Review Article

GENETICS AND GENOMICS OF AROMA OF RICE AND ITS QUALITY ENHANCEMENT PARAMETERS: A REVIEW

ABSTRACT

Rice or The ORYZA SATIVA L, is crucial cereal crop because it provides essential vitamins to more than 50% of the world's population. Almost 90% of the world's rice output is produced in Asia, particularly South Asia, where its cultivation is predominantly focused. People from different regions of the world have varying tastes in rice. The scent is influenced by more than 500 volatile chemical components. The most crucial for rice flavors among them has been found as 2 acetyl-1-pyrroline (2AP). It is observed that the fragrance characteristic is correlated with three quantitative trait loci (QTLs). The most important QTL for fragrance is called Qaro8.1, and it is located on chromosome 8. The identification of QTLs in the genome uses a variety of markers, including molecular markers and DNA markers.

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Oryza sativa L.

Keywords: aromatic rice, 2 acetyl-1-pyrroline (2AP), quantitative trait loci (QTLs), volatile organic compounds(VOCs).

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1. INTRODUCTION

Rice, which comes from the plant genus Oryza sativa L. and is more generally known as rice, is an essential source of vitamins and proteins that contribute to proper nutrition for more than half of the world's population. This multipurpose crop has a high concentration of a wide variety of minerals, including thiamine, riboflavin, niacin, vitamin E, zinc, potassium, and iron. [1]. In East African marketplaces, the predominant aspect that motivates purchasers is aroma, despite the fact that consumers' preferences about the quality of the grain are a matter of personal taste. Hence, rice farmers all over the globe who plant aromatic rice varieties may gain large profits from the unique scent of their product due to the fact that aromatic rice types have a higher demand. [2]. In 2018, India was the top exporter of basmati rice. Genetic factors influence rice fragrance, but environmental factors also play a part. Asia, especially South Asia, is the region where rice is grown for over 90% of the world's rice production. Both biotic and abiotic factors can affect rice production, although drought stress is the main one that affects rainfed areas.[3] Additionally, due to drought, climate change has a negative association with rice output. Consequently, it is essential to cultivate drought-tolerant cultivars. In the majority of Asian nations, rice serves as a significant source of protein. Six of the 27 species in the Oryza genus have diploid genomes (n = 12: AA, BB, CC, EE, FF, and GG), while five have polyploid genomes (n = 24: BBCC, CCDD, HHJJ, HHKK, and KKLL). More over half of the world's population eats rice as a staple diet, making it the most significant cereal crop [4]. Rice is divided into aromatic and non-aromatic varieties based on whether an aroma is present [5]. Non-aromatic rice varieties are typically developed in all nations that cultivate rice and are high yielding, show strong agronomic performance, and are highly adaptable to the environmental conditions. Contrarily, the majority of types of aromatic rice are produced in a small number of nations, have low yields, poor agronomic performance, and are very susceptible to environmental conditions [6].The fragrant rice is widely praised for its outstanding scent and superior grain quality despite its subpar performance [7] . According to phylogenetic study, the aroma genes derive from wild cousins (Oryza nivara and O. rufipogon), with the Indian subcontinent serving as their primary region of origin before spreading to other areas of the world [8]. Natural selection played a major role in the evolution of aromatic rice varieties over thousands of years. Local farmers then continued this process by selecting varieties that suited their preferred cultivation methods. Finally, plant breeders continued this process over time by making improvements [9]. As a result, it is possible to view the scent of rice as a natural occurrence that has been supported and maintained by the selection process.

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PREFERENCES OF RICE CONSUMERS AND FRAGRANCE

1.1 Rice Consumer Preferences

People from many regions of the world have varying tastes in rice. Regardless of the physical and chemical properties of rice, low-income individuals prefer inexpensive rice to Basmati in general [8]. However, Muhammad's research in Indonesia shows that wealthy people prefer rice with a nice flavor [10]. Due of the fragrance, rice prices are impacted. The Ugandan population prefers rice that is white in colour, whole grained, and aromatic. Rwandan urban residents, however, favour long-grained, fragrant rice. Tanzanian consumers like eating the nation's flavorful indigenous rice [8]. Additionally, rural residents and police and military personnel's employers consume rice of lowest possible quality [11]. Consumers in Western nations favoured rice with a fluffy texture and a softer scent, but those in Asian countries liked rice with a sticky texture and a strong perfume. Overall, research indicate that a range of elements, such as flavour, texture, scent, and cooking method, affect customer preferences for rice. Producers and marketers of rice may better match the demands and expectations of their target customers by being aware of these preferences.[12]

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1.2 AROMA OF RICE

Several civilizations throughout the world place a great emphasis on rice's scent as an essential quality. When rice is cooked, a variety of volatile organic compounds (VOCs) are emitted, giving rice its distinctive scent. Aldehydes, ketones, alcohols, esters, and other substances are among these VOCs. The type of rice, the way it is cooked, and the place where it is farmed can all affect the distinct scent of the grain. For instance, basmati rice has a nutty and fragrant scent, whilst jasmine rice is renowned for its sweet and flowery perfume. The scent of rice affects its perceived quality and nutritional worth in addition to its sensory appeal. According to studies, individuals frequently believe that rice with a strong scent is of a higher calibre and has more nutrients. Overall, many people all around the world appreciate and like rice's scent, which is a significant component of its total sensory experience. Rice is priced based on its scent in both domestic and foreign markets. More than 500 volatile chemical molecules, for example, impact the scent of rice, among other things[13]. The most crucial for rice flavouring among them has been discovered as 2 acetyl-1-pyrroline (2AP)[14, 15]. 2AP is an aromatic chemical that some researchers have also called 2-AcPy or 2-ACP. 2-AP is known by its IUPAC designation, 5-acetyl-3, 4-dihydro-2H-pyrrole. The content of 2AP in rice may be separated out and quantified using a variety of techniques, but the most practical method is gas chromatography combined with mass spectrometry, which is also the most expensive and time-consuming. Although both short and long grains include GC-MS 2AP and other aromatic chemicals. As a result, there are several ways to assess rice's scent. Generally speaking, scent may be measured by either boiling the kernel or vegetative component and then sniffing the cooked kernel for aroma[10, 16] or by testing the flavour by biting between the teeth[15] [8] [17]. The rice breeders employ a quicker method that Sood and Siddiq devised for assessing rice smell [18]. This states that any segment of the rice plant, except roots, can be treated with 0.1 M potassium hydroxide for 10–12 minutes before a panel of sensory specialists trained in rice fragrance assessment evaluates the emitted scent. Because each person's sensitivity to rice smell differs, a panel of specialists is required. This is currently accepted as a fundamental method for sensory evaluation of scent on a global scale. Different factors, such as variations in rice varieties and environmental factors, might affect 2AP content [19].

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2. GENETIC BASIS OF AROMATIC RICE

The scent of rice is thought to be controlled by a single recessive gene at first, but further research by other scientists showed that this attribute may also be controlled by a dominant gene or additional genes[20] [21] [22]. On chromosomes 4, 8, and 12, several rice aroma QTLs have been found, whereas in Pusa 1121, at least three QTLs have been found on chromosomes 3, 4, and 8 [23]. It has been shown that the fragrance characteristic is correlated with three quantitative trait loci (QTLs). The most important QTL for fragrance is Qaro8.1, which is situated on chromosome 8 [24]. This characteristic has been linked to another important QTL on chromosome 3 called qaro3-1 [25]. Additionally, several alleles of the badh1 gene, which is a part of the QTL qaro4.1 on chromosome 4, have been linked to fragrance in rice cultivars [8, 10]. It's interesting to note that non-aromatic types of rice have homozygous forms of the main gene responsible for scent. According to a research, the main factor influencing rice's scent is a non-functional variation of the badh2 gene, which produces the betaine aldehyde dehydrogenase enzyme. Certain rice types lack smell due to the existence of a functioning allele of the badh2 gene. There are currently 19 alleles connected to the badh2 gene that have been identified as influencing rice cultivar aroma. The badh2-E7 variation of these alleles was discovered to be the one that was present in the highest number in the Ugandan cultivars of aromatic rice.[26] . However, compared to the badh2-E7 gene, the badh2-p allele was shown to be more common in fragrant rice types in India. Both indica and japonica forms of cannabis included this gene, badh2-p. 8 bp deletion in exon 7 has been described as a functional signature of fragrant rice and is present in aromatic rice cultivars worldwide. [27]. Exon 13 in certain aromatic lines, however, exhibited a 3 bp gain rather than an 8 bp loss. Most of the described variants for

Comment [AB11]: There should be space before the addition of reference the badh2 gene contain the deletions and additions[28]. According to Bindusree et al., Seeragasamba, a short-grain aromatic rice variety similar to indica, has fragrance thanks to an 8 bp insertion in the badh2 gene's promoter region. In addition, the 8 bp deletion "GATTAGGC" is followed by two significant mutation events (A to T and T to A) and is linked to scent in rice. Twenty of the 23 aromatic accessions in the research by Akwero et al. in Uganda [28] carried the badh2-E7 allele with an 8 bp deletion and three SNPs [29],

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3. MOLECULAR MARKERS FOR RICE AROMA GENES

Numerous markers, including DNA and molecular markers are used to identify QTLs in the genome. Each sort of molecular marker has advantages and disadvantages, and they are used for a variety of purposes. [30]. Using molecular markers, we may rapidly and precisely identify the required trait controlled by a QTL in a single cultivar. [23]" To investigate genetic variation within and among populations, as well as to identify individuals or species and trace evolutionary history, researchers commonly employ markers such as restriction fragment length polymorphism (RFLP), random amplified polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLP), inter simple sequence repeats (ISSR), simple sequence repeats (SSR), and single nucleotide polymorphisms (SNPs). However, the selection of the appropriate marker for a given study depends on the research question and the organism's characteristics, as each marker has its own advantages and disadvantages.[31].

4. STANDARD OF BASMATI RICE

The most crucial aspect for consumers is the flavor and scent of the rice. The demand for high-quality rice is rising in tandem with population growth [32]. A sizable portion of India's economy continues to be devoted to basmati rice. After China, India ranks as the second-largest producer of basmati rice. Basmati rice was also produced in Pakistan **[33].**

5. GRAIN QUALITY IMPROVEMENT

5.1 Estimation of protein content

With the use of a hand dehusker, seeds from 118 genotypes were dried to produce brown rice, which was then crushed to a powder for the measurement of protein content. This procedure is being carried out using the micro Kedah approach. Afterward, the crude protein content was determined. From the chosen genotypes, 10 are high in protein, and 11 are not basmati [32]. The results are shown below after a frequency distribution table is produced and the protein content is checked.'

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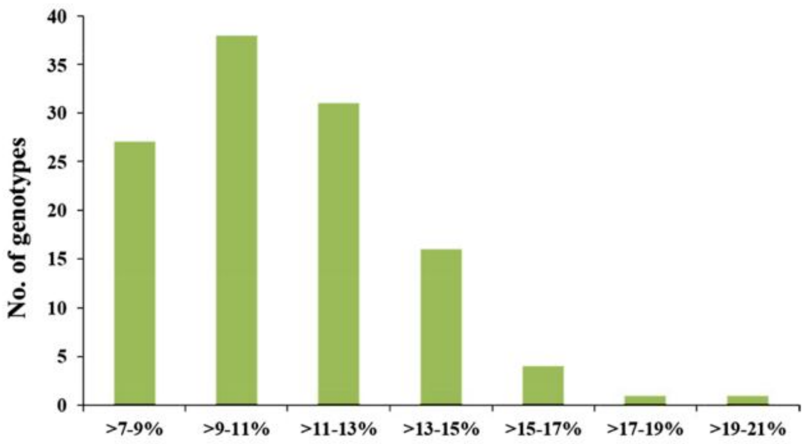

Fig. 1. Screening of genotypes based on protein content

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5.2 Amount of protein.

Between basmati, non-basmati, and wild rice species, there were significant variances in the protein content. Comparing wild accessions to basmati and non-basmati, they have higher protein content [34].

6. GRAIN CHARACTERISTICS

7.1 Milling quality

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Brown rice recovery, milled rice recovery, and head rice recovery are the variables used to evaluate quality and milling efficiency. Whole grain was defined as kernels with a length more than or equal to three-quarters [35]. The primary determinant of rice market value and one of the most crucial milled rice specifications is head rice recovery[36].

7.2 Qualitative Appearance

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Appearance also plays an important role in affecting its market value. The grain appearance is correlated with size shape, chalkiness, and translucency [37], Phenotype of rice is described with the help of grain length, width, and thickness. Chalkiness also affects the market value. For instance, greater chalkiness lowers the market value[38].

7. COOKING AND EATING STANDARDS

The cooking and eating quality of rice determines a number of characteristics, including how easily it may be prepared, how firm it remains, and how sticky it stays while being consumed. The ease with which certain physicochemical characteristics, such as apparent amylose content (AAC), gel consistency, gelatinization temperature (GT), and pasting viscosity, may be assessed is directly proportional to the degree to which they correlate with the cooking and eating quality of rice [39]. The starch that constitutes up to 90% of milled rice has qualities that are connected to all of these variables. The two types of molecules that make up starch are branching amyl pectin and linear and helical amylose. I2-KI solution is used in a streamlined process to quantify amylose content.[40] Rice's amylose content, as determined by the I2-KI solution technique, is more frequently referred to as the apparent amylose content (AAC). This is due to the fact that long chains of amylopectin may also bind to I2, which is why AAC is the more accurate term. Waxy milled rice (1-2%), very low milled rice (5-12%), low milled rice (12-20%), moderate milled rice (20-25%), and high milled rice (>25%) are the five various categories that milled rice may be placed into based on its AAC value. [41].

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8. NUTRITIONAL QUALITY

The most significant staple food's nutritional value is intimately connected to people's health. Protein is the second-most prevalent component of milled rice after carbohydrates. Additionally, lysine influences the nutritional value of food [42]. In an area with low development where a lack of micronutrients is evident. Rice's nutritional value may be improved by breeding in additional micronutrients. In comparison to milled rice, brown rice offers higher minerals, vitamins, dietary fiber, and phenolic [43].

9. GENETICS AND GENOMICS OF RICE GRAIN QUALITY

The most common quality traits used to evaluate rice grain quality are milling quality, attractiveness, nutritional content, and cooking quality. Numerous genes governing quality attributes have been cloned in rice utilizing cutting-edge technologies and genomics. Numerous significant quantitative loci (QTLs) including qBRR-10, which improves brown rice recovery, are correlated with rice milling quality [44]. Rice grain size and shape are influenced by the genes GS3, GW5, GLW7, GW8, GS2, and GS9 [45]. Starch is crucial for maintaining the integrity of rice grains, especially those used for cooking and eating[45] [46]**.**

CONCLUSION AND FUTURE PERSPECTIVE.

After all review, it's concluded that aroma and grain quality alternate by the environmental effect as well as genetic effect. Aroma is a significant trait that controls the prices of variety. The gene badh2 controls the proportion of aroma. Moreover, we can improve aroma with this gene. To further understand the variations in rice aroma's kind, strength, and stability as well as the minor genes driving it, sophisticated genomic and metabolomic methods must be used. Also, there is a need to enhance the marketing and manufacturing of short-grain aromatic rice types.

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