MAIZE GRAIN RESEARCH UPDATE 2022

PIONEER®
BRAND · PRODUCTS

CONTENTS

INTRODUCTION

Welcome to the Pioneer Maize Grain Research Update for 2022.

For many years we have produced Maize Grain Hybrid Performance Information which provides comprehensive hybrid yield data enabling growers to make informed decisions on which hybrids to plant. However, our research programme covers so much more than just hybrid evaluation. Every year we aim to deliver more value to growers by conducting a range of agronomic and environmental research. In this publication, we summarise some of the latest research which includes stress emergence and seed quality, an update on plant populations and information on greenhouse gas emissions from maize systems. We also present summary data from an analysis of Pioneer grain trials from 1992 to 2020.

A Pioneer IMPACT™ trial at Gordonton, Waikato. IMPACT is the acronym for “intensively managed product advancement and characterisation trials”.

Long term breeding delivers higher yields

The annual rate of yield gain in New Zealand is estimated to have been over 180 kg of maize grain per hectare per year over almost 60 years, as shown in the graph below. Crop management and the breeding of more defensive and higher yielding hybrids have both made significant contributions to yield increases over this time frame. As a result, a newly introduced Pioneer hybrid will usually have a considerable yield advantage over older hybrids.

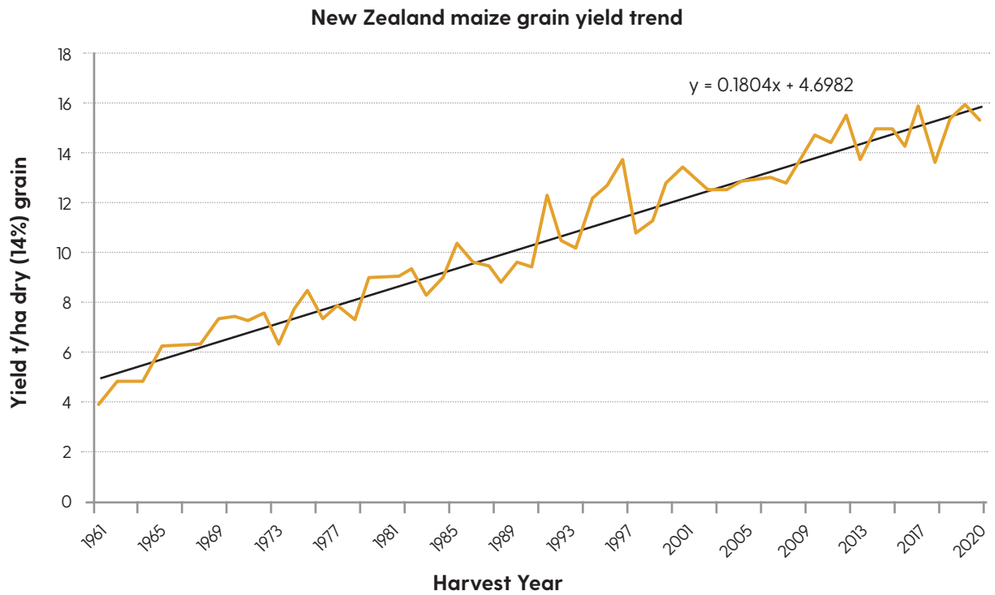
To maxmise their returns, grain growers should look to introduce new hybrids that are best suited to their farm system on a regular basis.

Desired harvest timing, soil type, cultivation methods and agronomic traits such as early growth, drought tolerance, stalk and root strength, disease resistances and grain quality are all important considerations to include in the hybrid selection process.

The most reliable way to select superior hybrids is to consider yield stability and quality performance information, gathered over several seasons and over a wide range of locations within a growing region. Individual on-farm trial results should not be used to select a hybrid because in isolation they are not a reliable predictor of hybrid performance in future seasons. A useful rule of thumb is that 20 locations over several seasons provide a reliable measure of comparative yield performance between two hybrids. This data should then be statistically analysed to establish the quality of the data and if there is a real yield difference between hybrids being compared. This publication provides a summary of the investment made to evaluate the grain yield performance of Pioneer® brand products and other brands of grain hybrids in five defined growing regions in New Zealand:

1. Northland and south Auckland
2. Waikato
3. Bay of Plenty
4. Gisborne and northern Hawke's Bay
5. Lower North Island & South Island

It is Pioneer's policy to only publish statistically significant results when comparing a Pioneer hybrid with that of another brand (see opposite page). As a result, we do not make any hybrid comparison inferences based on only a few trials. Consequently, comparisons involving new hybrids may take several seasons to generate sufficient data to publish.



Source: New Zealand Year Book (1961 to 1996) and Pioneer® brand products New Zealand Research Programme (1997 to 2020).

Interpreting the hybrid comparison t-test

The table below presents a summary of the possible t-test outcomes.

Understanding paired hybrid comparisons

Where stars (★) are shown beside each comparison, this indicates the level of confidence that a real yield difference exists between the two hybrids based on the yield data.

P value	Confidence level	Scientific designation	Level of significance	Yield advantage	Interpretation
<0.001	>99.9%	★★★	Very highly significant	YES	**Hybrid superiority for yield <u>can be claimed</u>.** Can confidently plant the winning hybrid providing no key agronomic traits are limiting. Check the trait ratings for any considerations.
<0.01	>99.0%	★★	Highly significant	YES	
<0.05	>95.0%	★	Significant	YES	
<0.10	>90.0%	CA	Commercially acceptable	YES	Not a significant result, but may be regarded as a commercially acceptable basis for a decision.
>0.10	<90.0%	NS	Not significant	NO	**Hybrid superiority for yield <u>cannot be claimed</u>.** Ignore the yield comparison and refer primarily to important trait ratings to select between the hybrids.

The more stars (★) present for the comparison, the more confident we can be that the measured average yield difference is due to an actual genetic yield difference between the two hybrids rather than just chance.

Where a result is commercially acceptable **(CA)**, the result is not designated as statistically significant, but it may be regarded as commercially acceptable.

Where a result is not significant **(NS)**, we cannot conclude there is a yield difference between the hybrids. There are two principle explanations;

1. Where the yields are very similar and the comparison has been made over more than 20 locations, no significance indicates there is no measurable difference between the two hybrids or;
2. Where there appears to be a large yield difference, no significance likely indicates there are too few trial locations, or there have been inconsistent or fluctuating results. It is therefore not possible to indicate that the difference is real.

In both instances above, growers should use regionally important hybrid trait ratings to select which hybrid to plant.

In other comparisons, yield differences may appear to be relatively small but still achieve significance – this happens in cases where yield data quality is high and the number of trial locations is large.

A t-test analysis of statistical significance is carried out on all Pioneer hybrid comparisons and we take great care to base our product yield statements and recommendations on the outcome.

NEW

HIGHLY PRODUCTIVE OPTION, FOR COOLER REGIONS.

P8333

CRM 83

Feature hybrid	Comparison hybrid	Number of trials	Harvest moisture difference (%)[1]	Yield advantage (kg/ha)[2]	Statistical significance[3]
Lower North Island					
P8333	Booster	10	1.32	1,382	★★★
P8333	Delitop	18	1.57	934	★★
P8333	P8000	27	-0.22	1,702	★★★
P8333	P8500	27	0.19	-774	★★
P8333	P8666	26	0.30	-766	★★★
P8333	P8805	22	0.24	-206	NS

[1]Positive harvest moisture differences means the bolded hybrid was drier at harvest, negative harvest moisture differences mean in was wetter. [2]A positive yield advantage means the bolded hybrid produced more yield, a negative yield advantage means it produced less. [3]For information on interpreting hybrid comparison data and statistical significance see page 4. Includes all data to the end of the 2021 harvest.

Recommended growing regions

Recommended established plant populations (000's/ha)

Challenging yield environments	85
Medium yield environments	95
High yield environments	105

YIELD LEADER WITH LOOKS TO MATCH.

P8500

CRM 85

Feature hybrid	Comparison hybrid	Number of trials	Harvest moisture difference (%)[1]	Yield advantage (kg/ha)[2]	Statistical significance[3]
Lower North Island					
P8500	Booster	13	1.00	2,901	★★★
P8500	Delitop	26	1.77	1,743	★★★
P8500	P8000	39	-0.53	2,082	★★★
P8500	P8333	27	-0.19	774	★★
P8500	P8666	44	0.14	182	NS
P8500	P8805	56	0.06	195	NS
P8500	P9127	43	0.72	-917	★★★
P8500	Titus	13	1.56	3,978	★★★

[1]Positive harvest moisture differences means the bolded hybrid was drier at harvest, negative harvest moisture differences mean in was wetter. [2]A positive yield advantage means the bolded hybrid produced more yield, a negative yield advantage means it produced less. [3]For information on interpreting hybrid comparison data and statistical significance see page 4. Includes all data to the end of the 2021 harvest.

Recommended growing regions

Recommended established plant populations (000's/ha)

Challenging yield environments	90
Medium yield environments	100
High yield environments	115

HIGH PERFORMANCE HYBRID WITH EXCELLENT AGRONOMIC PROPERTIES.

CRM 86

Feature hybrid	Comparison hybrid	Number of trials	Harvest moisture difference (%)[1]	Yield advantage (kg/ha)[2]	Statistical significance[3]
Lower North Island					
P8666	Booster	13	0.85	2,448	★★★
P8666	Delitop	18	1.42	2,005	★★★
P8666	P8000	29	-0.52	2,202	★★★
P8666	P8333	26	-0.30	766	★★★
P8666	P8500	44	-0.14	-182	NS
P8666	P8805	39	-0.14	94	NS
P8666	P9127	33	0.59	-1,402	★★★
P8666	P9400	14	0.51	148	NS
P8666	Titus	6	1.52	4,620	★★★
Waikato					
P8666	Booster	6	1.11	3,447	★★
P8666	Comet	20	0.12	1,362	★★
P8666	Delitop	15	1.55	2,112	★★★
P8666	P8000	15	-0.20	1,701	★★
P8666	P8500	20	-0.15	375	NS
P8666	P8805	14	-0.05	367	NS
P8666	P9127	21	0.34	-1,027	★★★

[1]Positive harvest moisture differences means the bolded hybrid was drier at harvest, negative harvest moisture differences mean in was wetter. [2]A positive yield advantage means the bolded hybrid produced more yield, a negative yield advantage means it produced less. [3]For information on interpreting hybrid comparison data and statistical significance see page 4. Includes all data to the end of the 2021 harvest.

Recommended growing regions

Recommended established plant populations (000's/ha)

Challenging yield environments	85
Medium yield environments	95
High yield environments	105

BRED TO DEFEND – YIELDS TO IMPRESS.

CRM 91

Optimum AQUAmax

Feature hybrid	Comparison hybrid	Number of trials	Harvest moisture difference (%)[1]	Yield advantage (kg/ha)[2]	Statistical significance[3]
Northland					
P9127	P8805	7	-0.97	1,326	★★
P9127	P9400	18	-0.06	370	NS
P9127	P9721	24	-0.05	41	NS
Waikato					
P9127	Booster	10	1.28	3,857	★★★
P9127	Comet	27	-0.12	1,920	★★★
P9127	Delitop	22	1.30	2,811	★★★
P9127	P8500	20	-0.03	1,240	★★
P9127	P8666	21	-0.34	1,027	★★★
P9127	P8805	36	-0.25	1,013	★★★
P9127	P9400	54	-0.30	126	NS
P9127	P9721	49	0.29	-681	★★★
P9127	Velocity	10	0.28	1,234	★★
Gisborne & Hawke's Bay					
P9127	P8500	12	-0.67	850	CA
P9127	P8805	15	-0.46	1,271	★★
P9127	P9400	21	-0.41	575	★★
P9127	P9721	27	0.24	-241	NS
Lower North Island					
P9127	Booster	14	1.05	3,956	★★★
P9127	C29-A1	31	0.69	840	★★★
P9127	Comet	27	0.17	1,368	★★★
P9127	Delitop	41	1.28	3,589	★★★
P9127	Obelix	9	-0.04	1,575	CA
P9127	P8333	16	-0.84	2,631	★★★
P9127	P8500	43	-0.72	917	★★★
P9127	P8666	33	-0.59	1,402	★★★
P9127	P8805	81	-0.53	892	★★★
P9127	P9400	64	-0.11	830	★★★
P9127	PAC249	25	0.65	1,184	★★★
P9127	Velocity	21	0.91	1,316	★★★

[1]Positive harvest moisture differences means the bolded hybrid was drier at harvest, negative harvest moisture differences mean in was wetter. [2]A positive yield advantage means the bolded hybrid produced more yield, a negative yield advantage means it produced less. [3]For information on interpreting hybrid comparison data and statistical significance see page 4. Includes all data to the end of the 2021 harvest.

Recommended growing regions

Recommended established plant populations (000's/ha)

Challenging yield environments	85
Medium yield environments	95
High yield environments	105

NEW

VERY PRODUCTIVE. VERY STABLE. VERY DEFENSIVE.

P9978

CRM 99

Feature hybrid	Comparison hybrid	Number of trials	Harvest moisture difference (%)[1]	Yield advantage (kg/ha)[2]	Statistical significance[3]
Northland					
P9978	P0021	15	-0.53	60	NS
P9978	P0362	16	0.81	181	NS
P9978	P9400	7	-1.03	791	NS
P9978	P9721	7	-1.36	1,063	NS
Waikato					
P9978	Afinity	7	-0.87	1,244	CA
P9978	C29-A1	11	-1.43	1,780	★★★
P9978	N39-Q1	16	-0.96	2,510	★★★
P9978	P0021	27	-0.74	1,338	★★★
P9978	P0362	28	0.82	345	NS
P9978	P9400	20	-1.94	2,012	★★★
P9978	P9721	17	-1.20	937	★★
P9978	PAC249	7	-1.30	2,978	★★★
P9978	PAC314	7	-0.77	1612	CA
P9978	PAC344	7	-0.84	921	★
P9978	Velocity	10	-0.92	2,247	★★★
Gisborne & Hawke's Bay					
P9978	P0021	20	-0.51	1,266	★★★
P9978	P0362	19	0.74	1,199	★★
P9978	P0547	7	-0.20	807	NS
P9978	P0640	17	1.28	710	★
P9978	P9400	12	-1.67	2,590	★★
P9978	P9721	17	-1.06	1,319	★★★
Lower North Island					
P9978	Afinity	9	-1.09	1,534	★
P9978	N39-Q1	15	-0.92	2,034	★★★
P9978	P0021	31	-0.91	758	★★★
P9978	P0362	28	0.98	132	NS
P9978	P0547	28	-0.40	326	NS
P9978	P9400	9	-3.13	1,589	★★★
P9978	P9721	18	-2.24	814	★★
P9978	PAC249	16	-1.32	1,981	★★★
P9978	PAC314	9	-0.99	1,810	★★
P9978	PAC343	9	-0.19	1,548	★★★
P9978	PAC344	7	-0.42	1,539	CA
P9978	Velocity	8	-0.77	2,912	★★★

[1]Positive harvest moisture differences means the bolded hybrid was drier at harvest, negative harvest moisture differences mean in was wetter. [2]A positive yield advantage means the bolded hybrid produced more yield, a negative yield advantage means it produced less. [3]For information on interpreting hybrid comparison data and statistical significance see page 4. Includes all data to the end of the 2021 harvest.

Recommended growing regions

Recommended established plant populations (000's/ha)

Challenging yield environments	85
Medium yield environments	95
High yield environments	110

HARD TO BEAT CONSISTENCY.

P0021

CRM 100

Feature hybrid	Comparison hybrid	Number of trials	Harvest moisture difference (%)[1]	Yield advantage (kg/ha)[2]	Statistical significance[3]
Northland					
P0021	P0362	35	0.89	-301	NS
P0021	P9721	93	-0.66	277	★
P0021	P9978	15	0.53	-60	NS
Waikato					
P0021	N39-Q1	69	-0.30	751	★★★
P0021	P0362	57	1.71	-628	★★★
P0021	P9400	170	-1.09	419	★★★
P0021	P9721	173	-0.55	-22	NS
P0021	P9978	27	0.74	-1,338	★★★
P0021	Velocity	18	-0.25	1,151	★★
Bay of Plenty					
P0021	P0362	12	1.05	-850	NS
P0021	P0547	33	0.25	-386	CA
P0021	P9400	13	-0.95	1,244	★★
P0021	P9721	10	-0.48	1,132	CA
Gisborne & Hawke's Bay					
P0021	P0362	41	1.37	-408	★
P0021	P0547	68	0.41	-279	★
P0021	P9400	71	-1.04	906	★★★
P0021	P9721	75	-0.41	-130	NS
P0021	P9978	20	0.51	-1266	★★★
Lower North Island					
P0021	Brutus	11	4.79	2,107	★★★
P0021	C29-A1	40	-0.67	1,302	★★★
P0021	N39-Q1	81	-0.23	349	★★★
P0021	P0362	73	1.92	-484	★★★
P0021	P0547	169	0.52	-531	★★★
P0021	P9400	201	-1.45	783	★★★
P0021	P9721	226	-0.98	27	NS
P0021	P9978	31	0.91	-758	★★★
P0021	PAC249	36	-0.44	540	★
P0021	Velocity	14	-0.17	1,441	★★★

[1]Positive harvest moisture differences means the bolded hybrid was drier at harvest, negative harvest moisture differences mean in was wetter. [2]A positive yield advantage means the bolded hybrid produced more yield, a negative yield advantage means it produced less. [3]For information on interpreting hybrid comparison data and statistical significance see page 4. Includes all data to the end of the 2021 harvest.

Recommended growing regions

Recommended established plant populations (000's/ha)

Challenging yield environments	85
Medium yield environments	95
High yield environments	100

ROBUST HYBRID WITH YIELD STABILITY AND "EYE APPEAL".

CRM 103

Feature hybrid	Comparison hybrid	Number of trials	Harvest moisture difference (%)[1]	Yield advantage (kg/ha)[2]	Statistical significance[3]
Northland					
P0362	P0021	35	-0.89	301	NS
P0362	P0640	47	0.21	-333	CA
P0362	P0891	13	0.63	827	★
P0362	P0937	16	0.68	-1,510	★★★
P0362	P9978	16	-0.81	-181	NS
Waikato					
P0362	Afinity	20	-0.83	1,082	★★
P0362	N39-Q1	17	-1.31	2,912	★★★
P0362	P0021	57	-1.71	628	★★★
P0362	P0640	60	0.41	-1,233	★★★
P0362	P0891	34	0.01	-718	★
P0362	P0937	28	1.26	-1,777	★★★
P0362	P9978	28	-0.82	-345	NS
P0362	PAC314	9	-1.24	2,345	★★
P0362	Plenitude	22	-0.03	938	★
Bay of Plenty					
P0362	N39-Q1	6	-1.05	1,620	CA
P0362	N51-N4	8	-1.14	2,024	★
P0362	P0021	12	-1.05	850	NS
P0362	P0640	28	-0.13	-337	NS
P0362	P0891	29	0.03	371	NS
P0362	P0937	24	0.78	-1,210	★★
P0362	P1253	22	0.18	377	NS
P0362	Plenitude	6	-1.02	1,377	CA
Gisborne & Hawke's Bay					
P0362	P0021	41	-1.37	408	★
P0362	P0640	42	0.49	-491	★
P0362	P0891	30	0.53	507	★★
P0362	P0937	20	0.81	-1,448	★★★
P0362	P1253	25	1.05	-371	NS
P0362	P9978	19	-0.74	-1,199	★★

[1]Positive harvest moisture differences means the bolded hybrid was drier at harvest, negative harvest moisture differences mean in was wetter. [2]A positive yield advantage means the bolded hybrid produced more yield, a negative yield advantage means it produced less. [3]For information on interpreting hybrid comparison data and statistical significance see page 4. Includes all data to the end of the 2021 harvest.

Recommended growing regions

Recommended established plant populations (000's/ha)

Challenging yield environments	85
Medium yield environments	95
High yield environments	105

THE RANGITIKEI PACE-SETTER.

CRM 105

Feature hybrid	Comparison hybrid	Number of trials	Harvest moisture difference (%)[1]	Yield advantage (kg/ha)[2]	Statistical significance[3]
Lower North Island & Taranaki					
P0547	Afinity	30	-0.74	747	★★
P0547	Brutus	11	3.70	2,894	★★★
P0547	Maximus	9	3.02	2,801	★★★
P0547	N39-Q1	49	-0.79	1,083	★★★
P0547	N51-N4	58	1.08	959	★★★
P0547	P0021	169	-0.52	531	★★★
P0547	P0362	75	1.30	56	NS
P0547	P0640	58	1.17	422	★
P0547	P0891	36	2.17	677	★★
P0547	P9721	114	-1.50	528	★★★
P0547	P9978	28	0.40	-326	NS
P0547	Plenitude	27	2.23	828	★★★
P0547	Velocity	13	-0.61	1,652	★★★

[1]Positive harvest moisture differences means the bolded hybrid was drier at harvest, negative harvest moisture differences mean in was wetter. [2]A positive yield advantage means the bolded hybrid produced more yield, a negative yield advantage means it produced less. [3]For information on interpreting hybrid comparison data and statistical significance see page 4. Includes all data to the end of the 2021 harvest.

Recommended growing regions

Recommended established plant populations (000's/ha)

Challenging yield environments	88
Medium yield environments	96
High yield environments	102

LEAF DISEASE CHAMPION DELIVERING YIELD STABILITY.

CRM 106

Feature hybrid	Comparison hybrid	Number of trials	Harvest moisture difference (%)[1]	Yield advantage (kg/ha)[2]	Statistical significance[3]
Northland					
P0640	P0021	39	-1.41	350	NS
P0640	P0362	47	-0.21	333	CA
P0640	P0891	47	0.32	576	★★
P0640	P0900	11	1.01	696	★
P0640	P0937	24	0.73	-652	★★
P0640	P9978	16	-0.97	18	NS
Waikato					
P0640	Afinity	15	-0.97	1,648	★★
P0640	Brutus	8	2.36	1,941	CA
P0640	N39-Q1	24	-1.86	1,872	★★★
P0640	N51-N4	72	-0.48	1,373	★★★
P0640	P0021	97	-1.45	1,067	★★★
P0640	P0362	60	-0.41	1,233	★★★
P0640	P0891	156	0.42	241	★
P0640	P0900	29	1.48	382	NS
P0640	P0937	59	1.05	-276	NS
P0640	P9978	19	-1.63	137	NS
P0640	PAC343	23	-0.57	1,114	★★★
P0640	PAC432	35	0.94	1,022	★★★
P0640	Plenitude	36	0.21	1,669	★★★
Bay of Plenty					
P0640	Afinity	9	-0.85	990	CA
P0640	N39-Q1	16	-1.03	1,315	★★
P0640	N51-N4	31	-0.21	617	★
P0640	P0021	24	-0.69	740	★
P0640	P0362	28	0.13	337	NS
P0640	P0891	108	0.42	352	★★
P0640	P0900	13	1.27	-356	NS
P0640	P0937	45	0.81	-536	★
P0640	P1253	103	0.64	-332	★
Gisborne & Hawke's Bay					
P0640	P0021	66	-1.38	474	★★
P0640	P0362	42	-0.49	491	★
P0640	P0891	79	0.40	386	★★
P0640	P0900	17	1.08	-21	NS
P0640	P0937	27	0.68	-1,002	★★★
P0640	P1253	72	1.23	-414	★
P0640	P9978	17	-1.28	-710	★

[1]Positive harvest moisture differences means the bolded hybrid was drier at harvest, negative harvest moisture differences mean in was wetter. [2]A positive yield advantage means the bolded hybrid produced more yield, a negative yield advantage means it produced less. [3]For information on interpreting hybrid comparison data and statistical significance see page 4. Includes all data to the end of the 2021 harvest.

Recommended growing regions

Recommended established plant populations (000's/ha)

Challenging yield environments	85
Medium yield environments	95
High yield environments	100

NEW

HARD TO FAULT, STABLE, ALL-ROUND HYBRID.

CRM 109

Optimum AQUAmax

Feature hybrid	Comparison hybrid	Number of trials	Harvest moisture difference (%)[1]	Yield advantage (kg/ha)[2]	Statistical significance[3]
Northland					
P0900	P0640	17	-1.08	21	NS
P0900	P0891	17	-0.74	309	NS
P0900	P0937	16	-0.47	-786	CA
P0900	P1253	17	-0.22	257	NS
Waikato					
P0900	P0640	29	-1.48	-382	NS
P0900	P0891	31	-0.84	715	CA
P0900	P0937	32	-0.44	-504	NS
P0900	P1253	28	-0.50	-360	NS
Bay of Plenty					
P0900	P0640	13	-1.27	356	NS
P0900	P0891	22	-0.39	829	CA
P0900	P0937	22	-0.27	-243	NS
P0900	P1253	22	-0.06	115	NS
Gisborne & Hawke's Bay					
P0900	P0640	17	-1.08	21	NS
P0900	P0891	17	-0.74	309	NS
P0900	P0937	16	-0.47	-786	CA
P0900	P1253	17	-0.22	257	NS

[1]Positive harvest moisture differences means the bolded hybrid was drier at harvest, negative harvest moisture differences mean in was wetter. [2]A positive yield advantage means the bolded hybrid produced more yield, a negative yield advantage means it produced less. [3]For information on interpreting hybrid comparison data and statistical significance see page 4. Includes all data to the end of the 2021 harvest.

Recommended growing regions

Recommended established plant populations (000's/ha)

Challenging yield environments	80
Medium yield environments	90
High yield environments	110

SOLID HYBRID WITH NEXT GENERATION GRAIN YIELD.

CRM 109

Feature hybrid	Comparison hybrid	Number of trials	Harvest moisture difference (%)[1]	Yield advantage (kg/ha)[2]	Statistical significance[3]
Northland					
P0937	P0362	16	-0.68	1,510	★★★
P0937	P0640	24	-0.73	652	★★
P0937	P0891	19	-0.42	1,733	★★★
P0937	P0900	11	0.56	927	★★
P0937	P1253	19	-0.19	1,564	★★★
Waikato					
P0937	Brutus	8	1.63	3,465	★★
P0937	N51-N4	13	-1.98	2,226	★★
P0937	P0362	28	-1.26	1,777	★★★
P0937	P0640	59	-1.05	276	NS
P0937	P0891	57	-0.80	1,133	★★★
P0937	P0900	32	0.44	504	NS
P0937	P1253	52	-0.41	746	★★★
P0937	PAC432	30	-0.05	1,081	★★
P0937	PAC456	15	-0.64	887	CA
P0937	Plenitude	18	-0.80	1,334	★
Bay of Plenty					
P0937	P0362	24	-0.78	1,210	★★
P0937	P0640	45	-0.81	536	★
P0937	P0891	52	-0.40	1,240	★★★
P0937	P0900	22	0.27	243	NS
P0937	P1253	48	-0.21	1,072	★★★
Gisborne & Hawke's Bay					
P0937	P0362	20	-0.81	1,448	★★★
P0937	P0547	10	-1.81	1,876	★★
P0937	P0640	27	-0.68	1,002	★★★
P0937	P0891	30	-0.68	1,615	★★★
P0937	P0900	16	0.47	786	CA
P0937	P1253	29	0.13	1,022	★★

[1]Positive harvest moisture differences means the bolded hybrid was drier at harvest, negative harvest moisture differences mean in was wetter. [2]A positive yield advantage means the bolded hybrid produced more yield, a negative yield advantage means it produced less. [3]For information on interpreting hybrid comparison data and statistical significance see page 4. Includes all data to the end of the 2021 harvest.

Recommended growing regions

Recommended established plant populations (000's/ha)

Challenging yield environments	85
Medium yield environments	95
High yield environments	110

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CRM 109

Feature hybrid	Comparison hybrid	Number of trials	Harvest moisture difference (%)[1]	Yield advantage (kg/ha)[2]	Statistical significance[3]
Waikato					
P1253	Brutus	7	2.77	2,790	★
P1253	N51-N4	88	-2.06	811	★★★
P1253	P0362	27	-0.29	817	★
P1253	P0640	140	-0.97	-7	NS
P1253	P0891	218	-0.57	249	★★
P1253	P0900	28	0.50	360	NS
P1253	P0937	52	0.41	-746	★★★
P1253	P1477W	37	2.41	-178	NS
P1253	PAC343	11	-1.25	940	CA
P1253	PAC432	32	-0.05	827	★★
P1253	PAC456	15	-0.49	1,128	★★★
P1253	Plenitude	17	-0.47	2,380	★★★
Bay of Plenty					
P1253	N51-N4	75	-1.35	750	★★★
P1253	P0362	22	-0.18	-377	NS
P1253	P0640	103	-0.64	332	★
P1253	P0891	183	-0.31	616	★★★
P1253	P0900	22	0.06	-115	NS
P1253	P0937	48	0.21	-1,072	★★★
P1253	P1477W	20	1.78	13	NS
P1253	Plenitude	9	-1.10	1,733	★★
Gisborne & Hawke's Bay					
P1253	P0362	25	-1.05	371	NS
P1253	P0640	72	-1.23	414	★
P1253	P0891	138	-0.82	648	★★★
P1253	P0900	17	0.22	-257	NS
P1253	P0937	29	-0.13	-1,022	★★
P1253	P1477W	8	1.94	-519	NS

[1]Positive harvest moisture differences means the bolded hybrid was drier at harvest, negative harvest moisture differences mean in was wetter. [2]A positive yield advantage means the bolded hybrid produced more yield, a negative yield advantage means it produced less. [3]For information on interpreting hybrid comparison data and statistical significance see page 4. Includes all data to the end of the 2021 harvest.

Recommended growing regions

Recommended established plant populations (000's/ha)

Challenging yield environments	88
Medium yield environments	94
High yield environments	100

GREENHOUSE GAS EMISSIONS FROM MAIZE SYSTEMS

Almost half of New Zealand's greenhouse gas (GHG) emissions come from agriculture. Few maize growers have modelled their GHG losses and there is limited grower understanding of how to decrease GHG emissions from maize cropping systems.

A recently published paper[1] co-authored by Pioneer® brand seeds and the Foundation for Arable Research (FAR) modelled annual GHG emissions for eight maize grain and 12 maize silage production systems.

Maize grain

Maize grain yields (14% moisture) ranged from 10.8 to 18.0 t/ha (average 14.6 t/ha). N fertiliser application rate to the maize crop ranged from 59 to 358 kg N/ha (average 213 kg/ha). Total annual GHG emissions for the maize grain systems ranged from ranged from 1,114 to 2,873 kg CO_2e/ha (average 2,036 kg CO_2e/ha).

Table 1: Maize grain yield, crop management, rotation history and biological GHG emissions

Region	Grain yield (t/ha)	Fertiliser N applied to maize (kg/ha)	Fertiliser N applied to winter crop (kg/ha)	N-surplus (kg/ha)	Prior years in pasture	Winter crop	Grazed	Annual biological GHG emissions (kg CO_2e/ha)
BOP	17.0	159	0	-46	8	Oats/ annual ryegrass	N	2,019
BOP	15.3	307	61	-4	0	Annual ryegrass	N	2,237
East Coast	18.0	267	0	48	0	Annual ryegrass	Y	2,873
Manawatu	13.5	223	0	61	0	Fallow	N	1,834
Manawatu	14.0	175	0	7	0	Fallow	N	1,794
Northland	15.4	358	0	172	0	Fallow	N	2,818
Northland	10.8	156	0	39	0	Vetch, lupin & ryecorn	N	1,599
South Auckland	13.0	59	0	-97	3	Brassica	N	1,114
Averages	**14.6**	**213**						**2,036**

Maize silage

Maize silage yields ranged from 15.0 to 26.8 tDM/ha (average 21.1 tDM/ha). N fertiliser application rate to the maize crop ranged from 131 to 310 kg/ha (average 220 kg/ha). Maize silage systems without livestock (n=3) had average biological GHG emissions of 1,850 kgCO_2e/ha. The range of emissions from non-livestock silage systems was 1,697 to 2,096 kg CO_2e/ha. Maize silage systems which included winter livestock produced average biological GHG emissions of between 1,512 to 6,135 kgCO_2e/ha (average 3,543 kgCO_2e/ha).

Table 2: Maize silage yield, crop management, rotation history and biological GHG emissions

Region	Maize silage yield (tDM/ha)	Fertiliser N applied to maize (kg/ha)	Fertiliser N applied to winter crop (kg N/ha)	Total fertiliser N	N-surplus (kg/ha)	Prior years in pasture	Winter crop	Grazed (G) or silage (S)	Annual biological GHG emissions (kg CO_2e/ha)
BOP	26.8	228	62	290	-217	0	Annual ryegrass	G	4,362
Canterbury	20.0	231	69	300	26	10	Forage oats	S	2,096
Manawatu	23.0	131	46	177	-143	10	Perennial ryegrass	G	2,846
Manawatu	21.0	133	0	133	-162	5	Perennial ryegrass	G	2,695
Northland	15.0	193	0	193	-178	9	Perennial ryegrass	G	1,512
Northland	16.0	183	30	213	-12	10	Perennial ryegrass	G	4,592
Northland	16.0	183	30	213	37	9	Annual ryegrass	G	4,717
Taranaki	26.0	292	0	292	-37	10	Annual ryegrass	G	2,709
Waikato	22.4	310	0	310	-2	0	Annual ryegrass	G	2,321
Waikato	22.0	268	69	337	-112	0	Perennial ryegrass	S	1,757
Waikato	24.5	261	92	353	-222	4	Annual ryegrass	S	1,697
Waikato	20.2	182	46	228	-76	0	Annual ryegrass	G	6,135
Averages	**21.1**	**220**	**37**	**253**					**3,120**

Discussion

In maize grain systems there were moderate to high correlations between annual biological GHG emissions and N-surplus (R^2 =0.4876), and total fertiliser N applied (R^2 = 0.7761).

In contrast there were poor correlations between annual biological GHG emissions from maize silage systems and total fertiliser N applied (R^2 = 0.097) and N-surplus (R^2 = 0.068) in silage systems. This was likely due to the contribution of methane from winter grazing.

Summary

Some take home message for maize growers are:

(i) **Know your number.** Use one of the available tools to calculate the GHG loss for your farm.

(ii) **Make sure your nitrogen application rate is appropriate.** Set realistic paddock yield expectations for your maize crop and consider paddock history and soil available nitrogen levels before determining crop nitrogen inputs.

(iii) **Consider the form, rate and timing of N application.** Incorporate urea or apply it prior to rain where possible. Alternatively consider the cost: benefit of using urease-coated N products.

(iv) **Account for livestock.** If you want to reduce GHG losses from your farm, consider winter management options which do not include livestock.

[1]Densley et al. 2022. Quantifying greenhouse gas losses from typical maize cropping systems and the impact of possible mitigation strategies using OverseerFM. In Press.

PIONEER® MAIZE GRAIN YIELD INCREASES

Introduction

Maize grain yield has a large impact on profitability however as crop input costs rise and environmental regulations tighten, there is increasing pressure to produce more from the same area. Research shows that maize yield has risen over time with around 50% of the yield gains coming from plant genetics and 50% from improved crop management practices.

Method

To quantify genetic maize yield gains over time historical data (1992-2020) from the Pioneer Maize Grain Research Programme were analysed.

Rather than plot year-on-year average data which includes experimental hybrids and is impacted by the growing environment (including weather) and crop management practices as well as hybrid genetics, this project looked specifically at the yields of individual hybrids and plotted them according to their first year of commercial release. To qualify to be included in the analysis, hybrids had to have remained in the Pioneer commercial line-up for at least five years. As an example, Pioneer® brand 34P88 was commercially released in 2006, it was included in 658 trial plots and its average yield was 14.6 t/ha.

The NZ data set included 66 Pioneer® brand grain hybrids (which met the above criteria) with a total of 28,000 data points.

Results

Average maize grain yield was 11.6 t/ha in 1991-93 but had increased to 15.7 t/ha in 2017-20 giving an average increase of 165 kg/ha/year. Grain yield increase was highest in the lower North Island and Canterbury (232 kg/ha/year) and lowest in Northland and South Auckland (38.3 kg/ha/year).

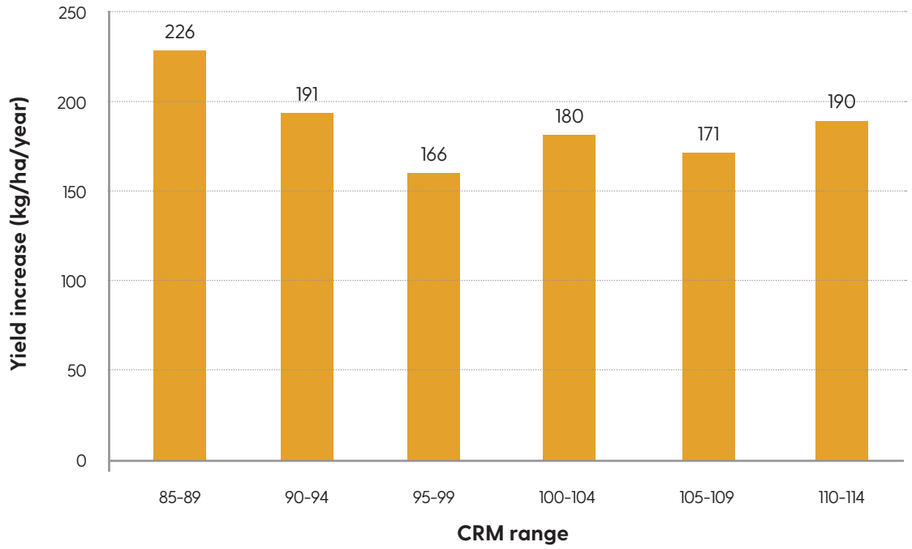
Table 1: New Zealand maize grain yield increase by region averaged over three seasons between 1991 and 2020

Season	91-93	95-97	98-00	01-03	05-07	08-10	11-13	14-16	17-20
Region	Grain yield (t/ha)								
BOP	12.1	12.2	13.0	13.5	14.5	14.9	15.4	15.6	16.1
Gisborne and Hawke's Bay	12.9	12.6	13.6	14.3	14.4	15.3	15.9	16.1	16.6
Lower NI and Canterbury	10.3	11.4	12.9	12.8	14.0	15.2	15.5	15.3	15.8
Northland and South Auckland	11.1	12.4	12.3	12.1	12.3	12.4	12.1	12.8	13.1
Waikato	11.6	12.1	12.6	12.8	13.5	14.4	14.5	15.2	15.8
National average (±standard error)	11.6 ±0.48	12.0 ±0.22	12.8 ±0.23	13.2 ±0.41	13.7 ±0.44	14.5 ±0.61	15.0 ±0.77	15.2 ±0.64	15.7 ±0.69

There were differences in yield increases by hybrid maturity, with the highest grain yield gains occurring in the shorter season hybrids (85-89 comparative relative maturity (CRM) segment; Figure 1). This is evidence that the yield gap between short and long CRM has decreased over the years.

In 1992 average grain yields for 85-90 CRM hybrids were on average, 19% lower than 100-104 CRM hybrids whereas by 2020 the difference was only 7%. Contrary to 30 years ago where long CRM were generally needed to maximise grain yields, short CRM hybrids can yield competitively provided they are adapted to the growing environment.

Figure 1: Maize grain yield increase by maturity across eight New Zealand regions (1991-2020)



Conclusions

Several USA studies have examined the yield of hybrids which were commercially released in different eras. In these studies, seed from old hybrids was planted alongside modern genetics allowing researchers to measure yield differences and plant characteristics which could potentially influence yield.

Donald Duvick, whose forty-year professional career was dedicated to the development and production of hybrid maize in the USA, measured average genetic yield gains of 65-75 kg/ha grain. He showed that genetic gains in maize yield over time was not related to plant height or leaf area, kernel weight or cob size.

Duvick's trials showed that yield gains could be attributed to the following factors:

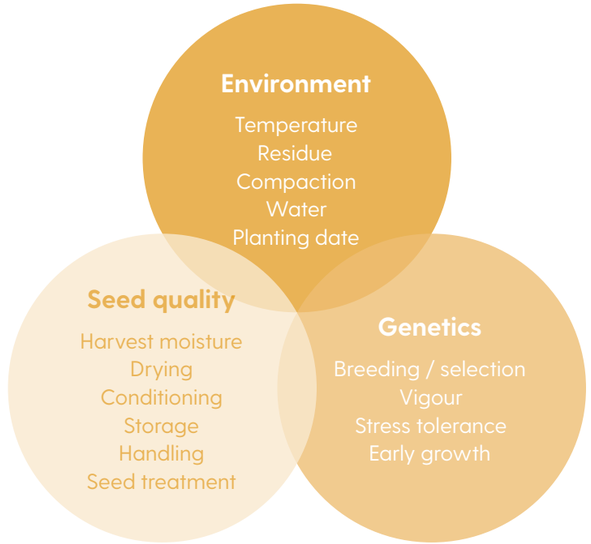
- **Improved staygreen.** Green leaves are the energy factory of a maize plant. The longer maize leaves stay green, the longer the plant can continue to photosynthesise producing fuel to produce more grain.
- **Better synchrony for pollination.** Modern hybrids have pollen and silks emerging at around the same time. This improves pollination which in turn sets a high yield potential for each and every plant.
- **Stress tolerance.** Newer hybrids outyield the older ones not only in high yield environments but also when crops are subjected to abiotic stress (e.g., heat and drought) or biotic stress (e.g., pests and diseases).
- **Traits which support higher plant populations.** This includes an increased leaf angle allowing for greater capture of sunlight and improved root and stalk strength which results in less lodging. There has also been an improvement in crowding stress tolerance, resulting in reduction in the number of barren plants at higher plant populations.

Our analysis shows an average yield gain of 165 kg/ha per year between 1991 and 2020. If we assume that around 50% of this gain is due to crop management improvements (more accurate planting, improvements in seed treatment technology, better weed and pest control), the genetic gain measured in NZ grain trials is around 80 kg/ha/year which is very close to the USA estimate of 65-75 kg/ha/year.

PIONEER STRESS EMERGENCE RATINGS

Introduction

Research shows that the highest maize yields come from uniform stands of plants which emerge at the same time and grow to produce even plants. Three factors interact during germination and emergence and together determine how well a maize crop establishes. These are seed quality, hybrid genetics and the growing environment.



While it is possible to influence some environmental factors (e.g., soil compaction and planting date) others are virtually impossible to control. In New Zealand, spring growing conditions can be challenging with fluctuating temperatures and saturated soils.

For the past three seasons, the quest for more uniform maize seed emergence has led to increased seed quality research to help characterise the performance of individual Pioneer hybrids under cold, wet emergence conditions. As a result of this work, Stress Emergence ratings have been included in the 2022 Pioneer Maize Grain Catalogue (see pages 54-55).

Seed quality and emergence

A number of tests can be used to quantify maize seed quality.

- Pioneer Stress Test (PST) – a proprietary vigour test which imposes extreme chilling and anaerobic stresses, beyond that of the industry standard saturated cold test.
- Saturated cold test – seed is planted into saturated trays which are kept at 10°C for seven days.
- Cold germination test – seed is planted into trays which are kept at 10°C for seven days.
- Warm germination test – seed is planted into trays which are kept at 25°C for seven days.

While warm germination tests - carried out according to International Seed Testing Association (ISTA) protocols - provide a good indication of paddock germination under ideal conditions, the proprietary Pioneer Stress Test (PST):

- Applies the highest level of vigour stress testing by providing a low temperature, waterlogged germination environment.
- Helps to further differentiate the quality of individual seed lines.
- Quantifies the impact of seed treatments on seed quality.
- Helps characterise the genetic stress tolerance of individual Pioneer maize hybrids.

Laboratory seed quality testing

Over the winter of 2019 and 2020 a total of 894 samples of New Zealand produced, commercial Pioneer maize hybrids (treated and untreated) were tested for physical purity, genetic purity, warm germination and through the Pioneer Stress Test (PST). This allowed us to characterise the relative vigour of individual hybrids under the toughest germination conditions.

Field stress emergence trials

In spring 2019, 24 hybrids were planted ultra-early at twice the normal planting depth (8.5 cm) into cold wet soils. There were a total of three Waikato and three lower North Island sites giving a total of 36 replicates per hybrid.

The Pioneer Research Team monitored the sites and measured the rate of emergence as well as final plant stand count. Due to the challenging establishment conditions, the mean established plant population was 82% of the planting rate. There were, however, significant differences between hybrids with an established population range of 70-90%.

Pioneer stress emergence ratings

All Pioneer seed supplied to the market is expected to establish excellent plant stands if planted well and under normal germination conditions. Data collected from the laboratory seed quality testing exercise and the field stress emergence trials, referred to above, were used to develop the Pioneer Stress Emergence Ratings. These ratings indicate each hybrids ability to establish under challenging cold, wet growing conditions. The table below groups hybrids into three classes as a result of this research.

Stress emergence rating	Commentary	Hybrids
7-9	Very good potential to establish normal stands under stressful environmental conditions of cold, wet soils.	P9721, P9978, P0021, P0900, P0937.
5-6	Good potential to establish normal stands under stressful conditions of cold, wet soils.	P8000, P8333, P8500, P8666, P8805, P9127, P0362, P0640, P1477W.
1-4	Below average potential to establish normal stands under stressful conditions of cold, wet soils. Should not be used if severe wet and cold conditions are expected after planting.	P9400, P0891, P1253.

Growers can be confident that every bag of Pioneer® brand maize seed they plant has been thoroughly tested in this extensive screening program and meets Pioneer's industry-leading standards.

MAIZE RESPONSE TO PLANT POPULATION

Introduction

Maximising maize grain yield requires matching the right maize hybrid with the optimal plant population.

- If plant density is too low, grain yield is low because the maize plant is not capable of "flexing" sufficiently to compensate for the reduction in plant density.
- If plant density is too high, the reduction in plant and ear size or grain fill due to extreme competition among plants may result in a drop in yield per plant that is not offset by the increase in the number of plants.
- A major genetic contribution to the lift in maize yields in recent years can be attributed to an increase in "crowding stress" tolerance. Although maize grain yield per plant declines with increased population, the overall yield per hectare increases, provided soil moisture and nutrition are not limiting.
- Optimum plant population density varies depending on a range of factors such as growing environment, yield level, soil moisture, hybrid choice and planting date. High yield environments (including high fertility soils straight out of long-term pasture) have higher recommended established plant populations than challenging yield environments including light, sandy or shallow soils with low fertility and/or drought risk. Short season hybrids (<100 CRM) are usually smaller statured and usually require more plants per unit area to achieve the optimum density needed to maximise grain yields.

Leaf area index

While Pioneer's earlier plant population research gathered agronomic and yield data from replicated plant density studies, current research is focusing on determining the plant population that optimises leaf area index (LAI).

- Maize grain yields are largely influenced by the amount of light intercepted by leaves during grain fill. Leaf area index is the amount of leaf area in a crop canopy relative to ground area and is directly related to the amount of light intercepted by the crop.
- When measured at or around silking, LAI can be considered a reliable parameter for estimating maize grain yield due to its strong relationship with radiation interception.
- Achieving a greater leaf canopy helps maximise photosynthesis allowing the plant to convert more sunlight into stored energy.
- Optimum LAI may vary by hybrid and environment but values around 6 appear adequate to maximise NZ maize grain yields in moderate to high yielding environments, but research is ongoing.
- Earlier maturing hybrids tend to be smaller or shorter statured than longer season hybrids and hence require a higher plant density to optimise LAI. The same also applies to cooler environments where plants can be of smaller stature.

Trial method

Over the past three seasons, the Pioneer Research Team has conducted maize plant density trials to assess the impact of plant population on LAI for a range of new Pioneer® brand maize hybrids. In this example we present a summary of field trial results for P9721, P9978, P0640 and P0900.

Maize was planted using a conventional Wintersteiger precision planter in plots sized four rows x 76.2 cm x 5.3 m at a slightly higher planting density than required. At around V2 – V4 maize development stage, plots were thinned to achieve established populations of 10,000, 45,000, 75,000, 100,000, 125,000 and 150,000 plants per hectare. Throughout the season, a range of records were collected. These included measurements of LAI around flowering time on a sunny day, close to solar noon (the time when the sun is highest in the sky) using an Accupar LP-80 Plant Canopy Analyser. At approximately 21 grain moisture, two centre rows of each plot were harvested using a small plot combine harvester.

Results

While kernel number and size per plant decreased with increased plant population, grain yield per hectare increased (Table 1). This research showed that despite a decrease in grain weight as plant population increased, grain yield per ha did increase. For instance, between 45,000 and 100,000 plants/ha, for every 10,000 plants/ha increase:

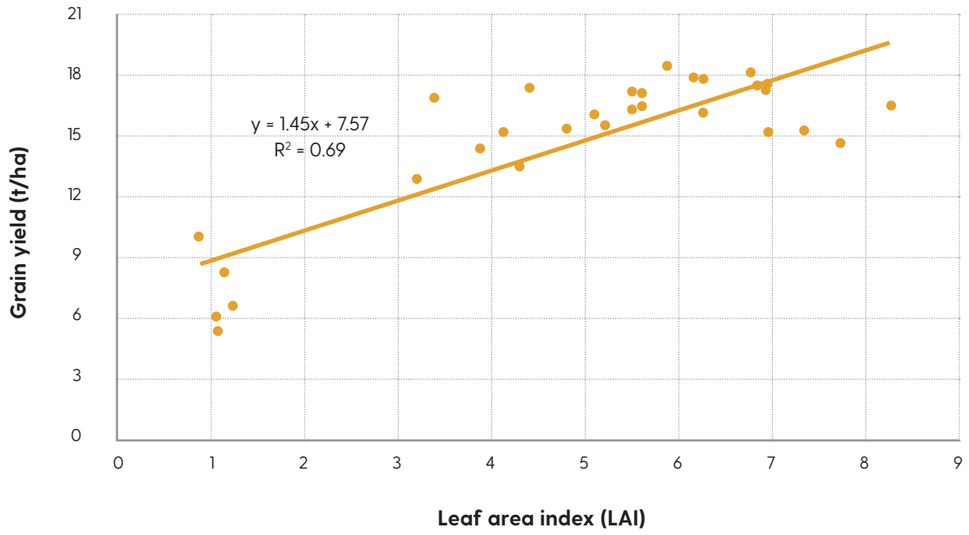
- Individual grain weight decreased by 26 g/plant.
- Grain yield increased by 573 kg/ha.

Table 1: Relationship between established maize plant population and leaf area index, average grain weight per plant and maize grain yield (±standard error of mean) at three Waikato sites for the 2020-2022 harvest seasons.

Plant population/ha	LAI	Kernel weight (g)/plant	Maize grain yield, t/ha (14%)
45,000	4.8±0.15	318±11.1	14.5±0.38
75,000	5.8±0.19	225±4.6	17.1±0.30
100,000	6.3±0.18	174±4.2	17.8±0.57
125,000	6.5±0.20	131±5.3	17.5±0.35

For each unit increase in LAI value, maize grain yield increased at a rate of 1.5 t/ha (Figure 1). At 125,000 plants/ha or greater, despite a continued increase in LAI, maize grain yield gain diminished due to increased plant competition for light, nutrients and/ or water.

Figure 1: Relationship between leaf area index at flowering time and maize grain yield at three Waikato sites over three seasons (2020-2022).



Conclusions

- While maize crops planted at a lower population can sometimes look impressive (e.g., bigger cobs), the maize plant cannot flex sufficiently to compensate for the reduced yield due to a decreased plant population.
- By using LAI growers can adjust seeding rates depending on time of planting, environment, hybrid choice etc. For instance, when planting early in cooler climates, plant size is likely to be smaller and a higher plant density will be required to achieve the optimum LAI required to maximise yield.
- Our current data indicates that in medium to high yield environments yields are maximised at LAI values around 6. Limited data indicates optimum values on light, drought-prone soils could be lower than 6 but more research is needed.
- Once the desired plant population to maximise yield is determined, downward population adjustments can be made to account for less favourable growing conditions such as soils with low water holding capacity or high lodging risk.
- To evaluate the adequacy of light interception during grain fill observe light penetration under the crop canopy at solar noon on a calm, sunny day. A paddock considered to be at an optimal plant population density should have very little sunlight hitting the soil surface with very few to no plants without an ear or an ear filled to the tip.
- Pioneer® brand recommended plant populations are for established stands. Plant 5-10% more seed than the recommended rates to allow for seedling mortality.

THANK YOU TO THE 2020-2021 TRIAL CO-OPERATORS

The results of the extensive research programme in this publication are only made possible with the willing assistance and co-operation of both farmers and contractors. Our special thanks go to all those involved with planting and harvesting grain trials across New Zealand.

Northland

Ambler, Paul & Susannah
Bamforth, Paul
Higham, Noel & Janet
Judd, Sidney & Janet
North Country Grains (Selwyn Garton)
Pioneer Research Station - Northland
Pukerimu Holdings
Scott, Dave
Smith, Jason
Taylor, Grant & Pauline
Waller, David
Waller, Neil
Wood, Nigel & Shirley
Wordsworth, David & Adrienne

Bay of Plenty, Gisborne and northern Hawke's Bay

Apanui Farms (Guy & Isobel Nicol)
Atkinson, Norma
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Bostock New Zealand Ltd
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Briant Brothers
Bryson, David & Tanya
Chesterman, John
De Costa, Mark
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Edkins, Ken
Ferkins Farming
Gibson, Paul & David
Gray, Stuart

Central Hawke's Bay, lower North Island and Taranaki

Alpe, Jim
Carter, Paul
Carey, Mark & Anne
Carter, Paul
Dalrymple, Heu
Duncan, William
Gibbons, Bruce
Glasgow, Stewart
Harding, Ross
Hill, Brian & Geoff
Jones, Andrew
Stone, Murray
J P Contractors
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Waikato

Austin, John
Babington, Cliff
Bain, Richard
Balle Brothers (Eamon Balle)
Bateup, Graeme
Brown, Alan
Coxhead, Murray
Gavin, Ian
Giltrap, Viva & Gladys
Greenhaven Farms Ltd
Henderson, Alan
Hodge, John & Margaret
Hunter, Paul
Krissansen, Grant
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Pellow, Chris
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Stobie, Donald & Craig
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Ngatapa Rugby Club
O'Sullivan, Sean
Phillips, David
P J Brogden Contracting Ltd C
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Powdrell, Matthew
Power Grain Ltd
Parapoupou
Stockland Agri Ltd (Nigel & Lauren Timbs) Roberts Agriculture Ltd
Te Tawa Kaiti Lands Trust
Thomas, Andrew
Turner, John

Moleta, Hugh & Michael
Newman, David & Nick
Nickel, Bruce
Nitschke, Dennis
Nitschke, Simon
Noaro Farms Ltd
O'Neill, Patrick
Redmayne, Richard
Saunders Co G 4 Ltd
Scott, Rhys
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