



“Valorizzazione della BIODiversità cerealicola in regime BIOlogico” (BIO&BIO),
programma di Sviluppo Rurale Regione Campania 2014/2020 GAL ALTO TAMMARO -
GAL TITERNO Misura 16, Sottomisura 16.1.1.2.

Monitoraggio Multispettrale Infrarosso per Coltivazioni di Cereali nell’ambito del progetto BIO & BIO

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Istituto di Scienze Applicate e Sistemi Intelligenti ‘E. Caianiello’
ISASI CNR – Pozzuoli (Na)

Una nostra breve introduzione...



ISASI - CNR

Pozzuoli (Na)



THERMOGRAPHY AND IR – IMAGING LAB

IR CAMERA



**PASSIVE AND
ACTIVE APPROACHES**

- LOCK-IN
- PT
- PPT
- DAC
- PCT

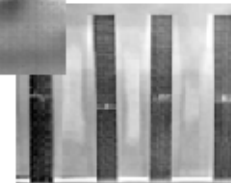
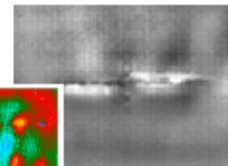
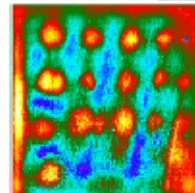
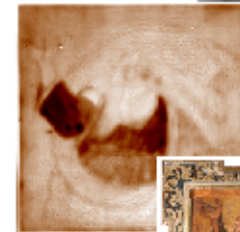
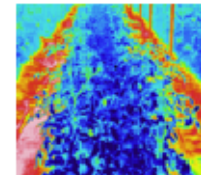
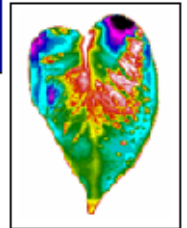
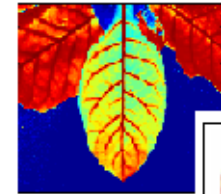


APPLICATIONS

- Agriculture
- Cultural Heritage
- NDT



Home-made Matlab code



- Introduzione all'Imaging Infrarosso
- Imaging Termico in Agricoltura: Esempi di applicazioni
- Monitoraggio Infrarosso nell'ambito del progetto BIO&BIO
- Conclusioni

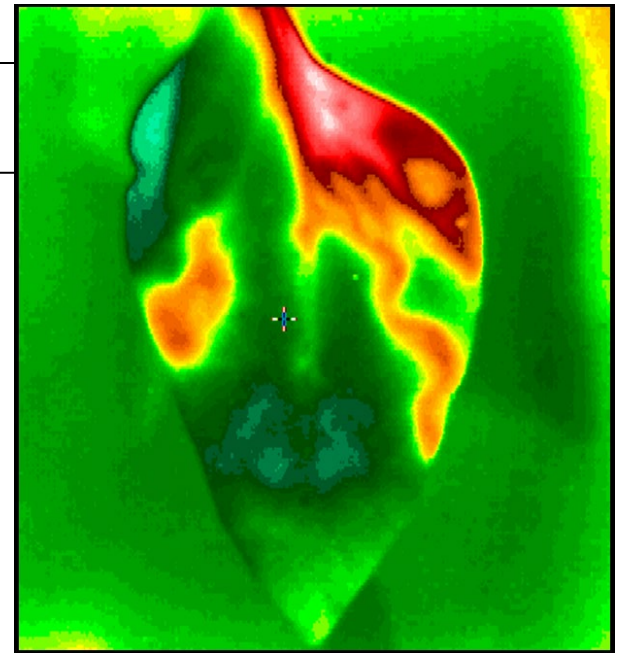
IMAGING INFRAROSSO E TERMOGRAFIA

REGISTRAZIONE DELLA **RADIAZIONE TERMICA** EMESSA IN MODO NATURALE DAI CORPI (CALORE) IMPIEGANDO CAMERE INFRAROSSE



INFORMAZIONI DIRETTE

MAPPA DELLA DISTRIBUZIONE DELLA TEMPERATURA DELLA SUPERFICIE DEL CAMPIONE SOTTO INDAGINE



ANALISI ED ELABORAZIONI DELLE IMMAGINI

CONDIZIONI DELLA SUPERFICIE E DEGLI STRATI SUB-SUPERFICIALI



INDIVIDUAZIONE E CARATTERIZZAZIONE DI AREE ANOMALE

MONITORAGGIO SOTTO NATURALI CONDIZIONI AMBIENTALI O QUANDO SOGGETTO A STIMOLI TERMICI ESTERNI






ANALISI DELLA RISPOSTA FUNZIONALE: STATO DI SALUTE

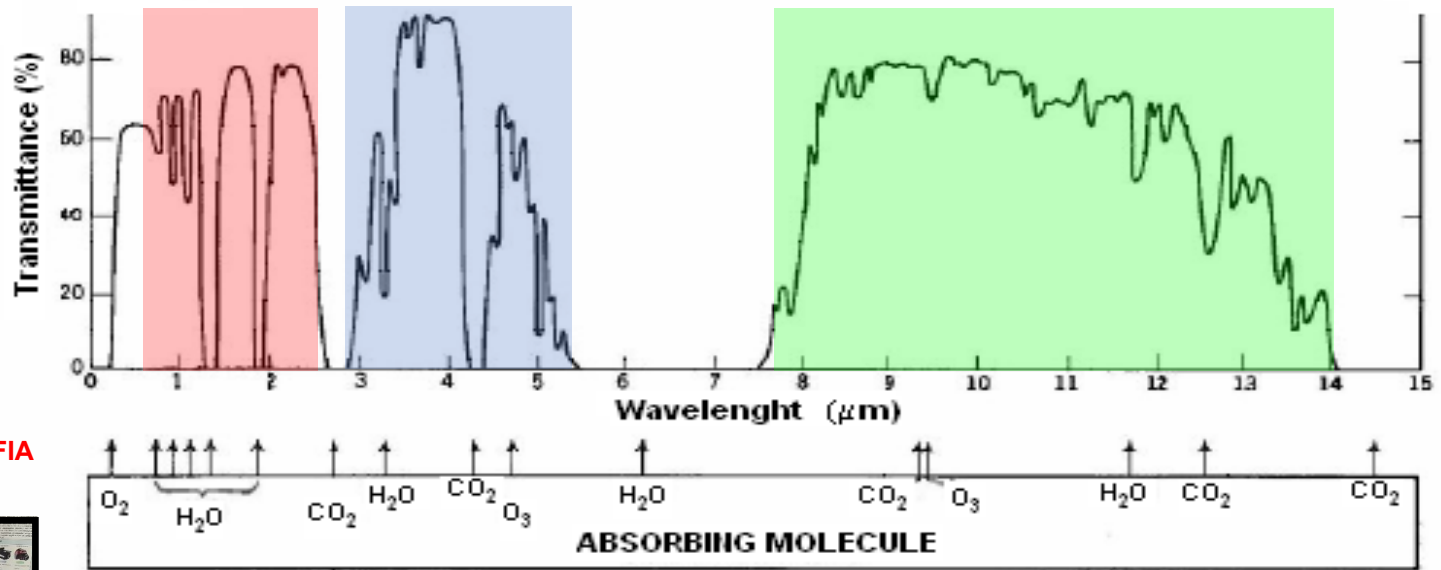
ULTERIORI VANTAGGI



- ANALISI NON INVASIVA
- INVESTIGAZIONE DI GRANDI AREE
- INFORMAZIONI IN TEMPO REALE E IN REMOTO

TRASMITTANZA ATMOSFERICA

-  NIR
-  MWIR
-  LWIR



LABORATORIO DI TERMOGRAFIA ED IMAGING INFRAROSSO



Xeva 320



FLIR X6580 sc

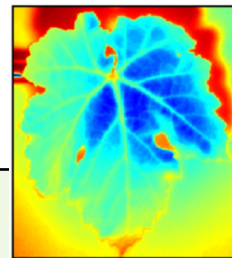


Avio TVS 500



Sensor	InGaAs – FPA 320X256	InSb – FPA 640X512	Microbolometer – FPA 320X240
Temperature Resolution	-	0.02 °C	0.05 °C
Image Resolution	12 bit	14 bit	14 bit
Max Frame Rate	12 kHz	130 Hz	60 Hz

IMAGING INFRAROSSO IN AGRICOLTURA.....



**MONITORAGGIO DELLO STATO DI STRESS DI
PIANTE E COLTURE**



- IRRIGAZIONE INSUFFICIENTE
- PRESENZA DI AGENTI PATOGENI (FUNGHI, VIRUS, ETC..)
- FATTORI BIOTICI E ABIOTICI

**INTERAZIONE CON DIVERSE SORGENTI
LUMINOSE (UV-VIS-NIR)**



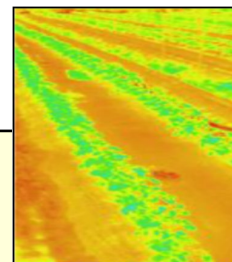
- UVA/UVB/UVC, VIS, NIR

UTILIZZO DA REMOTO



- MONITORAGGIO DI SERRE E CAMPI A DISTANZA
- IMPIEGO CON DRONI (SAPR, UAV)

AGRICOLTURA DI PRECISIONE & AGRICOLTURA 4.0



STRATEGIA

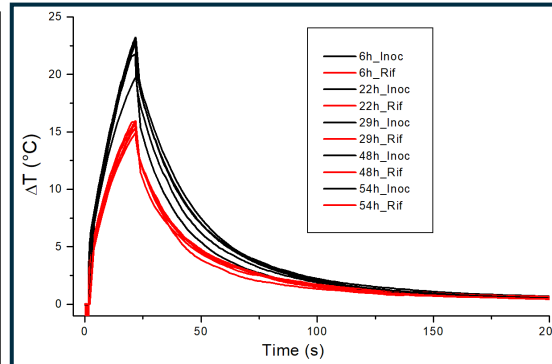
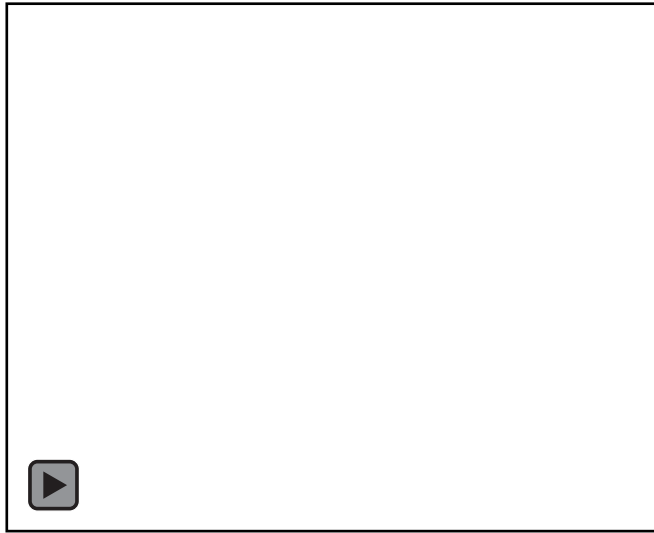
**IMPIEGO DI TECNOLOGIE PER
ACQUISIRE DATI CHE PORTINO A
DECISIONI FINALIZZATE ALLA
BUONA PRODUZIONE AGRICOLA**



OBIETTIVI

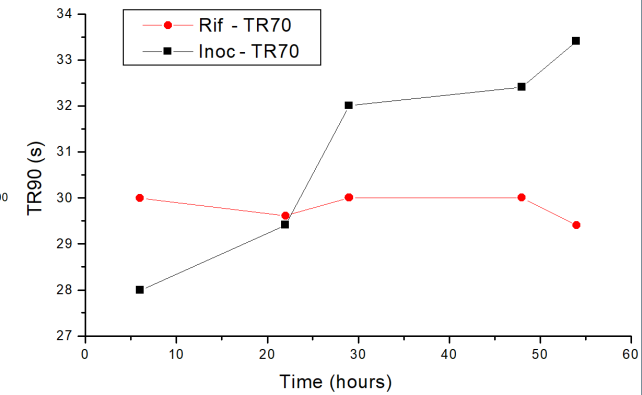
- UTILIZZO MIRATO DEI PRINCIPALI FATTORI DELLA PRODUZIONE (ACQUA, FERTILIZZANTI, FITOFARMACI)
- MONITORAGGIO IN TEMPO REALE DELLO STATO DI SALUTE DELLE COLTURE (CONTROLLO DELL'INSORGENZA DI FITOPATOGENI O DI CONDIZIONI AMBIENTALI SFAVOREVOLI)

Monitoring of Plants inoculated with Botrytis C.



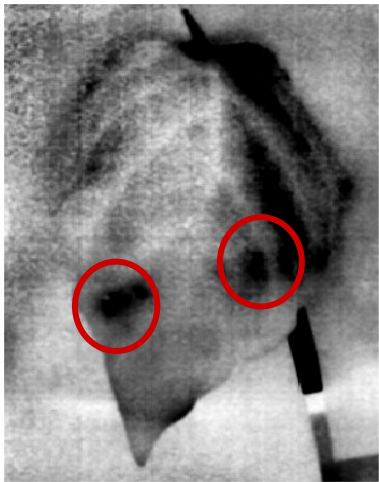
Recovery time trend →

← Temporal response

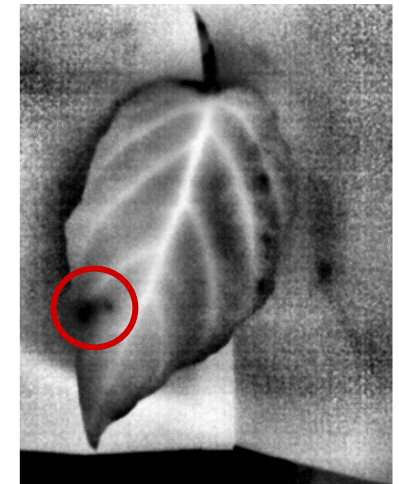
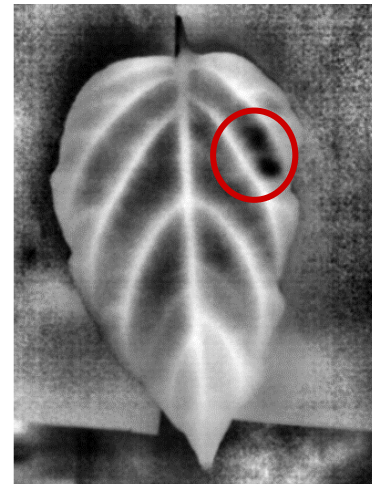


Thermal image

Visible image



Thermal images

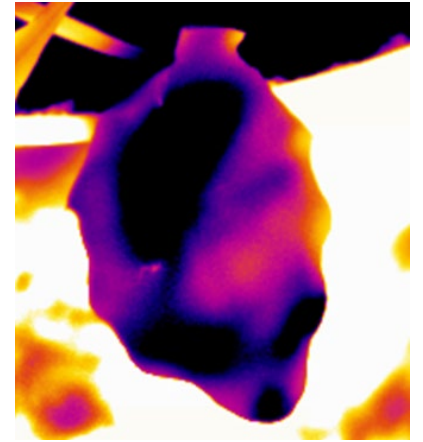
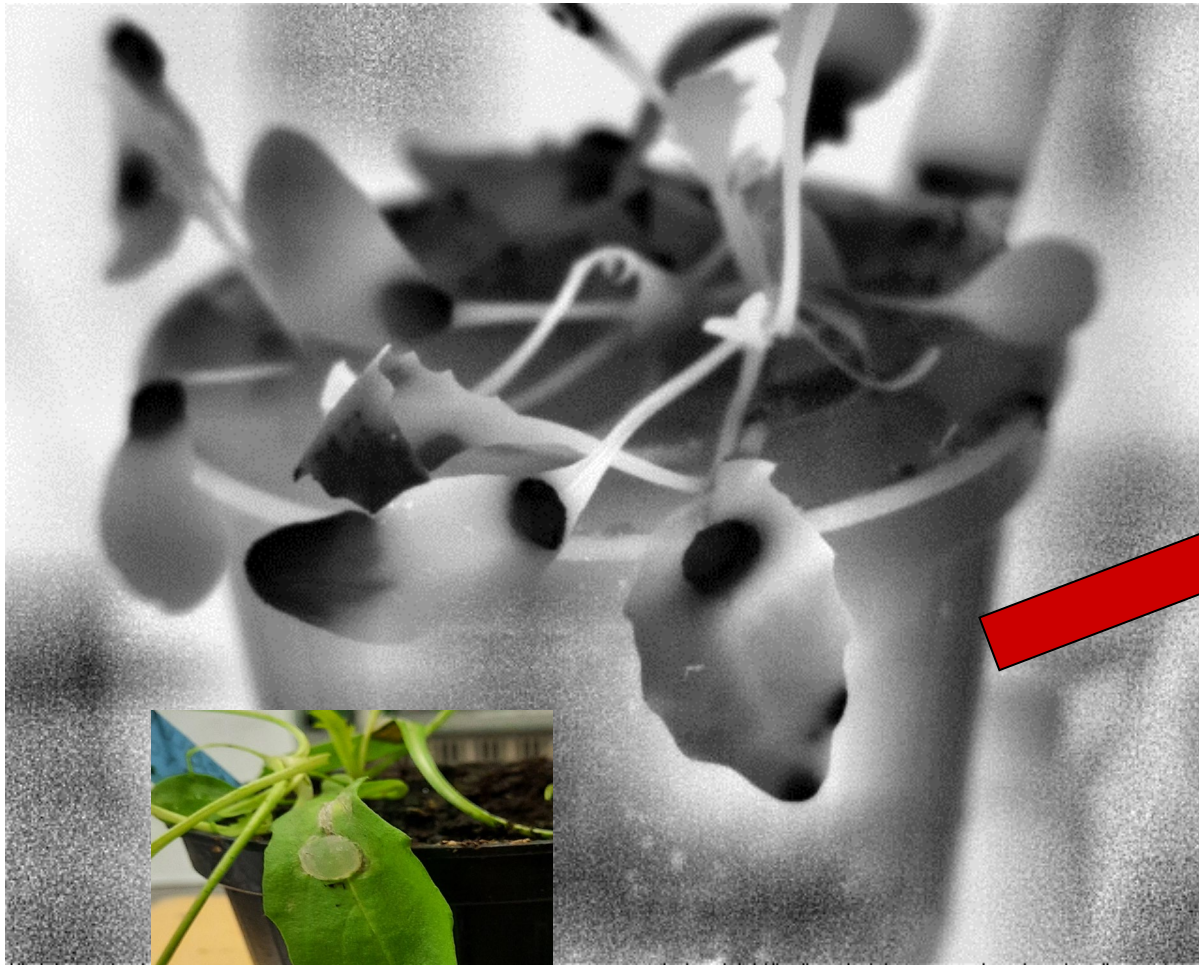


Monitoring of rocket plants inoculated with Sclerotinia

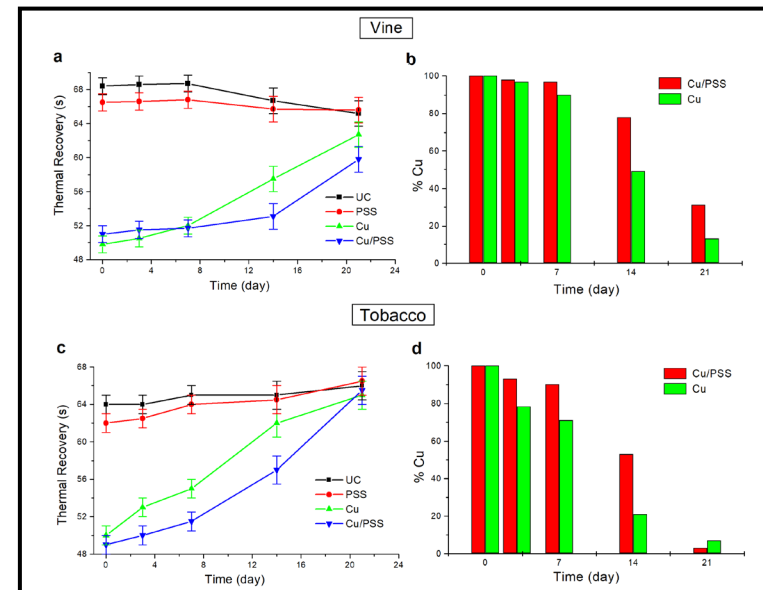
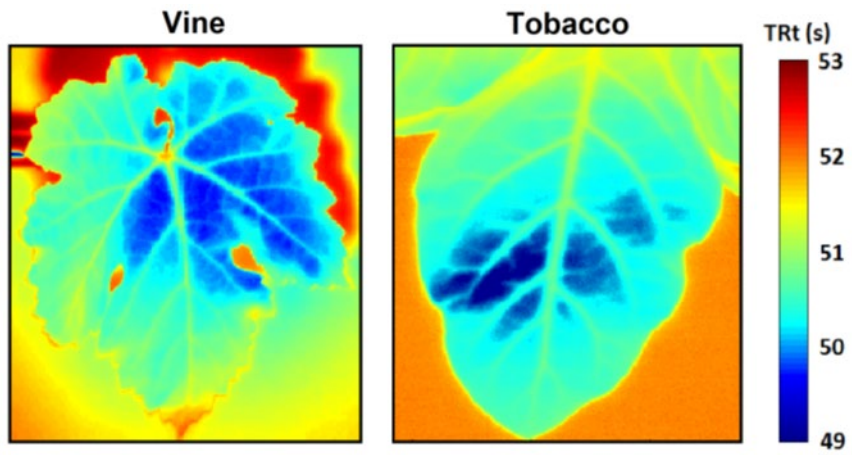
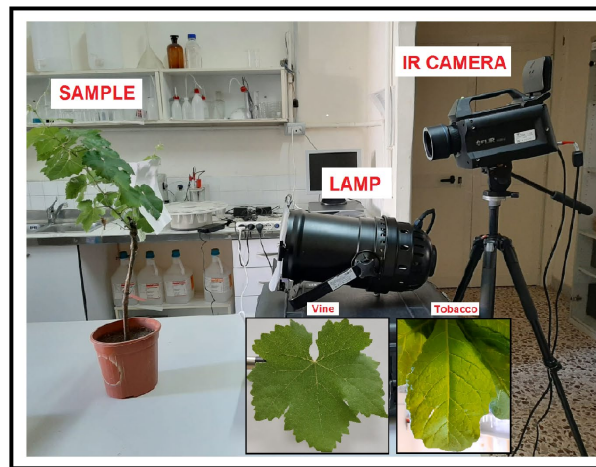
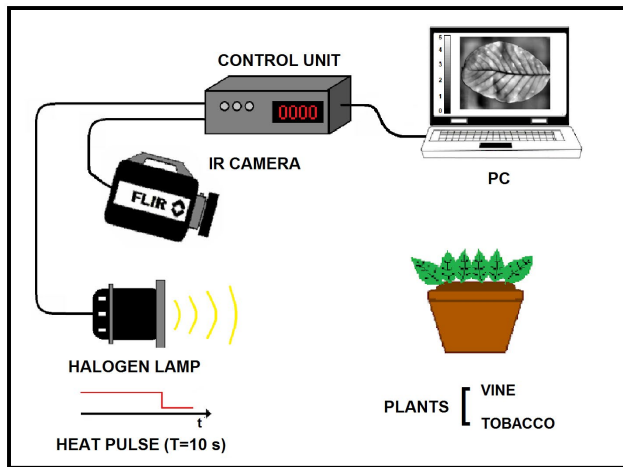


- Effect of the action of the pathogen on the plant





Monitoring of the Copper persistence on Plant Leaves using Pulsed Thermography



DI.BIO “Riduzione di input di ordine extra-aziendale per la Difesa delle coltivazioni BIOlogiche” - WP 5 “Strategie alternative all’uso del Rame in viticoltura in funzione dei cambiamenti climatici” – finanziato dal Mipaaf con D.M. 3400 del 28/12/2018.

Active Thermography to analyze the real-time Plant response to UV-B irradiation

UV-B - Piante
(280-320 nm)

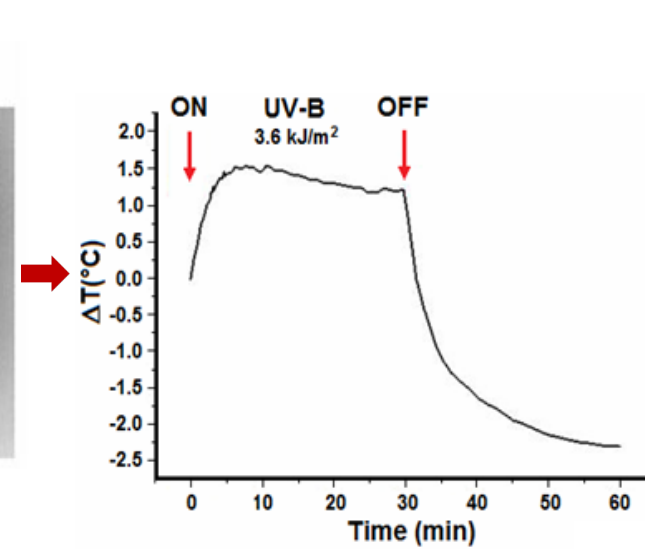
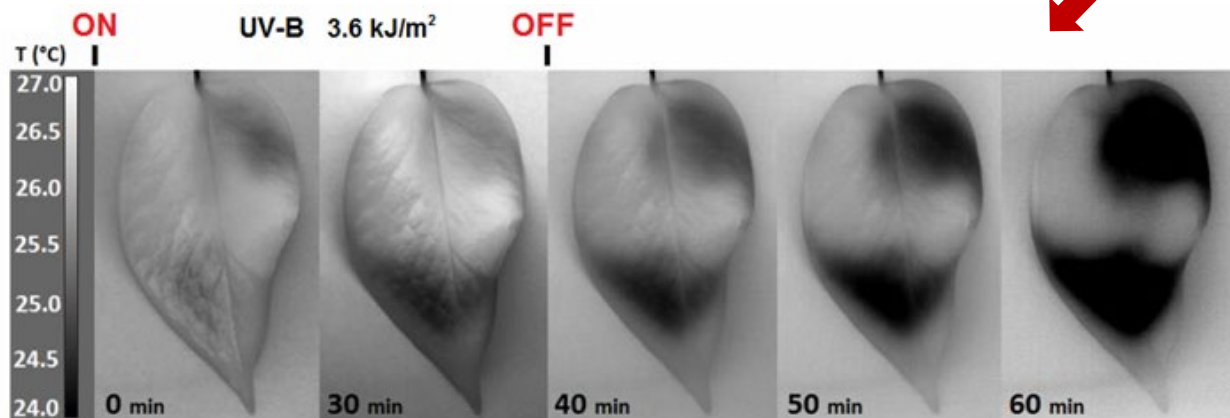
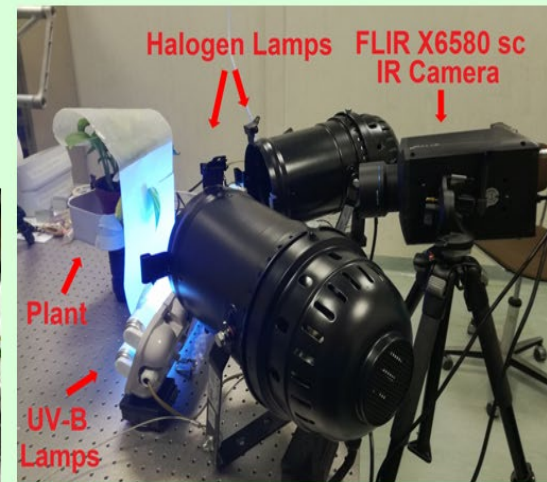


Increase of secondary metabolites
(Carotenoids, Anthocyanins, Phenolic compounds, Vitamin D, etc ...)

- M. Schreiner et al. *Optik&Photonik*, 9 (2014), pp. 34–37.
- V.P. Singh et al. *John Wiley & Sons Ltd*, 2017.
- P. Mormile et al. *Sci Food Agric* 2019; **99**: 6931–6936

Epipremnum aureum plant

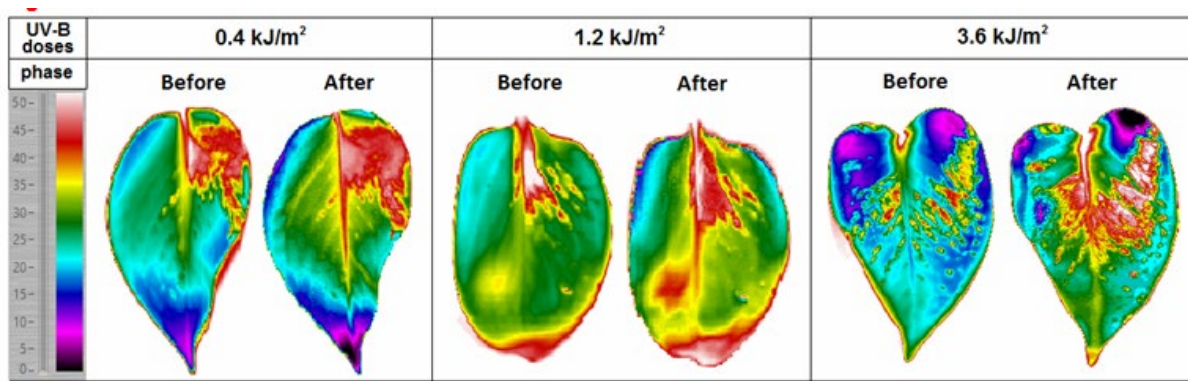
Experimental set-up →



UVB triggers a **cooling effect**

Active Thermography to analyze the real-time Plant response to UV-B irradiation

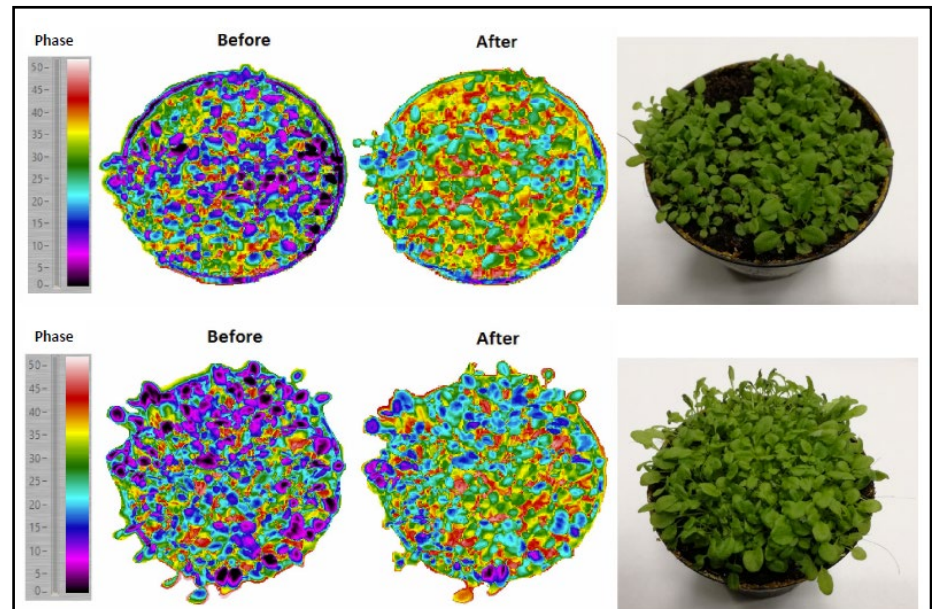
Lock-in Thermography: Phase images



Phase proportional to
Local Water Content (LWC)

UVB on *Arabidopsis thaliana*:
model organism

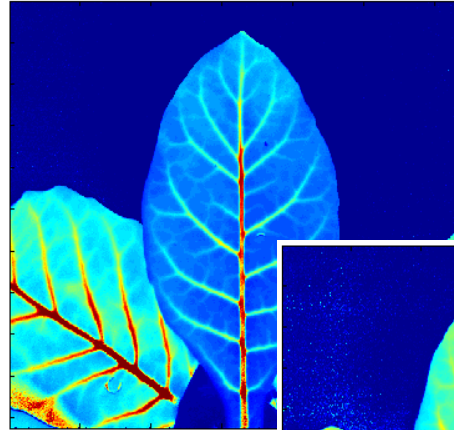
Response to UVB for sensing signal



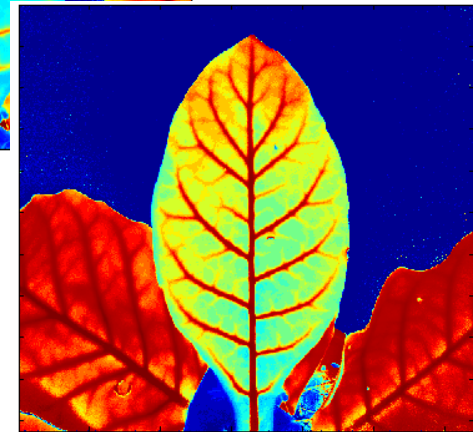
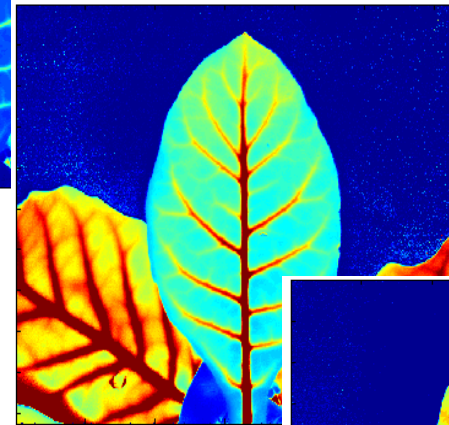
Analisi Morfologica e Funzionale di foglie di vario genere



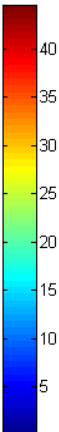
**Analisi
Morfologica**



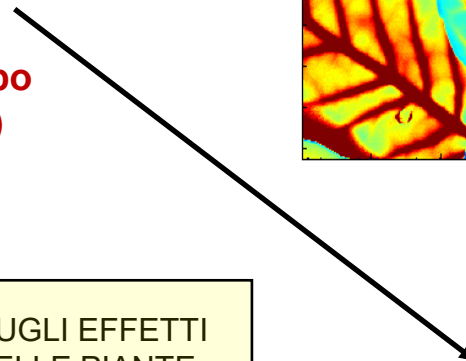
**Analisi del
contenuto
locale di acqua**



**Tempo di
recupero (s)**



**tempo
(s)**



Obiettivo

APPROFONDIMENTO SCIENTIFICO SUGLI EFFETTI PROVOCATI SULLA FUNZIONALITA' DELLE PIANTE DA AGENTI PATOGENI O CODIZIONI DI STRESS DI VARIO GENERE

Progetto BIO&BIO

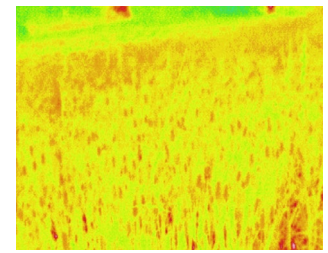


“Valorizzazione della BIOdiversità cerealicola in regime BIOlogico” **BIO&BIO** PSR Campania 2014-2020 - Misura 16 Sottomisura 16.1.1.2.



Obiettivo principale

Confrontare e **selezionare** le migliori qualità di cereali storici e le loro miscele che meglio si adattano alle condizioni microclimatiche delle aree rurali della Regione Campania oggetto del progetto (Sannio)



CNR- ISASI ➔ **WP3: Analisi infrarosse sulle diverse coltivazioni**

Campagne di Monitoraggio delle coltivazioni di cereali presenti nelle aziende coinvolte nel progetto



2-3 giorni



ogni 20-25 giorni



Durante l'intero periodo di coltivazione

MWIR camera



LWIR camera



Registrazione immagini Termiche

- In diversi momenti della giornata
- In diverse condizioni micro-climatiche
- In diversi momenti della crescita
- In diversi range spettrali



Aprile 2022



Maggio 2022



Giugno 2022



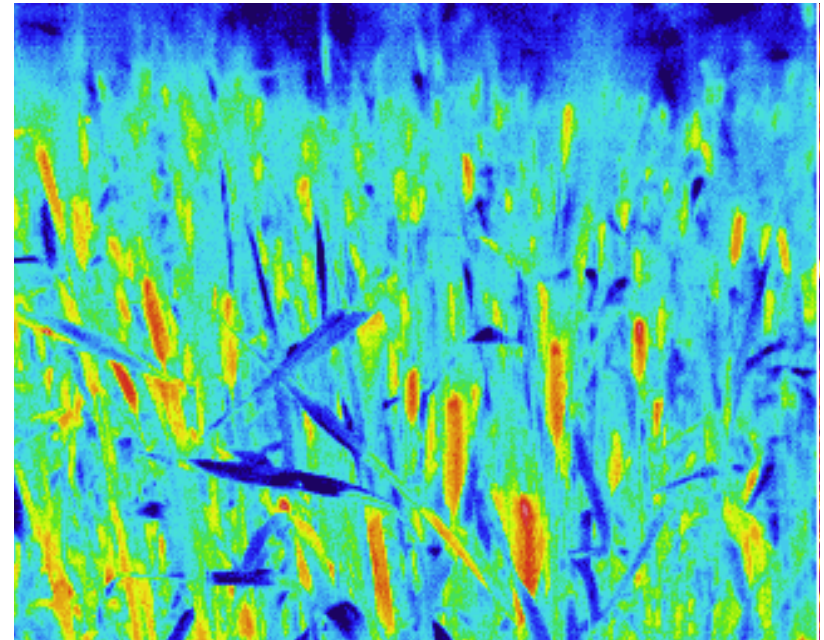
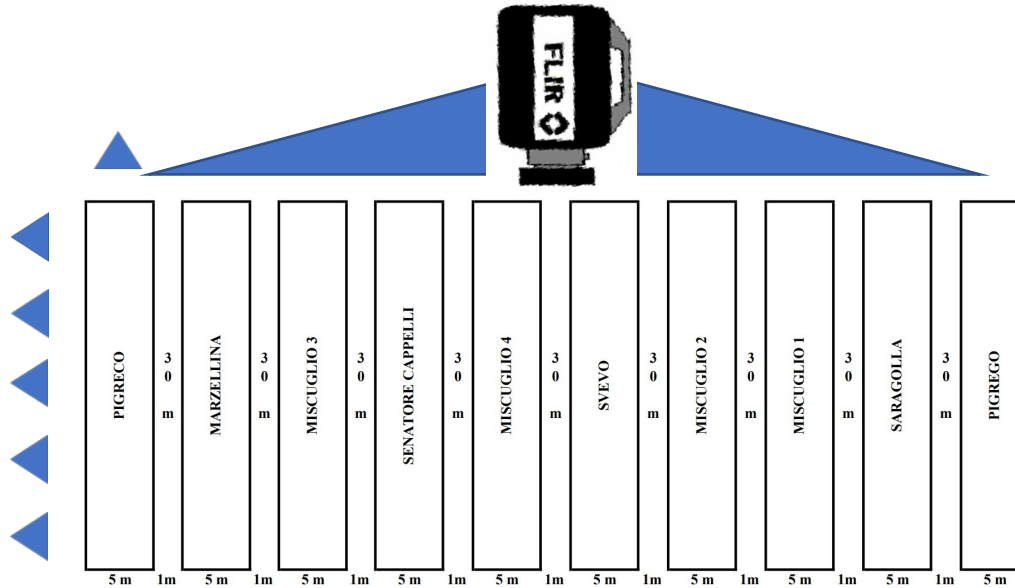
Luglio 2022



Monitoring infrarosso nel Progetto BIO&BIO

Rilevamento Remoto

Rilevamento Prossimale

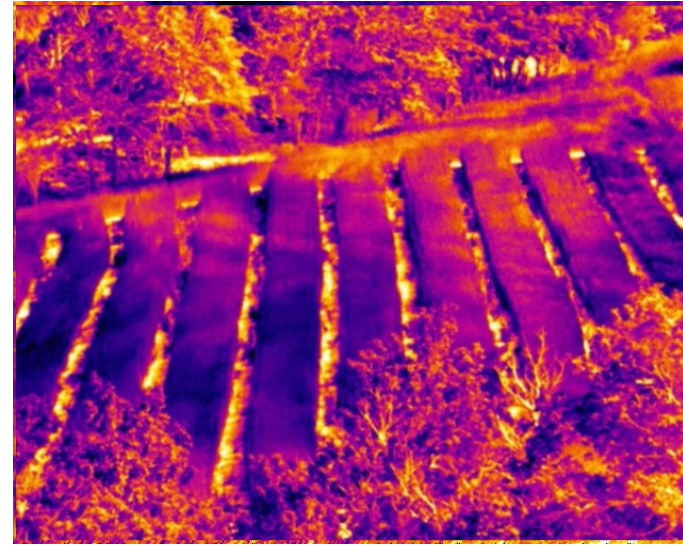


Monitoring infrarosso nel Progetto BIO&BIO

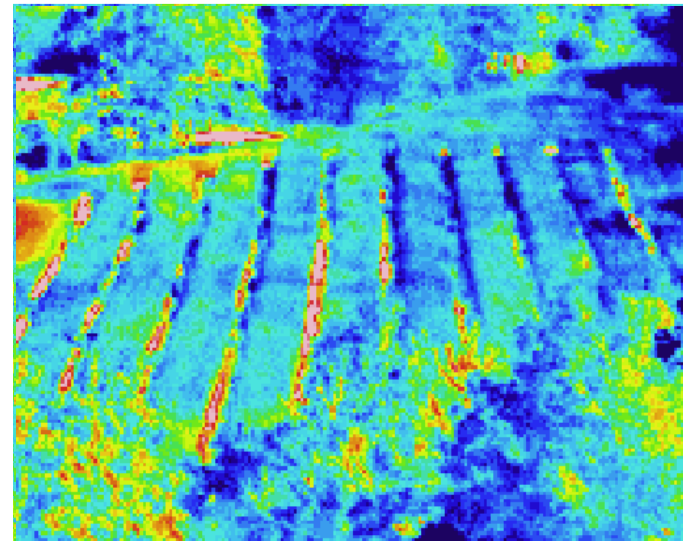
MWIR



Monitoraggio prossimale



LWIR



Obiettivi WP3

- Informazioni relative allo stato di stress delle colture
- Comparazione dello stato di salute e di adattamento tra le varie tipologie di cereali monitorate
- Feedback per una gestione ottimizzata
- Comparare le performance dei range MWIR ed LWIR
- Divulgare i risultati partecipando a conferenze nazionali ed internazionali

Rilevamento da Remoto



Rilevamento **Prossimale**



Monitoraggio livelli di stress **Grano tenero**: indice NRST

Steam elongation

Heading begins

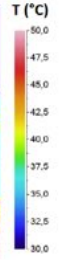
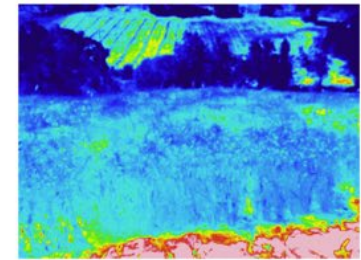
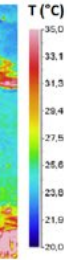
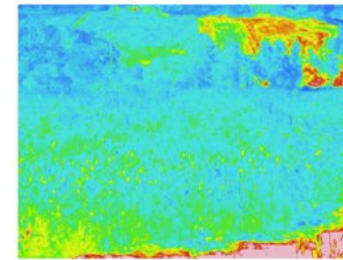
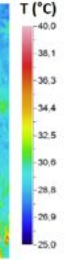
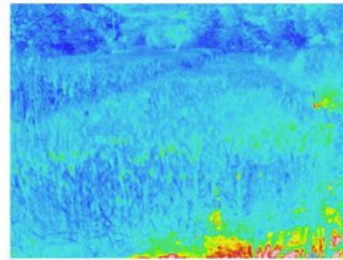
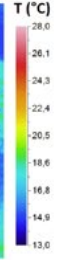
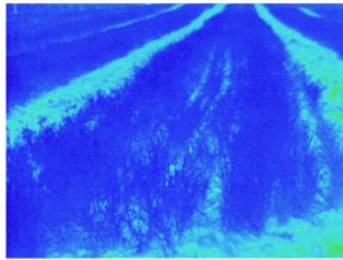
Milky-waxy ripening

Full ripening

Visible Images

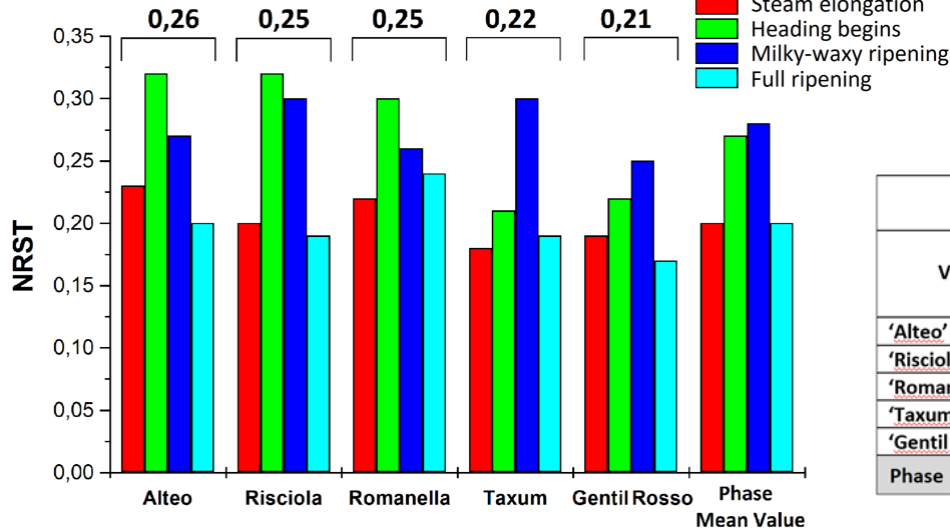


Thermal Images



VARIETY MEAN VALUES

Phenological phases



Normalized Relative Soil Temperature (NRST)

$$NRST = (T_{ms} - T_{mw}) / T_{ms}$$

Variety	NRST Index				Variety mean value
	Phenological phases				
	Steam elongation	Heading begins	Milky-waxy ripening	Full ripening	
'Alteo'	0.23	0.32	0.27	0.20	0.26
'Risciola'	0.20	0.32	0.30	0.19	0.25
'Romanella'	0.22	0.30	0.26	0.24	0.25
'Taxum'	0.18	0.21	0.30	0.19	0.22
'Gentil Rosso'	0.19	0.22	0.25	0.17	0.21
Phase Mean Value	0.20	0.27	0.28	0.20	

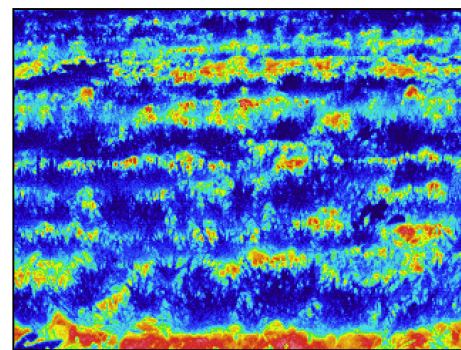
Valutazione del ricoprimento del suolo delle varietà di **Grano duro**

Cereal Coverage Estimation

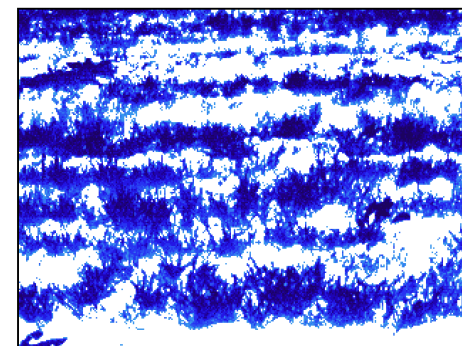
a Visible Image



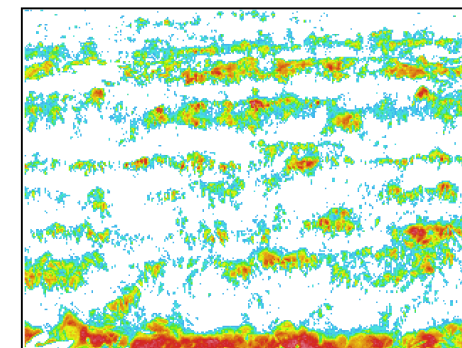
b Thermal Image



c T < T_{TH}



d T > T_{TH}

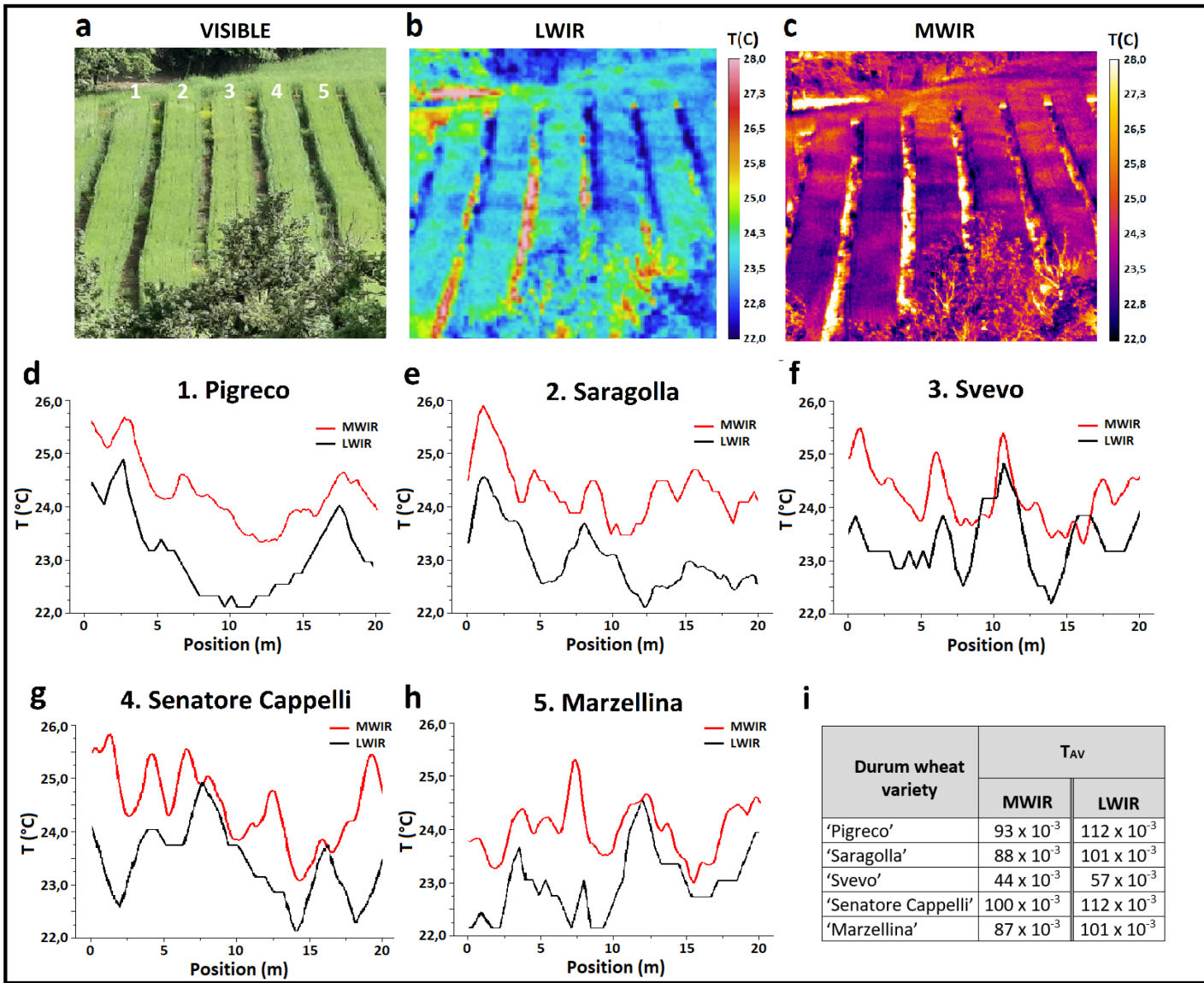


$$\% W_c = \frac{N_v}{N_v + N_s} \times 100$$

Durum wheat variety	%W _c	Common wheat variety	%W _c
'Pigreco'	83	'Alteo'	85
'Saragolla'	91	'Risciola'	86
'Svevo'	92	'Romanella'	88
'Senatore Cappelli'	93	'Taxum'	83
'Marzellina'	89	'Gentil Rosso'	93



Confronto dei risultati acquisiti nei range spettrali MWIR ed LWIR



BERLIN - September 2022



SPIE. Event: SPIE Remote Sensing, 2022, Berlin, Germany

Infrared Multispectral Monitoring of Cereal Crops

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¹Department of Agricultural Sciences, University of Naples Federico II, Portici, 80055, Italy

⁴Council for Agricultural Research and Economics (CREA)—Research Center for Cereal and Industrial Crops, Caserta, 81100, Italy

*m.rippa@issai.cnr.it, phone +390818675334, <https://www.issai.cnr.it/en/image-sensing-for-agricultural-cultural-heritage-and-adt-applications/>

ABSTRACT

Plants are subjected to a wide range of stresses which reduces the productivity of agricultural crops. In the case of cereal cultivations, climate change impacts on their production mainly through abiotic and biotic stress due for example to heat and water stress but also to pathogens such as bacteria, fungi, nematodes and others. The area under cereal cultivation is increasing worldwide, but, due to these problems, the current rates of yield growth and overall production are not enough to satisfy future demand. For this motivation, there is the needs to monitor and to control the cultivations, also developing new technological solutions useful to better optimize the management strategies, increasing both the quality of products and the quantity of the annual cereal harvest. Infrared imaging is a well-known non-invasive and non-contact technique that represents an outstanding approach of analysis applied in many fields: engineering, medicine, veterinary, cultural heritage and others. In recent years it has been gaining great interest in agriculture as it is well suited to the emerging needs of the precision agriculture management strategies. In this work, we performed an in-field multispectral infrared monitoring of different cereal crops (durum wheat and common wheat) through the use of both LWIR and MWIR cameras. The monitoring carried out made it possible to identify, among the crops analyzed, those subject to higher stress levels and their response to the different spectral ranges used. The results obtained open to the possibility of identifying new figures of merit useful for an effective monitoring of cereal crops and measurable through remote instrumentation.

Keywords: Thermography, Digital Agriculture, Precision Agriculture, Cereals, Infrared Imaging, Plant Stress

CONFERENCE

Remote Sensing for Agriculture, Ecosystems, and Hydrology

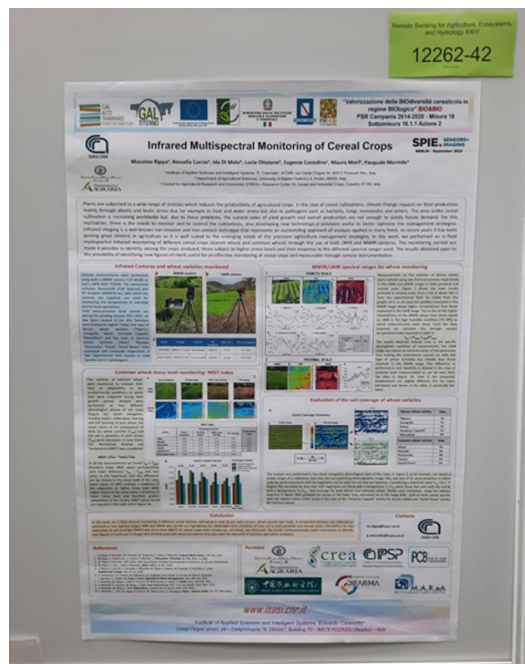


Poster **BIO&BIO**

ESTREL CONGRESS CENTER (ECC)



Aula dove si sono tenute brevi presentazioni orali del Poster



Collaborazioni



Riferimenti

1. M. Rippa, V. Pagliarulo, A. Lanzillo, et. al. **J. Nondestruct Eval.** 2021, 40 (1).
2. I. Papa, D. Mocerino, V. Pagliarulo, M. Rippa, A. Langella. **J. Compos. Mater.** First published August 24, 2021.
3. M. Rippa, A. Ambrosone, A. Leone, P. Mormile. **J. Photochem. Photobiol. B**, 208, 2020, 111900.
4. C. Yun, E. Liu, M. Rippa, P. Mormile, D. Sun, C. Yan, Q. Liu. **Sustainability** 2020, 12(23), 9833.
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*“Quando gli elefanti combattono è l'erba a soffrire”
(proverbio africano)*