UPOV
International Union for the Protection of New Varieties of Plants

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Technical Working Party for Agricultural Crops

TWA/55/5 Rev.

Fifty-Fifth Session
Seoul, Republic of Korea, June 15 to 18, 2026

Original: English
Date: June 11, 2026

DEVELOPMENT OF IMAGE ANALYSIS METHOD FOR DUS TESTING OF MAIZE VARIETIES

Document prepared by an expert from China

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The annex to this document contains a presentation “Development of image analysis method for DUS testing of maize varieties”, to be made by an expert from China, at the fifty-fifth session of the TWA.

[Annex follows]

DEVELOPMENT OF IMAGE ANALYSIS METHOD FOR DUS TESTING OF MAIZE VARIETIES

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TWA55, Seoul, June 15 to 18, 2026

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1. BACKGROUND

- Maize (*Zea mays* L.) is one of the world's three major food crops, and is the Chinese top food crop.
- Traditional DUS testing for maize heavily relies on the experience of the testers, and has some disadvantages such as high cost, large error margin, and low efficiency.

Year	PVP application	Proportion
1999-2015	5095	15.5%
2016-2025	27798	84.5%
Total	32893	100%

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2. MATERIALS AND METHODS

- From 2022 to 2025, we used image analysis technology to address the issues in traditional maize DUS testing, supported by national research projects.
- 258 maize varieties were used in this study, and the variety types included ordinary type, sweet type, waxy type, sweet-waxy type, popping type, and their reproductive types included inbred lines and single cross hybrid.

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2. MATERIALS AND METHODS

GB

中华人民共和国国家标准

GB/T 19557.24—2018

植物品种特异性、一致性和稳定性测试指南 玉米

Guidelines for the conduct of tests for distinctness, uniformity and stability—Maize (*Zea mays* L.)

2018-05-14 发布 2018-12-01 实施

国家市场监督管理总局
中国国家标准化管理委员会 发布

Trait No.	Trait name	Trait Type
2	Seedling: first leaf: anthocyanin coloration of sheath	Color
3	Foliage: intensity of green color	Color
8	Leaf: anthocyanin coloration of margin of blade	Color
9	Ear: anthocyanin coloration of silks	Color
10	Tassel: anthocyanin coloration of anthers	Color
12	Tassel: anthocyanin coloration at base of glume	Color
13	Tassel: anthocyanin coloration at apex of glume	Color
14	Tassel: anthocyanin coloration at medium of glume	Color
22	Stem: anthocyanin coloration of brace roots	Color
23	Leaf: anthocyanin coloration of sheath	Color
34	Ear: number of colors of grains	Color
35	Only varieties with ear type of grain: sweet: Grain: intensity of yellow color	Color
40	Ear: color of top of grain	Color
41	Excluding varieties with ear type of grain: sweet: Ear: color of dorsal side of	Color
43	Ear: anthocyanin coloration of glumes of cob	Color
11	Tassel: density of spikelets	Count
19	Tassel: number of primary lateral branches	Count
32	Ear: number of rows of grain	Count
4	Tassel: time of anthesis	Date
5	Ear: time of silk emergence	Date
1	Seedling: first leaf: shape of apex	Shape
6	Leaf: angle between blade and stem	Shape
7	Leaf: curvature of blade	Shape
15	Tassel: angle between main axis and lateral branches	Shape
16	Tassel: curvature of lateral branches	Shape
21	Stem: degree of zig-zag	Shape
33	Ear: shape	Shape
38	Only varieties with ear type of grain: sweet: Ear: shrinkage of top of grain	Shape
39	Ear: type of grain	Shape
42	Grain: shape	Shape
44	Only varieties with ear type of grain: pop: type of popped grain	Shape
17	Tassel: length of main axis above lowest lateral branch	Size
18	Tassel: length of main axis above highest lateral branch	Size
20	Tassel: length of lateral branch	Size
23	Leaf: length of blade	Size
24	Leaf: width of blade	Size
26	Plant: height of insertion of peduncle of upper ear	Size
27	Plant: length	Size
28	Plant: ratio height of insertion of peduncle of upper ear to plant length	Size
29	Peduncle: length	Size
30	Ear: length	Size
31	Ear: diameter (in middle)	Size
36	Grain: length	Size
37	Grain: width	Size

- There are 44 basic traits in the Chinese Maize Testing Guidelines.
- Image analysis primarily focused on the following four categories of traits.

Trait type	Number
Color	15
Shape	11
Size	13
Count	3

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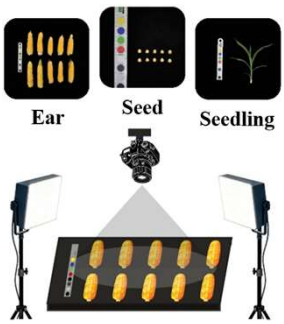
3. RESULTS AND ANALYSIS

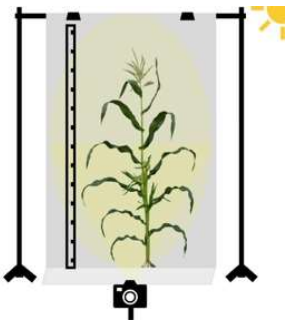
1. Developed a standard image acquisition

Shooting tools

Eight-color scale



Indoor image acquisition



Outdoor image acquisition

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3. RESULTS AND ANALYSIS

2. 15 categories of images throughout the entire growth period of maize

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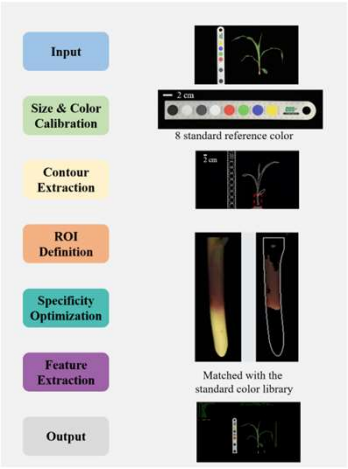
3. RESULTS AND ANALYSIS

3. Image processing workflow, from input to output



- We have developed image analysis algorithms for 15 categories of images, enabling the identification, extraction, and grading of 30 phenotypic traits.
- The left figure illustrates the image processing workflow (Seedling: first leaf: anthocyanin coloration of sheath).

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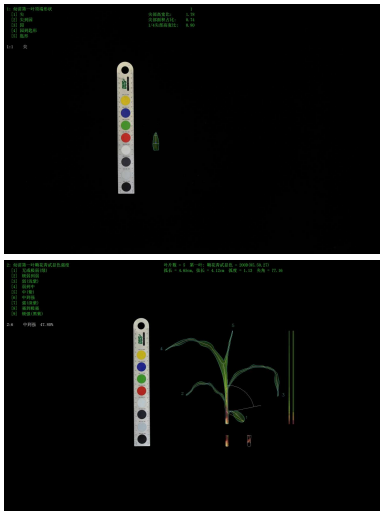
3. RESULTS AND ANALYSIS

4. Analysis and grading of seedling traits



- Image recognition and analysis of two seedling traits.

Trait No.	Trait name	Expression type	Observation type	Accuracy
1	Seedling: first leaf: shape of apex	PQ	VG	98.67%
2	Seedling: first leaf: anthocyanin coloration of sheath	QN	VG	71.21%

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3. RESULTS AND ANALYSIS

5. Analysis and grading of plant traits

- Image recognition and analysis of seven plant traits, and the trait No. 6, 22, 25, 26 used AI algorithm.

Trait No.	Trait name	Expression type	Observation type	Accuracy
6	Leaf: angle between blade and stem	QN	VG	83.52%
7	Leaf: curvature of blade	QN	VG	81.32%
22	Stem: anthocyanin coloration of brace roots	QN	VG	44.64%
25	Leaf: anthocyanin coloration of sheath	QN	VG	100%

Trait No.	Trait name	Expression type	Observation type	R^2	rRMSE%
26	Plant: height of insertion of peduncle of upper ear	QN	MS	0.9559	14.9860
27	Plant: length	QN	MS	0.9578	3.7789
28	Plant: ratio height of insertion of peduncle of upper ear to plant length	QN	MS	0.9325	6.6194

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3. RESULTS AND ANALYSIS

6. Analysis and grading of leaf traits

- Image recognition and analysis of four leaf traits.

Trait No.	Trait name	Expression type	Observation type	Accuracy
3	Foliage: intensity of green color	QN	VG	95.45%
8	Leaf: anthocyanin coloration of margin of blade	QL	VG	100%

Trait No.	Trait name	Expression type	Observation type	R^2	rRMSE%
23	Leaf: length of blade	QN	MS	0.9824	1.6356
24	Leaf: width of blade	QN	MS	0.9562	2.2928

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3. RESULTS AND ANALYSIS

7. Analysis and grading of floral organ traits

- Image recognition and analysis of three floral organ traits.

Trait No.	Trait name	Expression type	Observation type	Accuracy
9	Ear: anthocyanin coloration of silks	QN	VG	84.85%
10	Tassel: anthocyanin coloration of anthers	QN	VG	77.97%
11	Tassel: density of spikelets	QN	VG	19.70%

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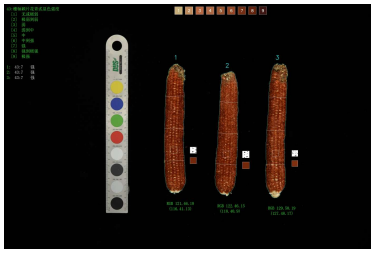
3. RESULTS AND ANALYSIS

8. Analysis and grading of ear traits



- Image recognition and analysis of seven ear traits.

Trait No.	Trait name	Expression type	Observation type	Accuracy
33	Ear: shape	QN	VG	84.85%
34	Ear: number of colors of grains	QL	VG	97.39%
40	Ear: color of top of grain	PQ	VG	95.93%
43	Ear: anthocyanin coloration of glumes of cob	QN	VG	93.51%
32	Ear: number of rows of grain	QN	MS	100%

Trait No.	Trait name	Expression type	Observation type	R^2	rRMSE%
30	Ear: length	QN	MS	0.9853	2.7931
31	Ear: diameter (in middle)	QN	MS	0.975	3.5483

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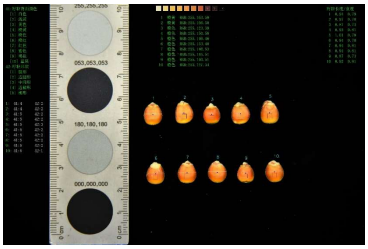
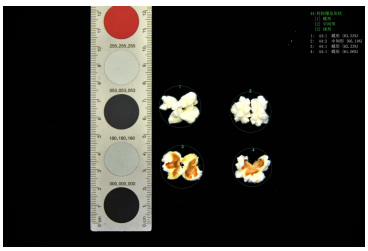
3. RESULTS AND ANALYSIS

9. Analysis and grading of grain traits





- Image recognition and analysis of five grain traits.

Trait No.	Trait name	Expression type	Observation type	Accuracy
41	Ear: color of dorsal side of grain	PQ	VG	82.14%
42	Grain: shape	PQ	VG	89.61%
44	Pop: type of popped grain	QN	VG	90%

Trait No.	Trait name	Expression type	Observation type	R^2	rRMSE%
36	Grain: length	QN	MS	0.9853	2.6185
37	Grain: width	QN	MS	0.975	1.5593

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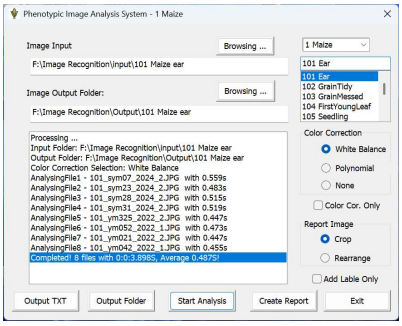
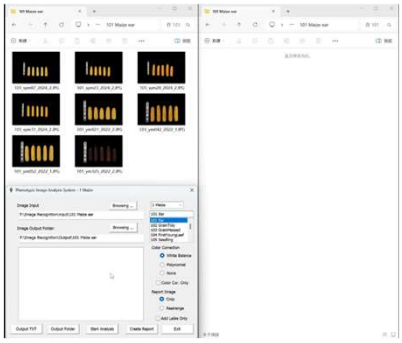
3. RESULTS AND ANALYSIS

10. Image analysis software of maize phenotype traits (single-machine version)





- Integrating 30 phenotypic traits parsing and grading algorithms.
- This tool provides Chinese and English versions, color correction functions, and image generation for rearrangement, cropping and reporting.
- It enables high-throughput photo analysis, and each image takes approximately 0.5 seconds to analyze.

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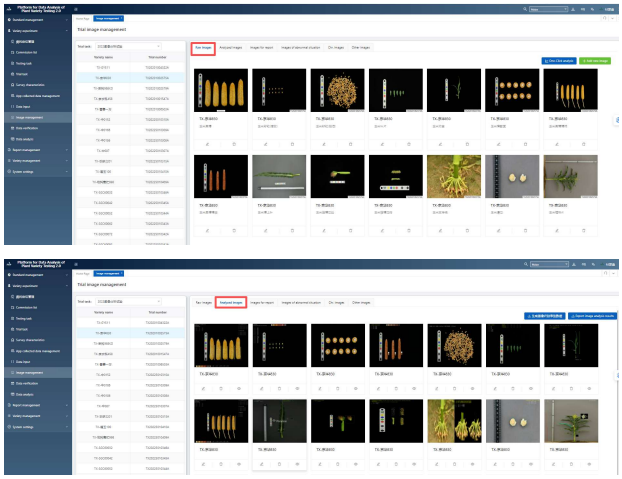
3. RESULTS AND ANALYSIS

11. Image analysis platform of maize phenotype traits (internet version)



- Integrating 30 phenotypic traits parsing and grading algorithms.
- This system provides Chinese and English versions, enabling high-throughput image and data analysis.
- Data analysis efficiency rises over 10 times, and the DUS accuracy is above 95%.

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3. RESULTS AND ANALYSIS

12. Conclusion

- Evaluating the accuracy of 18 VG traits against the results of three senior DUS test experts, eight traits had an accuracy greater than 90%, 14 traits had an accuracy greater than 80%, and the average accuracy was 82.82%, indicating that the system has high precision.
- Taking the testing of 258 varieties of ear samples as an example, the traditional testing method takes 56 hours, while using the image analysis method reduces the time to 21 hours, improving efficiency by 63% and saving costs by 63%.
- This study developed a low-cost, high-throughput, intelligent automatic extraction system for maize DUS traits.

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4. DISCUSSION

- The system still has many aspects that need improvement. Future research will focus on the following optimization areas:

(1) Algorithm optimization: Algorithms for complex traits and new AI algorithms should be optimized to improve trait recognition accuracy.

(2) Data sources: Three-dimensional imaging technology should be used to capture stereoscopic trait images of plants.

(3) Efficiency improvement: Hardware devices that can enhance operational efficiency in the field should be used to overall improve photography efficiency.

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[End of Annex and of document]