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Dry matter and nitrogen partitioning in sweet corn (*Zea mays* L.) for processing: plant density and nitrogen nutrition effects.

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Abstract

Increasing land values without comparable increases in yield or reduced input costs have reduced the attractiveness to growers of processing sweet corn (*Zea mays* L.) as a cropping enterprise at Gisborne, New Zealand. As a consequence, the problem of consistently sourcing adequate volumes of raw material has been one factor leading the region's major sweet corn processor to consider withdrawing from the region. Hence, the development of agronomic practices which reduce crop production costs, improve marketable yields, or both, will be important for maintaining the viability of the sweet corn processing industry in Gisborne for both growers and processors alike.

Two of the most important factors influencing yield of sweet corn are plant density and nitrogen (N) nutrition. The density range which maximised marketable yield of cobs and kernels for Jubilee and SS42, the two prominent cultivars grown at Gisborne, was 69-77,000 plants per hectare. Although yield response to fertiliser N was also investigated in the same study, the yield response was either negligible (SS42) or did not follow a trend consistent with incremental increases in N rate (Jubilee). The limited response was attributed to high background levels of soil available N (269 kg/ha). A second experiment was designed to investigate the yield response to fertiliser N on a soil with a low available N level. Although only 92 kg N/ha was available from the soil, yield response in this experiment was also negligible with N rates greater than 73 kg/ha. Combining the two years' results indicated that yield response to N fertiliser will be limited when soil available N levels are > 213 kg/ha.

The rate of yield improvement could be enhanced by greater understanding of the physiological processes limiting yield in maize and sweet corn. The study of source-sink relationships can provide useful insights into yield determinants. A field experiment was established with Jubilee and SS42 to study how variables influencing weight of primary and secondary ears (e.g., silk delay, tiller number per plant) adjust to plant density and N nutrition. Path analysis and canonical discriminant analysis indicated that tillers were important for supplying the secondary ears of both cultivars with photoassimilate at low densities (e.g., 40,000 plants per hectare) and were important for Jubilee, but not SS42, at high densities (e.g., 100,000 plants per hectare). A short silk delay for both the primary and secondary ear was important for both cultivars at low

densities to establish a large ear sink. Thus, at low densities, the presence of a secondary ear at low densities appeared to enhance kernel development on the primary ear.

To further understand the partitioning of DM and N to kernels, further experiments quantified sink strength (or source strength) of an organ (i.e., leaves, stems, roots, kernels, rachis, husk, or shank) between defined ontogenetic stages. Sweet corn grown at 70,000 plants per hectare with rates of applied N ranging from 0 to 230 kg/ha were harvested throughout ontogeny until R4. Although N rate generally did not influence partitioning of N or dry matter (DM) to any organ, significant cultivar differences were detected. Kernel sink strength of Jubilee was two-fold greater for DM than SS42 and three-fold greater for N between R1 and R3. As a consequence, kernels of Jubilee contained 34% more DM than those of SS42 at R4 and were significantly more efficient than SS42 kernels at translating endogenous N into kernel DM. The observation that DM was partitioned to vegetative organs during reproductive growth while N was being remobilised from these organs indicated that both Jubilee and SS42 were source limited for N, yet sink limited for current photoassimilate.

No published studies have been sighted which have identified a link between the source limitation for N and the sink limitation for DM in *Z. mays*. Investigating source-sink relationships indicated that the two events are linked and initiated by low kernel sink strength during early grain filling. SS42 partitioned large proportions of DM to both husks and stems between R1 and R3, in contrast to Jubilee which partitioned most DM directly to kernels. As partitioning DM to vegetative tissue and husks reflects photoassimilate not consumed in reproductive growth, excess photoassimilate resulting from limited sink strength may have decreased photosynthetic rates through 'feedback' inhibition. Consequently, the ability of Jubilee to partition DM to roots for N assimilation between R3 and R4 may reflect less inhibited photosynthesis than for SS42.

A subsequent experiment provided further evidence that kernel sink strength influences N and DM partitioning. This experiment also indicated that low kernel sink strength during early grain filling may actually initiate an inhibitory cycle. When maximum leaf area in maize and sweet corn is reached around R1, the ear is a relatively weak sink and unable to accumulate all the photoassimilate being produced. Although the excess is partitioned to stems and husks, these

organs can only accumulate a limited quantity before they become saturated. When the stem and husks become saturated, photoassimilate may accumulate in leaves causing feedback inhibition of photosynthetic enzymes to reduce the supply of photoassimilate. However, as N assimilation rate is dependent on the rate of photoassimilate supply to roots, the inhibited photosynthesis reduces N uptake and as a consequence, remobilisation of N is stimulated. Excessive remobilisation of N from leaves may further impair photosynthetic activity to further restrict the photoassimilate supply for root and shoot functions including grain filling. Hence, an inhibitory cycle may evolve from the limited capacity of kernels and rachis to accumulate photoassimilate. Since SS42 (*sh2* mutant) had a significantly lower kernel sink strength than Jubilee (*su1* mutant) during early grain filling, SS42 was apparently more influenced by the inhibitory cycle than Jubilee.

To add support to the theory that limited kernel sink strength during early grain filling may lead to an inhibitory cycle, a final experiment investigated the association of the endosperm storage protein, zein, with kernel sink strength. A high correlation (r=0.91) was observed between kernel DM and the level of zein. Further, the wild type (Furio) contained 25 and 49% more zein at R4, and accumulated 18 and 49% more DM, respectively than the *su1* (Jubilee) and *sh2* (SS42) mutants. Similarly, kernels of Jubilee, which contained 31% more zein than those of SS42., accumulated 38% more DM. Together these results indicate that the level of zein is associated with kernel sink strength and thus lends support to the inhibitory cycle theory.

Key words: **canonical discriminant analysis, endosperm mutants, nitrogen nutrition, non-linear regression, path analysis, photoassimilate partitioning, plant density, process sweet corn, *sh2*, *su1*, zein.**

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List of abbreviations

1^o	primary
2^o	secondary
^{14}C	carbon isotope
^{15}N	nitrogen isotope
^{32}P	phosphorous isotope
λ_i	*i*th eigenvalue of canonical discriminant function
$\bar{x}$	sample mean
$\sigma_{\bar{x}}$	standard deviation of the sample means
δ	rate of change between two ontogenetic stages
χ^2	chi-square statistic
a.i.	active ingredient
ADP	adenosine diphosphate
ANOVA	analysis of variance
bt2	*brittle*-2 endosperm mutant
C	degrees Celsius
CDA	canonical discriminant analysis
CDF_1	first canonical discriminant function
CEC	cation exchange capacity
DAP	days after pollination
DEFITS	Cook's D statistic (scaled and squared)
DM	dry matter
DMPC	dry matter partitioning coefficient
F	F-statistic
fl2	*floury*-2 endosperm mutant
GDD	growing degree day
Gw	grain dry weight
HI	harvest index
KCl	potassium chloride
kDa	kilo-Dalton
LSD	least significant difference
M	molar concentration
n	number of observations
N	nitrogen
Ns	quantity of nitrogen applied
Nt	total N content of the plant
NIWA	National Institute of Water and Atmospheric Research Ltd
NPC	nitrogen partitioning coefficient
NUPE	nitrogen uptake efficiency
NUSE	nitrogen use efficiency
NUTE	nitrogen utilization efficiency

o2	*opaque*-2 endosperm mutant
P	probability
PEPCase	*phosphoenolpyruvate carboxylase*
P_{ij}	path coefficient between the variables *i* and *j*
PPDK	*pyruvate pyrophosphate dikinase*
PPFD	photosynthetic photon flux density
pph	plants per hectare
PS	current photoassimilate
R1	silking stage (i.e., silks from the tip of the prophyll are visible)
R2	blister stage (i.e., kernels resemble a blister in shape)
R3	milk stage (i.e., kernel displays yellow colour on the outside and the inner fluid is milky white)
R4	dough stage (i.e., endosperm fluid is pasty in appearance)
R6	physiological maturity
r^2	coefficient of determination
R^2_{adj}	adjusted coefficient of determination
RER	rough endoplasmic reticulum
r_{ij}	correlation coefficient between the variables *i* and *j*
rpm	revolutions per minute
RSS	residual sum of squares
RUBISCO	*ribulose 1,5-bisphosphate oxygenase-carboxylase*
SD	standard deviation
SE	standard error of the mean
SEOD	standard error of difference between means
SMC	seed moisture content
SDS	sodium dodecyl sulphate
SDS-PAGE	sodium dodecyl sulphate polyacrylamide gel electrophoresis
su1	*sugary*-1 endosperm mutant
sh2	*shrunken*-2 endosperm mutant
T_{50}	time at which 50% of plants have 'silked'
t/ha	tonnes per hectare
TSS	total sum of squares
USDA	United States Department of Agriculture
V3	ligule of the third leaf is visible
V5	ligule of the fifth leaf is visible
X_1	$\log_e$ nitrogen uptake efficiency
X_2	$\log_e$ nitrogen utilization efficiency
z^*	z-score

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