



Poster paper

Could the ecophysiological basis of sugarcane be of help in improving sugar yield gains?

MM Acreche^{1,2}, J Chalco Vera^{1,2}, JV Saez³, L Martínez Calsina³ and L Erazzú³

¹*Instituto Nacional de Tecnología Agropecuaria, EEA Salta. Ruta Nac. 68, Km 172, 4403, Cerrillos, Salta, Argentina; acreche.martin@inta.gob.ar*

²*CONICET, Argentina*

³*Instituto Nacional de Tecnología Agropecuaria, EEA Famaillá. Ruta Prov. 301, Km 32, 4132, Famaillá, Tucumán, Argentina*

Abstract

Sugar yield (SY) gains worldwide have been slowing down since the 1980s. This study aimed to identify how this trend could be reversed by exploring the ecophysiological basis associated with yield increments. Nitrogen, water and radiation use efficiencies were explored. Thirteen cultivars were grown during three consecutive cycles at Tucumán, Argentina. Cane yield (CY), sugar content (SC), SY, average-stem-weight (ASW), nitrogen-use-efficiency (NUE) and water-use-efficiency (WUE) increased linearly with the year of release of the cultivars. Sugar yield was associated with CY, SC, ASW, NUE and WUE ($r>0.65$; $P<0.05$), whereas CY was only related to ASW, NUE and WUE ($r>0.81$; $P<0.01$). Stem number at harvest was not increased by breeding and was not related to SY and CY. This could be because breeding did not modify the dynamic of generation and mortality of stems. However, breeding modified the canopy architecture of the crop. This was associated with increases in the amount of radiation intercepted by the crop during its cycle; modern cultivars had higher maximum interception and needed fewer days to reach maximum interception than older cultivars. However, sugarcane breeding did not increase the radiation-use-efficiency. In summary, using ecophysiological tools could help breeders to improve SY.

Key words

Genetic gains, radiation-use-efficiency, nitrogen-use-efficiency, water-use-efficiency

INTRODUCTION

Breeding has played a relevant role in sugarcane yield increments worldwide leading to genetic gains ranging from 0.08 to 0.18 t sugar/ha/year (Acreche *et al.* 2015). In general, genetic gains in sugar yield have been associated with cane yield increases, whereas there are controversial reports regarding sugar content (Jackson 2005; Acreche *et al.* 2015). The rate of increase in sugar yield has been actually slowing down since the 1980s.

The analysis of physiological traits that were instrumental in breeding achievements in the past could be relevant for future yield increments (Reynolds *et al.* 2001). Thus, breeding strategies using physiological information could help breeders to ensure a growing trend in yield increments. Similar studies have been conducted in wheat (Austin *et al.* 1980), maize (Tollenaar 1991) soybean (Morrison *et al.* 1999), sunflower (de la Vega *et al.* 2007), and recently in sugarcane in Argentina (Acreche *et al.* 2015; Acreche 2017).

Our aim was to identify how the ecophysiological basis associated with yield increments could help breeders to increase sugar yield.

MATERIALS AND METHODS

The experiment was conducted in Famaillá, Tucumán, Argentina (27°03' S, 65°25' W, 363 m a.s.l.) in a fertile soil classified as Aquic Argiudoll during the three consecutive seasons of 2010/11, 2011/12 and 2012/13, under rainfed

conditions. Rainfall during the growing seasons ranged from 993.3 mm to 1417.1 mm. During 2011/12 and 2013/14 fertilizers were broadcast at the tillering phase at a rate of 110 kg N/ha.

We compared 13 sugarcane cultivars that were important for the development of sugarcane breeding in Argentina. The following (year of release in Argentina in brackets) were used: TUC 26-45 (1940), CP 34-120 (1950), NCo 310 (1960), NA 56-79 (1964), CP 48-103 (1970), NA 56-30 (1970), NA 63-90 (1977), CP 65-350 (1987), CP 65-357 (1989), TUCCP 77-42 (1994), LCP 85-384 (2001), RA 87-3 (2005) and INTANA 91-209 (2015). The cultivars were planted in a randomised complete-block design with three replications. Each plot had five rows and was 80 m². Weeds and insects were controlled or prevented using recommended products.

At ripening, all plants from 1 m from the three central rows were taken in order to determine the number of stalks (NS), average stalk weight (ASW), cane yield (CY) and sugar yield (SY) on a fresh-weight basis. A sub-sample of cane was used to determine laboratory quality characters such as brix (soluble solids), pol in juice (%; juice sucrose concentration), juice purity (%), pol in cane (%; cane sucrose concentration) and sugar content (SC). The intercepted radiation during each of the crop cycles was also measured. For the 2010/11 and 2011/12 seasons total above ground dry biomass (TADB), dry stem weight (DSW), the partitioning of TADB to stems and to sugar, and the partitioning of DSW to sugar were also determined. The radiation use efficiency (RUE), nitrogen-use efficiency (NUE) and water-use efficiency (WUE) were also determined. RUE (kg TADB/MJ) was determined as the ratio of TADB and accumulated intercepted radiation during the crop cycle; NUE (kg DSW/kg N in soil) was determined as the ratio of DSW and total nitrogen available in the soil during the crop cycle; WUE (kg DSW/mm) was determined as the ratio of DSW and water use.

RESULTS AND DISCUSSION

Sugar yield, CY, SC, ASW, NUE and WUE increased linearly with the year of release of the cultivars. Sugar yield was associated with CY, SC, ASW, NUE and WUE ($r>0.65$; $P<0.05$), whereas CY was only related to ASW, NUE and WUE ($r>0.81$; $P<0.01$). Total above ground dry biomass and DSW were also increased by breeding. However, the partitioning of TADB to stalk or to sugar, and the partitioning of DSW to sugar were not increased by breeding. Stalk number at harvest was not increased by breeding and was not related to SY and CY. This could be because breeding did not modify the dynamic of generation and mortality of stalks. However, breeding modified the canopy architecture of the crop. This was associated with increases in the amount of radiation intercepted by the crop during its cycle: modern cultivars (in general those released since 1987) had higher maximum interception and needed fewer days to reach maximum interception than older varieties. However, sugarcane breeding did not increase the RUE. The dynamic of intercepted radiation could be the reason for the improved NUE and RUE because the soil water of the inter-row that normally evaporates could have been absorbed by the crop for growth.

Thus, it is apparent that using ecophysiological basis could help breeders to develop cultivars with high resource-use efficiency and thus improve SY.

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Les paramètres écophysiologiques de la canne à sucre pourraient-ils contribuer à améliorer les gains en sucre ?

Résumé. Les gains en rendement en sucre (SY) à l'échelle mondiale ralentissent depuis les années 1980. Cette étude visait à déterminer comment cette tendance pourrait être renversée en explorant la base écophysiologique associée aux augmentations de rendement. L'efficacité de l'utilisation de l'azote, de l'eau et du rayonnement a été étudiée. Treize variétés ont été cultivées pendant trois cycles consécutifs à Tucumán, en Argentine. Le rendement en canne (CY), la teneur en saccharose (SC), le rendement en sucre (SY), le poids moyen par tige (ASW), l'efficacité d'utilisation de l'azote (NUE) et l'efficacité d'utilisation de l'eau (WUE) ont augmenté de façon linéaire par rapport à l'année d'homologation des variétés. Le rendement en sucre était associé à CY, SC, ASW, NUE et WUE ($r>0,65$; $P<0,05$), tandis que CY n'était associé qu'à ASW, NUE et WUE ($r>0,81$; $P<0,01$). Le nombre de tiges à la récolte n'a pas augmenté par l'amélioration variétale et n'était pas lié au SY et au CY, qui pourrait être dû au fait qu'elle n'a pas modifié la dynamique de production et de mortalité des tiges. Cependant, l'amélioration variétale a modifié l'architecture du couvert végétal. Cela a été associé à une augmentation de la quantité de rayonnement intercepté par la culture au cours de son cycle: les nouvelles variétés ont une interception maximale plus élevée et ont besoin de moins de jours pour atteindre l'interception maximale que les vieilles variétés. Cependant, la sélection de la canne à sucre n'a pas augmenté l'efficacité de l'utilisation des rayonnements. Il est donc évident que l'utilisation d'outils écophysiologiques pourrait aider les sélectionneurs à améliorer le SY.

Mots-clés: Gains génétiques, efficacité d'utilisation des rayonnements, efficacité d'utilisation de l'azote, efficacité d'utilisation de l'eau

¿Pueden las bases ecofisiológicas de caña de azúcar ayudar a incrementar las ganancias en el rendimiento de azúcar?

Resumen. Las ganancias en el rendimiento de azúcar (RA) a nivel mundial han disminuido desde 1980. El objetivo de este estudio fue identificar como esta tendencia puede ser revertida explorando las bases ecofisiológicas asociadas a incrementos en los rendimientos. Además, se exploraron las eficiencias en el uso del nitrógeno, agua y radiación. Durante tres ciclos consecutivos se cultivaron en Tucumán, Argentina, trece cultivares de caña de azúcar. El rendimiento cultural (RC), el contenido de azúcar (CA), el RA, el peso medio de tallo (PMT), la eficiencia en el uso del nitrógeno (EUN) y agua (EUA) se incrementaron de manera lineal con el año de liberación de los cultivares. El RA se asoció al RC, al CA, al PMT, la EUN y la EUA ($r>0,65$; $P<0,05$), mientras que el RC solo se asoció al PMY, la EUN y la EUA ($r>0,81$; $P<0,01$). La mejora genética no incrementó el número de tallos a cosecha, los cuales no se asociaron al RA y el RC. Esto se puede deber a que la mejora genética no cambió la dinámica de generación y mortalidad de tallos. Sin embargo, la mejora genética modificó la estructura de la canopia del cultivo. Esta modificación se asoció con incrementos en la cantidad de radiación interceptada por el cultivo durante su ciclo: cultivares modernos tuvieron mayores intercepciones máximas y necesitaron menos días para alcanzar la misma respecto a cultivares antiguos. Sin embargo, la mejora genética de caña de azúcar no incrementó la eficiencia en el uso de la radiación. En resumen, la utilización de herramientas ecofisiológicas puede ayudar a los mejoradores a incrementar el RA.

Palabras clave: Ganancias genéticas, eficiencia en el uso de la radiación, eficiencia en el uso del nitrógeno, eficiencia en el uso del agua