Using unmanned aerial vehicle and active-optical sensor to monitor growth indices and nitrogen nutrition of winter wheat

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A paper from the Proceedings of the
14th International Conference on Precision Agriculture
June 24 – June 27, 2018
Montreal, Quebec, Canada

Abstract. *Using unmanned aerial vehicle (UAV) remote sensing monitoring system can rapidly and cost-effectively provide crop canopy information for growth diagnosis and precision fertilizer regulation. RapidScan CS-45 (Holland, Lincoln, NE, USA) is a portable active-optical sensor designed for timely, non-destructive obtaining plant canopy information without being affected by weather condition. UAV equipped with RapidScan, is of great significant for rapidly monitoring crop growth and nitrogen (N) status. Two field experiments with different N rates were carried out. Canopy spectral data were measured by RapidScan mounted on the platform of multi-rotors UAV from jointing stage to flowering stage. Growth indices, plant dry matter (PDM), leaf dry matter (LDM) and leaf area index (LAI) were obtained synchronously. And N indicators, plant N accumulation (PNA) and leaf N accumulation (LNA) were measured. The result indicated good relationships between normalized difference red edge index (NDRE) and agronomic parameters (LAI, PDM, PNA, LDM and LNA), with* R^2 *reaching 0.65, 0.57, 0.53, 0.43 and 0.51, respectively; Independent experimental data also validated that UAV-based RapidScan can be used to rapidly monitor growth status and nitrogen nutrition of wheat.*

.***Keywords.*** *Wheat, unmanned aerial vehicle, RapidScan, growth index, nitrogen nutrition*

Introductions

Wheat is one of the most important food supply in China. Production and quality of wheat are directly related to national food security and social stability. Nitrogen (N) management is a key technology associated with increasing wheat production sustainably. With the development of modern agricultural science and technology, research on nitrogen monitoring based on active light source sensors has been very mature, the UAV presents a unique advantage over ground test platforms, another possibility for monitoring crop nitrogen nutrition and growth status is provided. In this study, UAV equipped with RapidScan, is of great significant for rapidly monitoring crop growth and nitrogen (N) status.

Objectives

- To evaluate the difference of RapidScan spectral index based on different platforms.
- To elucidate the responses of the spectral indices based on RapidScan to different nitrogen nutrition and growth indices.
- To rapidly, timely, non-destructive and cost-effectively monitor crop growth and nitrogen (N) status.

Instrumentation

Fig. 1 RapidScan and methods of measurements

- RapidScan CS-45, Holland Scientific Inc., Lincoln, NE, USA (Fig. 1). It's an active sensor with 3 spectral bands (780nm, 730nm, 670nm).
- UAV：eight-rotors (zhizhuque DW-03, dezhongtiandi, Beijing, China).

Site Descriptions

- Located in Sihong (33.4°N, 118.3°E) and Rugao (32.27’N, 120.76’E), Jiangsu Province, east China.
- Two field experiments involving five (0, 90, 180, 270, 360 kg N ha^{-1}) and three N rates (0, 150, 300 kg N ha^{-1}) were conducted respectively to develop regression models.

Methods

- Agricultural parameters: leaf area index（LAI), leaf dry matters (LDM); plant dry matters (PDM); leaf N accumulation (LNA) and plant N accumulation (PNA).
- Canopy reflectance was collected using RapidSCAN CS-45 at key growth stages
- Software: Agisoft PhotoScan and Professional, ArcMap 10.2.2.

Results

- Comparison of each growth stage, relationship after heading growth stage shows higher R^2 than before heading growth stage (satisfactory (Fig. 2).

- Table 1).
- Relationships between NDRE and agronomic parameters (LAI, PDM, PNA, LDM and LNA), with R^2 reaching 0.65, 0.57, 0.53, 0.43 and 0.51.
- For NDVI, R^2 reaching 0.70, 0.55, 0.66, 0.45 and 0.44, respectively.
- The relationship between NDVI and LAI is satisfactory (Fig. 2).

Table 1 The coefficient of determination (R^2) of relationships between vegetation indices and agronomic parameters at different growth stages

Vegetation Index	NDRE			NDVI		
	Before heading	After heading	All growth stages	Before heading	After heading	All growth stages
LAI	0.61	0.77	0.65	0.61	0.82	0.70
LDM	0.39	0.64	0.43	0.32	0.82	0.35
LNA	0.46	0.62	0.51	0.39	0.80	0.44
PDM	0.47	0.26	0.57	0.59	0.47	0.54
PNA	0.41	0.65	0.53	0.52	0.81	0.66

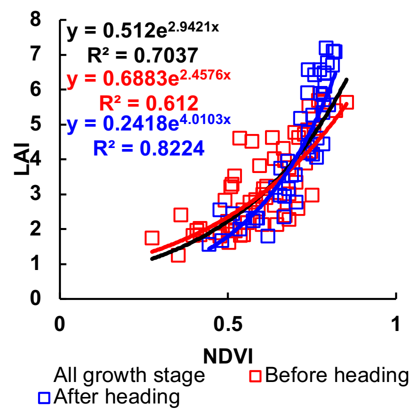

Fig. 2 The relationship between NDVI and LAI at different growth stages

Table 2 Verification result of relationships between agronomic parameters and vegetation indices

Vegetation Index	NDRE			NDVI		
	RE(%)	R^2	RRMSE	RE(%)	R^2	RRMSE
LAI	19.0	0.31	0.25	29.4	0.30	0.24
LDM	17.9	0.17	0.52	24.1	0.29	0.44
LNA	29.7	0.34	0.74	40.0	0.39	0.59
PDM	44.8	0.64	0.60	41.1	0.67	0.44
PNA	43.4	0.55	0.69	49.0	0.60	0.60

Conclusion

- After heading stages, the relationships between vegetation indices and agronomic parameters showed better than those before heading stages.
- The quantitative correlation models of vegetation index and agronomic parameters were constructed, and these models were verified by using independent experiment data.
- The validation result also showed that UAV-based active-optical sensor (RapidScan) can be used to timely, non-destructive and rapidly monitor growth status and nitrogen nutrition of winter wheat.