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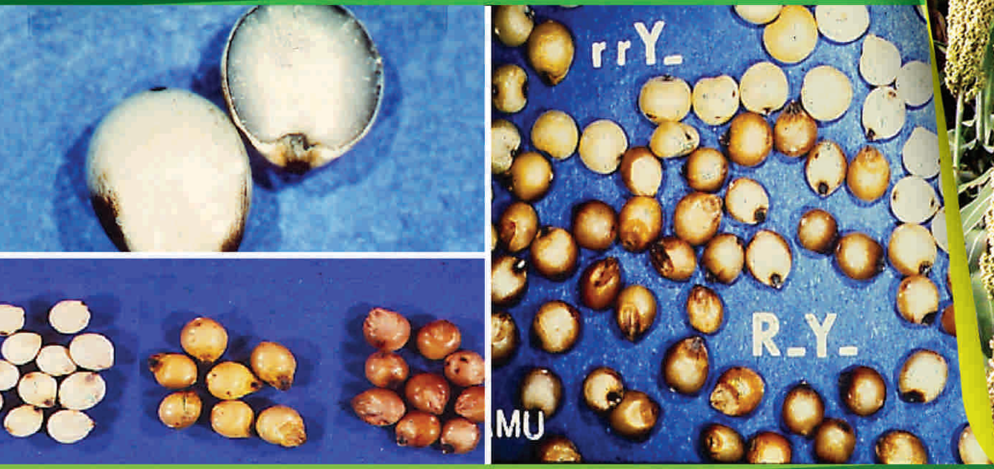
René Clará Valencia
INTSORMIL-CENTA

William L. Rooney
Texas A&M University



Centro Nacional de Tecnologia Agropecuaria y Forestal
(CENTA),
San Andres, km 33 1/2, highway to Santa Ana.
Postal Apdo.: 885,
Tel.: (503) 2302-0200 Ext. 239

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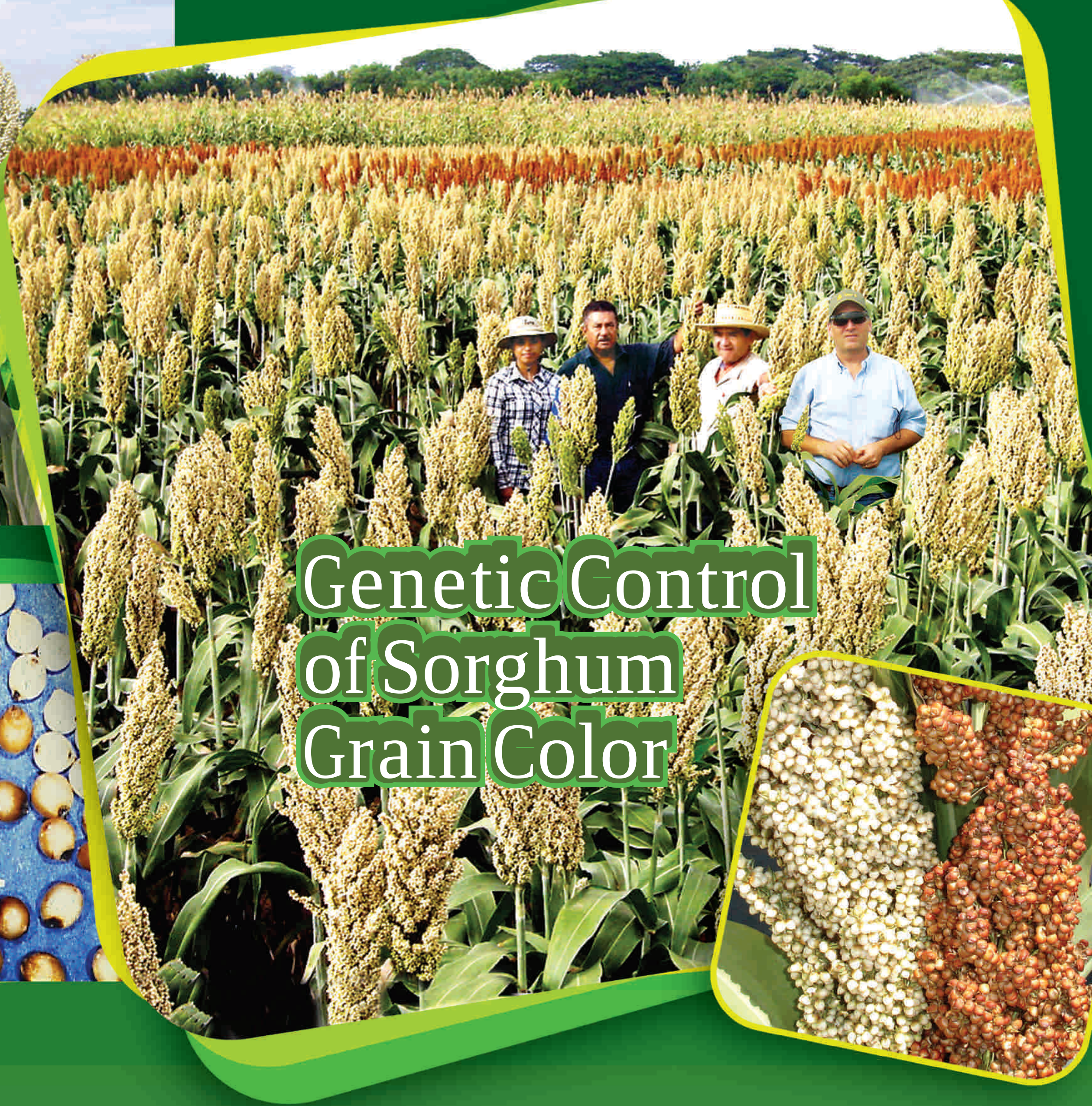

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AUTORES:

René Clará Valencia
Sorghum Breeder (CENTA-INTSORMIL) AND Local Regional Coordinator

Dr. Bill Rooney
Sorghum Breeder (Texas A&M University, USA)
and Central America Coordinator

Ing. Ever Adalberto Hernández
CENTA Board President (El Salvador)

Ing. Abraham E. López Deleón
Executive Director of CENTA (El Salvador)

Dr. John M. Yohe
INTSORMIL Director (University of Nebraska. Lincoln, USA)

Dr. Gebisa Ejeta
Sorghum Breeder (Purdue University, USA) and INTSORMIL East Africa
Regional Coordinator (contribution of photographs)

Review of Spanish text:
Lic. Berta Nely Menjívar
Department of Communications, CENTA.

Spanish to English translation
MSc. Vilma Calderón (CENTA) and
Dr. Bill Rooney (Texas A&M University)

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PROLOGUE

The first Memorandum of Agreement between **INTSORMIL** and the National Center of Agricultural and Forest Technology **(CENTA)** was initiated in the year 2000 and endorsed by means of Executive Agreement No. 1133 of the branch of foreign relations and Legislative Decree No. 183 published in the Official Newspaper No. 231, December 8, 2000. This agreement indicates the importance that sorghum cultivation deserves in El Salvador. It establishes the collaborative relationship between **CENTA** scientists and **INTSORMIL** scientists in initiating activities to generate and transfer technology that is beneficial to producers in El Salvador and the Central America Region.

There have been many sorghum varieties and hybrids generated under this Agreement which are beneficial to farmers in El Salvador, other countries in Central America and other latitudes. For this reason, **CENTA** and **INTSORMIL** take pleasure in supporting this scientific publication to clarify the concept of sorghum grain color with the intent of improving sorghum grain quality and in contributing to the development of better products from sorghum which will be beneficial to all in the sorghum food value chain.

John Yohe
Program Director
Sorghum, Millet and Other Grains CRSP

Genetic Control of Sorghum Grain Color

INTRODUCTION

Today there is a real interest in the utilization of sorghum grain as a substitute for wheat in baked goods and as a substitute for yellow maize in animal feed. Sorghum grain color and quality are important characteristics in the baking and livestock feed industries. For that reason it is necessary to develop varieties that are suitable for the food and feed industries.

The purpose of this bulletin is to briefly describe the main genetic characteristics that objectively affect sorghum grain appearance and quality.

The pericarp and glume color affect the color of the finished products made with sorghum grain. Until now at least 10 pair of genes that affect sorghum grain color have been identified The pericarp color is determined by the genes: R_Y_I_S_B_1_B_2_. The genes P_Q and Tp_ affect the expression of this basic pool of genes.

SORGHUM GRAIN

The sorghum grain is the fertilized mature ovary (Fig. 1) which consists of the by the embryo, endosperm and pericarp. The pericarp determines the color of the grain because genes that control color are concentrated in this layer.

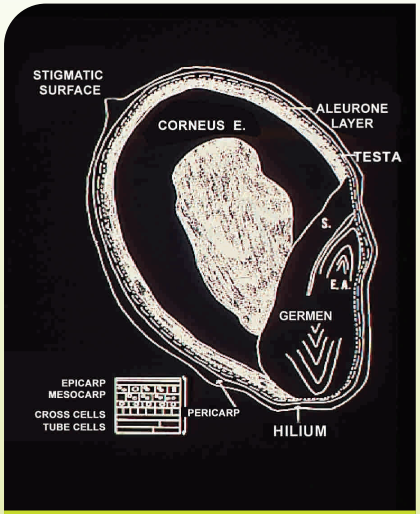

Fig. 1.
Cross section of a sorghum grain.

Genotypes and Gene Effects on Grain Color

I - PERICARP COLOR

The epicarp is the outer thin layer of the sorghum pericarp and surrounds the entire seed. The genes RR and YY determine the grain color and its appearance.

R_Y_ red epicarp
R_yy white epicarp
rrY_ lemon yellow epicarp
rryy white epicarp

These genes interact epistatically to produce the observed colors.

Fig. 2. High variability of sorghum grain color

The lemon yellow pericarp color (Figs. 3 and 4) is not related to yellow factor(s) of the endosperm and could be confused with it.

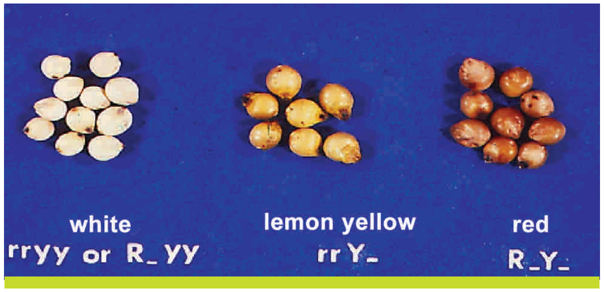

Fig. 3
Both R_ and Y_ genes are related epistatically to produce the observed colors and act in a complementary way.

The endosperm makes up 80-85% of the grain size and determines grain quality. It is composed of two types of starch cells: amylose and amylopectin. One locus controls the type of starch in the endosperm. The dominant allele Wx controls the amylose and the recessive homozygotic allele (wx) results in amylopectin starch and a waxy phenotype.



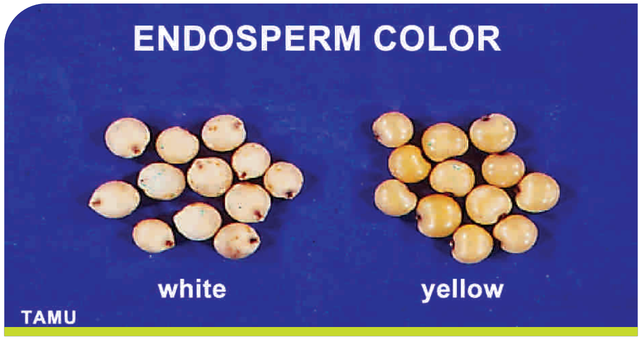

Fig. 4
Endosperm color

The dominant allele of the intensifier gene (I_), acts over the pericarp color intensifying the red color (Fig. 5) and the lemon yellow color, but the white color appears opaque.

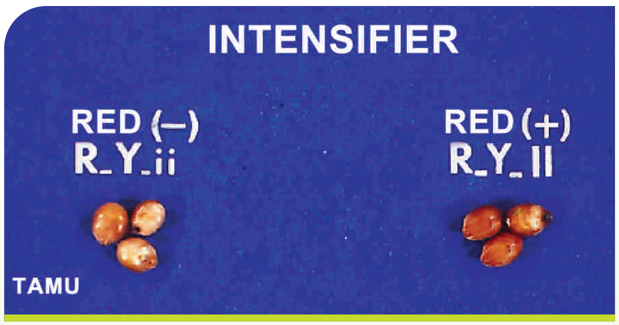

Fig. 5
Intensifier gene effect (I_) on pericarp color

II - COLOR OF THE TESTA LAYER

The color of the testa layer is dependent on the Tp_, tp tp genes. The dominant Tp_ presents a brown pigmentation and the recessive (tptp) a purple pigmentation.

The pigmentation (Fig. 6) is determined by B_1B_1 and B_2B_2 genes in the following manner:

B_1_ B_2_	pigmented testa
B_1_ b_2b_2	non pigmented testa
b_1b_1 B_2_	non pigmented testa
b_1b_1 b_2b_2	non pigmented testa

If the spreader gene (S_) is present in the dominant form (Figs. 7, 8 and 9), the brown pigments of dominant gene B_1_B_2_ are spread throughout the pericarp. When the homozygous recessive gene (ss) is present the brown color of dominant alleles B_1_B_2_ occurs only in the testa layer. This means that the brown color appears in the pericarp if genes B_1_B_2 are present.

Fig. 6
White endosperm grain with a non pigmented (left) and pigmented (right) testa.

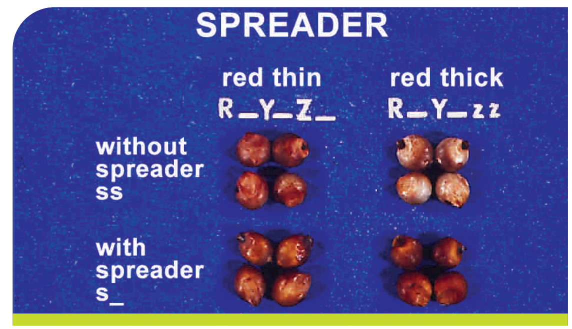

Fig. 7
Interaction of the spreader gene (S_) in the red color of the thin and thick pericarp.

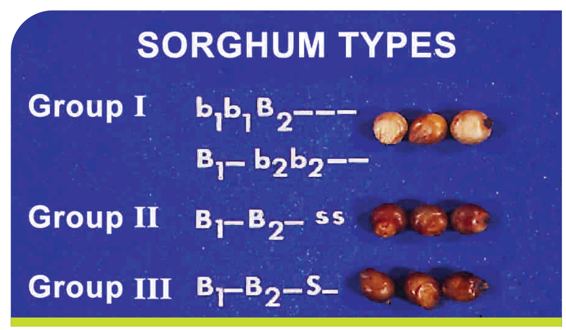

Fig. 8
Effect of the spreader gene (S_) interacting with B_1_B_2_ for red grain color

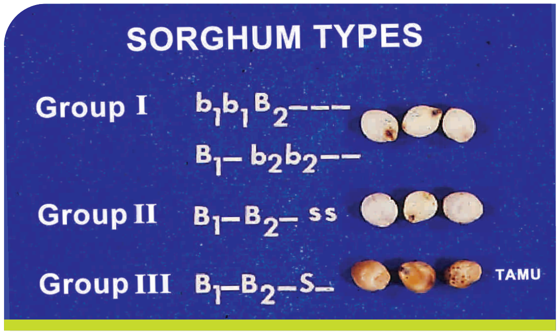

Fig. 9
Effect of the spreader gene (S_) interacting with B_1_B_2_ for white grain color

The presence of tannins in the testa layer is positively correlated with the presence of dominant genes B_1_B_2_. The pigmentation in the testa layer produced by these genes is the effect of the condensate phenols.

The amount of tannin is determined by the presence of the intensifier (I_) and spreader genes (S_), interacting with genes B_1_B_2_, Tp_, tp tp and other genes that control mesocarp thickness.

III - MESOCARP

Mesocarp layer thickness is determined by genes Z_ and zz (Fig. 10). The dominant gene Z_ results in a thin pericarp and white color grain. The thin pericarp is translucent and permits the color of the testa layer and the endosperm to affect the appearance of the grain. The recessive homozygous (zz) causes a thick pericarp with a chalky appearance due to a high starch concentration.

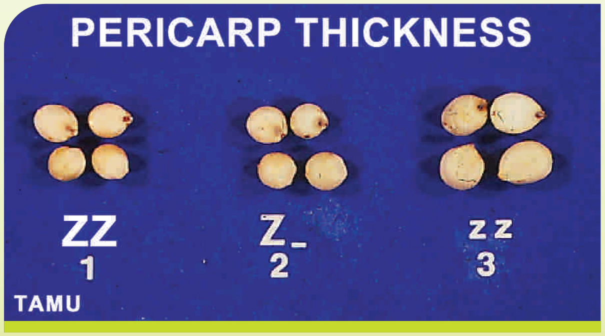

Fig. 10
Z_ zz genes that control pericarp thickness in white grain

IV - PLANT COLOR

Plant color is controlled by the PP and QQ genes. The P_Q_ gene determines the purple color, the P_ qq gene determines the red color, the pp Q_ and ppqq genes for tan plant color. The glume color is generally associated with these pairs of genes (Fig. 11, 12, 13 and 14). The P_Q_ gene affects the maternal tissue of the grain and modifies the effects of other direct color factors.

Fig. 11
Plant color and purple glumes (P_Q_)

Fig. 12
Plant color and red glumes (P_qq)

Fig. 13
Tan plant color (pp qq).

Fig. 14
Hybrid ESHG-3 obtained of lines with ppQ_ and ppqq genes.

The sorghum plant phenotype is determined by the expression of the genes described in this bulletin, but there are other types of genes in the sorghum plant that have not yet been identified.

V. IMPORTANT INTERACTIONS

- A white grain crossed with another white grain may give as a result an F1 white, brown or purple, depending on whether there is an interaction between genes R_yy, rr yy, B_1_B_2_, S_, I_, tp tp.
- A white grain could be affected by the presence of gene Z_, when it is dominant, the mesocarp is thin and has a white pearl color appearance but if it is recessive homozygous the mesocarp will be thick and the grain has a white and chalky appearance.
- A white grain (R_yy) with pigmented testa (B_1_B_2_), thick mesocarp (zz zz,) crossed with another yellow grain (rr Y_), with spreader (S_), intensifier (I_) and testa (tp tp),the F1 will have a purple grain in appearance.
- The presence of genes B_1_B_2 indicate that there are tannins present in the testa layer which can be increased in the pericarp if there is interaction between I_, S_, zz zz, Tp_, tp tp genes.
- Gene I_ interaction with red or yellow grain color genes intensifies the color in these grains but it is not the same result with white grain color.
- Genes P_ Q that affect plant color, in general, are correlated with glume color but some plants have a glume color different from the plant color.

In summary, there are allelic interactions that change the basic expression of grain color and this explains why the crossing of two white color grains results in a grain that has a brown or purple appearance.

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