0.171	bcd
96	924.NG10	73	b	3,464	b	5,144	d	44.0	a	6.94	ab	4.28	bcd	59.6	bc	1.173	b	2.75	bc	0.317	abc	0.242	ab	0.179	abc
92	K5N.NG10	112	ab	5,293	ab	9,505	ab	38.8	a	7.65	a	4.53	ab	58.6	d	1.168	b	2.70	c	0.336	a	0.254	a	0.186	ab
	ave. Mand	94		4,459		7,862		40		6.87		4.41		59.5		1.180		2.75		0.315		0.243		0.179	

Table 32. Yield and grain quality of nine hybrids grown on five sites relative to commercial check.

RM	Hybrid	Grain Yield		Stover Yield	Harvest Index	Grain Protein	Grain Oil	Grain Starch	Grain Density	Ethanol Yield	Lysine	Methionine	Cysteine
days		values as % of FOS8500											
105	FOS 8500	100	100	100	100	100	100	100	100	100	100	100	100
108	17.2B24	74	74	101	84	113	106	98	100	97	111	121	114
105	17.461	98	98	140	79	114	108	98	102	97	111	121	113
105	UR65.461	71	71	104	81	108	112	98	100	98	115	115	108
103	15.461	69	69	100	80	122	102	97	103	97	115	131	119
97	9215.461	61	61	71	95	122	112	96	101	96	118	125	115
96	924.461	64	64	94	82	107	110	98	101	98	110	119	109
96	924.NG10	56	56	65	93	118	105	97	100	97	115	123	114
92	K5N.NG10	86	86	120	82	130	111	96	100	95	122	129	118
	ave. Mand	72	72	99	85	117	108	97	101	97	115	123	114

Table 33. Analysis of variance for characteristics of hybrids grown in varietal trials in 2020.

		moist grain bu/acre		dry grain lbs/acre		stover lbs/acre		Harvest Index (%)		Grain Protein (%)		Grain Oil (%)	
Source	DF	SS	P	SS	P	SS	P	SS	P	SS	P	SS	P
Pedigree	8	14615	0.123	32725991	0.123	94790711	0.02	453.9095	0.838	11.6882	0.011	1.30352	0.0036
plant pop	1	25246	<.0001	56531432	<.0001	2.45E+08	<.0001	96.7532	0.356	0.50868	0.31	0.06052	0.2526
δ15NAir (‰)	1	6291	0.02	14086379	0.02	11972481	0.107	1093.459	0.004	46.0015	<.0001	0.69277	0.0004
% var hybrid		32		32		27		28		20		63	
% var pop		55		55		70		6		1		3	
% var $\delta^{15}N$		14		14		3		67		79		34	
effect of $\delta^{15}N$		positive		positive		negative		positive		positive		negative	
		Grain Starch (%)		Grain Density		Ethanol Yield		Lysine % whole		Methionine %		Cysteine %	
Source		SS		SS	P	SS	P	SS	P	SS	P	SS	P
Pedigree		21.0349	<.0001	0.006923	0.263	0.060538	0.003	0.011924	2E-04	0.01268	9E-04	0.00339	0.0064
plant pop		0.25997	0.436	2.6E-07	0.984	0.002891	0.24	0.000439	0.213	9E-05	0.616	6.6E-05	0.4777
δ15NAir (‰)		12.4965	<.0001	0.007492	0.002	0.123482	<.0001	0.011358	<.0001	0.01119	<.0001	0.01107	<.0001
% var hybrid		62		48		32		50		53		23	
% var pop		1		0		2		2		0		0	
% var $\delta^{15}N$		37		52		66		48		47		76	
effect of $\delta^{15}N$		negative		positive		negative		positive		positive		positive	

Table 34. Agronomic characteristics and linear equations for hybrid trials in 2020.

	Agronomic characteristics.					Regression coefficients x=δ15N, y= %N in grain.						
Hybrid	no of plants/acre		δ15Nin grain	%N in grain	N uptake in grain lbs/a	intercept	std error	Prob>|t|	δ15N	std error	Prob>|t|	R^2
FOS8500	24,692	abc	3.11	1.15	73	0.0043	0.0014	0.0507	0.0022	0.0004	0.0131	0.9
17.2B24	24,427	bc	3.18	1.16	50	0.0089	0.0011	0.0043	0.0010	0.0003	0.0522	0.77
17.461	23,630	bc	**3.76**	**1.35**	**82**	**0.0104**	0.0030	0.0401	**0.0003**	0.0008	0.6819	0.06
UR56.461	25,091	abc	3.51	1.17	54	0.0036	0.0016	0.1007	0.0019	0.0004	0.0218	0.87
15.461	22,966	c	3.07	1.21	41	0.0070	0.0017	0.0279	0.0011	0.0005	0.1306	0.59
9215.461	30,268	a	3.36	1.31	72	0.0071	0.0018	0.027	0.0013	0.0005	0.0706	0.72
924.461	25,489	abc	3.52	1.25	55	0.0045	0.0009	0.0131	0.0021	0.0002	0.0027	0.97
924.NG10	29,073	ab	3.33	1.33	62	0.0078	0.0035	0.115	0.0013	0.0010	0.3127	0.33
K5N.NG10	20,577	c	3.40	1.40	60	0.0056	0.0028	0.1408	0.0022	0.0008	0.0741	0.71

Diagram 7. Relationships between $\delta^{15}N$ and %N for hybrids.

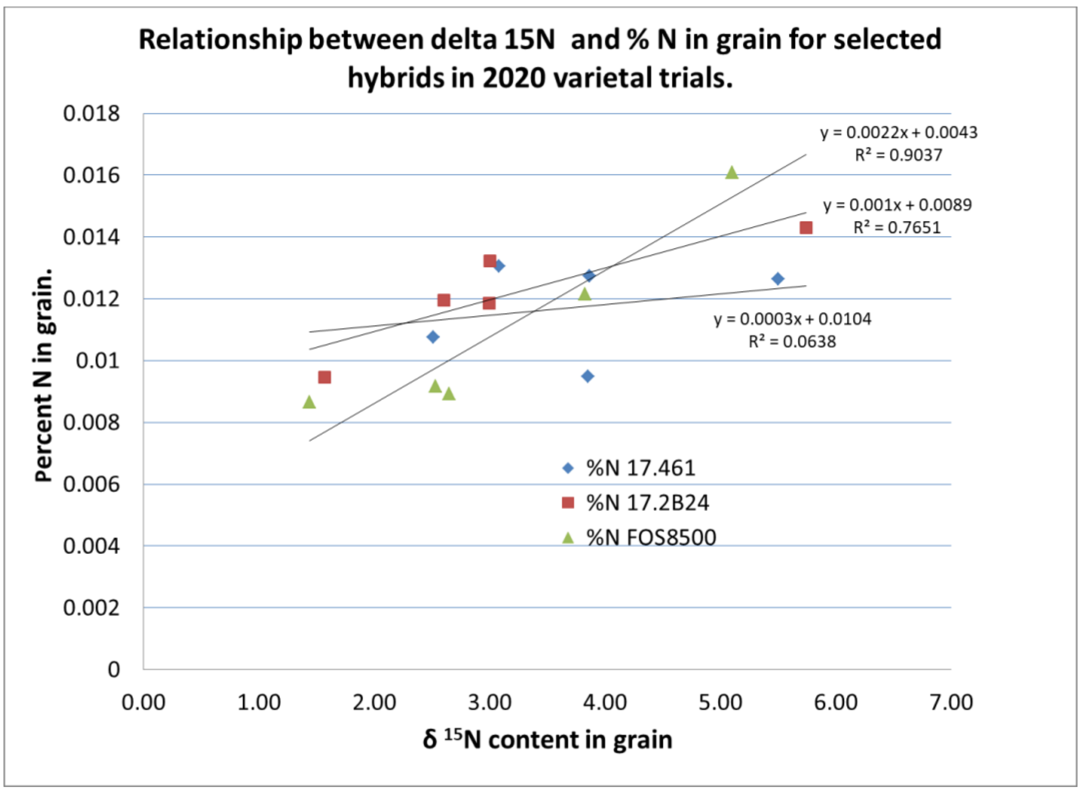


Table 35. Analysis of variance for stover parameters of the 2020 varietal trials, showing p values for significance and the % of the total SS associated with the different sources of variation.

		Parameter analyzed			
	DF	δ15N	Stover yield	Stover N	%N
Source variation		Prob > F			
Pedigree	8	0.6759	0.0547	0.104	0.026
δ15NAir (‰)	1		<.0001	<.0001	0.015
plants/a	1	0.0332	0.8064	0.2501	0.145
% of tot SS from Pedigree		54	28	30	21
% of tot SS from δ15N			0.1	3	53

Table 36. Effects of hybrids on stover yield and N content; varietal trials 2020.

hybrid	δ15N		Stover yield		Stover N		N	
	(‰)		lbs/acre				%	
FOS8500	1.66	a	7993	bc	59	abc	0.677	b
17.2B24	1.71	a	8029	abc	49	bc	0.601	b
17.461	2.53	a	10863	a	81	ab	0.677	b
UR65.641	1.81	a	8131	abc	58	abc	0.699	b
15.461	1.86	a	7994	bc	56	bc	0.675	b
9215.461	1.28	a	5758	c	32	c	0.596	b
924.461	2.40	a	7374	bc	59	abc	0.705	b
924.NG10	1.61	a	5282	c	30	c	0.646	b
K5N.NG10	2.86	a	9378	ab	93	a	0.979	a
data as % of FOS8500 control								
FOS8500	100		100		100		100	
17.2B24	103		100		83		89	
17.461	153		136		137		100	
UR65.641	109		102		98		103	
15.461	112		100		95		100	
9215.461	77		72		54		88	
924.461	144		92		101		104	
924.NG10	97		66		51		96	
K5N.NG10	172		117		158		145	

Table 37. Results of an analysis of variance of grain composition analyzing pedigree, plants/acre, δ^{15}N, and plant density for varietal trials in 2020.

		%N	%C	Ca	Cu	Fe	K	Mg	Mn	P177	S180	Zn
Source	DF	Prob > F										
Pedigree	8	**0.0699**	**0.0059**	0.195	0.143	0.2992	0.2569	0.212	0.1128	**0.0026**	0.179	0.337
δ15NAir (‰)	1	**<.0001**	0.1546	0.517	**0.095**	**0.0001**	**0.0736**	**<.0001**	0.3989	**<.0001**	**0.002**	**0.01**
plants/a	1	0.2379	0.948	**0.01**	**0.016**	**0.0214**	0.942	**0.03**	0.1115	0.3735	0.346	0.839
% of tot SS from Pedigree		18	93	60	59	29	76	31	81	38	50	56
% of tot SS from δ15N		81	7	2	13	54	24	55	4	61	46	44
relation with δ15N		positive			positive	positive	positive	positive		positive	positive	positive

Table 38. Quantities of mineral components in grain of different hybrids in varietal trials 2020.

Hybrid	δ15N	N	C	Ca	Cu	Fe	K	Mg	Mn	P177	S180	Zn
		%		concentration in grain in µg/g								
FOS 8500	3.11	1.19	45.41	29.9	1.10	29.4	4347	1142	4.35	3079	969	18.7
17.2B24	3.18	1.19	45.63	38.8	0.93	22.1	4337	1156	4.91	3233	1033	22.1
17.461	**3.76**	1.30	45.61	110.6	2.18	23.3	4120	1254	6.12	3356	1155	25.4
UR65.461	3.51	1.15	45.70	40.8	1.13	19.4	3978	1121	5.20	3193	1081	19.2
15.461	3.07	1.27	45.59	45.2	1.74	24.7	4236	1135	5.05	3334	1107	26.6
9215.461	3.36	1.28	45.72	25.3	0.96	20.4	4279	1262	4.64	3777	1183	23.9
924.461	3.52	1.22	45.63	53.3	1.16	23.7	4132	1242	5.47	3398	1080	25.1
924.NG10	3.33	1.31	45.68	15.5	0.92	19.7	4010	1233	5.04	3367	1137	21.1
K5N.NG10	3.40	1.43	45.90	61.1	1.52	23.9	3951	1218	5.90	3368	1074	23.0

Table 39. Relationships between Mandaamin hybrids and a hybrid check for mineral composition of grain; varietal trials 2020.

	δ15N	%N	%C	Ca	Cu	Fe	K	Mg	Mn	P177	S180	Zn	ave. minerals
Level	values in % of relevant FOS8500 check value.												
FOS 8500	100	100	100	100	100	100	100	100	100	100	100	100	**100**
17.2B24	102	100	100	130	**84**	**75**	100	101	113	105	107	118	**105**
17.461	121	109	100	**370**	**199**	**79**	**95**	**110**	**141**	**109**	**119**	**136**	**161**
UR65.461	113	**97**	101	136	103	**66**	**92**	**98**	119	104	111	103	**105**
15.461	**99**	106	100	151	158	**84**	**97**	**99**	116	108	114	142	**119**
9215.461	108	108	101	**84**	**87**	**69**	**98**	111	107	123	122	128	**102**
924.461	113	103	100	178	105	**81**	**95**	109	126	110	111	134	**119**
924.NG10	107	110	101	**52**	**83**	**67**	**92**	108	116	109	117	113	**93**
K5N.NG10	109	120	101	204	138	**81**	**91**	107	136	109	111	123	**127**
ave. Mandaamin	109	107	101	163	120	**75**	**95**	105	122	110	114	124	117

Table 40. Analysis of variance of relative values for mineral composition of grain with FOS8500 as the standard for varietal trials in 2020.

Source	DF	SS	F Ratio	Prob > F
Pedigree	8	159194	5.4968	<.0001
plant pop	1	14299	3.9498	0.0474
δ15NAir (‰)	1	23844	6.5865	0.0106
mineral	13	190914	4.0567	<.0001
Pedigree*mineral	104	359411	0.9546	0.6062
%ss for pedigree		21		
%ss for delta 15N		3		
% ss for mineral		26		
% ss for pedigree x mineral		48		

Table 41 shows relative values for nutrient composition of grain based on an analysis of variance with pedigree, mineral, pedigree x mineral as main factors and $\delta^{15}N$, and plant population density as covariates.

	Hybrid									
Mineral	FOS8500	17.2B24	17.461	UR65.461	15.461	9215.461	924.461	924.NG10	K5N.NG10	
	% relative to FOS8500 based on means									ave Mand
%C	99	100	105	102	101	94	101	95	107	101
%N	99	105	125	105	109	110	110	114	131	113
Ba	99	59	**282**	103	66	88	97	117	103	114
Ca	99	125	**355**	139	124	172	190	119	137	170
Cu	99	83	**223**	110	154	125	118	114	131	132
Fe	99	85	99	82	90	82	96	86	96	90
K	99	100	101	93	99	93	97	88	98	96
Mg	99	102	119	101	102	101	111	102	118	107
Mn	99	114	147	123	116	110	129	120	140	125
P 177	99	106	119	108	111	117	114	106	119	112
P 213	99	105	118	107	110	116	114	105	118	112
S 180	99	107	128	114	116	115	114	111	120	116
S 181	99	103	123	109	112	113	114	108	116	112
Zn	99	128	164	108	163	137	162	130	142	142
std error	27	27	27	27	27	27	27	27	27	
average	99	102	158	107	113	112	119	108	120	117
average min -C	99	102	162	108	113	114	120	109	121	119
ave.-C, P213, S181	**99**	**101**	**169**	**108**	**114**	**114**	**122**	**110**	**121**	120

Table 42. Analysis of variance table for stover composition results from 2020 variety trials.

		%N	%C	Ca	Cu	Fe	K	Mg	Mn	P177	S180	Zn
Source	DF	Prob > F										
Pedigree	8	0.1447	0.2744	0.3481	0.7573	0.6639	0.7175	**0.0556**	0.7191	0.3411	0.9059	0.8267
δ15NAir (‰)	1	**0.0147**	**0.088**	0.8617	**0.0246**	0.5996	**0.0072**	**<.0001**	**0.1036**	**0.0257**	0.3492	**0.0639**
plants/a	1	**0.0264**	**0.0237**	**0.0041**	**0.0055**	0.7542	**0.0005**	**0.0967**	**0.0582**	0.4851	0.9111	0.7334
% of tot SS from Pedigree		53	55	49	26	94	19	36	44	61	78	53
% of tot SS from $\delta^{15}N$		26	16	0.2	28.7	4.5	28.9	58.1	23.4	35.4	21.4	45.8
rel with $\delta^{15}N$		positive	positive		positive		positive	negativ	negativ	negative		negative

Table 43. LS mean values for stover composition results from 2020 variety trials.

Hybrid		%N	%C	Ca	Cu	Fe	K	Mg	Mn	P177	S180	Zn
		concentration of minerals in µg/g										
FOS 8500		0.677	45.04	2176	4.88	259	11509	1871	42.5	2928	635	53.9
17.2B24		0.601	45.03	2721	3.72	229	11685	1954	41.3	2764	637	49.2
17.461		0.677	44.47	2551	4.80	228	13715	2099	37.1	3594	729	57.8
UR65.461		0.699	44.65	2599	4.59	248	11351	2346	44.6	3848	807	64.5
15.461		0.675	45.15	2349	4.87	163	11749	1880	39.8	3217	659	46.8
9215.461		0.596	45.20	2127	3.57	204	10128	2352	29.2	3103	752	48.5
924.461		0.705	44.70	2752	3.52	213	10333	2402	37.6	3310	757	49.0
924.NG10		0.646	44.66	2365	3.81	172	10797	2281	39.8	3709	821	59.2
K5N.NG10		0.979	44.69	2315	5.03	195	13771	2031	46.1	3703	845	52.4

Table 44. LS mean values for stover composition results from 2020 variety trials relative to the check.

Hybrid		%N	%C	Ca	Cu	Fe	K	Mg	Mn	P177	S180	Zn	ave min.
		values in % of relevant FOS8500 check value.											
FOS 8500		100	100	100	100	100	100	100	100	100	100	100	100
17.2B24		89	100	125	76	89	102	104	97	94	100	91	97
17.461		100	99	117	98	88	119	112	87	123	115	107	107
UR56.461		103	99	119	94	96	99	125	105	131	127	120	112
15.461		100	100	108	100	63	102	100	93	110	104	87	97
9215.461		88	100	98	73	79	88	126	69	106	118	90	93
924.461		104	99	126	72	82	90	128	88	113	119	91	101
924.NG10		96	99	109	78	67	94	122	94	127	129	110	102
K5N.NG10		145	99	106	103	75	120	109	108	126	133	97	112
average Mand.		103	100	114	87	80	102	116	93	116	118	99	103

Table 45. Analysis of variance considering minerals as a factor. Hybrid trials 2020.

Source	DF	SS	F Ratio	Prob > F
Pedigree	8	16279.08	2.7484	**0.0056**
mineral	13	46246.32	4.8048	**<.0001**
Pedigree*mineral	104	43896.73	0.5701	0.9997
δ15NAir (‰)	1	6911.476	9.335	**0.0024**
plants/a	1	3836.774	5.1822	**0.0232**

Table 46 shows least square values for the concentration of minerals in stover and grain relative to FOS8500 and the actual stover and grain yields.

Hybrid	Stover conc.		Grain conc.		Stover yield		Grain yield	
	% relative to FOS8500				lbs dm/acre			
FOS 8500	101	c	99	b	7,908	bcd	6,173	a
17.2B24	103	bc	102	b	7,987	bc	4,558	ab
17.461	107	bc	158	a	11,077	a	6,033	a
UR56.461	118	a	107	b	8,218	bc	4,400	ab
15.461	103	bc	113	b	7,941	bcd	4,241	ab
9215.461	102	bc	112	b	5,613	cd	3,759	b
924.461	103	bc	119	b	7,410	bcd	3,928	b
924.NG10	109	abc	108	b	5,144	d	3,464	b
K5N.NG10	111	ab	120	b	9,505	ab	5,293	ab

Table 47. Total mineral uptake by stover for different hybrids as a % of the FOS8500 check. 2020 variety trials.

	Hybrid									
Mineral	FOS8500	17.2B24	17.461	UR65.461	15.461	9215.5	924.461	924.NG10	K5N.NG10	
	% relative to FOS8500 based on LS means									ave Mand
%C	101	102	99	100	103	98	97	96	102	99
%N	101	96	109	113	106	116	106	116	149	114
Ba	101	112	91	102	91	101	90	98	92	97
Ca	101	126	115	121	106	128	109	117	98	115
Cu	101	79	104	104	100	84	98	97	96	95
Fe	101	116	99	125	92	93	105	88	95	102
K	101	103	125	104	96	100	105	110	109	106
Mg	101	109	103	126	108	115	114	114	108	112
Mn	101	98	82	103	93	82	78	100	96	91
P 177	101	97	115	130	115	104	97	119	125	113
P 213	101	97	116	132	114	104	98	118	125	113
S 180	101	106	113	134	113	120	122	124	130	120
S 181	101	108	118	138	115	119	122	127	136	123
Zn	101	94	106	119	90	83	88	101	95	97
std error	12	12	12	12	12	12	12	12	12	
average	101	103	107	118	103	103	102	109	111	107
average min -C	101	103	107	119	103	104	102	110	112	108
ave.-C, P213, S181	**101**	**103**	**106**	**116**	**101**	**102**	**101**	**108**	**108**	106

Table 48. Analysis of variance for total mineral uptake in lbs/acre. Varietal trials, 2020.

Source	Nparm	DF	SS	F Ratio	Prob > F
Pedigree	8	8	115386	15.6	**<.0001**
mineral	13	13	20145	1.7	**0.0617**
Pedigree x mineral	104	104	26329	0.3	1.0000
plants/a	1	1	40691	44.1	**<.0001**
δ15N stalk	1	1	23579	25.6	**<.0001**
δ15N grain	1	1	10556	11.4	**0.0008**
%ss pedigree			49		
% ss ped x min			11		
%ss δ15N			9		

Table 49. Relative uptake of minerals for different hybrids using mineral as a factor In analysis.

Hybrid	%	
FOS 8500	103	c
17.2B24	101	cd
17.461	132	a
UR65.461	119	b
15.461	89	e
9215.461	101	cd
924.461	87	e
924.NG10	94	cde
K5N.NG10	91	de

Table 50. LS mean values for the hybrid x mineral interaction for uptake of minerals in grain and stover and grain + stover for varieties grown in 2020.

	Ba	**Ca**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**P 177**	**P 213**	**S 180**	**S 182**	**Zn**	**N**	**C**
Hybrid	uptake by grain in lbs/acre													
FOS 8500	0.0037	0.167	0.00629	0.182	25.6	6.7	0.026	18.3	18.5	5.75	6.20	0.122	72.9	2685
17.2B24	0.00075	0.145	0.00363	0.086	17.8	4.82	0.020	13.5	13.5	4.43	4.46	0.087	50.1	1940
17.461	0.01348	0.845	0.01611	0.151	24.2	7.56	0.038	20.1	20.1	7.04	7.21	0.158	81.7	2645
UR65.461	0.00166	0.172	0.00548	0.090	17.6	5.12	0.023	14.7	14.7	5.03	5.02	0.084	54.1	2041
15.461	0.00072	0.120	0.00532	0.077	14.4	3.84	0.016	11.3	11.3	3.82	3.88	0.087	41.5	1566
9215.461	0.00196	0.278	0.00773	0.141	22.7	6.38	0.027	19.9	19.9	6.10	6.45	0.131	72.1	2422
924.461	0.00219	0.253	0.00588	0.110	17.0	4.99	0.023	14.1	14.2	4.50	4.83	0.099	54.5	1884
924.NG10	0.00128	0.163	0.00554	0.102	18.7	5.46	0.024	15.5	15.6	5.17	5.33	0.095	62.5	2112
K5N.NG10	0.00107	0.146	0.00508	0.091	15.8	5.04	0.022	13.9	14.0	4.48	4.62	0.095	59.5	1815
average Mand.	**0.00289**	**0.265**	**0.00685**	**0.106**	**18.5**	**5.40**	**0.024**	**15.4**	**15.4**	**5.07**	**5.22**	**0.105**	**59.5**	**2053**

	Ba	Ca	Cu	Fe	K	Mg	Mn	P 177	P 213	S 180	S 182	Zn	N	C
Hybrid	uptake by stover in lbs/acre													
FOS 8500	0.1385	17.08	0.03780	1.895	88.5	14.63	0.347	22.4	22.3	5.01	4.92	0.415	89.8	3524
17.2B24	0.1615	20.71	0.02496	1.782	83.5	15.46	0.337	21.3	21.1	4.83	4.92	0.374	87.0	3482
17.461	0.1714	25.19	0.05323	2.084	141.9	19.01	0.329	32.2	32.2	7.12	7.39	0.529	139.1	4536
UR65.461	0.1424	21.04	0.03570	2.042	87.5	19.35	0.364	31.6	31.8	6.62	6.93	0.533	94.6	3709
15.461	0.1075	14.65	0.02664	1.081	69.8	13.49	0.262	22.9	22.6	4.29	4.43	0.318	79.9	3069
9215.461	0.1649	23.44	0.04415	2.098	129.2	18.85	0.337	24.7	24.7	6.38	6.52	0.389	119.2	4030
924.461	0.1469	21.71	0.03433	1.603	95.7	16.31	0.303	23.4	23.4	5.38	5.50	0.330	96.0	3447
924.NG10	0.1555	21.59	0.03855	1.468	109.1	16.59	0.364	27.2	26.9	5.99	6.12	0.438	101.9	3476
K5N.NG10	0.1140	14.70	0.03371	1.300	87.8	13.32	0.285	24.2	24.0	5.70	5.94	0.349	97.8	3054
average Mand.	**0.14551**	**20.379**	**0.03641**	**1.682**	**100.6**	**16.55**	**0.323**	**25.9**	**25.8**	**5.79**	**5.97**	**0.408**	**102.0**	**3600**

	Ba	Ca	Cu	Fe	K	Mg	Mn	P 177	P 213	S 180	S 182	Zn	N	C
Hybrid	uptake by grain and stover in lbs/acre													
FOS 8500	0.1422	17.25	0.04	2.08	114	21.3	0.372	40.7	40.7	10.76	11.1	0.536	163	6209
17.2B24	0.1623	20.86	0.0286	1.869	101	20.28	0.357	34.8	34.7	9.26	9.4	0.461	137.1	5422
17.461	0.1848	26.03	0.0693	2.235	166	26.58	0.367	52.4	52.3	14.16	14.6	0.686	220.8	7181
UR65.461	0.1440	21.22	0.0412	2.132	105	24.48	0.387	46.2	46.5	11.65	12.0	0.617	148.7	5750
15.461	0.1082	14.77	0.0320	1.158	84	17.33	0.279	34.1	34.0	8.11	8.3	0.405	121.4	4635
9215.461	0.1669	23.71	0.0519	2.240	152	25.23	0.363	44.6	44.6	12.48	13.0	0.520	191.3	6451
924.461	0.1491	21.97	0.0402	1.713	113	21.30	0.326	37.5	37.6	9.87	10.3	0.430	150.5	5331
924.NG10	0.1568	21.76	0.0441	1.570	128	22.06	0.389	42.8	42.6	11.16	11.4	0.533	164.4	5588
K5N.NG10	0.1151	14.85	0.0388	1.392	104	18.36	0.307	38.1	38.0	10.18	10.6	0.444	157.4	4869
average Mand.	**0.14840**	**20.645**	**0.04325**	**1.788**	**119.1**	**21.95**	**0.347**	**41.3**	**41.3**	**10.86**	**11.19**	**0.512**	**161.5**	**5653**

Table 51. Total uptake of minerals by hybrids in 2020 as % of FOS8500.

	FOS8500	17.2B24	17.461	UR56.461	15.461	9215.461	924.461	924.NG10	K5N.NG10	Ave. Mand.
Mineral	% relative to FOS8500 based on LS means									
Ba	103	114	123	109	82	92	91	89	84	**98**
C	103	101	120	107	87	92	83	83	84	**95**
Ca	103	131	157	135	101	117	117	115	92	**121**
Cu	103	82	143	119	97	100	76	89	86	**99**
Fe	103	103	128	113	69	112	79	85	86	**97**
K	103	102	150	110	87	108	84	97	91	**103**
Mg	103	101	125	121	90	106	93	94	90	**103**
Mn	103	98	112	110	84	83	75	98	89	**94**
N	103	105	126	114	84	98	92	97	110	**103**
P 177	103	94	131	125	95	99	87	94	95	**102**
P 213	103	94	131	126	95	100	87	93	95	**102**
S 180	103	98	132	125	92	109	88	96	97	**105**
S 182	103	99	132	123	92	110	88	97	97	**105**
Zn	103	98	134	127	87	88	77	90	84	**98**
Std error	14	14	14	14	14	14	14	14	14	**14**
ave.	**103**	**101**	**132**	**119**	**89**	**101**	**87**	**94**	**91**	**102**
ave. -C	103	101	133	120	89	102	87	95	92	**102**
ave.-C,P213,S182	103	102	133	119	88	101	87	95	91	**102**

Table 52. Probabilities and percent allocation of sums of squares for analysis of variance of harvest indices with pedigree as a main factor and covariates.

Anova Factor	Ba	Ca	Cu	Fe	K	Mg	Mn	P 177	P 213	S 180	Zn	%N	%C	Average
	Prob > F													
Pedigree	0.374	0.6678	0.7268	0.6629	0.7006	0.3621	0.8259	0.4198	0.3884	0.4208	0.3337	0.808	0.808	**0.5768**
δ15N grain	0.5358	0.4387	**0.0174**	**0.0258**	**0.0274**	**<.0001**	**0.0049**	**0.0003**	**0.0003**	**<.0001**	**0.0125**	**0.0004**	**0.0004**	**0.0967**
δ15N stalk	0.8673	0.5324	0.1289	0.1687	**0.0368**	**0.0689**	**0.0652**	**0.0876**	**0.0856**	**0.0214**	0.9051	**0.0097**	**0.0097**	**0.2298**
plants/a	0.1155	0.2157	0.2384	0.9156	0.0852	0.8699	0.4304	0.9854	0.9984	0.2931	0.5352	0.7804	0.7804	**0.5572**
SS% Pedigree	75	69	34	44	29	26	24	30	31	22	56	16	16	**36**
SS% δ15N	3	12	57	56	54	74	72	70	69	75	41	84	84	**58**
SS% Plants/a	22	19	9	0	17	0	4	0	0	3	2	0	0	**6**
rel with δ15N grain			positive	positive	positive	positive	positive	positive	positive	positive	positive	positive	positive	
rel. with δ15N stalk					negative	negative	negative	negative	negative	negative	negative	negative	negative	

Table 53. Results of manure and inoculation trials on three farms in 2018.

Grain yield for farms and hybrids on 3 farms in 2018.

Farm	Hybrid	group	bu/acre
S	FOS8507	a	174.4
S	C461.C2B4	b	124.3
B	FOS8507	b	135.7
B	C461.C2B4	c	95.1
C	FOS8507	d	59.6
C	C461.C2B4	d	57.6

Table 54. P level of significance or the effect of factors hybrid, parts (grain, stalk, roots) and the hybrid x part interaction for farm A in 2019.

Nutrient	hybrid	part	part x hybrid
%N	0.9154	<.0001	0.0005
%C	<.0001	<.0001	<.0001
Ca	0.2898	<.0001	0.6168
Al 237.312	0.0871	<.0001	0.0995
Al 394.401	0.0902	<.0001	0.0876
Copper	0.219	0.0019	0.0655
Iron	0.6126	<.0001	0.7943
Potassium	<.0001	<.0001	<.0001
Magnesium	<.0001	<.0001	<.0001
Manganese	0.8388	<.0001	0.8011
P177.434	0.27	<.0001	0.0027
P213.62	0.309	<.0001	0.0026
S 180.669	<.0001	<.0001	<.0001
S 181.972	<.0001	<.0001	<.0001
Silicon	0.0667	0.0668	0.0319
Zinc	0.0339	0.0097	0.0369

Table 55. The relationship between hybrid and plant part on Anibas farm in 2019. Significant differences between hybrids for the same plant part are shown in bold print.

	%N		Ca		K		Mg		P 177		P 213		S 180		S 181	
Corn,17.461	**1.33**	**a**	79	c	3769	e	1077	de	**3170**	**a**	**3175**	**a**	**1047**	**b**	**1087**	**b**
Corn,FOS 8500	**1.11**	**b**	72	c	3840	e	1003	e	**2810**	**b**	**2816**	**b**	**891**	**c**	**890**	**c**
Stalk,17.461	**0.92**	**c**	3446	a	**14806**	**c**	**1941**	**b**	1460	d	1446	d	**700**	**e**	**762**	**d**
Stalk,FOS 8500	**1.03**	**bc**	3390	a	**17638**	**b**	**2140**	**a**	1947	c	1936	c	**874**	**cd**	**937**	**bc**
Root,17.461	0.62	d	1553	b	**10326**	**d**	**1157**	**d**	325	e	326	e	**726**	**de**	**797**	**cd**
Root,FOS 8500	0.75	d	1407	b	**26487**	**a**	**1701**	**c**	502	e	469	e	**1497**	**a**	**1607**	**a**

	%C		Fe		Al 237		Al 394		Mn		Cu		Zn		Si	
Corn,17.461	**44.4**	**c**	124	b	26	c	25	c	8.71	c	0.50	b	14.6	b	65	b
Corn,FOS 8500	**43.9**	**d**	154	b	26	c	26	c	7.82	c	0.56	b	11.0	b	61	b
Stalk,17.461	44.2	cd	343	a	144	bc	141	bc	46.64	a	10.67	ab	29.5	b	**313**	**a**
Stalk,FOS 8500	44.1	cd	341	a	132	bc	131	bc	48.30	a	12.37	ab	28.3	ab	**101**	**b**
Root,17.461	**47.2**	**a**	435	a	326	a	332	a	25.58	b	15.81	a	63.1	a	147	b
Root,FOS 8500	**44.9**	**b**	440	a	229	ab	235	ab	25.76	b	6.70	ab	23.4	b	169	b

Table 56. fertilization x hybrid x inoculate interaction grain yield in bu/a for the Weiss/Bauer farm in 2019.

Hybrid	Fertilization	Inoculate	LS Mean	
FOS8500	manure + N	none	194.9	a
FOS8500	manure + N	yes	163.4	bc
FOS8500	N	none	153.5	bcd
FOS8500	N	yes	176.5	b
17. 461	manure + N	none	138.0	cde
17. 461	manure + N	yes	134.7	de
17. 461	N	none	124.7	e
17. 461	N	yes	113.8	e