

SIGNIFICANCE OF DIFFERENT TECHNICAL METHODS ON SUGARCANE RATOONING ABILITY IN PAKISTAN

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ABSTRACT

Sugarcane is the 2nd most important cash crop of Pakistan after cotton. It can be subjected to ratooning for several years in different countries like Brazil, America, Australia, South Africa, China and India. In Pakistan it can be subjected to rationing for mostly 1-2 years. Quality improvement, efficiency enhancement, reduced costs and energy use are some of benefits of ratooning. The genotype, environment, cultivation management, and harvesting technology affect the productivity and longevity of ratoon cane, with the genetic basis being the most critical factor. However, the majority of research has been focused on only limited genotypes. They mainly focus on the comparison among different genotypes or among plant cane, different selection strategies for the first and second ratoon crops, together with screening indicators for the selection of stronger ratooning ability. In this paper, previous studies are reviewed in order to analyze the importance of sugarcane ratooning, the indicative traits used to evaluate ratooning ability, the major factors influencing the productivity and longevity of ratooning, the genetic basis of variation in ratooning ability, the shortcomings of the existing research on sugarcane ratooning are highlighted. We then discuss the focus of future ratoon sugarcane research and the technical methods that will shorten the selection cycle and increase the genetic gain of ratooning ability, particularly the development of linked markers. This review is expected to provide a reference for understanding the mechanisms underlying the formation of ratooning ability and for breeding sugarcane varieties with a strong ratooning ability.

INTRODUCTION

Sugarcane (*Saccharum* spp. hybrids) is an important sugar crop that can be subjected to ratooning over multiple years. Sucrose from sugarcane accounts for 86% of the worlds. In Pakistan, approximately 20–25% of sugar production costs are spent on raw sugarcane stalks. Compared with newly planted sugarcane, plant cane, ratoon cane has multiple rewards including faster leaf spreading, more rapid plant growth, earlier strike maturity, and reduced production costs due to

savings on fertilizers, seed cane, field preparation, planting and early field management. Sugarcane stalks are a fresh agricultural product that must be processed as soon as possible after harvesting. The immediate processing is performed to minimize the conversion of sucrose into reducing sugars within the sugarcane stem to increase the sugar output. Previous data also suggest that the non-optimum germination or sprouting temperatures, too low or too high, may be a factor for yield decline in ratoon cane. Compared with

plant cane, ratoon plants have an established and strong root system, representing the unique skeleton of carbon and energy source for the initial plant development. The root system, which is essential for regrowth of sugarcane and the ratoon vigor of each cycle, can be used for water transport to leaves during the period of photosynthesis, in which photosynthetic products are accumulated and in turn promote a rapid leaf expansion and plant growth during the early growing stage. Therefore, ratoon plants have more

effective accumulated temperature and longer effective growth period, resulting in more sugar accumulation and earlier technical maturity. In contrast, newly planted sugarcane plants firstly need to grow roots, especially permanent roots, which requires a relatively longer period and a higher effective accumulated temperature. As a result, the newly planted sugarcane does not use light and thermal sources efficiently at this stage. Therefore, from the perspective of energy utilization, ratoon sugarcane has a significant energy-saving characteristic. Sugarcane ratooning is a planting system that is generally adopted by each sugarcane-producing country. The proportion of the ratoon cane is generally around 50% of the cultivated area, and can even reach 75% in some regions. The average proportion is 50–55% in tropical areas, while approximately 40–45% in subtropical areas (Singh *et al.*, 2015).

The cost of sugarcane production is much higher in Pakistan than in other countries including Brazil. Except for the low cost of arable land, better ecological and soil conditions, and the complete mechanical operations in sugarcane production, sugarcane variety with a strong strike is one of the most important reasons for the low cost in Brazil. In Pakistan, it has been reported that the cost of ratoon crop is 20–25% lower than that of plant cane (Bashir *et al.*, 2013). However, due to low

yields (30–40 t/ha), ratoon crop accounts for only 40% of the total cane area and sugarcane is only ratooned for one to two years in Pakistan (Bashir *et al.*, 2013), resulting in the relatively higher cost in sugarcane production. This is supported by another report, which suggests that ratoon cane contributes only 30% of the total cane production, though it accounts for over 50% of the acreage (Aslam *et al.*, 2020). Another report also pointed out the problem of low yields of ratoon crop, indicating only 25–30 t/ha as compared to 65–75 t/ha of plant cane in Pakistan. In Pakistan, there is a high proportion of ratoon cane. Therefore, the short longevity of ratooning is considered to be the major cause of high sugarcane production costs in Pakistan.

From above studies, ratoon crop reduces production costs and benefits growth through energy saving by the reduction of inputs and utilization of residual manure and moisture. With the rising labor costs, the gap in cost between ratooning and replanting will further be widened. Additionally, ratooning is undoubtedly a simple and easy way to improve the efficiency of sugarcane production. However, the yields of ratoon cane decline with age. In this paper, we review the achievements of sugarcane ratooning research, high-light shortcomings, and propose research ideas. We hope that this review enhances the understanding of the research progress of ratooning ability

and is beneficial to develop sugarcane variety with strong ratooning ability.

Sugarcane Ratooning Ability

Ratooning ability is the yield of second ratoon as a percentage of the yield of newly planted sugarcane (Ding *et al.*, 2020); ratoon crop performance as a percentage of a reference yield, usually that of the plant cane, first ratoon or the mean of these two crops (Silva *et al.*, 2017); the yield of the ratooning year as a percentage of the yield for the reference variety of that year. The longer the ratooning cycle and the smaller yield decline in ratoon crops, the stronger ratooning ability.

Phenotypes of Ratooning Ability in Sugarcane in other countries of the world

Ratooning increases the income of sugarcane growers due to the saving cost in cultivation, and increases the income of industry because of mature earlier, better juice quality and thus improves sugar recovery at times of the crushing season compared with plant cane (Chumphu *et al.*, 2019). For example, in Australia, in plant cane and the second ratoon, the average sucrose content was 14.84% and 16.54%, respectively. Most studies on sugarcane ratooning ability have focused on analyzing the variation in ratooning ability based on phenotypic traits (Singh *et al.*, 2015 and Rafiq *et al.*, 2006).

Generally, the most effective way for the improvement of

sugarcane ratooning ability is to select lines directly based on the yield performance of ratoon crops. However, it is not conducive to shortening the selection cycle, and the huge segregated population in sugarcane hybrid F₁ limits this measure due to considerable time and resources. For example, to identify one commercial quality variety from the original F₁ population requires 11 years of sequentially planted selection from approximately 75,000 genotypes. An alternative approach is to select lines based on the yields of plant cane because varieties with high plant cane yields normally produce high ratoon crop yields (Hassan *et al.*, 2017; Qin *et al.*, 2014).

Indirectly selecting genotypes with strong resistance to diseases and insect pests may also increase the ratooning ability of the selected sugarcane breeding materials (Ding *et al.*, 2020). In some cases, the ratooning ability has been indirectly evaluated by assessing the biomass or light utilization efficiency of sugarcane, and assessing drought tolerance in those arid or semi-arid cultivated regions is also suggested (Qin *et al.*, 2014). Ratooning ability is a trait that a commercial quality variety must have. Indicative traits of a strong ratooning ability include both morphological indicators of sugarcane root residue/stubble and traits that directly contribute to cane yield and sugar output, such as a high number of stalks, high viability of buds, large number of viable buds, large

number of viable roots, high cane yield, high sugar output (Singh *et al.*, 2015; Ding *et al.*, 2020; Qin *et al.*, 2014; Hassan *et al.*, 2017; Ramburana *et al.*, 2013) and high tillering rate in plant cane. Additionally, a higher stubble germination rate and the larger shoot number were observed in the ratoon crops, which result in high stalk number and higher cane yields than those in plant-cane. A similar observation was obtained by other reports (Aslam *et al.*, 2020; Ramburana *et al.*, 2013). It is also believed that the ratooning ability of sugarcane is mainly identified by four important factors, namely, root traits, the total number of strikes or shoot population, stalk number, and cane yield. Good performance on the four aspects above in its plant cane and the ratoon crops is necessary for the selection of varieties with a strong ratooning ability. The morphological characteristics of sugarcane stubble are closely related to the ratooning ability of the sugarcane (Bashir *et al.*, 2013). In addition, sugarcane varieties with strong ratooning ability have a low stubble mortality rate and a short inter-nodal length of underground stems, together with the obviously larger total number of underground buds and the effective tillers (Bashir *et al.*, 2013). Generally, if there is an increased number of effective tillers formed by the lower buds of the main stems, and there is an increased total number of effective tillers on the main stems, then the

variety likely has strong ratooning ability (Bashir *et al.*, 2013).

There was a significant interaction effect between varieties and growing seasons for all yield and qualitative traits except for the purity of sugarcane juice. Based on an investigation of later crop, Olaoye found that single stalk weight, cane yield, total soluble solids (Brix), and sucrose percentage, were highly heritable traits that displayed the potential to obtain high genetic gain. Additionally, a study on the genetic relationships among sugarcane traits in a large population indicates that stalk number was the primary determinant of cane yield and thus became more important trait in determining cane yield in the ratoon crops, much higher than those of stalk diameter and stalk length (Ramburana *et al.*, 2013). Research also indicated that, for varieties with poor ratooning ability, the ratoon crops had a much lower cane yield than the plant cane (Bashir *et al.*, 2013) or a sharp decline in cane yield in the first ratoon compared with plant cane (Silva *et al.*, 2017). Meanwhile, the yield decrease was only observed in varieties with strong ratooning ability in the second ratoon crop. In brief, for the selection of ratooning ability, direct indicators are the stubble morphology, stalk number, and the germination and tillering rates in the plant cane and the ratoon crops, while indirect indicators included disease resistance especially smut, pest

resistance, biomass, light use efficiency, and hormone content during stubble bud germination. The number of indicators used in selection may vary, but researchers have the same or a similar opinion on those indicators. In addition, more attention should be paid to the selection of the experimental location, mostly due to the reason that the effect of the location on ratooning ability is visible.

Factors influencing longevity and productivity of ratoon sugarcane

The ratooning ability or good ratooning potential is an essential pre-requisite or the most critical factor for good ratoon (Aslam *et al.*, 2020). The genotype, cultivation management, and environment contribute to the ratoon crop in descending order (Aslam *et al.*, 2020). The ratoon crop yields decline typically with age. Studies have also shown that, in subtropical regions, a major bottleneck for improving ratoon productivity is the poor germination rate of buds in the stubble remaining after winter harvesting (Singh *et al.*, 2015). The trait of stalk number has the greatest impact on sugarcane yield. Therefore, the ratooning ability is one of the most important target traits in sugarcane breeding and has always been valued by breeders (Singh *et al.*, 2015; Rafiq *et al.*, 2006). From both the perspective of reducing production costs and improving the productivity of the ratoon crops, breeding and growing varieties with a

strong ratooning ability is the most important prerequisite for extending the number of ratooning years and increasing the yield of the ratoon crops.

Furthermore, in sugarcane-producing areas with low temperatures, frost, drought, pests, diseases (especially smut), stem borers, or extensive management, the ratooning ability of sugarcane varieties is particularly important for extending the number of ratooning years and increasing the yield of ratoon crops.

Variation in ratooning ability between different sugarcane genotypes

Sugarcane genotypes with higher proportions of the genetic background of *Saccharum spontaneum* display stronger ratooning ability (Burnera *et al.*, 2017) because the characteristics of a species can be affected by kinship (Huang *et al.*, 2018), i.e., hereditary basis. Sugarcane 'nobilization' breeding aimed at bringing the genes controlling vigor, vitality, stress resistance, and strong ratooning ability from wild species into original cultivated species, i.e., 'noble' *S. officinarum*. A wild species *S. spontaneum*, the mostly used and studied, was the first species to naturally hybridize with *S. officinarum* (Liu, 2018). Meanwhile, the ratooning ability was negatively correlated with single stalk weight and commercial cane sugar (CCS). Therefore, strengthening CCS through selection without considering the ratooning ability is not

conducive to pyramiding the genotypes with strong ratooning ability (Liu, 2018).

Limitations of Existing Research

It is precisely because of this highly heterozygous genetic background that the offspring of sugarcane hybrids are widely segregated and the probability of aggregation of excellent traits is extremely low (1/100,000–1/300,000). Therefore, for a long time, sugarcane cross breeding had to rely on large segregating populations. In Pakistan, a very low number of seedlings being planted in the field, a commercial cultivar with high yield, disease resistance, especially primary diseases including smut resistance, and strong ratooning ability has not been yet identified or developed. Approximately 95–97% of planted seedlings are discarded after observation in the first year, without ratooning. Therefore, in Pakistan, the problem of the short ratooning longevity of the leading sugarcane varieties needs to be solved. Sugarcane cross breeding relies on a huge, segregated population. There is still a lack of effective and high-throughput selection technology suitable for early segregating generations and large populations. Although the selection of ratooning ability based on phenotype is intuitive and effective in general, it is still difficult to identify and select varieties with strong ratooning ability, disease resistance, and high yield simultaneously.

CONCLUSIONS

Ratooning can largely reduce production costs compared with replanting sugarcane. Labor costs increase yearly, and the cost difference between ratooning and

replanting sugarcane widens. In this paper, previous studies on sugarcane ratooning ability were reviewed in terms of the definition, phenotypic traits and major influencing factors. In addition, the limitations of existing research on ratooning ability

were highlighted. We do hope that this review can provide a reference for understanding the limitations underlying sugarcane ratooning ability, and for breeding sugarcane varieties with strong ratooning ability.

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