# Heritability of Taproot Weight:
# Leaf Weight Ratio in Sugarbeet*

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## INTRODUCTION

Since the early 1970's, numerous reports have indicated that the relative partitioning of photosynthate among plant parts affects economic yield (4, 5, 6, 7). These reports suggest that economic yield increases as the ratio of the economic to the biological portion increases for both reproductive- and vegetative-phase crops.

Sugarbeet is a good vegetative-phase plant to use for examining the relative partitioning of photosynthate among plant parts. In this report, we give an estimate of the heritability of the taproot to leaf weight ratio (TLWR) of breeding line EL40.

## MATERIALS AND METHODS

Most of the details of the controlled-environment regime used in these studies have been reported (5). Selection of seedling plants to serve as parents was based solely on TLWR, which was calculated according to the formula

$$\text{TLWR} = \frac{\text{taproot \& hypocotyl fresh weight}}{\text{leaf blade fresh weight}}$$

This formula has been successful in detecting differences in the partitioning of photosynthate between leaves and taproot (5). Seedlings were harvested at about the 10-leaf stage. Leaf blades larger than 0.5 cm in length were removed and weighed immediately. Petioles remaining after removal of the blades were excised at the crown and

Table 1. The mean taproot to leaf weight ratio (TLWR) for parental selections and their polycrossed progeny se-
lected for high and low TLWR.

| Selection Cycle | Parental selections | | Progeny performance | |
|---|---|---|---|---|
| | High TLWR | Low TLWR | High TLWR | Low TLWR |
| | --------------------------------Number of plants and average TLWR[1]/---------------------------- | | | |
| 1 | (13) 0.217 $\pm$ 0.022 | (11) 0.124 $\pm$ 0.014 | (217) 0.176 $\pm$ 0.016 | (175) 0.132 $\pm$ 0.008 |
| 2 | (21) 0.236 $\pm$ 0.019 | (21) 0.108 $\pm$ 0.007 | (144) 0.160 $\pm$ 0.015 | (144) 0.097 $\pm$ 0.006 |

[1]/Numbers in parentheses are the number of plants selected at 21 to 23 days. Parental plants of cycle 2 were
selected from the progeny of cycle 1.

discarded.     The     seedling then was removed from the    pot,
and all fibrous roots were removed from the taproot.        The
seedling taproot with attached hypocotyl and growing point
was weighed.     Each taproot was then immediately replanted
to   be polycrossed for progeny seed production.     Thirteen
high  TLWR and 11 low TLWR plants were selected   from   156
seedlings   for the first cycle of selection.     An   outline
for the selection procedure is presented in Table 1.

Progeny   plants from the first cycle of selection were
harvested 21 to 23 days after emergence.     These differen-
ces in harvest date may have led to some variation in   re-
sults.     Progeny   from   the first cycle of  selection   for
TLWR   were   evaluated in growth chambers at East   Lansing,
MI;   progeny   from the second cycle of selection   were   e-
valuated   in growth chamers at Beltsville,   MD.     Although
temperature and photoperiod were consistent across   growth
chamber experiments,   differences in photosynthetic photon
flux   density (PPFD) could not be avoided.     For   example,
the   PPFD of one model of growth chamber ranged from a low
of 320 to a high of 540,   and in another model from 350 to
640 uE.s-1.m-2.     To determine whether correcting the TLWR
to   a uniform PPFD would affect the   correlation   results,
correlations   were run between the PPFD corrected and   un-
corrected parent-TLWR and the progeny-TLWR (Table 2).     We

Table 2.   Correlation   coefficients of parent and progeny taproot to
          leaf weight ratio   (TLWR) in the first selection cycle   with
          adjusted and unadjusted PPFD.

| Parental TLWR | Progeny selections | | Parental selections | |
|---|---|---|---|---|
| | High TLWR | Low TLWR | High TLWR | Low TLWR |
| PPFD adjusted | 0.111 | 0.087 | 0.818** | 0.99** |
| PPFD unadjusted | 0.085 | 0.098 | ----- | ------ |

**Indicates significance at the 0.01 level of probability.

found   that correlations were similar with PPFD   corrected
or uncorrected values.     Based on these results, data from
the   second cycle of selection for low and high TLWR   were
not   corrected for PPFD.     Polycrossed seed from high   and
low   TLWR selections were evaluated for root weight,   suc-
rose,   and recoverable sugar in replicated field tests but

the results are not presented here.

The genetic background of breeding line EL40 has been described (2). Although this line essentially was derived from a single plant, the TLWR of seedling plants from this line differed by nearly three-fold in initial studies at East Lansing, MI.

We calculated the heritability of TLWR for each selection cycle by use of the parent-progeny regression method (3). The TLWR raw data were transformed to standard units before plotting the regression to minimize the effects of environment and time of harvest (1). The slope of the regression line (b) indicates the heritability. This coefficient is expressed as a percentage when multiplied by 100.

## RESULTS AND DISCUSSION

The TLWR values for parents and progeny for selection cycle one and two are presented in Tables 3 and 4, respectively. The mean TLWR values for high parent selection was about twice as high as the low selection means for both cycles of selection (0.22 vs 0.13 and 0.24 vs 0.11). When the TLWR data were transformed to standard units,

Table 3. Female parent and progeny taproot to leaf weight ratio (TLWR) values for first cycle of selection.

| Low-TLWR selections | | | High-TLWR selections | | |
|---|---|---|---|---|---|
| Parent | | Progeny | Parent | | Progeny |
| Plant No. | TLWR | Mean TLWR | Plant No. | TLWR | Mean TLWR |
| L- 1 | 0.11 | 0.13 + 0.01 | H- 1 | 0.20 | 0.19 + 0.03 |
| L- 2 | 0.11 | 0.13 + 0.02 | H- 2 | 0.20 | 0.17 + 0.03 |
| L- 3 | 0.12 | 0.14 + 0.02 | H- 3 | 0.18 | 0.14 + 0.02 |
| L- 4 | 0.10 | 0.14 + 0.02 | H- 4 | 0.26 | 0.16 + .02 |
| L- 5 | 0.13 | 0.12 + 0.02 | H- 5 | 0.22 | 0.20 + 0.02 |
| L- 6 | 0.13 | 0.15 + 0.03 | H- 6 | 0.21 | 0.17 + 0.04 |
| L- 8 | 0.14 | 0.14 + 0.02 | H- 7 | 0.22 | 0.20 + 0.04 |
| L- 9 | 0.13 | 0.13 + 0.02 | H- 8 | 0.21 | 0.18 + 0.03 |
| L-10 | 0.14 | 0.13 + 0.02 | H- 9 | 0.23 | 0.19 + 0.04 |
| L-11 | 0.14 | 0.13 + 0.01 | H-10 | 0.25 | 0.17 + 0.03 |
| L-15 | 0.14 | 0.12 + 0.02 | H-11 | 0.22 | 0.18 + 0.02 |
| | | | H-12 | 0.23 | 0.18 + 0.03 |
| | | | H-13 | 0.20 | 0.16 + 0.02 |
| Mean | 0.13 | 0.13 | | 0.22 | 0.18 |
| SD | 0.01 | 0.01 | | 0.02 | 0.02 |

Mean of low + high TLWR parents = 0.176 + 0.050
Mean of low + high TLWR progenies = 0.156 + 0.026

Table 4.   Female  parent  and progeny TLWR values for second cycle  of
          selection.

| | Low-TLWR selections | | | High-TLWR selections | |
| Parent | | Progeny | Parent | | Progeny |
| Plant No. | TLWR | Mean TLWR | Plant No. | TLWR | Mean TLWR |
|---|---|---|---|---|---|
| 201 | 0.10 | 0.09 ± 0.02 | 101 | 0.22 | 0.17 ± 0.02 |
| 202 | 0.11 | 0.10 ± 0.02 | 102 | 0.24 | 0.16 ± 0.02 |
| 203 | 0.11 | 0.09 ± 0.02 | 103 | 0.23 | 0.16 ± 0.03 |
| 204 | 0.11 | 0.09 ± 0.01 | 104 | 0.23 | 0.19 ± 0.02 |
| 205 | 0.11 | 0.10 ± 0.01 | 105 | 0.22 | 0.16 ± 0.03 |
| 206 | 0.10 | 0.10 ± 0.04 | 106 | 0.22 | 0.17 ± 0.02 |
| 207 | 0.11 | 0.11 ± 0.02 | 107 | 0.22 | 0.15 ± 0.02 |
| 208 | 0.09 | 0.10 ± 0.02 | 108 | 0.22 | 0.15 ± 0.01 |
| 209 | 0.11 | 0.10 ± 0.02 | 109 | 0.24 | 0.14 ± 0.02 |
| 210 | 0.10 | 0.10 ± 0.02 | 110 | 0.22 | 0.14 ± 0.02 |
| 211 | 0.11 | 0.09 ± 0.02 | 111 | 0.24 | 0.15 ± 0.02 |
| 212 | 0.11 | 0.09 ± 0.01 | 112 | 0.24 | 0.14 ± 0.01 |
| 213 | 0.11 | 0.09 ± 0.01 | 113 | 0.22 | 0.14 ± 0.02 |
| 214 | 0.11 | 0.09 ± 0.01 | 114 | 0.29 | 0.18 ± 0.05 |
| 215 | 0.11 | 0.09 ± 0.01 | 115 | 0.24 | 0.14 ± 0.03 |
| 216 | 0.11 | 0.10 ± 0.02 | 116 | 0.26 | 0.16 ± 0.02 |
| 217 | 0.11 | 0.10 ± 0.03 | 117 | 0.26 | 0.18 ± 0.02 |
| 218 | 0.11 | 0.10 ± 0.01 | 118 | 0.25 | 0.18 ± 0.03 |
| 219 | 0.11 | ---- | 119 | 0.26 | ---- |
| 220 | 0.10 | ---- | 120 | 0.22 | ---- |
| 221 | 0.10 | ---- | 121 | 0.24 | ---- |
| Mean | 0.11 | 0.10 | | 0.24 | 0.16 |
| SD | 0.01 | 0.01 | | 0.02 | 0.02 |

Mean of low + high TLWR parents = 0.172 ± 0.066
Mean of low + high TLWR progenies = 0.128 ± 0.034

heritability was  0.90 and 0.91 for the first  and  second
cycles of selection, respectively.  These high heritabili-
ty  values agree with the effectiveness of  selection  for
TLWR in altering root and sucrose yields that has been re-
ported earlier (4,   5,   7).   The selection progress indi-
cated  in  this experiment was determined with a  breeding
line that has a very narrow gene base.   One would  expect
greater  selection progress from more heterogeneous paren-
tal populations.

     Variation  in PPFD among growth chambers was noted  in
these  studies,  although their effects on TLWR  data  and
heritability  estimates were minimal.  Transformation  of
TLWR  data to standard deviation units helped minimize any
differences in PPFD.

## SUMMARY

Two cycles of selection for low and for high taproot to leaf weight ratio (TLWR) were made in 10-leaf-stage sugarbeet seedlings. Heritabilities of TLWR determined with standard units and parent-progeny regression were .90 and .91 for the first and second selection cycle, respectively. Each group of selected parental plants produced polycrossed seed, which was used for progeny testing. The high-TLWR progenies had significantly greater root weights and recoverable sucrose per hectare than the low-TLWR progenies (data not presented).

## REFERENCES

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