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Physiologic Maturity in Grain Sorghum[1]

Jerry D. Eastin, Joe H. Hultquist, and C. Y. Sullivan[2]

ABSTRACT

External visualization of the apparent dark closing layer in the placental area near the sorghum [*Sorghum bicolor* (L.) Moench] kernel attachment point coincides closely with the cutoff of radioactive assimilate translocation to the kernel. Dark layer determination permits identification of physiologic maturity or date of maximum dry weight accumulation. This judgment is meaningful because yield is a function of both time and metabolic efficiency. Genotypes can be characterized in terms of grain filling-period duration by noting the dates of bloom and dark layer formation. Yield data plus physiologic maturity data permit direct field quantitation of the time and metabolic efficiency components of grain dry weight accumulation.

Additional key words: **Dark closing layer, Grain-filling period, Physiologic maturity, Translocation.**

GRAIN yield is essentially a function of both the length of the grain-filling period and the metabolic or synthetic efficiency during that period, provided that sink capacity is not a limiting factor. Precise, rapid determination of physiologic maturity is of interest because it permits an accurate measure of the grain-filling period or time factor of yield. The determination of physiologic maturity in sorghum [*Sorghum bicolor* (L.) Moench] apparently has been done largely on the basis of measuring maximum dry weight date determined by repeated sampling and drying (Pauli, Stickler, and Lawless, 1964; Collier, 1963; Clegg, Webster, and Grabouski, 1958; Wikner and Atkins, 1960; Kersting, Stickler, and Pauli, 1961). This approach is rather tedious and time-consuming and is unsatisfactory for routine breeder use. Consequently, the practice in the field has been to use bloom dates as indices to physiologic maturity as reported by Dalton (1967).

Daynard and Duncan (1969), reflecting on earlier work by Johann (1935) and Kiesselbach and Walker (1952), proposed using the formation of a dark closing layer in the placental region of corn (*Zea mays* L.) kernels as an indicator of translocation cutoff and hence physiologic maturity or time of maximum kernel dry weight. Daynard, Tanner, and Duncan (1971) further speculated that this may be a feasible approach for judging length of grain filling period and hoped it would correlate well with yield. Rench and Shaw (1971) have shown that initial dark closing layer formation correlates well with maximum grain dry weight in corn. Moisture varied considerably among their genotypes, however, at the time of dark layer formation.

Maunder (1970) and Quinby (1971) considered use of the dark layer formation in sorghum as an indication of physiologic maturity. We also collected dark layer data on several genotypes at the same time. However, the effectiveness of this approach remained to be quantified. The purpose of this research was to attempt correlation of external visual dark layer appearance with cutoff of assimilate translocation to the kernel using ^{14}C labelled assimilate as a marker.

MATERIALS AND METHODS

Sorghum test plants, hybrid 'RS 626' (a single cross), were chosen in 1971 for the first experiment where external evidence of the darkened closing layer was obvious in kernels removed from the head tip. All plants used in this test were in field stands at 200,000 plants/ha. Six plants were fed 50 μCi of $^{14}CO_2$ in a plexiglass leaf chamber at 10 AM in the flag leaves and were left 24 hours before harvest. The $^{14}CO_2$ was generated by adding acid to $NaH^{14}CO_3$ (Aronoff, 1956). Panicle branches from the middle of the head were selected for analyzing ^{14}C content of the seed. Replication consisted of 13 panicle branches chosen from six individual RS 626 heads.

A second experiment was run where $^{14}CO_2$ was fed to the flag leaves of RS 626 and 'DeKalb E 57' (a single cross). Ten heads of each genotype were harvested 24 hours later. Five randomly chosen kernels from each of two panicle branches located in the tips, midsections, and basal portions of the heads were analyzed for ^{14}C. Kernels with a dark closing layer were generally evident in the tip portion and generally absent in both the middle and basal sections of the panicle. However, randomly selected kernels were not checked for dark layer. The RS 626 heads were slightly more mature than the E 57 heads since the latter is a longer season genotype.

Individual kernels w[illegible]dized in a Model 305 Packard tricarb sample oxidizer. The CO_2 was collected in ethanolamine. The sample was counted in a cocktail consisting of 9 ml of PPO solution (15 g 2,5-Diphenyloxazole l of toluene), 5 ml of ethanolamine, and 6 ml of methanol in a Unilux II Nuclear

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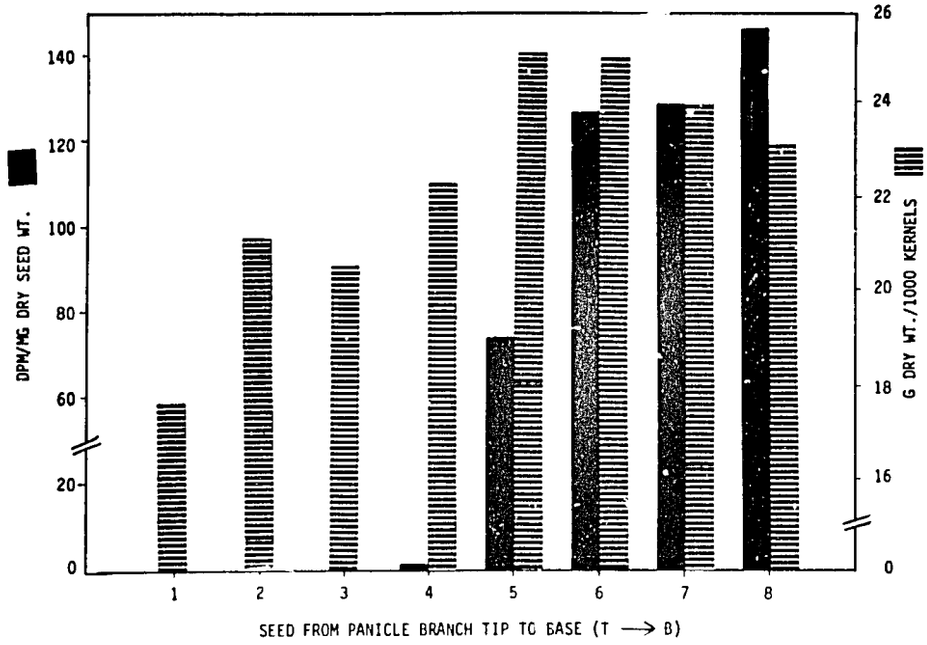

Fig. 1. Dry weights/1000 kernels (LSD = 2.2 g/1000) and ^{14}C labeled assimilate transported to seeds located between the tip (1) and base (8) of a maturing RS 626 sorghum panicle branch.

Chicago Scintillation Counter. Data were corrected for counting efficiency by the channels ratio method. All data were converted to disintegrations/min/mg dry weight (dpm/mg).

RESULTS AND DISCUSSION

Results from the first experiment follow. Kernels analyzed from the 13 replications of RS 626 require further description. Four kernels chosen from the tip toward the middle of the panicle branch had external visible evidence of the dark layer. Kernel number 1 had a pronounced dark layer and the point of attachment was pinched from desiccation. Some desiccation was obvious in the second kernel chosen. The third and the fourth kernels had little evidence of desiccation. Dark layer was just apparent in the fourth kernel. The fifth through eighth kernels (progressing from the middle to basal portions of the panicle branch) had no apparent dark layer on the basis of external visual judgment.

Since photographs of dark-layered kernels in 1971 experiments were not good, a single plant of 'Prairie Valley 700' was fed $^{14}CO_2$ in 1972 and treated the same as in 1971. Photographs taken again are illustrated in Fig. 2. The fourth kernel from the left shows a faint darkening at the point of attachment and correspond to kernel 4 in Fig. 1. One kernel of five tested contained a small amount of radio-carbon. Kernel 3 from the left (Fig. 2) illustrates the first clear evidence of dehydration and represents about a 1-day time lapse after appearance of the faint dark layer. Appreciable water loss has occurred in the left kernel (21.4% moisture) compared to a relatively high water content (30.0% moisture) in kernel 4.

Dry weight and radiocarbon uptake in the 8 RS 626 kernels, selected within individual panicle branches on the basis of external visual evidence of progressive dark layer formation, are illustrated in Fig. 1. Sorghum pollinates from the tip to the base of the head and matures in the same directional fashion. A complete cutoff of assimilate movement into kernels 1, 2, and 3 (pronounced dark layer) is clear. Only 2 of the 13 kernels classified as number 4 (faint dark layer) contained radioisotope. A progressive trend toward increasing transport of ^{14}C into the kernels is noted between kernels 5 to 8 (no apparent dark layer). Kernel 8 was presumably the most immature kernel being situated at the base of the panicle branch. Table 1 contains the analysis of variance for dpm/mg dry tissue weight and illustrates unequal variances for kernels 1, 2, 3, and 4 compared to 5, 6, 7, and 8. Orthogonal comparisons were made within the treatment category to compare seeds 1, 2, 3, and 4 (dark layer visible) vs 5, 6, 7, and 8 (dark layer not visible). Note

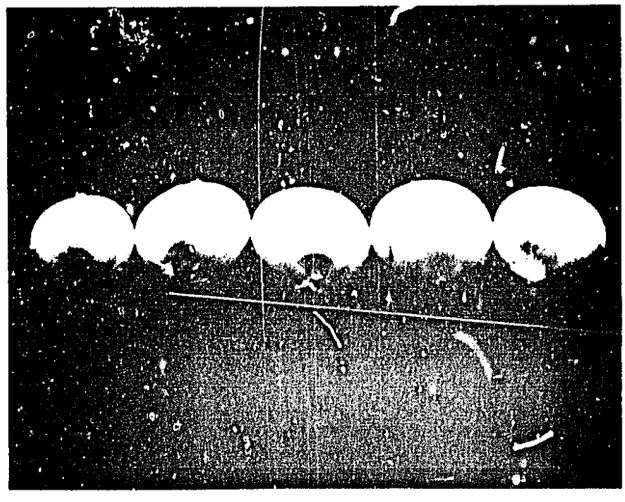

Fig. 2. External visualization of the apparent dark layer in Prairie Valley 700 sorghum. The fourth kernel from the left has just reached the assimilate cutoff point.

Table 1. Analysis of variance for ^{14}C content (dpm mg^{-1} dry wt) RS 626 seeds selected within a panicle branch. Seeds 1 through 4 had a visible dark layer at the point of kernel attachment. Seeds 5 through 8 had no visible dark layer.

Source	df	Mean square	F
Total	103		
Reps (R)	12	11,808.38	
Treatments (T)	7	75,546.73	21.85
1, 2, 3, 4 vs. 5, 6, 7, 8 (C_1)	1	481,847.87	37.89*
Among 1, 2, 3 and 4 (C_2)	3	305.30	1.47
Among 5, 6, 7 and 8 (C_3)	3	15,354.51	4.24*
R × T	84	3,458.54	
C_1 × R	12	12,717.97	
C_2 × R	36	207.59	
C_3 × R	36	3,623.03	

* Significant at 0.01 level.

the f value relating to the obvious difference in assimilate transport. The comparison for testing variation among the kernels that had a dark layer was nonsignificant. However, the significant f value for among kernels 5, 6, 7 and 8 points to the variation in amount of carbon uptake in those kernels. The most label appeared in the most immature kernels. These data suggest quite clearly that visibility of the dark closing layer in RS 626 coincides with the cutoff of assimilate translocation to individual kernels.

Dry weights of the seeds analyzed for ^{14}C are reported in Fig. 1. Interestingly, dry weights of the immature kernels (black layer absent in 5, 6, 7, and 8) did not vary compared to sizable variation (Fig. 1) among the dark-layered kernels (1, 2, 3, and 4). Weights of the first-matured kernels and the most immature kernels were 17.7 and 23.0, respectively, for a range of 5.3 g/1000 kernels. The LSD for dry weight is 2.2 g/1000 seeds. Possibly the weight loss was due to post-dark layer respiration prior to kernel dry down. However, this experiment was not designed to exclude the possible confounding effect of a seed weight gradient due to kernel position on the panicle branch. Therefore, no firm statement regarding causes of the weight differences can be made. A weight gradient may normally exist for a variety of reasons when all kernels have dried in the field to the point where respiratory mechanisms no longer function. The relationship between post-dark layer respiratory losses and the weight differences among kernels needs further investigating.

A second portion of the experiment was designed to check the amount of activity in general areas of the E 57 and RS 626 heads that had a dark layer compared to those that did not. Kernels selected in a head section were not checked individually for a dark layer. Activities in the tip, middle, and bottom sections of RS 626 and E 57 heads are illustrated in Fig. 3 and 4, respectively. Also, the percent of water is illustrated. While most kernels in the tip in both genotypes had a dark layer, note that a small amount of activity was found in each head, suggesting that a few kernels had no dark layer and that the progression of dark layer from tip to base is not completely uniform. While occasional nondark layered radioactive kernels were found, the cutoff appears quite sharp on the average. Cutoff was determined quite precisely where kernels were judged individually for dark layer as in Fig. 1. The middle portions were quite radioactive. The bases contained the most immature kernels and were the most radioactive. The RS 626 hybrid was more mature than E 57 and the moisture content of the tip kernels was the lowest (Fig. 3).

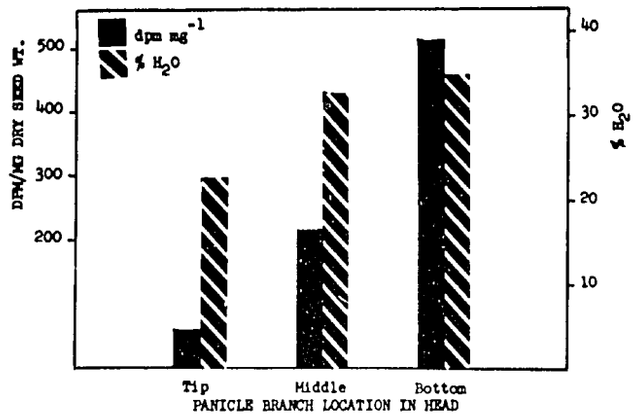

Fig. 3 Assimilate (^{14}C labeled) accumulation in RS 626 sorghum grain where the black layer was formed in tip kernels only. $^{14}CO_2$ was fed to the flag leaf. 1971.

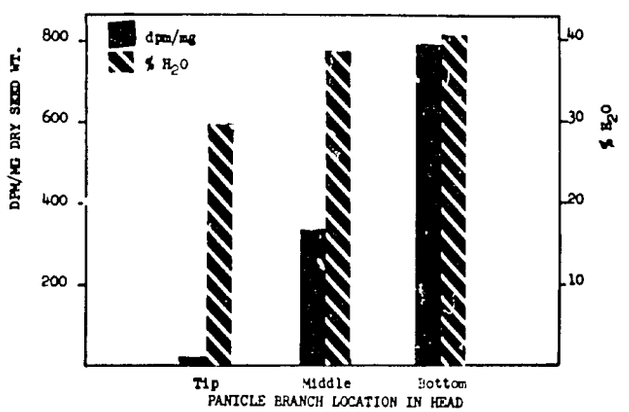

Fig. 4. Assimilate (^{14}C labeled) accumulation in E 57 sorghum grain where the black layer was formed in tip kernels only. $^{14}CO_2$ was fed to the flag leaf. 1971.

The analysis of variance for assimilate transport to respective sections of heads in both genotypes showed that treatments were significant, indicating that the dark layer appearance coincided with cessation of assimilate transport to kernels. Lack of significance in either genotypes or treatments × genotypes suggests that dark layer function is consistent between the three genotypes and probably can be safely used as an indicator of physiologic maturity and the realization of maximum dry weight.

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