Application of Plasma in Rice Crops with AI approaches

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Abstract: Plasma, as a green technology, can be applied in agricultural production with increasing crop yield and improving crop quality. In our study, rice seed treatment by atmospheric plasma was conducted, and then the treated seeds were applied in field planting. In order to effectively recognize and classify plasma treated rice crops, artificial intelligence (AI) approaches were used, which showed the effectiveness of AI in plasma rice recognition and classification. In addition, AI was also effectively used to predict plasma rice yield. These results show the practical application and advantages of the multidisciplinary combination of plasma, agriculture and AI.

Keywords: plasma agriculture, artificial intelligence

1. Introduction

Low temperature plasma (LTP) technology is a green technology, efficient and environmentally friendly. Up to now, it has achieved good applications in the fields of material processing, energy conversion, environmental remediation, biomedicine, aerospace, agriculture and food [1]. Since the overall gas temperature of LTP can be as low as room temperature, great progress has been made in the research on the application of LTP technology in agriculture. Many studies [2-7] have shown the applications of LTP in agriculture such as decontaminating seeds, breaking of dormancy, enhancement of seed germination, improving plant adaptation, etc. Rice is one of the most important food crops in the world. Low temperature can improve the yield and quality of rice. However, there is a lack of research on the identification and classification of plasma treated rice.

In recent years, with the rapid development of artificial intelligence [8-12], it has been widely used in many fields, such as transportation, medical treatment, etc. In plasma agriculture, in order to effectively recognize agricultural objects by plasma treatment, it is feasible and effective to combine with artificial intelligence. In addition, as the agricultural production level improved, plasma technology is expected to be used in agriculture on a large scale, which also needs the combination with artificial intelligence.

In this study, taking plasma application in rice crops as the example, the applications of AI technology in plasm rice recognition and classification in different stage of rice planting were shown. The application prospects of these studies were also analyzed.

2. Experiment

In this study, the rice variety chosen for experiment is Nanjing 9108. The selected rice was treated by atmospheric plasmas with different discharge parameters. Then the rice groups with and without plasma treatment were planted in Taizhou City, Jiangsu Province, China, with the longitude and latitude of E119.97 and N32.64. The growth process of rice was from 20 May to 2 November from seedling to harvest. The growth data including phenotypic images and characteristics in different stages was collected, which was used to construct datasets.

3. Results and Discussion

When rice seeds are exposed to plasma under atmospheric pressure, the formed active ingredients such as reactive oxygen species (ROS) and reactive nitrogen species (RNS) can disinfect rice seeds, disrupt dormancy, influence enzymatic activity, stimulate germination and growth, and improve yield [13-15]. Our rice planting experiment showed that the growth data of plasma-treated rice groups with different treatment parameters exhibit a certain degree of similarities and subtle differences on both intra-class and inter-class. Meanwhile, the rice growth data can be graded accordingly on the primary classification criterion of rice. In addition, during the process of data acquisition, the collected images may be distorted by attitude, light, visual angle, occlusion, vibration, vapor and so on. As a result, in some circumstances, the intra-class differences may be far greater than the inter-class differences, which results in a significant loss in identifying accuracy and robustness while using AI to identify plasma rice groups.

In order to identify different plasma rice groups at tillering stage, an AI model with three shortcut link connections were attached to the traditional CNN structure to improve the identification performance, because shortcuts from the bottom layers to fully connected layers can be established feasibly in order to utilize spatial and local information of plasma rice from the bottom layers, which contain small distinctions necessary for plasma rice fine-grain identification. And grating layers were attached to each shortcut to create a one-dimensional feature vector. After that, the feature maps were connected to utilize the fusion of plasma-treated rice growth features. Consequently, the model improved the utilization rate of key information. The results on plasma-treated rice growth dataset showed that compared with several other mainstream models, the proposed model achieved the best performance in terms of accuracy, recall, precision and F1 score, respectively. In addition, the ablation experiment showed that the best performance was acquired by the model with three shortcuts, which provided the highest accuracy (about 93%).

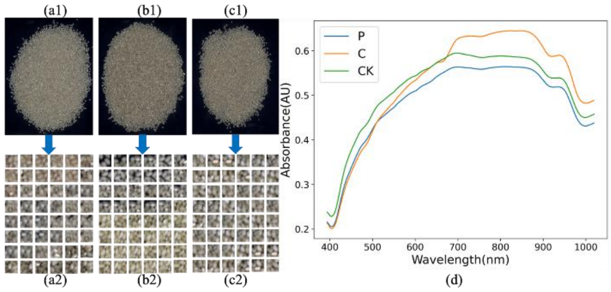

Fig.1. Rice HSI data.

AI can also be used to identify plasma rice after harvest. In this part, the rice hyperspectral image (HSI) dataset was constructed, which contains the rice with and without plasma seed treatment. The selected spectra are within 400–1000 nm with a total of 176 wavelength data in each spectral curve. The resolution of HSI image data collected in our experiment was 960×1440×176, then the original HSI image data was clipped into 32×32×176 through date clipping, shown in Fig.1(a1-c1) and (a1-c1), respectively). The average spectral of the selected three rice groups were shown in Fig. 1(d). The differences between these spectra indicates that the classification of the three types of rice can be obtained through HSI image data.

A plasma rice HSI recognition model based on 3D ResNet was constructed [16], which extracts spatial spectral features of rice HSI data cube. In addition, an attention mechanism based on spectral channels 3D attention module is proposed, which can extract important features of rice spectra. It shows that the proposed model is superior to other methods in recognition accuracy, and its overall accuracy can reach 97%. In addition, the floating point operations and the parameters quantities shows the higher performance with lower complexity of the proposed model.

Accurate yield prediction and evaluation can promote the integration of rice resources and planting. In our study, a plasma rice yield prediction model based on bi-directional long short-term memory (Bi-LSTM) artificial neural network is constructed, which can effectively predict plasma rice yield. Compared with multiple linear regression (MLR) and support vector machine (SVM) methods, the results showed the Bi-LSTM prediction model could well predict plasma rice yield, shown in Fig.2.

These results showed that the proposed AI approaches can effectively be used in the field planting of plasma agriculture with the practical application prospect.

4. Conclusion

AI approaches can be used and play an important role in plasma rice recognition, classification and plasma rice yield prediction. These results also show the practical application and advantages of the combination of plasma agriculture and AI.

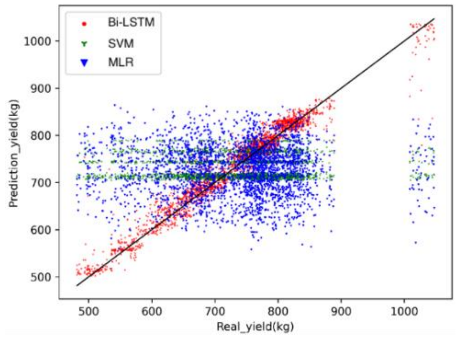

Fig.2. Plasma rice yield prediction by different models.

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