サトウキビの栄養状態の階層的光センシングとその利用技術の開発

沖縄県のサトウキビ生産に対するバガス炭施用時の分光反射特性

Spectroscopy on Estimation of Baggage Charcoal for Sugarcane Production in Okinawa

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Md. Akbar HOSSAIN, Masami UENO, Yasuaki KOMIYA, Hijiri HAGA and Yoshinobu KAWAMITSU

University of the Ryukyus

The Objectives are:

1. To study the effect of baggage charcoal on
   (a) Reflectance characteristics of sugarcane,
   (b) Photosynthetic rate of sugarcane,
   (c) Soil water conservation, and
   (d) Recovery of crop from drought damage.
2. To determine the proper dose of baggage charcoal for sugarcane production.

Introduction

Baggage is a bi-product of sugarcane processing. The sugar mills in Okinawa, baggage production output averaged 241542 metric tons. About 7.85% baggage is used as manure by farmers in the form of baggage cake consisting with press mud.

Baggase → **Baggase Charcoal**

Benefits of baggase charcoal to Okinawa Agricultural are:

(a) Additional supplementation of fertilizer,

(b) Improvement in soil water holding capacity,

(c) Controlling soil erosion to improve the agro-echo systems.

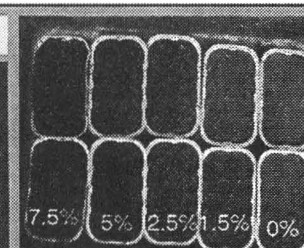
Methodology of the Study

1. Sugarcane: NiF 8

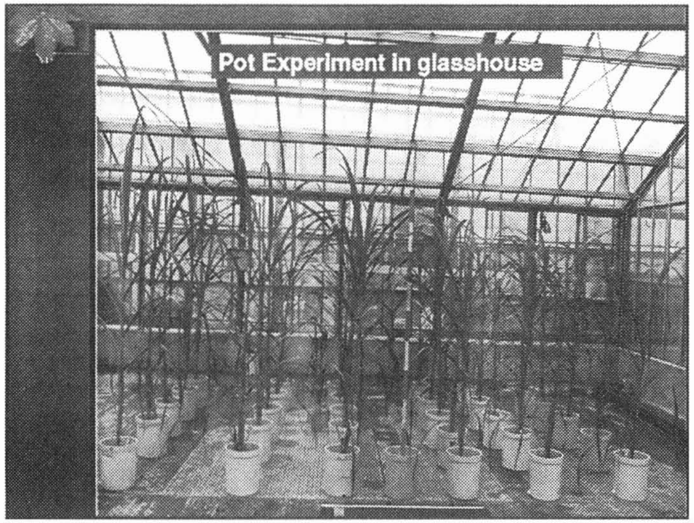
(a) Pot Experiment in 2004.

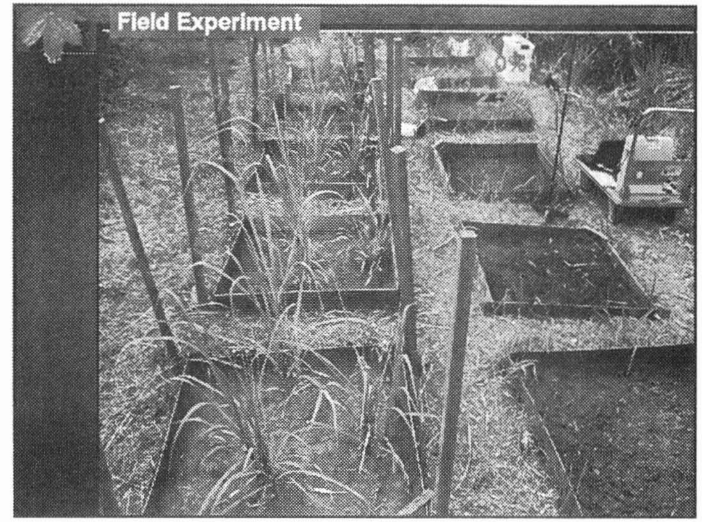
(b) Field experiment in 2005.

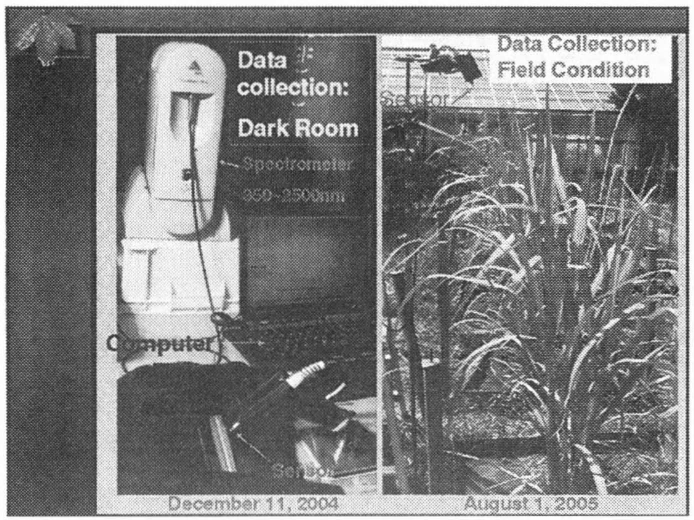
2. Baggage charcoal mixed with soil @ of:

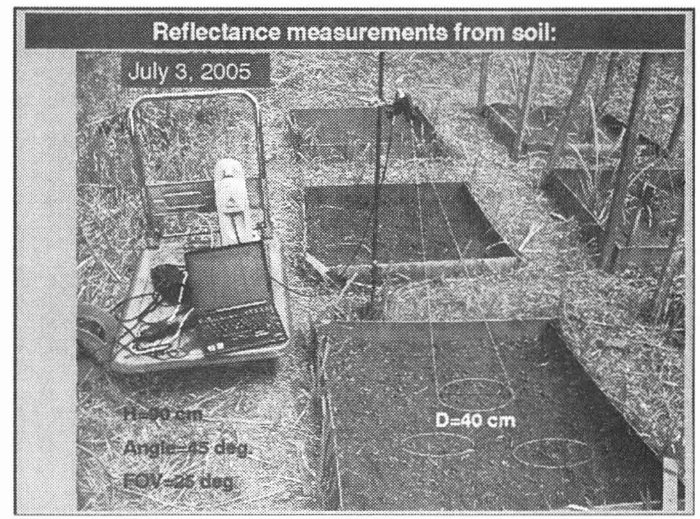


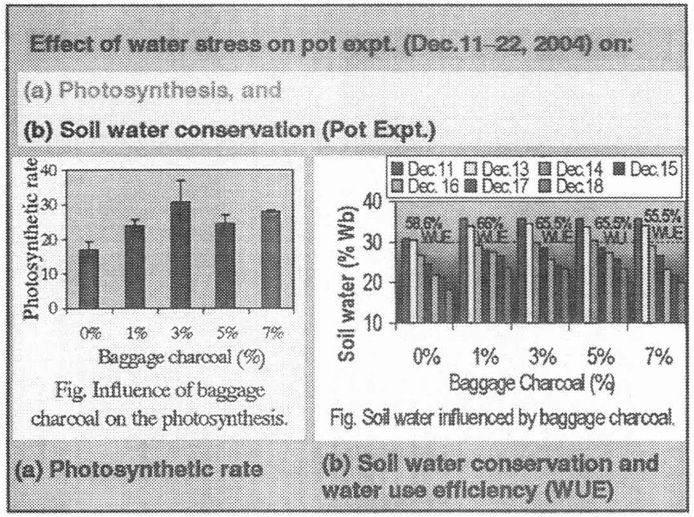
Pot Experiment	Field Experiment
1. Soil + 0% baggage charcoal	1. Soil + 0% baggage charcoal
2. Soil + 1% baggage charcoal	2. Soil + 1.5% baggage charcoal
3. Soil + 3% baggage charcoal	3. Soil + 2.5% baggage charcoal
4. Soil + 5% baggage charcoal	4. Soil + 5% baggage charcoal
5. Soil + 7% baggage charcoal	5. Soil + 7.5% baggage charcoal

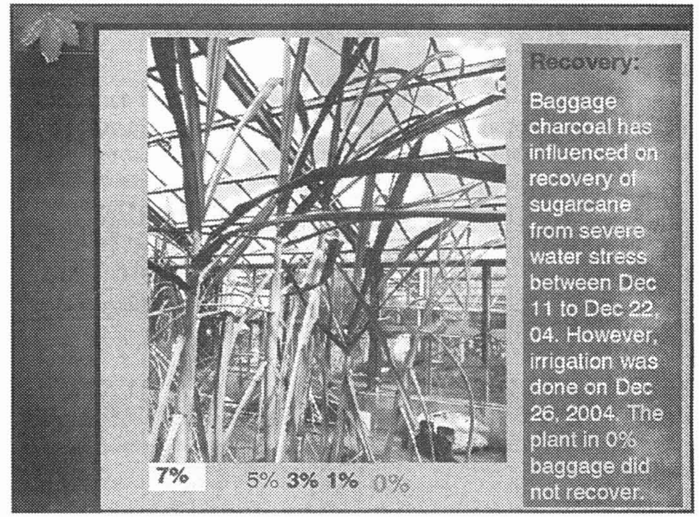

Pot Experiment in glasshouse

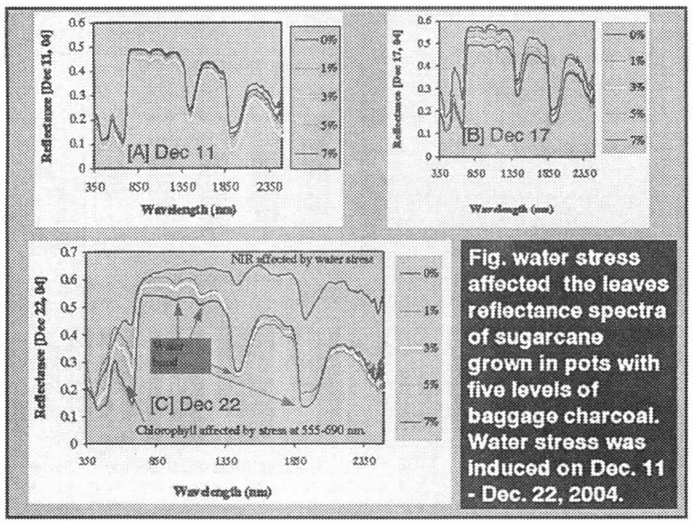

Field Experiment

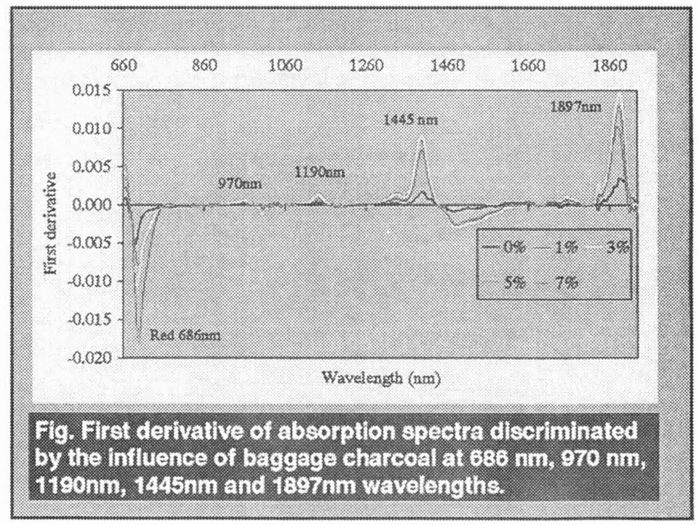

Data
collection:
Dark Room
Spectrometer
350~2500nm
Computer
Sensor
December 11, 2004
Data Collection:
Field Condition
Sensor
August 1, 2005

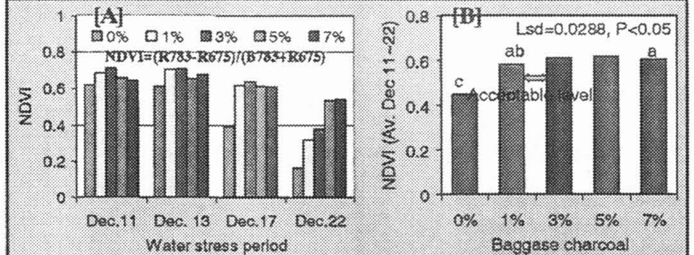

Reflectance measurements from soil:
July 3, 2005
D=40 cm
Angle=45 deg.
FOV=25 deg.

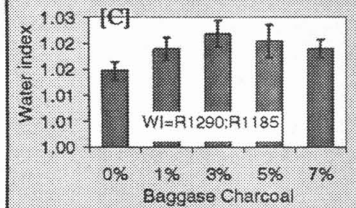

Effect of water stress on pot expt. (Dec.11–22, 2004) on:
(a) Photosynthesis, and
(b) Soil water conservation (Pot Expt.)
Photosynthetic rate
Baggage charcoal (%)
Fig. Influence of baggage charcoal on the photosynthesis.
Soil water (% Wb)
Dec.11 Dec.13 Dec.14 Dec.15 Dec. 16 Dec.17 Dec.18
Baggage Charcoal (%)
Fig. Soil water influenced by baggage charcoal.
(a) Photosynthetic rate
(b) Soil water conservation and water use efficiency (WUE)


7%
5% 3% 1% 0%
Recovery:
Baggage charcoal has influenced on recovery of sugarcane from severe water stress between Dec 11 to Dec 22, 04. However, irrigation was done on Dec 26, 2004. The plant in 0% baggage did not recover.


[A] Dec 11
[B] Dec 17
[C] Dec 22
NIR affected by water stress
Chlorophyll affected by stress at 555-690 nm
Wavelength (nm)
Fig. water stress affected the leaves reflectance spectra of sugarcane grown in pots with five levels of baggage charcoal. Water stress was induced on Dec. 11 - Dec. 22, 2004.


First derivative
Wavelength (nm)
Red 686nm
970nm
1190nm
1445 nm
1897nm
0% 1% 3% 5% 7%
Fig. First derivative of absorption spectra discriminated by the influence of baggage charcoal at 686 nm, 970 nm, 1190nm, 1445nm and 1897nm wavelengths.



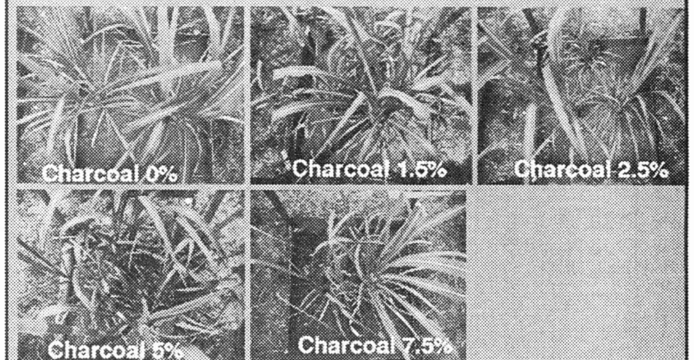


[A] Water stress on NDVI.

[B] Baggase charcoal on NDVI.

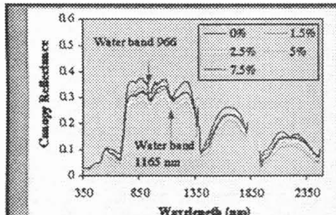
[C] Charcoal on water index.

Result: Indices of 3% baggase charcoal is high.

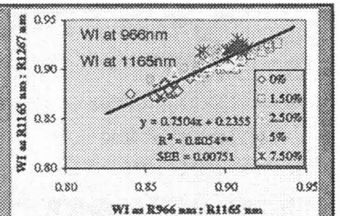


Field Experiment:

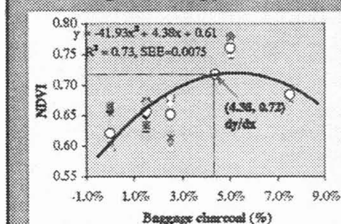
Reflectance data were taken at a height of 1.95 meter from the canopy of sugarcane. The photographs shows the canopy. Results are presented in next slide.



A. Changes of canopy reflectance.



B. Water index affected by charcoal.



C. Quadratic response curve of baggage.

(A) Reflectance was high for 0%.

(B) Water index is an indicative of leaf water contents. Water index can be used to detect stress in crop.

(C) NDVI increased up to 5% charcoal and decreased with increasing rate. Differentiation of regression equation determined the optimum dose of baggage as 4.3%.

Table: Correlation ships of NIR wavelengths at 960-980 nm with soil water contents (Wb%).

	NIR960-980 nm	Moisture (0-2 cm)	Moisture (0-10 cm)
NIR960-980 nm	1.000		
Moisture (0-2 cm)	-0.821	1.000	
Moisture (0-10 cm)	-0.902	-0.868	1.000

* Correlation is significant at P<0.05.

Soil water at 0-2 cm profile did not correlate with NIR spectrum but showed a negative correlation with soil moisture retained at 0-10 cm profiles.

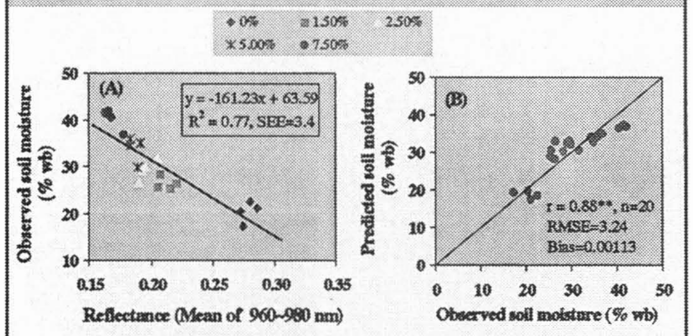
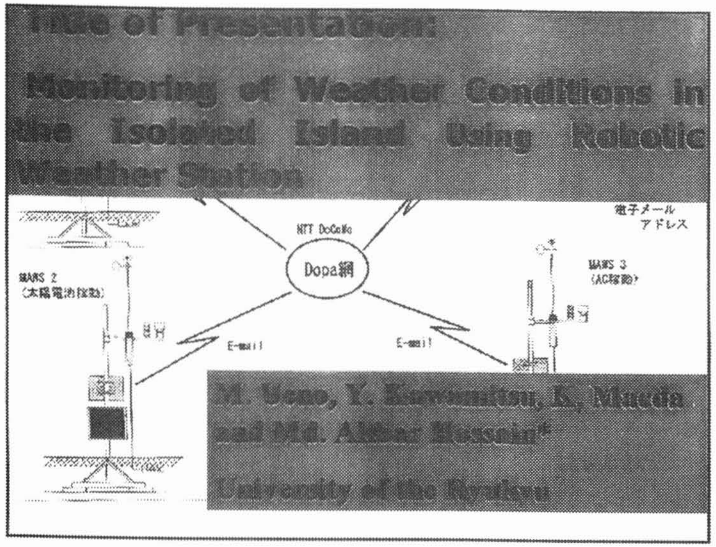


Fig. (A) Relationship between reflectance at NIR wavelength (960-980 nm) & soil moisture contents in 0~10 cm profiles, (B) Validation of the regression model.

Conclusions are:

1) In pot culture, the performance of 3% baggage charcoal was better in relation to photosynthesis, WUE, and the indices of NDVI and WI.
2) In field condition, absorption of radiation was higher when sugarcane was grown in soil mixed with baggase charcoal @1.5-5%.
3) However, quadratic response curve for NDVI determined 4.3% baggage charcoal is suitable for Raton crop.
4) Overall, 1-3% baggage charcoal should be mixed with soil for sugarcane production.



Introduction: -1-

Agricultural water is a limited resource in the islands of Okinawa and its management is the crucial issue in increasing the production of sugarcane (75~80 t/ha) against the present yield of 58.2 t/ha. Drought in summer season is the major constraints for production of this crop. Three Robotic weather stations have been established in North Daito Island to develop a database on evapo-transpiration (ETc) of crops for water management. GIS was used to classify the productivity of each farmland to produce a map of effective irrigation schedule based on the existed irrigation systems and soil properties of North-Daito Island.

Objectives:

1. Monitoring the effect of weather conditions on evapotranspiration and crop factors of sugarcane.
2. Evaluation on the effective rainfall, drought and daily water deficit to develop an effective irrigation systems for sugarcane in Kita-Daito.
3. Studies on the physiological properties of soil for irrigation scheduling.

METHODOLOGY: Meteorological data are receiving from three Robotic Weather stations established in Kita-Daito in Aug, 2003.

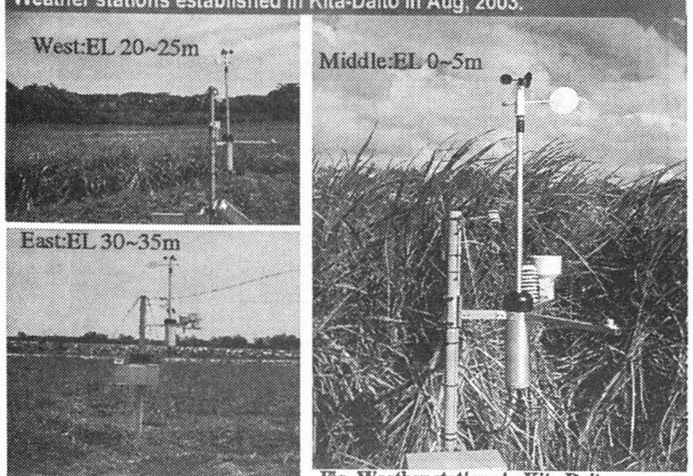
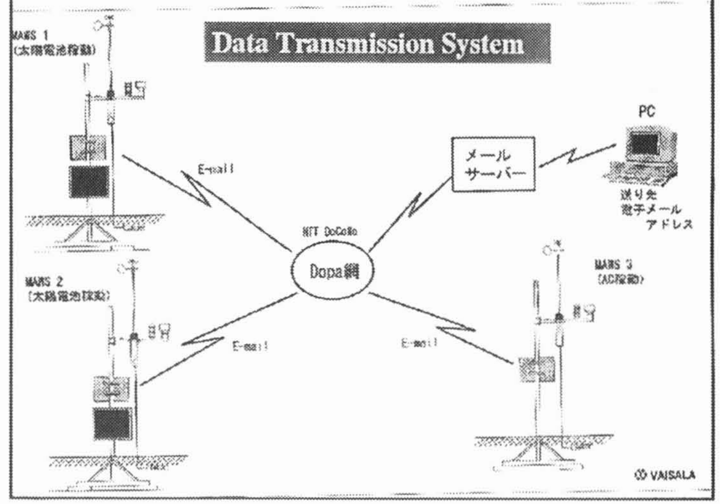


Fig. Weather stations in Kita Daito.

Data Transmission System



The Penman Monteith model:

$$ETp = \frac{0.408\Delta(Rn - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

Where,

Δ = Slope of saturated vapor pressure at mean air temperature (hPa/°C)

γ = Psychometric constant (= 0.66 hPa/°C)

R_n = Net solar radiation (MJ/m².day)

G = Ground heat flux (MJ/m².day)

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u_2 = Wind speed at 2 meter height (m/s)

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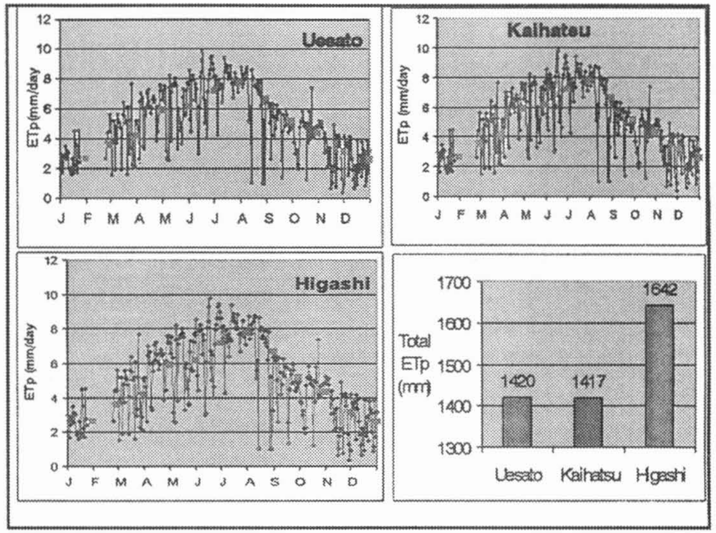
e_a = Vapor pressure at normal air temperature (mbar)

Data from Weather Stations:

1. Air Temperature
2. Sunshine
3. Solar Radiation
4. Relative Humidity
5. Wind Speed

Remarks: Absent data has been calculated with empirical equations.



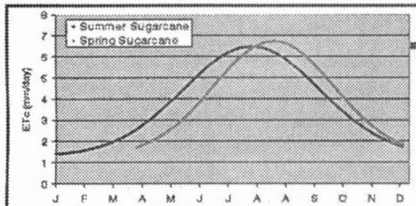


Fig. Actual ET of sugarcane calculted using the ETp of robotic weather stations.

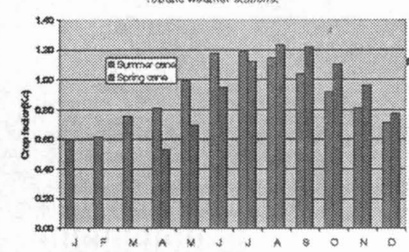


Fig. Crop factors (Kc) of sugarcane.

Actual ET (ETc) has been calculated using weather data of Kita Daito and regression models developed for summer and spring planted sugarcane in Naha conditions.

Crop factor (Kc),

Kc = ETc ÷ ETp

ETp obtained from weather data.

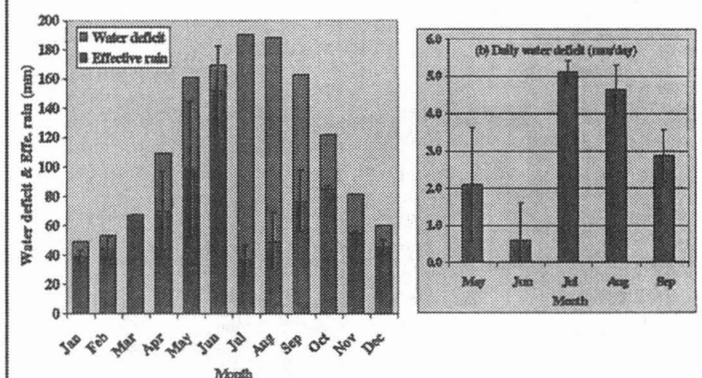


Fig. (a) Monthly effective rainfall and water deficit, (b) Daily irrigation need in Aug, 03–Aug, 04.

Conclusions:

1. For irrigation scheduling, farmlands of Kita-Daito Island can be classified into 3 categories depending on "Total Available Water Content (TAWC)" in soil and farmland's elevation:
   A: Elevation 0~10m (High TAWC = 39mm/40cm depth)
   B:Elevation 20~50m (Medium TAWC = 25~26 mm/40 cm depth)
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2. High elevated weather station (East, EL:30~35m) recorded the higher Evapotranspiration compared to low elevated stations in the middle (El:0~5m) and west (EL:20~25m).
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5. Irrigation interval for farmland A, B & C were 6~13, 5~12, and 3~7 days.
6. Effective rainfall among three stations were 600~635 mm.

RESULTS:

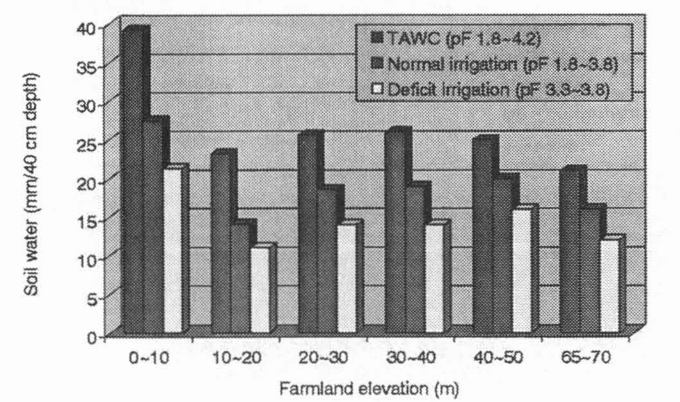


Fig. Total available water content (TAWC), Normal and Deficit irrigation.

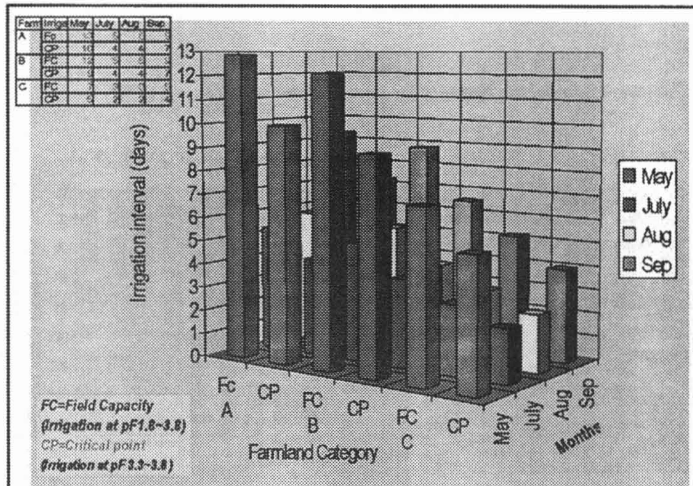
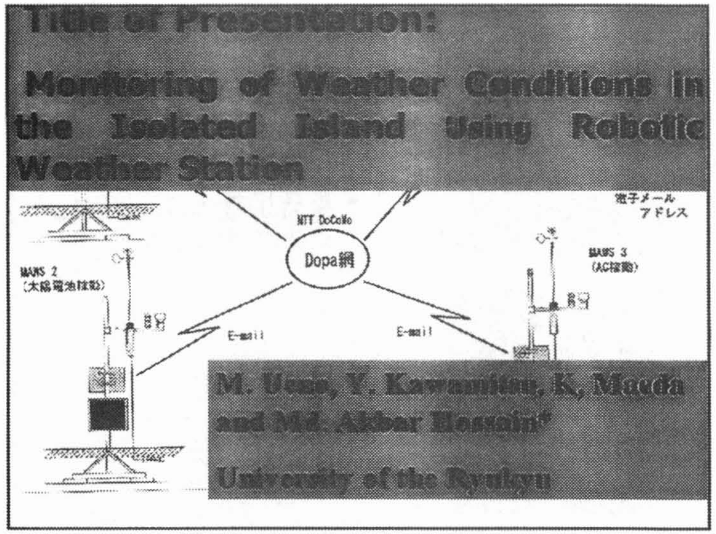


Fig. Irrigation interval for 3 categories farmlands in Kita-Daito.



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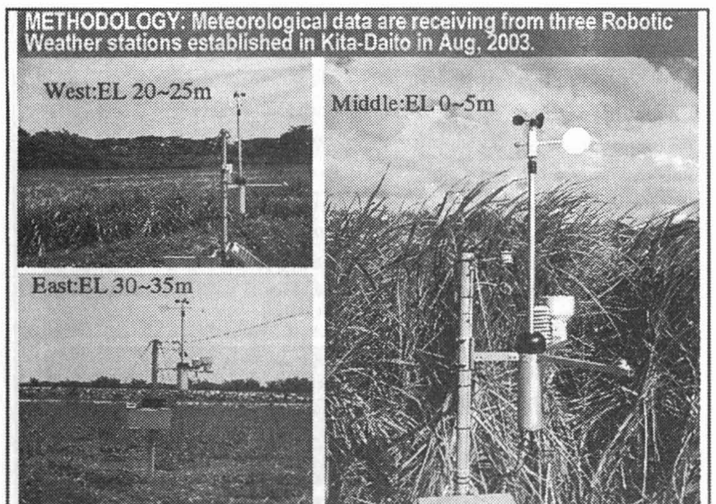

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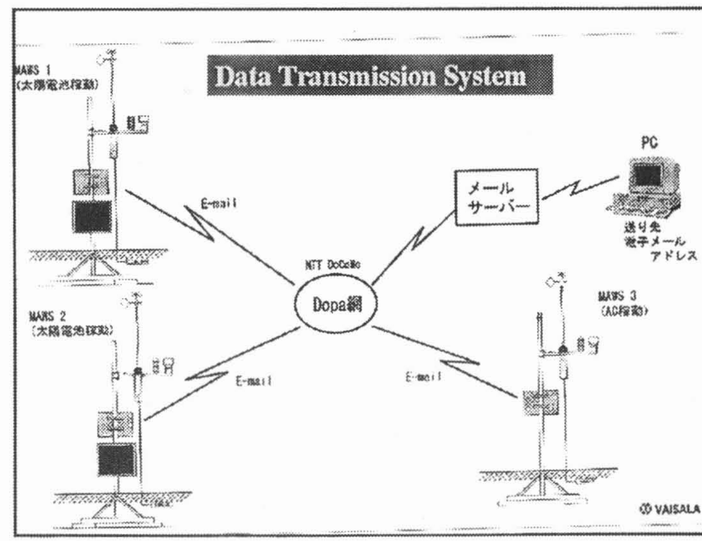

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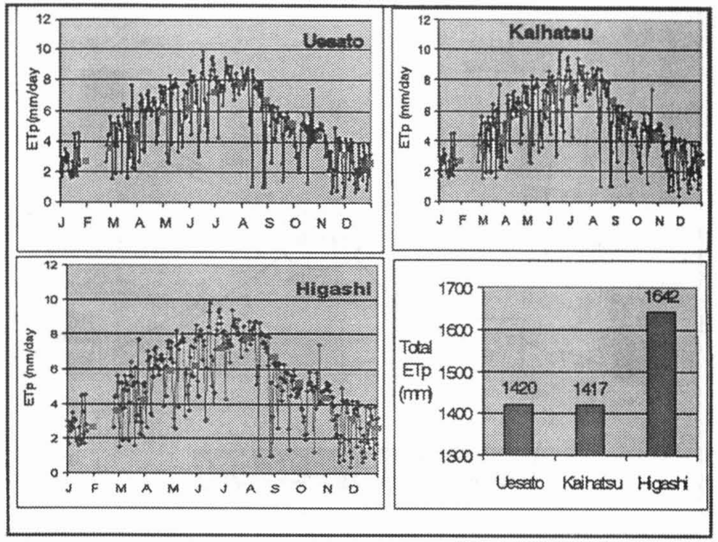

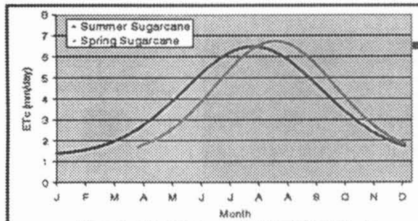

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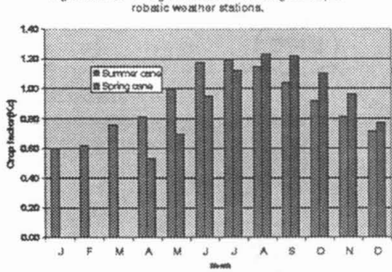

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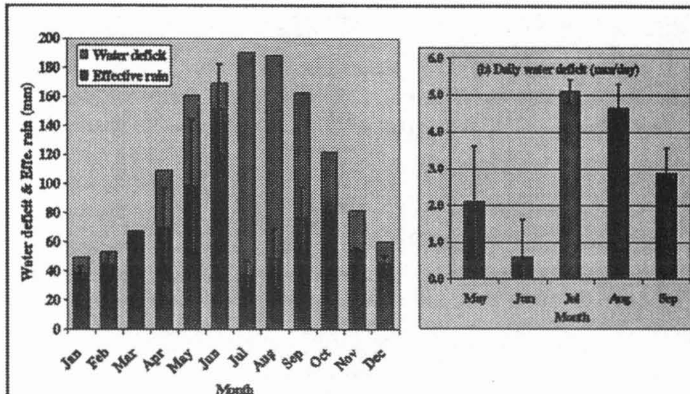

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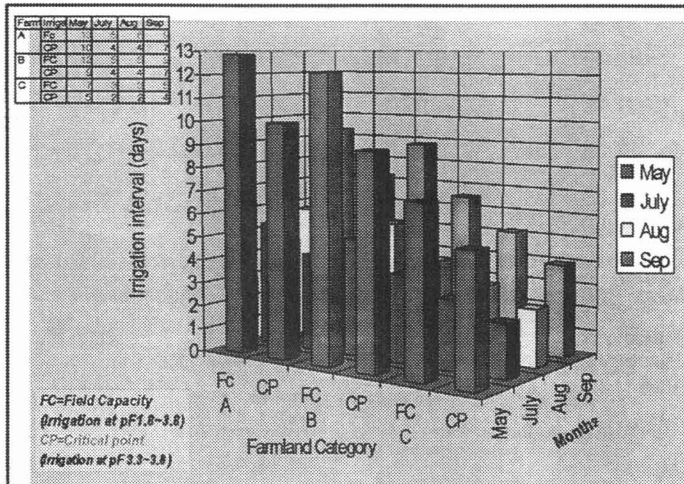


Fig. Irrigation interval for 3 categories farmlands in Kita-Daito.

RESULTS:

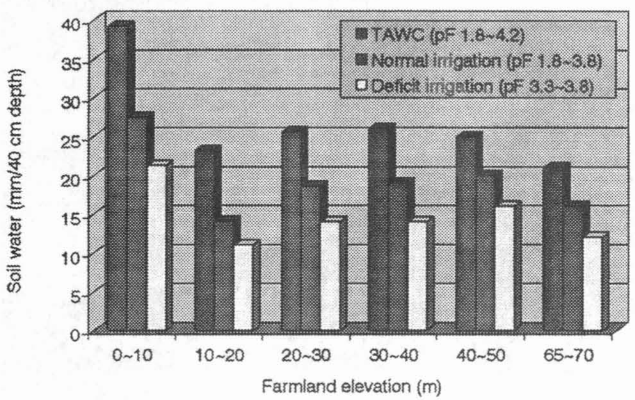
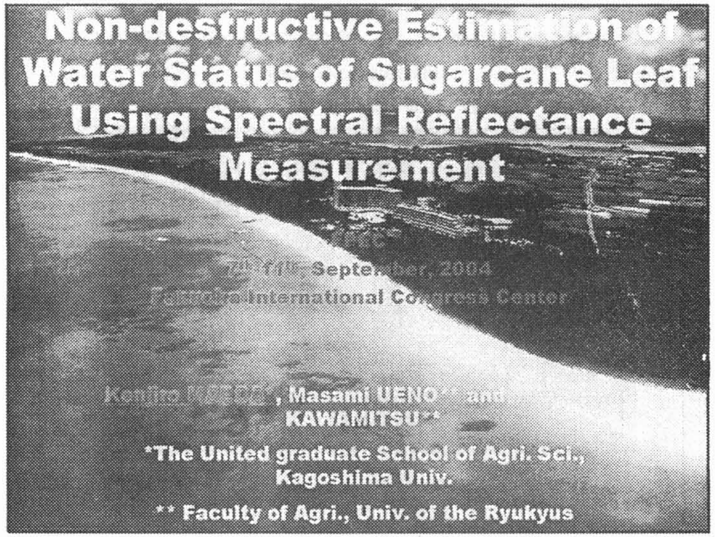
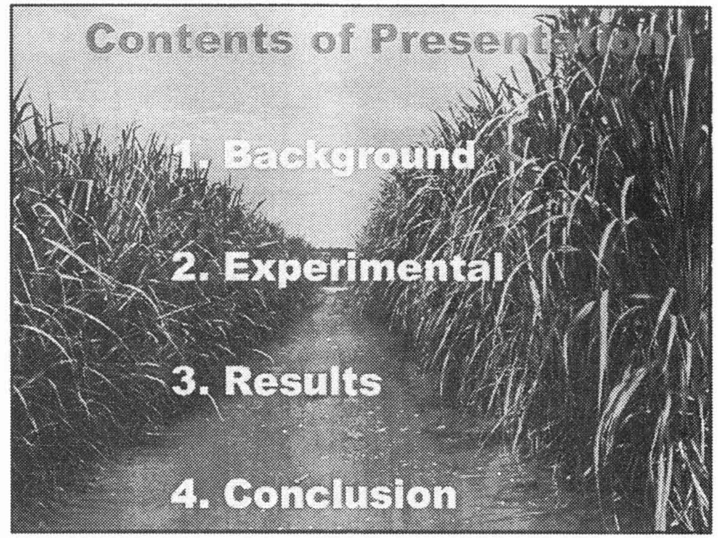
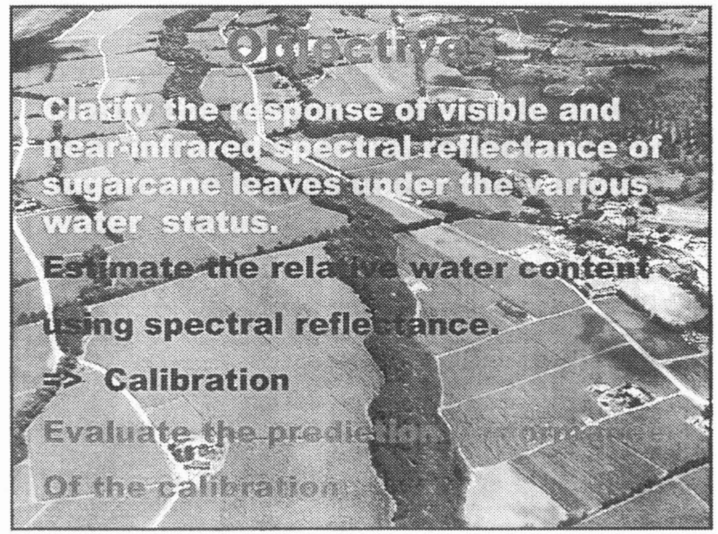


Fig. Total available water content (TAWC), Normal and Deficit Irrigation.


Non-destructive Estimation of
Water Status of Sugarcane Leaf
Using Spectral Reflectance
Measurement
, Masami UENO** and
KAWAMITSU**
*The United graduate School of Agri. Sci.,
Kagoshima Univ.
** Faculty of Agri., Univ. of the Ryukyus

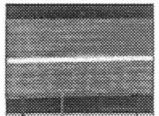

1. Background
2. Experimental
3. Results
4. Conclusion


1. Water shortage for sugarcane production
in Okinawa islands.
3. Lack of basic studies on the
characteristics of reflectance.
× Applications of Remote Sensing

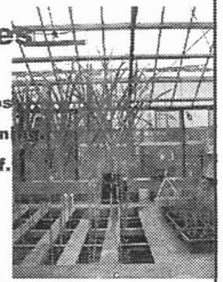

Clarify the response of visible and
near-infrared spectral reflectance of
sugarcane leaves under the various
water status.
Estimate the relative water content
using spectral reflectance.
=> Calibration

Experimental Method

Sampling leaf and test pieces

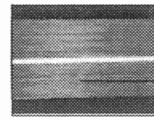


Top-most fully expanded leaves were cut in water in early morning.
4 pieces sampled from the leaf.
(15mm×15mm)



- Initial RWC
- Spectral Reflectance & RWC
- Chlorophyll Content

Measurement of Spectral reflectance



- RWC (Relative Water Content)
- Spectral reflectance

Spectroradiometer

Measuring spectral range: 400 ~ 1000 nm

Sampling interval: 1.6nm

FOV: 25°

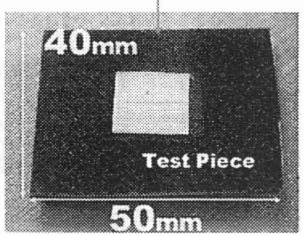
Conditions

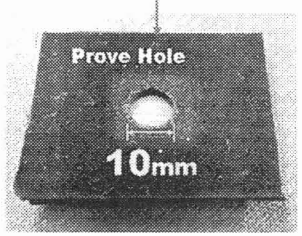
Measuring distance: 1mm

Measuring interval: 3min.

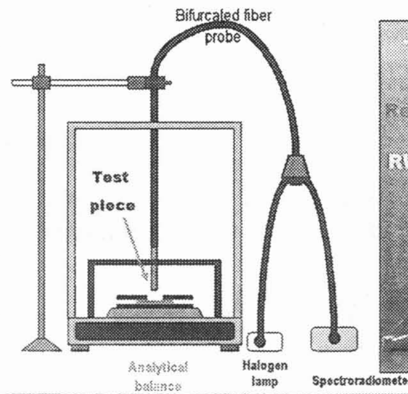
the same timing as weight measuring

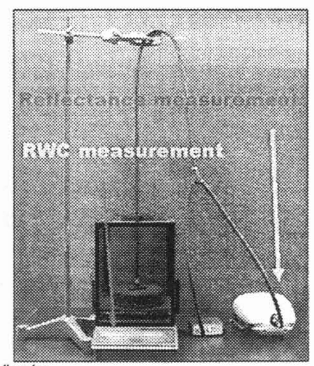
Test piece and black colored plates



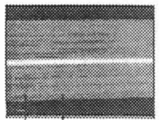


Experimental Apparatus and Setup





Measurement of RWC



Spectral reflectance

$$RWC = RWC_{int} \times \frac{FW - DW}{FW_{int} - DW} \ [\%]$$

Initial RWC (RWC_{int})

$$RWC_{int} = \frac{FW - DW}{TW - DW} \times 100 \ [\%]$$

By Barr and Weatherley (1962)

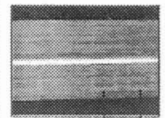
Initial fresh weight (FW_{int})

Fresh weight (FW)

Dry weight (DW)

Turgid weight (TW)

Measurement of Chlorophyll content



Measure absorbances at 649, 665 and 750 nm in 96%(v/v) ethanol

By Wintermans and De Mots (1965)

$Chl_a = 13.70(A_{665}-A_{750})-5.76(A_{649}-A_{750})$

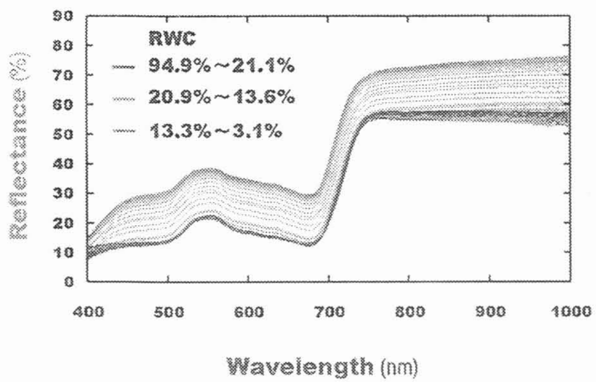
$Chl_b = 25.80(A_{649}-A_{750})-7.60(A_{665}-A_{750})$

$Chl_{a+b} = 6.10(A_{665}-A_{750})+20.04(A_{649}-A_{750})$

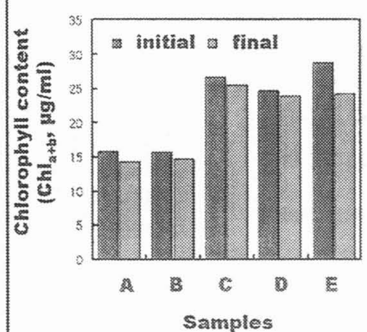
Initial chlorophyll content

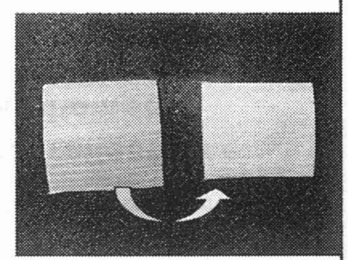
Final chlorophyll content

Change in reflectance spectra with RWC



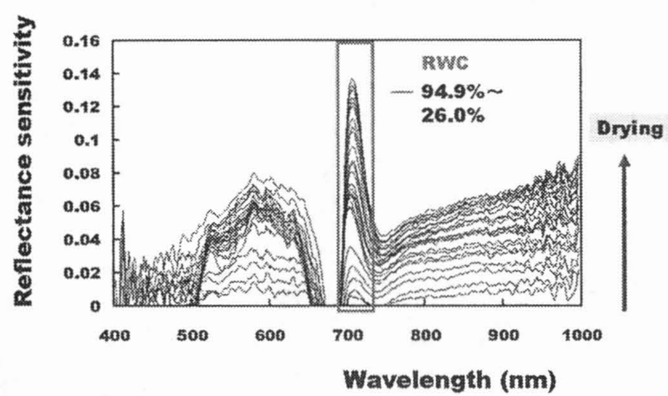
Changes in Chlorophyll Content With decrease of RWC





Leaf color turns to white in drying.

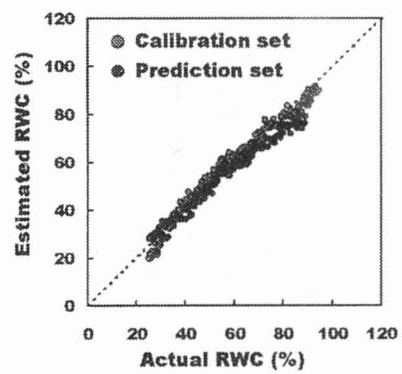
Reflectance sensitivity to RWC



Spectral Indices with high correlation to RWC

Spectral Indices	Correlation Coefficients (Standard Error)					
	A	B	C	D	E	All
R(709.7)	-0.95	-0.90	-0.97	-0.98	-0.99	-0.21
	(6.18)	(9.70)	(5.32)	(3.86)	(2.52)	(19.88)
R(532.0)/R(700.2)	0.99	0.99	0.98	0.99	0.97	0.79
	(3.06)	(3.58)	(4.09)	(3.24)	(5.05)	(12.58)
R(519.3)-R(700.2)	0.98	0.99	0.98	0.99	0.99	0.46
	(4.17)	(2.97)	(4.01)	(2.72)	(3.23)	(18.08)
R(408.2)/R(495.5)	0.90	0.93	0.87	0.93	0.87	0.88
	(8.31)	(8.30)	(10.15)	(7.36)	(10.00)	(9.75)
R(846.2)- R(962.0)	0.88	0.92	0.90	0.94	0.94	0.89
	(9.33)	(8.79)	(8.82)	(7.00)	(6.95)	(9.19)

Measured RWC vs. estimated RWC



Conclusions

(A) Reflectance spectra increased with the reduction of RWC of sugarcane leaves. The change was small until to 25%, and then it turned large from 25% to 15% of RWC.

(B) The indices by the reflectance near 700nm showed high correlation with RWC to each sample, in addition, R(846.2)-R(962.0) showed comparatively good correlation with to all samples.

(C) RWC of a same plant can be predicted non-destructively with a sufficient accuracy.