

Retraction

Retracted: Quantitative Evaluation of Leaf Morphology with Different Rice Genotypes Based on Image Processing

Mathematical Problems in Engineering

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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Research Article

Quantitative Evaluation of Leaf Morphology with Different Rice Genotypes Based on Image Processing

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Prostrate growth 1 (PROG1) gene is vital in controlling the prostrate growth habit of rice. Studying the effect of *PROG1* gene on rice canopy structure is crucial in elucidating the molecular mechanism of rice plant type evolution. Herein, the morphological characteristics of different rice genotypes were collected at different growth stages and leaf nodes using image processing techniques. The morphological characteristics included leaf length, leaf width, and leaf area. The image processing techniques involved boundary mean oscillation (BMO) filtering and minimum bounding rectangle extraction of the target image. On this basis, the effect of the *PROG1* gene on rice leaf morphology was quantitatively assessed. Also, the feasibility of image processing techniques in detecting the morphological characteristics of rice leaves was discussed. Under the influence of the *PROG1* gene, the length, width, and area of rice leaves decreased by 45.1%, 12.7%, and 44.8%, respectively, at the booting stage. Similarly, the length, width, and area of flag leaves decreased by 15.8%, 32.0%, and 33.7% at the heading stage and by 25.4%, 16.2%, and 19.7% at the filling stage, respectively, and that of secondary leaf reduced by 23.2%, 13.6%, and 54.2% at heading stage and by 24.1%, 17.3%, and 37.0% at filling stage, respectively. Furthermore, the length, width, and area of other leaves reduced by 32.3%, 9.8%, and 51.6% at the heading stage and by 28.6%, 7.3%, and 36.7% at the filling stage, respectively. The leaves in the rice canopy were shorter, narrower, and smaller in leaf area. Notably, no significant differences were found between image processing technology and manual measurement methods regarding the values of leaf morphological characteristics obtained ($P < 0.05$). Thus, these results show that image processing technology is effective in studying the morphological characteristics of rice leaves. This study provides a reliable foundation for molecular breeding studies and will guide the application of the *PROG1* gene in molecular breeding.

1. Introduction

Rice is the largest grain crop in China in terms of production and a staple food for more than 60% of the Chinese population. At present, increasing the output of major grain crops is a top priority in China, owing to the alarming rise in population and sharp reduction of arable land. According to FAO [1], the rice yield in China mainland has increased by 121.1% since the Green Revolution in the 1960s. This can be attributed to the improvement of rice plant type [2]. Plant architecture refers to the size, shape, and orientation of the shoot components, including plant height, tiller number, leaf shape, panicle shape, and other factors. Rice plant architecture is a critical factor in rice yield [3].

Rice yield mainly depends on photosynthesis at the reproductive stage and carbohydrate accumulation in the stem before heading [4]. Dry matter production in rice after heading results from photosynthesis in the leaves, followed by temporary storage in the stems and sheaths [5]. Thus, morphological characteristics and physiological functions of rice leaf vastly affect the final yield [6]. The leaf is the main photosynthetic and respiratory organ in rice canopy and the main influencing factor of plant type. Leaf characteristics, such as leaf length, leaf width, leaf angle, leaf area, and leaf color, determine the photosynthetic efficiency per unit leaf area, thus affecting the final rice yield.

Several studies on DNA molecular marker and bioinformatics models [7–10] have relied on QTL to map genes specific for most rice traits, including yield, plant type, and

stress resistance. Among these, *TAC1* [11] and *PROG1* [12, 13] are related to plant type. *PROG1* gene is located on the short arm of chromosome 7 and expressed as a Cys2-His2 zinc finger protein which controls the creeping growth of wild rice [12]. During rice evolution, a mutation in the coding region of the *PROG1* gene resulted in the loss of gene function. This altered the rice growth habit from prostrating in the wild rice to erectile in the cultivated rice [12]. The change in rice growth habit significantly increased rice yield, suggesting that the *PROG1* gene was vital in the evolution of rice yield. A three-dimensional structure model of rice with *PROG1* gene was reconstructed using 3D digital technology in a previous study. This enabled quantitative evaluation of rice canopy structure, including tiller angle, leaf inclination angle, and leaf area index [14]. It was observed that *PROG1* inflicted significant effects on tiller angle, leaf inclination angle, and leaf area index of rice canopy [14]. However, changes in leaf morphology, such as length, width, and leaf area at different stages and leaf nodes, have not been studied in detail.

Traditional breeders usually adopt manual measurement methods to determine the characteristics of rice plant type. These include measuring plant height, leaf length, and leaf width using a ruler and leaf angle and tiller angle using an angle meter. However, this approach is time-consuming and cannot accurately describe the characteristics of canopy structure. At present, large phenotypic data are mainly obtained through high-throughput phenotypic analysis [15]. Image processing technology is one of the most convenient and rapid digital measurement methods used to obtain phenotypic data of rice. The method mainly acquires rice phenotypic characteristics through image acquisition, image preprocessing, image segmentation, target contour recognition, and target pixel statistics [16, 17].

In this study, *Indica* varieties Teqing (TQ) and YIL18 (*O. sativa* L.) were used. TQ is a conventional *Indica* variety with excellent yield, whereas YIL18 is a variety with TQ *PROG1* gene. TQ exhibits an erect stature, whereas YIL18 has a prostrate growth habit. Digital images of the leaves at different nodes of the two rice varieties were obtained at various growth stages, including the booting stage, heading stage, and grain filling stage. The images were preprocessed using boundary mean oscillation (BMO) filter for denoising and enhancement [18–20] and binarized with adaptive threshold [21]. The minimum bounding rectangle extraction of target and target pixel statistics were used to obtain the morphological characteristics of the leaves (leaf length, leaf width, and leaf area) from preprocessed images. Based on these data, the effect of *PROG1* gene on leaf morphology of rice was quantitatively analyzed. In addition, the feasibility of image processing technology was discussed.

2. Materials and Methods

2.1. Experimental Materials. *Indica* varieties Teqing (TQ) and YIL18 (*O. sativa* L.) were used in this study. TQ is a super high-yielding conventional *Indica* cultivar with erect plant type. It is bred in China and is an important parent of two-line hybrid rice. The YIL introgression lines used an

accession of YJCWR (*Oryza rufipogon*) from Yuanjiang, Yunnan, China (23°37'N, 102°01' E), with a creeping growth habit as the donor and the *Indica* variety TQ with erect growth habit as the recipient [22]. The YIL18 line is one of the introgression lines that harbor two YJCWR chromosomal segments on the long arm of chromosome 3 and the short arm of chromosome 7. *PROG1* gene is located on the short arm of chromosome 7 and expresses a Cys2-His2 zinc finger protein which controls the creeping growth habit of wild rice [12]. During evolution, mutation of the *PROG1* gene resulted in gene function loss, therefore altering the growth habit of rice from prostrate to erectile. This had a significant impact on the rice canopy structure and yield.

Field experiments were conducted from May to September of 2012 and 2013 at Shangzhuang experimental station of China Agricultural University in Beijing (40°08'N, 116°10'E). The sowing time was May 5th of each year. Seeds were propagated on a seedbed and then potted (one plant per pot) after they grew to the trifoliate stage (May 20th). The planting area of each rice variety was 30 m² with a north-south planting direction. Plant spacing was 0.20 m, and row spacing was 0.25 m. Fertilizer was adequately supplied according to the local standard of rice cultivation. Weeds were artificially removed. No pests and diseases were observed during the growth period. The canopy structure of rice was not disturbed by artificial or strong wind during the experiment period.

2.2. Acquisition of Digital Images. Digital images of rice leaves were acquired at the booting stage (BS), heading stage (HS), and grain filling stage (FS) on July 28th, August 29th, and September 9th, respectively. Leaves from nine randomly selected plants were collected at each rice growing stage to represent the average growth condition in the field. The leaves were classified into three categories based on node position, i.e., flag leaf, secondary leaf, and other leaves. The flag leaf and secondary leaf were not collected at the booting stage; therefore, all leaves collected at this stage were classified as other leaves. Leaf area was measured using a leaf area meter (LI-3000C Portable Area Meter, LI-COR, USA). The length and width of the leaves were determined using a ruler. The leaves were then placed on a scanner (ScanMaker i800 Plus, Microtek) and covered with a transparent plate to make them flat for scanning. The gray scale scanning mode was used, and the images were saved in a TIF file format. The pixels of the captured digital images were 2400 × 3435 with a resolution of 0.01 cm/pixel.

2.3. Morphological Characteristics of Rice Leaf. To study the leaf morphology of different rice genotypes, image processing technology was used to perform image preprocessing, minimum bounding rectangle extraction of target leaf, target leaf pixel statistics, and leaf length, leaf width, and leaf area calculations.

The digital images of rice leaves were preprocessed through image graying, image denoising and enhancement, and image segmentation. After converting color images to gray images, BMO filter was used to denoise and enhance the edges of the image using the formula below [18]:

$$Z^Q(u, x, r) = \frac{2}{9r} \sum_{k=i-1}^{i+1} \sum_{l=j-1}^{j+1} |u_{i,j} - \bar{u}|, \quad (1)$$

$$\bar{u} = \frac{1}{9} \sum_{k=i-1}^{i+1} \sum_{l=j-1}^{j+1} u_{i,j},$$

where $Q(x, r)$ is a square neighborhood with x as the midpoint and $2r$ as side length and $u(x)$ is a function on the image plane.

After image denoising and enhancement, the Otsu threshold segmentation method was used to segment the images and obtain the binary images (Figures 1(a)–1(d)).

The leaf morphological characteristics measured from the images were leaf length, leaf width, and leaf area. Binary images were obtained after preprocessing the digital images by extracting the minimum bounding rectangle of the target leaf [23]. The length and width of the leaves were calculated by multiplying the total number of pixels in the direction of length and width in minimum bounding rectangle by the resolution (Figure 1(d)). Leaf area was the total area of pixels on the leaf. Previous studies have shown that the interannual variation does not significantly mask the effect of *PROG1* gene on rice canopy structure [14]. Therefore, data on morphological characteristics from different years were averaged and presented as the final results in this study. Manual measurement results were considered as a control.

3. Results

3.1. Application of Image Processing Technology on Evaluation of Rice Leaf Morphology. Image processing technology has been extensively used in measuring plant phenotypic traits. In this study, BMO filter was used to denoise and enhance the edge of the target leaf image. Morphological characteristics of rice leaves, including leaf length, leaf width, and leaf area, were determined from binary images by calculating the minimum bounding rectangle and target leaf pixel statistics. There was no significant ($P > 0.05$) difference between image processing technology and manual measurement methods regarding the values of leaf morphological characteristics obtained from various leaf types at different growth stages (Table 1). However, the values obtained using the image processing technology were slightly lower than those obtained using the manual measurement methods.

BMO filter was accurate and stable in processing digital images of the rice leaves. However, there was a slight difference between the values obtained using image processing technology and manual measurement methods. This can be attributed to the loss of some edge information during digital image acquisition. Moreover, subjective judgment while taking manual measurements of the leaf length and width could have slightly affected the final results.

3.2. Effect of *PROG1* Gene on Rice Leaf Morphology. Given that there was no significant difference in the values of morphological characteristics of rice leaves obtained using image processing technology and manual measurement

methods, this study assessed the effect of *PROG1* gene on rice leaf morphology based on data obtained using the image processing technology. At the booting stage, the average length and width of YIL18 leaves were 45.1% and 12.7% shorter than that of TQ (Table 1). The length and area of the rice leaves were significantly reduced. The YIL18 leaves were shorter and narrower, and the leaf area was only 44.8% of the TQ leaf area. The flag leaves of rice canopy emerged during the heading stage. The length, width, and area of flag leaves in the YIL18 canopy were 15.8%, 32.0%, and 33.7% lower than that of TQ. The length, width, and area of the second leaf from the top were 23.2%, 13.6%, and 54.2% lower in YIL18 than in TQ. Regarding the other leaves, the length, width, and area were 32.3%, 9.8%, and 51.6% lower in YIL18 than in TQ (Table 1). At the heading stage, the difference between the leaf length of YIL18 canopy flag leaf and that of TQ was reduced, but the leaf width of YIL18 was smaller than that of TQ. Furthermore, the decrease in leaf length of the second leaf from the top and the other leaves was significantly larger than that of leaf width, directly affecting the leaf area. At the grain filling stage, the growth of rice canopy leaves peaked and then declined gradually due to senescence. Indeed, most leaves at the bottom of the rice canopy turned yellowish and drooped. At this stage, leaf length, width, and flag leaf area in YIL18 canopy were 17.93 cm, 1.09 cm, and 16.07 cm², respectively. Those of the second leaf from the top were 25.48 cm, 0.91 cm, and 18.09 cm², while those of other leaves were 26.48 cm, 0.76 cm, and 15.52 cm², respectively. Compared with TQ, leaf length of these three types of leaves decreased by 25.4%, 24.1%, and 28.6%, leaf width decreased by 16.2%, 17.3%, and 7.3%, and leaf area decreased by 19.7%, 37.0%, and 36.7%, respectively. At the grain filling stage, the decrease in leaf length of all leaf types in YIL18 canopy was similar. However, changes in the leaf width of the flag leaf and the second leaf from the top were larger than in the other leaves.

4. Discussion

Divergence in plant growth characteristics of rice from prostrate to erectile was a crucial event in rice domestication. *PROG1* gene is one of the vital genes controlling rice growth characteristics. Quantitative analysis of leaf morphology variations between different rice genotypes is essential for understanding the effect of *PROG1* gene on leaf morphology and applying it in the molecular breeding of rice. In this study, BMO filter was used to denoise and enhance images. Minimum bounding rectangle extraction and target pixel statistics were employed to analyze binary images and reveal the differences in morphological characteristics of rice leaves, such as leaf length, leaf width, and leaf area.

4.1. Application of Image Processing Technology in Crop Phenotype Measurement. A fast, accurate, and reliable method is essential in evaluating rice phenotypic traits. Most of the existing measurement methods are manual, involving various tools, such as a ruler, caliper, and protractor. However, manual measurement methods are labor-intensive

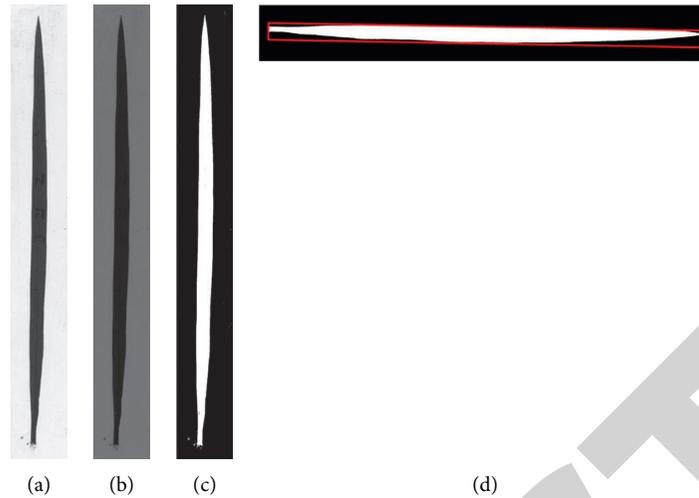


FIGURE 1: Images of the TQ leaf at booting stage after image preprocessing. (a–c) Images of the whole leaf after image graying, BMO filtering, and image segmentation. (d) Minimum bounding rectangle extraction of the target leaf.

and prone to errors. Thus, there is a need to apply alternative measurement methods to improve the accuracy of obtaining statistical data [24].

The rapid development of modern computer, machine vision, and information and automation technology has accelerated the development of phenotyping technologies. High-throughput phenotyping technology has been extensively used in the acquisition of massive crop phenotypic data. For example, LiDAR [25], CT technology [26, 27], and helicopters have been applied to monitor the canopy characteristic [28]. Most of these techniques are based on image processing technology. However, due to equipment and technology limitations, much noise gets captured during the image acquisition process. This affects further image analysis. Therefore, denoising and edge enhancement of digital images are important in image preprocessing. At present, a denoising method based on partial differential equation (PDE) is commonly used in image processing technology that belongs to the anisotropic diffusion model. The diffusion speed is determined by image gradient, which considers both noise elimination and feature preservation [29]. The BMO filter used in this study was constructed based on the bounded mean oscillation model and partial differential equation. It detects edge features by determining new derivative format and uses integral averaging to eliminate noise influence [19, 20]. The algorithm is simple and can detect more fine edge features involving less computation and calculation steps. Thus, BMO filter can not only achieve noise cancellation but also retain the edge details. This has led to the extensive application and continuous development of the BMO algorithm in recent years [18]. In this study, BMO filter was used to denoise and enhance the digital image of rice leaves. This study lays a solid foundation for future research on accurate acquisition of leaf morphological characteristics. Notably, no significant difference was found between leaf morphological characteristics obtained using image processing technology and manual measurements ($P > 0.05$). Moreover, its filtering

effect was stable for leaf images of different rice varieties. However, the values obtained using image processing technology were slightly lower than those obtained using manual measurement methods. This might be due to image resolution or subjective error caused by manual measurement. In addition, the discrete format is an important factor for the accuracy of the results. In this study, the BMO filter was discretized by 3×3 discrete format. An appropriate discrete format for the BMO model should be selected when dealing with different objects. The larger the scale, the better the processing effect; however, this also increases the calculation required.

In addition to leaf size, rice leaf morphology includes leaf curl degree, thickness, and leaf color. However, because digital images are two-dimensional, obtaining this additional information from digital images is practically impossible. Therefore, future research should focus on combining image processing technology with other high-throughput phenotypic techniques. This is necessary for the development of an advanced and comprehensive digital technology for rice leaf morphology evaluation.

4.2. Effect of *PROG1* Gene on Rice Yield. Light is required for photosynthesis, which is vital for rice growth and development. Photosynthesis in rice canopy is essential to energy accumulation, which ultimately affects the quality of rice grains. Leaf morphology of rice is directly related to the spatial distribution of canopy leaves and leaf photosynthetic area, thus affecting the utilization rate of light energy in rice canopy and yield per unit area. IRRI studies on IR8 at the milky stage demonstrated that 93.6% of total CO_2 assimilation was through green leaves, and the rest was through leaf sheath and stem (4.3%) and ear (2.1%) [30]. The upper three leaves (flag leaf, second and third leaf from the top) are the main sources of grain assimilates, accounting for about 80% of rice grain assimilates. The flag leaf is the most important among the upper three leaves, providing about 40%

TABLE 1: Morphological characteristics of leaves of TQ and YIL18 at three growth stages obtained by image processing technology and manual measurement.

Growth stage	Cultivar	Measurement method	Leaf length			Flag leaf Leaf width			Leaf area		
			Mean (cm)	SD (cm)	P value	Mean (cm)	SD (cm)	P value	Mean (cm ²)	SD (cm ²)	P value
BS	TQ										
	YIL18										
HS	TQ	Image	21.25	3.10	0.265	1.25	0.11	0.305	19.56	4.28	0.928
		Manual	22.30	4.04		1.28	0.10		19.77	4.34	
	YIL18	Image	17.90	3.22	0.210	0.85	0.09	0.088	12.97	2.99	
		Manual	19.20	2.32		1.08	0.13		13.68	3.38	
FS	TQ	Image	24.03	4.22	0.073	1.30	0.15	0.339	20.04	6.39	0.253
		Manual	25.15	4.03		1.34	0.17		21.93	6.53	
	YIL18	Image	17.93	2.51	0.149	1.09	0.13	0.296	16.07	3.88	
		Manual	19.68	2.69		1.18	0.11		16.26	3.69	

Growth stage	Cultivar	Measurement method	Leaf length			Secondary leaf Leaf width			Leaf area		
			Mean (cm)	SD (cm)	P value	Mean (cm)	SD (cm)	P value	Mean (cm ²)	SD (cm ²)	P value
BS	TQ										
	YIL18										
HS	TQ	Image	28.99	4.01	0.165	1.03	0.11	0.464	24.82	3.95	0.416
		Manual	30.84	4.42		1.12	0.10		25.94	4.50	
	YIL18	Image	22.26	3.87	0.148	0.89	0.08	0.896	11.36	3.77	
		Manual	23.11	4.55		0.93	0.10		12.85	4.05	
FS	TQ	Image	33.59	7.63	0.546	1.10	0.14	0.431	28.73	6.55	0.132
		Manual	34.18	7.47		1.15	0.13		30.23	7.54	
	YIL18	Image	25.48	5.94	0.248	0.91	0.06	0.635	18.09	5.49	
		Manual	26.10	5.48		0.97	0.10		18.94	5.74	

Growth stage	Cultivar	Measurement method	Leaf length			Other leaves Leaf width			Leaf area		
			Mean (cm)	SD (cm)	P value	Mean (cm)	SD (cm)	P value	Mean (cm ²)	SD (cm ²)	P value
BS	TQ	Image	25.93	10.52	0.574	0.71	0.11	0.321	11.94	6.36	0.367
		Manual	26.74	10.93		0.80	0.16		12.83	6.89	
	YIL18	Image	14.24	5.37	0.412	0.62	0.15	0.795	6.59	3.48	
		Manual	14.77	5.21		0.66	0.13		7.17	3.51	
HS	TQ	Image	35.12	5.87	0.298	0.82	0.09	0.674	22.81	6.84	0.895
		Manual	36.34	6.65		0.87	0.10		23.06	7.16	
	YIL18	Image	23.79	5.84	0.132	0.74	0.31	0.486	11.03	3.29	
		Manual	24.62	5.75		0.80	0.30		11.79	3.86	
FS	TQ	Image	37.11	6.64	0.646	0.82	0.14	0.874	24.51	6.12	0.445
		Manual	37.70	6.68		0.89	0.12		25.26	7.61	
	YIL18	Image	26.48	5.12	0.365	0.76	0.13	0.187	15.52	5.78	
		Manual	27.30	5.79		0.83	0.15		16.29	5.69	

Here, BS refers to booting stage, HS refers to heading stage, and FS refers to grain filling stage, while SD means standard deviation.

of photosynthetic products required for grain formation [30]. A study showed that the contribution rate of flag leaf towards yield per plant is 44%–48%, of which the contribution rate to seed setting rate is 40%, and that to a thousand seed weight is 10% [31]. Indeed, the thousand seed weight increases with the growth of flag leaves. Thus, rice leaf morphology is an important factor in the development of high-yielding rice plant types.

Previous studies have shown that *PROG1* gene plays a significant role in rice canopy structure. Under the influence of *PROG1* gene, rice canopy characteristics include shorter plant height, more tillers, shorter and narrower leaves, and lower leaf area index [14]. In this study, the

effects of *PROG1* gene on leaf morphology of rice canopy were analyzed. Under the influence of *PROG1* gene, leaf length, leaf width, and leaf area of flag leaves reduced by 15.8%, 32.0%, and 33.7% at the heading stage and 25.4%, 16.2%, and 19.7% at the filling stage, whereas those of the second leaf from the top reduced by 23.2%, 13.6% and 54.2% at heading stage and 24.1%, 17.3%, and 37.0% at the filling stage, and those of other leaves decreased by 32.3%, 9.8%, and 51.6% at heading stage and 28.6%, 7.3%, and 36.7% at filling stage. The leaves in rice canopy were shorter and narrower with a smaller leaf area. Loose canopy structure, shorter plant height, and more tillers increase the leaf cover area in the canopy, which is not beneficial in

improving photosynthetic efficiency. Although leaf area index of YIL18 increased gradually with the growth period, no significant difference was observed between YIL18 and TQ. The number of grains per panicle and thousand seed weight of YIL18 was significantly lower than that of TQ [14].

PROG1 gene is vital in controlling rice plant type. In this study, the effect of *PROG1* gene on rice leaf morphology was quantitatively analyzed. Data obtained in this study provide a reliable foundation for molecular breeding research, which will guide the application of *PROG1* gene in breeding programs.

5. Conclusions

In this study, leaf morphological characteristics of two rice genotypes were obtained from digital images using image processing technology. Further, the feasibility of applying the image processing technology in evaluating rice leaf morphology was assessed and discussed. Also considered was the effect of *PROG1* gene on rice leaf morphology. *PROG1* gene is critical in controlling the prostrate growth habit of wild rice. Herein, image processing technology was used to quantitatively evaluate the effect of *PROG1* gene on rice leaf morphology. Under the influence of *PROG1* gene, leaf length, leaf width, and leaf area of the flag leaf, second leaf from the top, and other rice leaves decreased by various degrees at different growth stages. The leaves in rice canopy were shorter and narrower, with a smaller leaf area. These results show that the *PROG1* gene significantly affects leaf morphology and validate the potential application of the gene in the molecular breeding of rice. Notably, no significant difference was found between the leaf morphological characteristics obtained using image processing technology and manual measurement methods. This finding suggests that image processing technology can be applied in studying rice leaf morphology. However, due to the limitation of two-dimensional digital images, the method cannot be used to examine all the phenotypic characteristics of the leaf. Thus, future research should focus on combining image processing technology with other high-throughput phenotypic characterization techniques. This will ensure a more accurate and comprehensive evaluation of leaf morphological characteristics.

Abbreviations

PROG1: Prostrate growth 1
 TQ: Teqing
 YJCWR: Yuanjiang common wild rice
 BMO: Boundary mean oscillation.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

Acknowledgments

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