

## DEVELOPMENT OF SUGARCANE VARIETIES IN COLOMBIA FOR SITE-SPECIFIC AGRICULTURE

By

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**KEYWORDS:** Sugarcane, Varieties, Agroecological  
Zones, Site-Specific Agriculture.

### Abstract

SUGARCANE variety CC 85-92 is currently planted on more than 69% of the area in sugarcane in Colombia, a situation that is of concern in light of possible disease problems that could affect the productivity of the industry. Thus, CENICAÑA has focused on selecting varieties within the framework of site-specific agriculture. After the regional trials, from three to five varieties per series that are equal to or better than the check used in these trials are made available to the sugar mills, The most promising varieties then undergo a process of multiplication and monitoring to determine response to different agroecological zones and to make available to the growers more varieties with site-specific adaptation. To date, varieties CC 92-2804, CC 93-3895 and CC 93-4418 stand out. In the semidry zone, these three varieties yielded equal to or better than CC 85-92, thereby constituting promise for the industry.

### Introduction

The Colombian Sugarcane Research Center (CENICAÑA) considers the selection and development of a sugarcane variety as the result of integrating the knowledge of its researchers, agronomists from the sugar mills, and sugarcane growers who seek to increase the productivity and profitability of a given agroecological zone. The approach used in CENICAÑA's field research is site-specific agriculture (SSA), which provides the framework for the Variety Program in its varietal selection and development processes. The fourth version of the agroecological zoning of the Cauca River Valley, based on a detailed study of soils and the regional water balance, established the existence of 149 agroecological zones in the 216 764 ha studied (Carbonell *et al.*, 2009).

The progress made in selecting and developing varieties within the framework of SSA, the identification of the agroecological zones where certain varieties have greater productivity, and the definition of different alternatives for planting varieties in the different agroecological zones of the Colombian sugar sector are presented here.

### Materials and methods

#### Agroecological zoning

The fourth approximation of the agroecological zones for the sugarcane crop in the Cauca River Valley was based on a detailed study of soils (scale 1:10 000) that the sector carried out in the total area planted with sugarcane (216 764 ha) as of 2002 and on more complete information on daily rainfall coming from 216 pluviometric stations for more than 15 years. The new agroecological zones were formed in accordance with the following factors: (a) regional water balance, which includes rainfall and evapotranspiration; (b) a detailed study of soils in the area planted with cane in the Cauca River Valley; (c) homogeneous soil groups, defined on the basis of soil texture, moisture regime and effective depth of the soil or the distance that the roots of plants can penetrate without chemical or physical barriers; and (d) water regime groups formed in accordance with the water balance and the permeability of the soil and adjusted for signs of poor drainage, depth and the slope of the terrain. The agroecological zoning was generated with the

Geographic Information System, while statistical methods and geostatistics were used to analyse the data. A total of 149 zones were identified (Carbonell *et al.*, 2009).

### **Selection sites**

To facilitate the selection of varieties within the SSA approach, the 149 agroecological zones were regrouped on the basis of two criteria: water regime and soil texture, forming three zones: Semidry, Wet and Piedmont. Selection sites were established in each zone, where parallel processes of plant breeding are being carried out, facilitating the selection and development of varieties for the different agroecological zones of the sugar sector.

Selection for the Semidry Zone is centralised at CENICAÑA's San Antonio de los Caballeros Experiment Station (SAES). Selection for the Wet Zone is carried out at the Cachimbalito Sugar Estate (Incauca S.A.) and occasionally at the La Cabaña or La Victoria sugar estates (La Cabaña Sugar Mill). Selection for the Piedmont Zone is done primarily on the Piedechinche Sugar Estate (Providencia Sugar Mill) and occasionally on Los Ranchos Sugar Estate (Central Castilla Sugar Mill).

### **Germplasm evaluation**

At each of the varietal selection sites, CENICAÑA's germplasm bank (1305 entries) was evaluated, identifying the varieties that were adapted best to each zone and then forming elite parental groups. The selection of the parents to be used in the crosses was done using the System of Information of Varieties – SIVAR, where there is a specific module for programming crosses. This module uses an algorithm that takes into account varietal traits such as sucrose (% cane), stalk diameter, leaf shedding, flowering, tillering, lodging, population and height, which are scored by means of descriptors that are expressed in relation to the check, as well as resistance to smut, rust and mosaic diseases, which are scored in accordance with the international scales proposed by the International Society of Sugar Cane Technologists (ISSCT) (Viveros *et al.*, 2009).

### **Selection of clones**

For each of the varietal improvement sites, specific crosses are designed and made each year, both at the SAES and at the Sugarcane Research Station in Tapachula, Mexico, due to high naturally flowering induction. True seed is planted in each varietal improvement site to establish seedling populations where selection is carried out at the different stages. In Stage I, the selection is done by family, identifying the best crosses for sucrose in the plant crop, and then in the first ratoon selecting the best individuals phenotypically that pass on to Stage II. Then, the best clones are selected for continuing on to Stage III and are planted in two agroecological zones for two crops, at the end of which varieties are selected for the regional trials, which are planted in the principal agroecological zones of the Cauca River Valley. The regional trials are established at the sugar mills with the largest area in the agroecological zones of greatest interest in order to obtain the best coverage possible. The regional trials are set up in experiments with a lattice design: 6-furrow strips along the plot with 3 replications over 3 crops. This experimental design gives varietal production results very similar to their performance on a commercial scale (CENICAÑA, 2008).

### **Monitoring and multiplication**

At the end of the process, approximately 9–9.5 years after several cycles of selection, certain varieties stand out for their productivity in terms of TCH, sucrose (% cane) and TSH. Although the information that is available about these varieties comes from small areas, the results characterise the best varieties with respect to the check and orient the multiplication for conducting the final evaluations on harvest, lifting, transportation and delivery of the cane, as well as factory processes. CENICAÑA, together with the sugar mills and growers, carries out the planting and multiplication of the new varieties, identifying the sites or agroecological zones where those new varieties have a level of productivity higher than the most cultivated variety in the zone. Similarly, agroecological zones are identified where those varieties are equal to or have slightly less productivity than the

most cultivated variety in the same zone. In this way, the sites, agroecological zones or niches are identified where the new varieties warrant planting or where they should be because of low productivity.

## Results and discussion

### Selection sites

The 149 agroecological zones identified by Carbonell *et al.* (2009) were regrouped according to the water regime groups and the textural classes of the soil, thereby forming (a) the **Semidry Zones** (H0, H1 and H2 as described by Carbonell *et al.* (2009)), comprising 41 of the 149 agroecological zones, except for those located in the Piedmont of the Eastern and Western Andean mountain ranges, for a total of 135 975 ha; (b) the **Wet Zones** (H3, H4 and H5), which comprise 47 of the 149 agroecological zones, excluding those located in the Piedmont of the Eastern and Western Andean mountain ranges, for a total of 55 345 ha; and (c) the **Piedmont Zones**, which comprise 61 of the 149 agroecological zones in accordance with the groups of soils located in the Piedmont of the Eastern and Western Andean mountain ranges, but without taking into account the water regime conditions. This zone is comprised of 25 444 ha.

### Evaluation of the germplasm bank

In each of the varietal improvement sites, CENICAÑA's germplasm bank (approximately 1305 entries) were evaluated and characterised in two crops. The best varieties are identified based on production of cane, sucrose (% cane) and health, establishing elite groups of varieties that are used in crosses specific for each improvement site.

The design of the crosses is done using a tool that simultaneously takes into account all the traits with their respective restrictions, seeking complementarity and beginning by comparing the first variety of the group with the second and so on with the others. Then, the second variety is compared with those that follow and so on until finishing the comparisons between all the varieties in the group.

The basic principle of the algorithm consists of adding the values of the two varieties being considered for a given trait; if the sum is equal to or less than a given critical value, this process continues on to the second trait and so on until completing all the comparisons. If at any time the sum of a trait goes over the critical level, that cross will not be made.

### Selection of clones

Every year, the selection process is begun with 120 000 seedlings that are distributed among the three selection sites. The best genotypes (clones and varieties) are selected in each of three stages and selection sites in accordance with the criteria or traits that the selected genotypes should have, referred to as *fundamental* (i.e. high content of total reducing sugars, high production of cane per ha, low flowering, and resistance to smut, rust and mosaic) and *desirable* (e.g. erect, high leaf fall, hairless leaf sheaths, resistance to yellow leaf virus, ratoon stunting disease, leaf scald and the yellow sugarcane aphid).

When the varieties have all the fundamental traits and some of the desirable ones, they continue the selection process through the three stages in each of the selection sites, until reaching the end of the process when 10–15 varieties are considered apt for establishing the regional trials located in the Semidry, Wet and Piedmont Zones, depending on their respective selection site.

Given that the conditions of these selection sites represent agroecological zones with different levels of productivity, specific objectives have been established as follows: (1) for the **Semidry zone**, varieties are selected that increase the minimum sucrose content by 5% and maintain the TCH in comparison with the check in the zone; (2) for the **Humid zone**, varieties are selected that increase the minimum sucrose content by 5% and increase the TCH by 15%; (3) for the **Piedmont zone**, varieties are selected that maintain the sucrose content and increase the TCH by 15%.

At the end of the process, approximately 9–9.5 years after having planted all the progeny of a given cross, some clones stand out for their productivity in TCH, sucrose (% cane) and TSH. Although the information that is available on these varieties comes from small plots, the results characterise the best varieties with respect to the check and orient the multiplication of the same for conducting final evaluations on the harvest, lifting, transportation and delivery of the cane, as well as factory processes.

#### **Multiplication and monitoring of the new varieties**

CENICAÑA's agronomists, together with agronomists from the sugar mills and the growers, carry out the planting and multiplication of the new varieties, identifying the sites or agroecological zones where those new varieties have a higher level of productivity than the most cultivated variety in a given zone. Similarly, agroecological zones are identified where those varieties are equal to or have a lower level of productivity than the most cultivated variety in the same zone. In this way, the sites, agroecological zones or niches where the new varieties merit being planted and where not are determined. As a result of the selection, development, monitoring and multiplication of the varieties that are being carried out, there is a renovation of the varieties that the Colombian sugar sector has been planting for several years (see Table 1).

When comparing this information with that obtained in previous years, it can be seen that varieties V 71-51, PR 61-632, MZC 74-275, RD 75-11 and Co 421 have been decreasing their area planted, being replaced by new higher yielding varieties in the respective agroecological zone. The sugar sector's dependency on CC 85-92 can also be observed in more than 69% of the zone, which is a risk from a sanitary standpoint given that it is not exempt from the influx of a new pest or disease that can cause losses in production as has occurred in other countries (Magarey *et al.*, 2001).

**Table 1**—Commercial varieties grown by the Colombian sugar industry up to 31 December 2008.

Varieties	Total (ha)	%
CC 85-92	146 890	69.3
CC 84-75	27 330	12.9
V 71-51	8691	4.1
PR 61-632	3872	1.8
CC 93-3895	2203	1.0
MZC 74-275	1934	0.9
CC 93-4418	1477	0.7
RD 7511	1472	0.7
CC 92-2198	1441	0.7
CC 93-7510	991	0.5
CC 92-2804	780	0.4
CC 87-434	745	0.4
Co 421	728	0.3
CC 93-4181	650	0.3
CC 93-3826	593	0.3
CC 87-505	408	0.2
Others	5869	2.8
Renovation	5857	2.8
Total/ha	211 932	100.0

As a result of the multiplication and monitoring of the new varieties, data are given on the monitoring and multiplication of varieties CC 93-3895, CC 92-2804 and CC 93-4418, as an example of the three varieties with greatest growth in the industry during the past two years.

Variety CC 93-3895 has been harvested on 3857 ha in 51 agroecological zones, and has been equal to or higher in productivity (TCH, real factory yield and TSH) in 35 of them. Figure 1 shows the zones (10H2, 5H2, 7H0, 23H2, 29H1, 8H5, 6H2, 11H4, 6H4, 10H4 and 11H5) that cover 23 242 ha (11%) of the total area planted in cane, where CC 93-3895 is significantly higher in productivity (green colour) than the checks CC 85-92 and CC 84-75. Agroecological zones (15H0, 23H1, 11H1, 11H0, 15H1, 6H1, 5H4, 5H5, 30H2, 30H0, 5H3, 18H1, 31H0, 6H0, 22H0, 13H2, 18H3, 7H2, 10H5, 1H1, 8H3, 21H2, 6H3 and 8H2) where CC 93-3895 is equal in productivity (blue colour) to the checks cover 132 615 ha (65%) of the total area planted in cane. Those agroecological zones (30H1, 14H2, 11H3, 18H5, 14H1, 13H3, 18H2, 11H2, 24H2, 15H2, 8H4, 30H3, 23H4, 31H2, 17H5 and 18H0) where CC 93-3895 is lower in productivity (red colour) than the checks cover 33 446 ha (16%) of the total area planted in cane. The zone where the variety has been planted most is 6H1, where 954 ha have been harvested; the commercial results over the various crops are given in Table 2. Productivity has been stable over the four crops despite the decrease in the age of the cane at harvest.

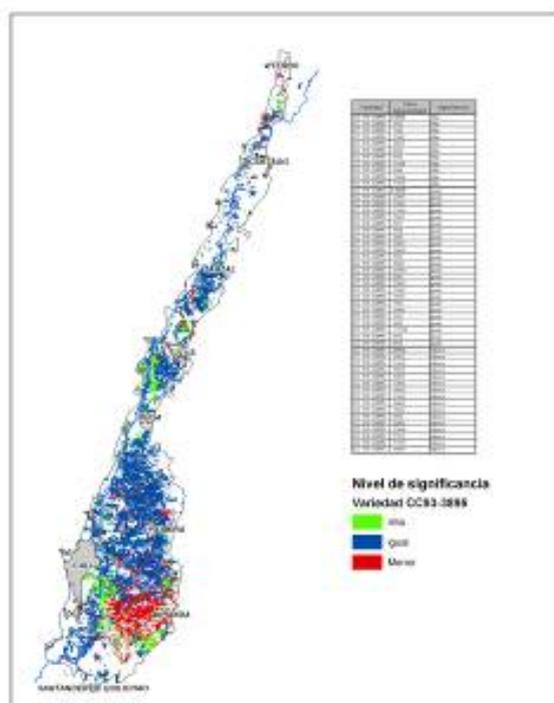


Fig. 1—Agroecological zones where CC 93-3895 had a productivity (TSHM) higher (green), equal to (blue) or less (red) than the commercial varieties (CC 84-75 and CC 85-92) most planted historically at the same site.

**Table 2**—Commercial productivity of CC 93-3895 over five cuts in agroecological zone 6H1.

Cut	Area (ha)	Age at Cut (mo)	TCH	TCHM	Yield	TSHM	TSH
1	528	14.3	138.0	9.7	12.6	1.216	17.3
2	327	13.1	129.1	9.9	12.3	1.207	15.8
3	79	12.5	122.1	9.8	12.1	1.172	14.7
4	17	12.2	100.4	8.1	12.3	1.009	12.5
5	3	12.9	77.8	6.0	14.5	0.876	11.3

Variety CC 92-2804 has been harvested on 1103 ha located in 24 agroecological zones, resulting in productivity equal to or higher than the checks CC 85-92 and CC 84-75 in 19 of them. Figure 2 shows the agroecological zones (32H2, 13H2, 15H2, 11H1, 15H1, 18H1, 1H1, 11H3, 6H3, 31H0, 22H1 and 27H1) which cover 56 278 ha (28%) of the land in cane, where CC 92-2804 has been significantly higher in productivity (green colour) than the checks. The agroecological zones (11H0, 6H1, 30H0, 11H2, 6H2, 7H0 and 10H4) where CC 92-2804 is equal in productivity (blue colour) to the checks, which represent 78 672 ha (39%) of the total area planted in cane. The agroecological zones (18H0, 23H2, 22H0, 15H0 and 26H1) where CC 92-2804 is lower in productivity (red colour) than the checks cover 8161 ha (4%) of the area planted in cane. The agroecological zone where the variety has been planted most is 6H1, where 388 ha have been harvested; the commercial results are shown in Table 3. Productivity has been quite stable over the seven crops, despite decreases in the age at harvest.

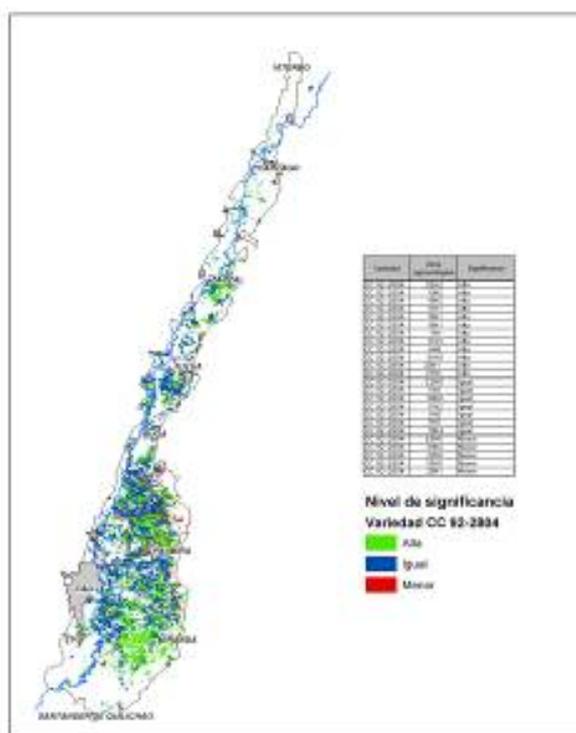


Fig. 2—Agroecological zones where CC 92-2804 had a productivity (TSHM) higher (green), equal to (blue) or less (red) than the commercial varieties (CC 84-75 and CC 85-92) most planted historically at the same site.

**Table 3**—Commercial productivity of CC 92-2804 over seven cuts in agroecological zone 6H1.

Cut	Area (ha)	Age at Cut (mo)	TCH	TCHM	Yield	TSHM	TSH
1	204	14.1	144	10.3	12.3	1.250	17.5
2	86	12.1	128	10.6	11.5	1.209	14.7
3	48	11.5	112	9.7	12.1	1.187	13.8
4	22	11.5	133	11.6	12.0	1.385	16.0
5	23	11.4	124	10.9	11.3	1.226	14.0
7	4	11.3	94	8.3	11.8	0.980	11.0

Variety CC 93-4418 has been harvested on 721 ha located in 17 agroecological zones, resulting equal to or higher in productivity than the checks CC 85-92 and CC 84-75 in 12 of the zones. Figure 3 shows the zones(30H2, 11H3, 6H1, 23H1, 11H2, 6H2 and 10H3) where CC 93-

4418 was significantly higher in productivity (blue colour) than the checks, representing 72 286 ha (36%) of the total area planted in cane.

The zones (30H1, 11H0, 18H0, 11H1 and 22H0) where CC 93-4418 was equal in productivity (blue colour) to the checks represent 52 623 ha (26%) of the total area planted in cane. The zones (30H0, 18H1, 18H2, 26H1 and 6H0) where CC 93-4418 was lower in productivity (red colour) than the checks, cover 12 627 ha (6%) of the area planted in cane. The agroecological zone where the variety has been planted most is 11H0, where 216 ha have been harvested. The commercial results are given in Table 4. Productivity has been quite stable over all crops.

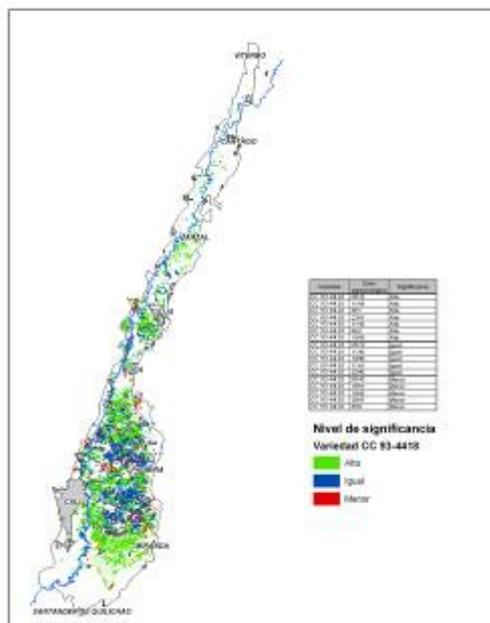


Fig. 3—Agroecological zones where CC 93-4418 had a productivity (TSHM) higher (green), equal to (blue) or less (red) than the commercial varieties (CC 84-75 and CC 85-92) most planted historically at the same site.

**Table 4**—Commercial productivity of CC 93-4418 over four cuts in agroecological zone 11H0.

Cut	Area (ha)	Age at Cut (mo)	TCH	TCHM	Yield	TSHM	TSH
1	104	13.7	144	10.5	12.2	1.276	17.5
2	74	12.9	131	10.2	12.0	1.233	15.8
3	37	14.8	134	9.0	11.4	1.020	15.0
4	1	13.9	156	11.2	11.6	1.297	18.0

More precise and specific information by agroecological zone and other varieties in terms of productivity can be consulted on CENICAÑA's Web page <http://www.cenicana.org>, Site-Specific Agriculture and Map Server, where one enters the property of the grower according to the sugar mill, lot and agroecological zone. With that information, you can construct the graphic representation of TCH, % sugar yield and TSH in so called isoproductivity curves for the agroecological zone of interest, using the same Map Server.

### Conclusions

- Of the 16 varieties most cultivated by the Colombian sugar sector, 11 were developed by CENICAÑA and occupy 87% of the 211 932 ha planted.

- CC 85-92 continues to be the most widely planted although its percentage of participation in the sector last year did not increase, perhaps reaching its maximum % adoption in 2009.
- Varieties CC 93-3895, CC 93-4418 and CC 92-2804 have increased their area of planting the most in the last two years.
- By multiplying and monitoring CC 93-3895, CC 93-4418 and CC 92-2804 in the different planting sites, it was possible to prove the stability of their productivity over plant cane and several ratoons in the main agroecological zones where each of them is planted.

#### REFERENCES

- Carbonell, J., Osorio, C.A., Quintero, R., Torres, J.S., Isaacs, C. and Victoria J.I.** (2009). Zonificación agroecológica del valle del río Cauca. Cuarta versión. Serie Técnica. CENICAÑA. In press.
- CENICAÑA.** (2008). Comparación de los tonelajes en pruebas regionales y en cultivos comerciales. In: Informe Anual. 67–68.
- Magarey, R.C., Croft, B.J. and Willcox, T.G.** (2001). An epidemic of orange rust on sugarcane in Australia. Proc. Int. Soc. Sugar Cane Technol. 24: (2): 410–416.
- Viveros, C.A., Cassalett, C., Amaya, A. and Victoria, J.I.** (2009). A tool for designing crosses for sugarcane improvement in CENICAÑA. In Proc. 9th ISSCT Sugarcane Breeding and Germplasm Workshop. Cairns, Australia. 17–21 August, 2009, P 24.

#### DÉVELOPPEMENT DES VARIÉTÉS DE CANNE À SUCRE EN COLOMBIE POUR DES SITES SPÉCIFIQUES

Par

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**MOTS CLÉS:** Canne à Sucre, Variétés,  
Zones Agro-Écologiques, Sélection Ciblée.

#### Résumé

LA VARIÉTÉ de canne à sucre CC 85-92 est actuellement cultivée sur plus de 69% de la surface cannière en Colombie. C'est une situation inquiétante, du point de vue maladies, qui peuvent affecter la productivité de l'industrie. Ainsi, CENICAÑA a mis l'emphase sur une sélection qui cible des zones spécifiques de la production cannière. Après les essais régionaux, trois à cinq variétés émanant de chaque série, et dont leurs performances sont égales ou supérieures aux témoins, sont mises à la disposition des sucreries. Les variétés les plus en vue ont été soumises à un processus de multiplication et de contrôle afin de déterminer leur comportement dans diverses zones agro-climatiques dans le but de mettre à la disposition des planteurs celles qui sont adaptées à leurs conditions spécifiques. À ce jour, les variétés CC 92-2804, CC 93-3895 et CC 93-4418 se sont avérées les plus prometteuses. Dans la zone semi-aride, ces variétés ont une performance égale ou supérieure à celle de CC 85-92, ce qui est prometteuse pour l'industrie.

## DESARROLLO DE VARIEDADES DE CAÑA DE AZÚCAR EN COLOMBIA PARA AGRICULTURA ESPECÍFICA POR SITIO

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**PALABRAS CLAVE:** Variedades, Caña de Azúcar,  
Zonas Agroecológicas.

### Resumen

EL SECTOR azucarero de Colombia tiene actualmente sembrada la CC 85-92 en más del 69% el área en caña de azúcar, situación que preocupa por la posibilidad de aparición de enfermedades que puedan afectar esa variedad y la industria. Por esa razón CENICAÑA adelanta de manera continua la obtención y selección de variedades con el enfoque de agricultura específica por sitio. Una vez finalizadas las pruebas regionales del proceso de selección, se entregan a los ingenios azucareros entre tres a cinco variedades por serie, las cuales igualan o superan al testigo empleado en dichas pruebas. Esas variedades consideradas promisorias deben seguir un proceso de multiplicación y seguimiento que determina su respuesta en las diferentes zonas agroecológicas. Cada día el número de variedades disponibles para los cultivadores es mayor con adaptación específica por sitio, buscando así aumentar la productividad del sector azucarero colombiano. En el proceso de multiplicación y seguimiento se destacan las variedades CC 92-2804, CC 93-3895 y CC 93-4418 entre otras, sembradas en campos comerciales de los diferentes ingenios azucareros. Los resultados indican que bajo las condiciones de la zona semiseca estas variedades se comportaron iguales o superiores a CC 85-92 en las zonas agroecológicas en donde se evaluaron y para la industria se constituyen en alternativas de siembra.