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SPECTRAL REFLECTANCE CHARACTERISTICS OF CERTAIN EGYPTIAN CROPS TOWORDS FUTURE MONITORING AND MAPPING BY SATELLITE DATA

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ABSTRACT: *The current investigation aims at acquiring the spectral characteristics of two Egyptian crops (wheat c.v. Gimiza I and faba bean Giza 716 cultivars) at different phenological stages as a trail for precise discrimination of the two crops by the aid of image data.*

Crop area estimation for the strategic crops in Egypt by satellite data are affected by the overlap effect of numerous factors (parcel partitions, crop admixture, varieties in crop calendar and soil management regime varieties in addition to the variations associated with the irrigated agriculture). Two field experiments were carried out during two successive seasons. The two crops were simultaneously planted and received the same common agronomic management (fertilization and irrigation regimes). The reflectance measurements were acquired at six phenological stages, namely, tillering (I), maximum tillering (II), preheading (III), heading (IV), dough ripe (V) and full ripe (VI) for wheat. The corresponding stages for faba bean were early vegetative growth (I), vegetative growth (II), flower initiation (III), fruiting (IV), pod filling (V) and maturity (VI).

The spectral reflectance at different spectral bands of both wheat and faba bean were distinctive and quite variable during the different phenological stages. TM1, TM2 and TM3 values were low at different phenological stages with slight difference, however, TM2 registered minute peaks. TM4 values recorded the highest figures. The reflectance values, however, are not identical in the two successive seasons for the two crops.

The current investigation declares that significant correlations have been detected between TM4 and both of leaf area index and chlorophyll content. Highly significant correlations are existed among TM1, TM2 and TM3. The current investigation declares also that the most appropriate phenological stages for discriminating wheat from faba bean could be arranged according to the following descending order: II > VI > III, using combinations of TM4 with any of TM1, TM2 or TM3. Synchronous of field observation and image capture during the former periods are vital for crop differentiation and mapping by RS data.

Under the Egyptian conditions and from economical point of view, crop area estimation using image processing and analysis is costing. Accordingly, it is feasible to apply such technology under crop rotation agriculture and also under high capital intensity farming. Both exert big parcel area, homogenized crop patterns and irrigation (soil moisture) and management system. Otherwise, the application under parcel partition (small area) with dissimilar irrigation and management systems in addition to crop pattern admixture, the realistic of encountered statistics seem to be highly affected. This could be ascribed to uncompleted separability of the digital number (dn value) of the crops.

***Key words**: Wheat, faba bean, spectral reflectance satellite data, image processing.*

INTRODUCTION

Remote sensing is an important data source to estimate the vegetation cover fraction in wide areas (Xiao and Moody, 2005). Satellite based indices have been used in many researches to estimate vegetation cover (Gilabert *et al.,* 2002; Kallel *et al.,* 2007 and Jiang *et al.,* 2008). By using these indices, many vegetation parameters such as leaf area, biomass and physiological activities can be evaluated (Baret and Guyot, 1991 and Verrelst *et al.,* 2008). Spectral vegetation indices that are based on red and near infrared reflections have the high correlation with leaf area index and canopy cover (Broge and Leblanc, 2000).

However, in sparse vegetated areas, the reflection of soil and sand are much higher than reflection of vegetation and so detection of vegetation cover reflection is difficult. Therefore, soil reflectance adjusted indices such as Soil Adjusted Vegetation Indices (SAVI), Optimized Soil Adjusted Vegetation Indices (OSAVI) and Modified Soil Adjusted Vegetation Indices (MSAVI) had been developed in the past (Karnieli *et al.,* 2001; Gilabert *et al.,* 2002; Shupe and Marsh, 2004).

Soil reflectance as affected by some soil parameters was studied by Khalil *et al.* (1995). Moreover, the soil parameters contributions to variations in soil reflectance were studied by Khalil (1999).

Recently, image data introduce variety of facilities such as assistance in updating the land cover maps which rely on the discrimination of the timely themes changes.

The spectral response of certain crop may overlap with that of one or more of the others. This may take place in crop area monitoring and acreage estimation using the image data. This case is common under the Egyptian conditions, owing to parcels partition, crop admixing, different crop calendar for certain crops in addition to crops management regime levels dissimilarity.

The goal of the current investigation is to follow up the variations in the spectral reflectance of faba bean and wheat at different phenological stages during two successive years. This will define the period of spectral reflectance overlap of the two crops. In turn assisting in defining the proper time for field truth and image capture synchronous which are vital for crop differentiation and crop area estimation by RS data.

MATERIALS AND METHODS

Two field experiments were carried out in two successive years. Wheat (c.v. Gimiza 1) was planted in three seeding rates (50, 60 and 70 kg/fed.), two sowing methods (broad casting and rows: 40 cm apart with 20 cm spacing between plants in each row).

The soil of the experiment was fertilized by calcium superphosphate (15.5 % P_2O_5) and urea (46%N), with the rates of 200 and 60 kg/fed respectively.

Faba bean (Giza 716) was planted in rows with 40 cm apart and spacing 10, 15 and 20 cm in two directions: N-S and E-W. The soil was fertilized by calcium superphosphate and ammonium nitrate (33% N) witth rates of 150 and 20 kg/fed respectively. Each treatment was planted in plot (2 x 3 m diameter). The treatments were arranged in randomized complete block design with five replicates. The experimental soil was analyzed as shown in Table (1).

Field spectral measurements:

The acquired spectral data were achieved at different phenological stages during the two growing seasons as shown in Table (2). In the second growing season the spectral measurements were only acquired for five phenological stages. The mean monthly temperature values indicate warmer growing season. So the life span of wheat and faba bean were shorter comparing to the first season (Fig.1).

Field portable multiband radiometer (model Spectron SE 590) was used to acquire the spectral measurements with high precision condition according to Philipson *et.al.* (1989). The individual spectron data file was transferred from the spectron to PCI. The data were normalized and the equivalent TM1, TM2, TM3 and TM4 values were calculated by the aid of EXCEL software. Macro was used to automate the former calculations. TM1, TM2, TM3 and TM4 correspond to the wave lengths (µm): 0.45-0.52 (blue), 0.52-0.60 (green), 0.63-0.69 (red, R) and 0.76-0.90 (near infrared, NIR) respectively. The normalized difference vegetation index (NDVI) values were calculated according to Rouse *et.al.* (1974) as follows:

$$NDVI = (NIR-R) / (NIR+R).$$

Table (1): Particle size distribution and some chemical analyses of the experimental soil.

Particle size distribution (%)				pH	EC	CEC	Organic	Available Nutrients (mg. kg^{-1})					
Coarse sand	Fine sand	silt	clay	(soil paste)	,$ds.m^{-1}$ (soil paste extract)	(mole.kg^{-1})	Matter (g. kg^{-1})	N	P	K	Ca	Mg	Na
8.6	35.5	34.2	21.7	7.9	3.8	34.7	4.1	80	48	125	310	151	325

Table (2): The sampled phenological stages of Wheat and Faba bean.

Growing stages	Age (day)		Phenological stages	
	1st season	2nd season	Wheat	Faba bean
I	17	33	Tillering	Early vegetative growth
II	40	45	Maximum tillering	Vegetative growth
III	63	-	Pre-heading	Flower initiation
IV	85	70	Heading	Fruiting
V	130	100	Dough ripe	Pod filling
VI	160	140	Full ripe	Maturity

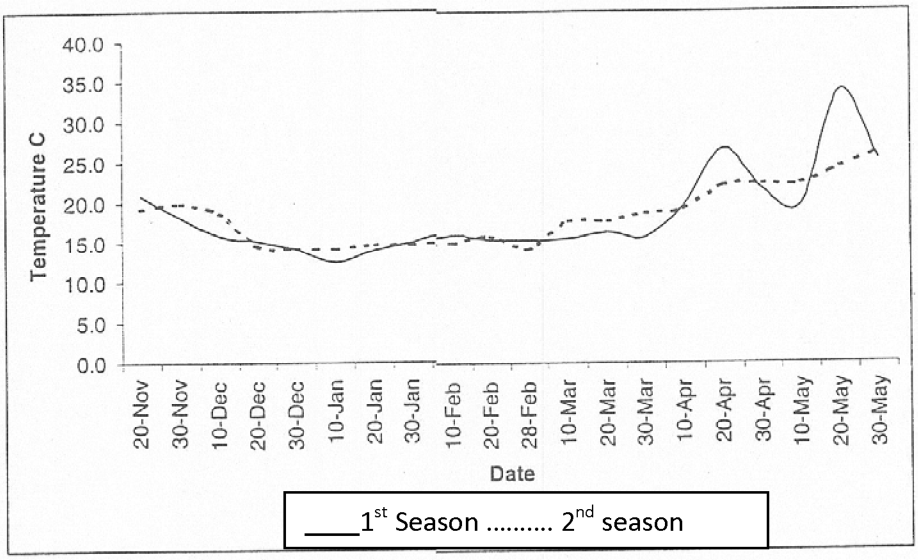

Fig. (1): Mean daily temoerature of the two growing seasons .

The NDVI values are low for the bare soils and water surfaces, and high for green vegetation. The index ranges from -1.0 to 1.0. Two of canopy characteristics namely; leaf area index (LAI) and chlorophyll content were estimated according to Waston (1952) for the former and Monje and Bugbee (1992) for the latter respectively.

RESULTS AND DISCUSSION

The spectral reflectance measurements of both wheat and faba bean varied irregularly with insignificant differences and were not agronomic treatments regime variations dependant certainly. This declaration has been recognized and agreed with the findings of Khalid (2000). The chlorophyll content and the LAI are shown in Figs 2 & 3 respectively.

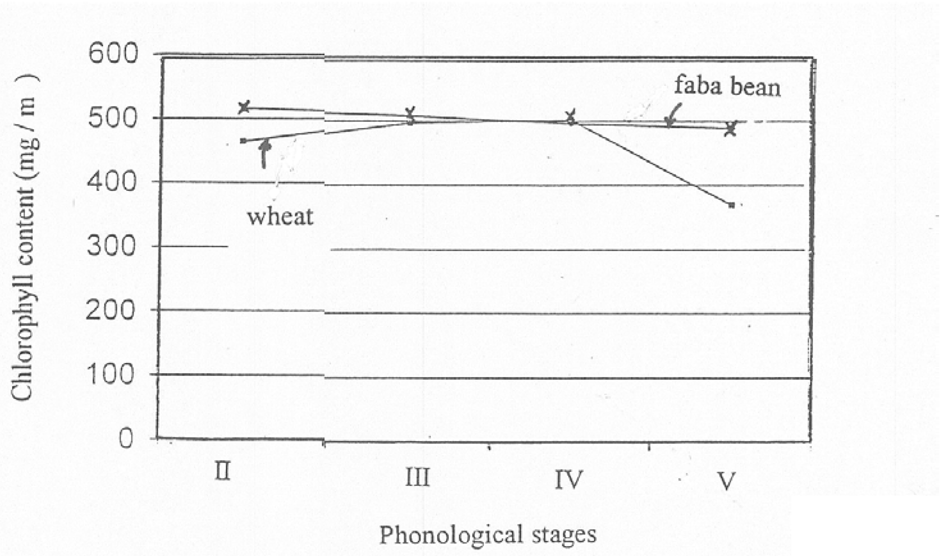

Fig. (2): Chlorophyll content of wheat and faba bean leaves during the different phenological stages.

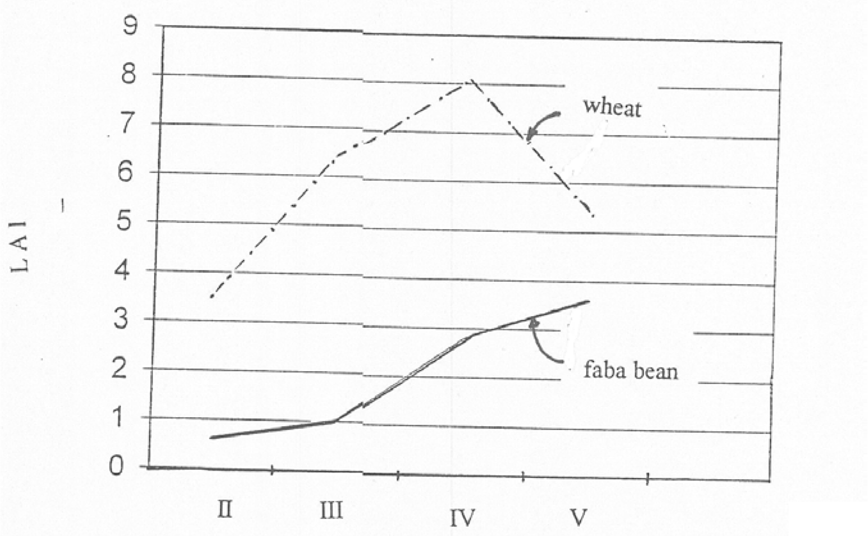

Fig. (3): L A I of wheat and faba bean at the different phenological stages.

The spectral reflectance measurements of wheat and faba bean were acquired at six stages (Fig. 4). The first sample (I) correspond to tillering stage in case of wheat. The second (II), the third (III), the fourth (IV), the fifth (V) and the sixth (VI) correspond to maximum tillering, pre heading, heading, dough ripe and full ripe phenological stages respectively. In the case of faba bean, the detected six phenological stages were early vegetative growth, vegetative growth, flower initiation, fruiting, pod filling and maturity.

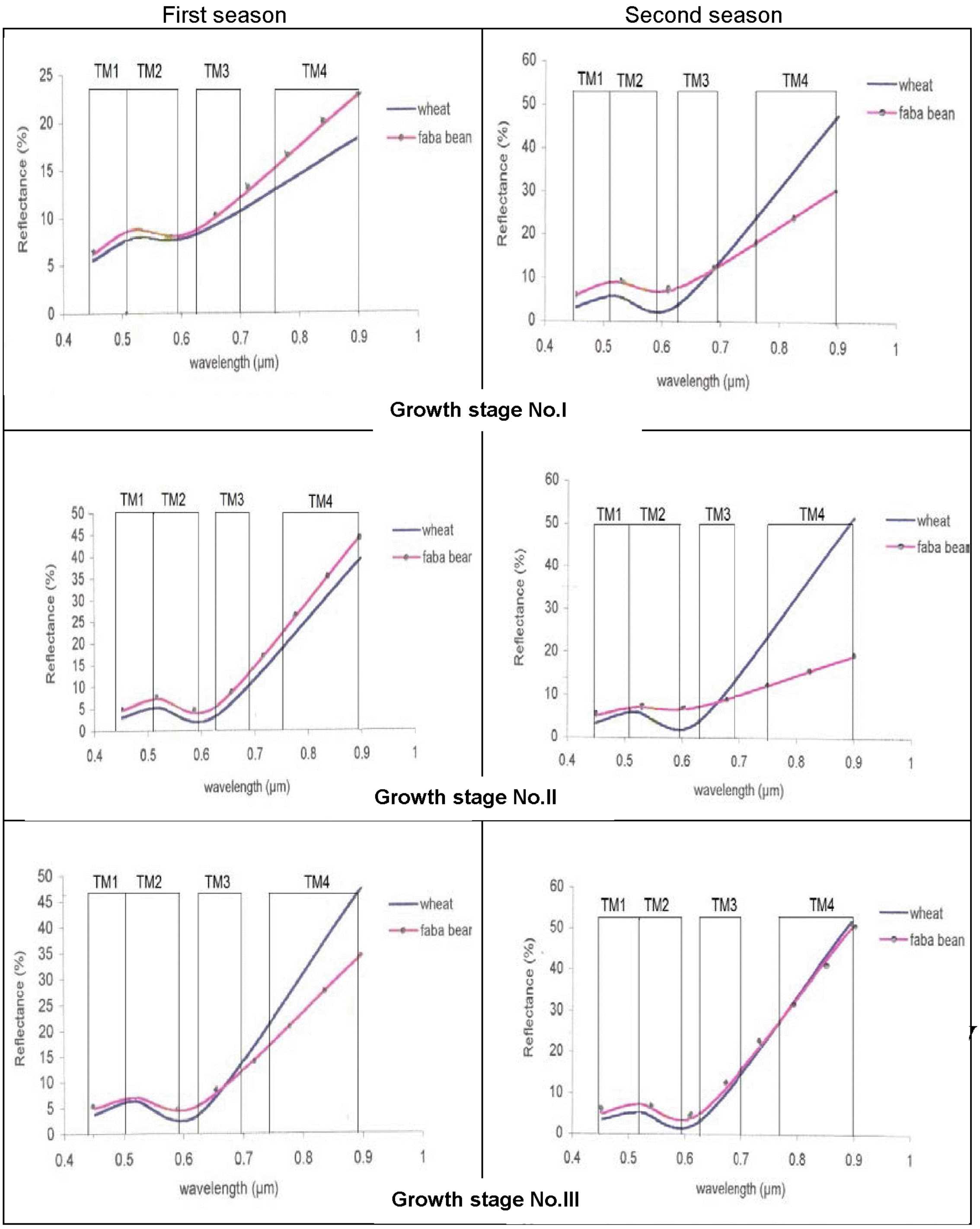

Fig. (4): Spectral reflectance of wheat and faba bean at the different phenological stages.

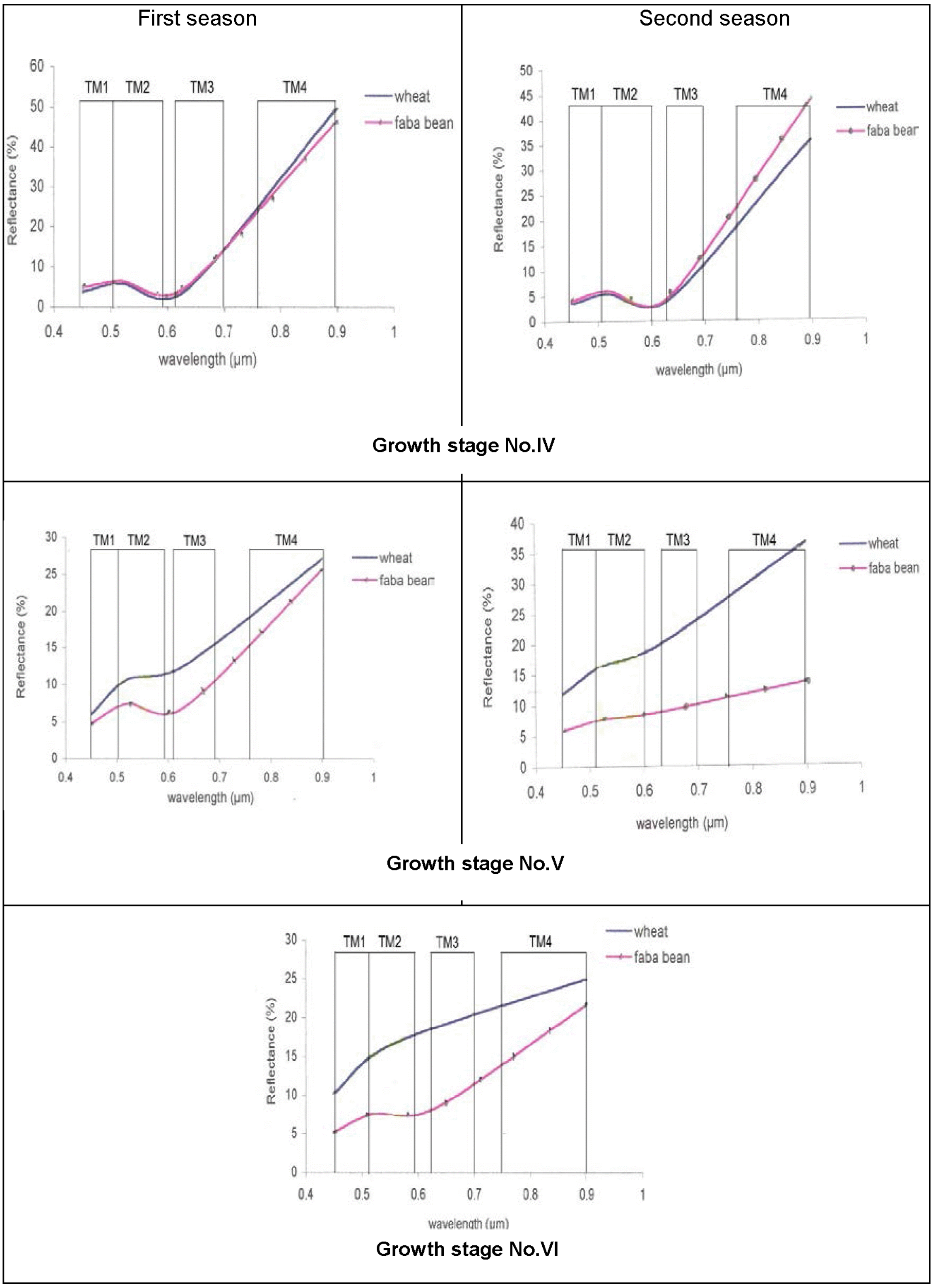
First season
Second season
TM1
TM2
TM3
TM4
wheat
faba bean
Reflectance (%)
wavelength (µm)
Growth stage No.IV
Growth stage No.V
Growth stage No.VI

Fig. (4): Cont.

Generally, the spectral reflectance from both wheat and faba bean were distinctive and quite variable for the different portions of spectrum under study of the two growing seasons.

Though obvious differences between the spectral reflectance (separability) from both wheat and faba bean at different phenological stages were detected in the first season, however, the levels of differences in the second season were not unique and steady as exactly as in the first season.

In the first season, the reflectance values with respect to TM1 spectrum show the lowest spectral values for both wheat and faba bean throughout the different phenological stages (Fig. 4). Similarities in reflectance trend from wheat and faba bean are obvious in stages Nos. I, II and III, otherwise, faba bean reflectance values are the highest. Differences between wheat and bean reflectance, however, exert broad differences with phenological stages promotion in phases V and VI and the wheat reflectance values are the highest.

The spectral reflectance (TM1) values from faba bean and wheat in the second season coincide with those of the first season. The TM2 reflectance values from faba bean and wheat in the first season exert a little higher values than those of TM1 showing a small obvious peak. This is true for phases I to V in particular. The reflectance values of TM2 from faba bean are the highest in phases I to IV. Contradictory to that in V and VI phases, wheat reflectance values are the highest. In the second season, the TM2 values of both wheat and faba bean coincide with those of the first season with small variations in reflectance.

Wheat and faba bean TM3 values (Fig. 4) detected in the first season show a tendency of increase in all of the growing seasons. The reflectance values of faba bean are the highest in phases I and II and the trend is not strait forward in phases III and IV with more or less negligent differences. Contradictory to that, the TM3 values of wheat register the highest reflectance values in V and VI phases. The variations between TM3 values of wheat and faba bean are more or less close to that in phases I to IV, but this difference becomes remarkable in phases V and VI.

The TM3 values of wheat and faba bean in the second season register also an increasing trend in all phenological stages. TM3 values of faba bean are the highest in phase I and this trend is not clear in phase II. The TM3 values of faba bean are the highest in phases III and IV. In the aforementioned statements, the very small differences in TM3 values of wheat and faba bean cause difficulty to differentiate faba bean from wheat. Accordingly, overlap in the digital number of both two crops may be encountered in such case.

The TM3 values of wheat and faba bean in phase V coincides with the correspondence of the first season.

The TM4 values of both wheat and bean exert the highest reflectance values (Fig. 4). In the first season, the TM4 values of wheat are higher than those of bean in phases I and II. On the contrary, they are lower for the rest of the phenological stages.

In the second growing season, excluding phase IV, wheat reflectance values are higher than those of faba bean.

NDVI has shown high correlation with parameters associated with plant health and productivity such as vegetation density and cover (Wiegand, *et al.,* 1973); leaf area index (Wiegand, *et al.,* 1979); chlorophyll content (Chapplle *et al.,* 1992) and crop condition (Wiegand, *et al.,* 1992).

The NDVI values of wheat and faba bean at the different phenological stages during the two seasons are shown in Figure (5). The NDVI values of wheat registered high level and was increased progressively during the phenological stages Nos. I, II, III and IV in the two growing seasons. This was also true for faba bean with smaller NDVI levels. This trend coincide with the high proportional increase in LAI (Fig. 3). However, contradictory trend were encountered in the later phenological stages (Nos. V and VI) for wheat and faba bean.

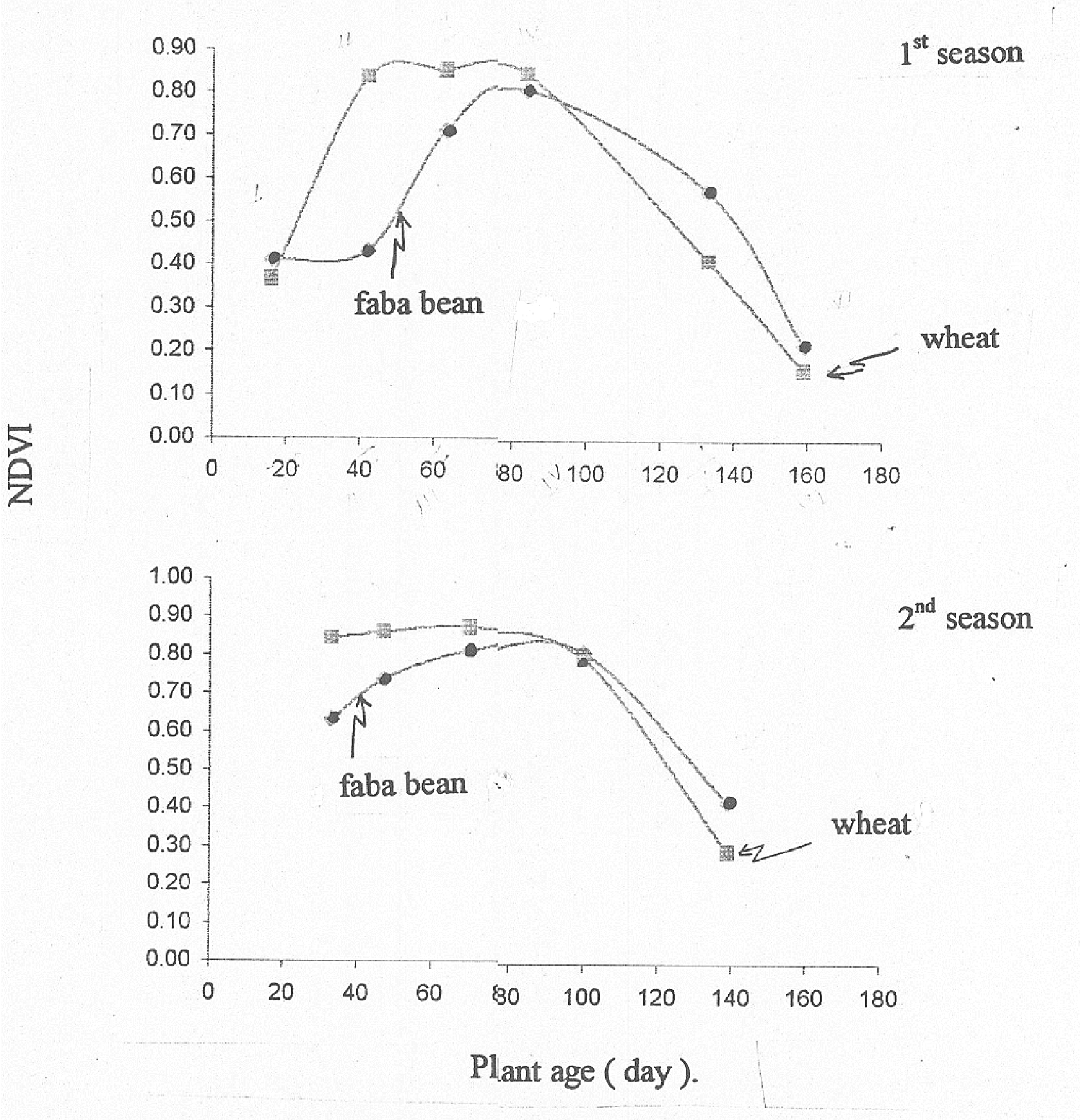

Fig. (5): N DVI values of faba bean and wheat at the different pheonological stages.

NDVI values are mainly green vegetation amount dependent (Wiegand, *et al.,* 1991 and Gutman, 1991), this may interpret the low values of NDVI at the early growing stages. As the plant age increase, the NDVI tend to decrease owing to the amount of green vegetation decrement, due to leaf senescence.

The correlation coefficients among TMs, NDVI, LAI and chlorophyll content are listed in Table (3). Significant correlation coefficients have been detected between TM4 and both of LAI and chlorophyll content (Table 3). This can be due to that chlorophyll strongly absorbs energy in the wave length bands centered at about 0.45 and 0.67µm.

Otherwise reflectance of visible to near-infrared portion increases dramatically by healthy vegetation (Lillesand and Kiefer, 1994). Highly significant correlations are existed among TM1, TM2 and TM3. That means using any of them (to avoid redundancy) in addition to TM4 is capable to differentiate the crops under consideration by supervised classification.

The reflectance separability percentages, detected in the different phenological stages of the two crops during the two seasons, are summarizes in Table (4) where:

$$\text{Separability\%} = \frac{\text{Difference between the reflectance of the two crops X 100}}{\text{Maximum reflectance values of the two crops during certain growing season}}$$

Table (3): Simple correlation coefficients among TMs, NDVI, LAI and chlorophyll content

	Stage	LA1	CHL	TM1	TM2	TM3	TM4	NDVI
Stage	1	0.122	-0.079	0.716	0.694	0.825*	0.104	-0.465
LA1		1	0.906	-0.563	-0.611	-0.380	0.846*	0.717
CHL			1	-0.654	-0.717	-0.541	0.869*	0.874*
TM1				1	0.994**	0.922**	-0.569	-0.902*
TM2					1	0.926**	-0.592	-0.924**
TM3						1	-0.314	-0.825*
TM4							1	0.785
NDVI								1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is highly significant at the 0.01 level (2-tailed).

Table (4): Wheat and faba bean spectral reflectance separability percentage.

Phenological stages	TMs							
	TM1		TM2		TM3		TM4	
	Seasons							
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
	Separability %							
I	9.09	23.07	5.88	20.59	11.11	9.09	22.72	33.33
II	9.09	7.69	5.88	14.70	8.33	0.0	22.72	66.66
III	9.09	15.38	5.88	5.88	0.0	4.54	45.45	6.06
IV	9.09	11.54	2.94	2.94	0.0	4.54	13.63	9.09
V	18.18	3.84	29.41	0.0	22.22	4.54	13.63	24.24
VI	45.45	61.54	64.70	64.70	61.11	63.64	18.18	63.63

The current investigation declares that TM1, TM2 and TM3 portions of spectrum are highly correlated; TM4 portion of spectrum is correlated with chlorophyll content as well. Lillesand and Kiefer (1994) pointed out that plant reflectance in the range 0.7 to 1.3 µm results primarily from the internal structure of plant leaves. Because this structure is highly variable among plant species, reflectance measurements in this range often permits the discrimination among species even if they look the same in visible wave- lengths. On the light of the aforementioned findings, the variations of TM4 (0.76 and 0.90µm) could be considered as an effective indicator for plant species discrimination. Because the TM4 values are plant species and phenological stages dependant, discriminating crops from each other could be possible when the differences between TM4 values are wider (Table 4). The seperability percentages of the different phenological stages could be arranged according to the descending order: II > VI > III. That means that, the most appropriate phenological stages for discriminating wheat from faba bean could be arranged to the descending order: II > VI > III using a combination of TM4 with any of TM1, TM2 or TM3.

In conclusion, the current investigation declares that the digital number is not only crop pattern dependant, but also phenological stage, environmental conditions, and amount of green vegetation dependant. This highlights the urgency of the synchronous between the dates of image data capture and field truth for efficient crop differentiation and crop area estimation aided by RS data. The current investigation recommends generalization of this task for all the rest of strategic Egyptian crops, in order to gain a complete vision about the reflectance characteristic and the probable phenological stage for future differentiation and mapping tasks.

Under the Egyptian conditions and from economical point of view, crop area estimation using image processing and analysis is costing. Accordingly, it is feasible to apply such technology under crop rotation agriculture and also under high capital intensity farming. Both exert big parcel area, homogenized crop patterns and irrigation (soil moisture) and management system. Otherwise, the application under parcel partition (small area) with dissimilar irrigation and management systems in addition to crop pattern admixture, the realistic of encountered statistics seem to be highly affected. This could be ascribed to uncompleted separability of the digital number (dn value) of the crops.

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دراسة الانعكاسات الطيفية لبعض المحاصيل المصرية ضمن فعاليات انتاج خرائط التركيب المحصولى مستقبليا باستخدام مرئيات الأقمار الصناعية

خليل ابراهيم خليل ، ممدوح خليل عبد الغفار و مجدى حسين رياض

وحدة الأستشعار عن بعد ونظم المعلومات الجغرافية– معهد بحوث الأراضى والمياه والبيئة– مركز البحوث الزراعية.

الملخص العربى

تهدف الدراسة الى تحديد أنسب مراحل النمو لبعض المحاصيل والتى يمكن فيها تمييز المحاصيل باستخدام مرئيات الأقمار الأصطناعية. من أجل ذلك أقيمت تجربتين حقليتين فى موسمين زراعيين متتاليين حيث تم زراعة نبات القمح (صنف جميزة ١) تحت ثلاث معدلات تقاوى (٥٠، ٦٠، ٧٠ كجم/فدان) بطريقتى الزراعة نثرا و فى سطور. وتم زراعة الفول البلدى (صنف جيزة ٧١٦) بكثافة زراعة ١٠، ١٥، ٢٠ سم بين النبات والآخر وبمسافة ٤٠ سم بين السطور– وكانت اتجاهات التسطير: شمال – جنوب، شرق – غرب ولقد تم زراعة المحصولين متزامنين فى الموسمين الزراعيين.

تم دراسة الأنعكاسات الطيفية للفول البلدى خلال مراحل النمو المختلفة (النمو الخضرى المبكر(I)– النمو الخضرى (II)– بداية الأزهار (III)– تشكل القرون (IV)– امتلاء القرون (V)– النضج (VI)). وكانت مراحل نمو القمح المقابلة للمراحل السابقة هى: التفريع – التفريع الأعظم – ماقبل طرد السنابل – طرد السنابل – النضج العجينى – الحصاد. وهذه المراحل للمحصولين تطابق الأعمار : ١٧، ٤٠، ٦٣، ٨٥، ١٣٠، ١٦٠ يوم من الزراعة فى الموسم الأول – ولقد أختلفت هذه الأعمار فى الموسم الثانى وذلك للأرتفاع الملحوظ فى درجة الحرارة للموسم الثانى مقارنة بالأول.

تم استخدام جهاز مقياس الطيف الحقلى متعدد الأطوال الموجية فى المدى ٠.٣٩ – ١.١ ميكرومتر لأربع نطاقات طيفية والتى تقابل الأربع نطاقات الطيفية المستخدمة فى القمر الصناعى الأمريكى Landsat (TM) وهى: الزرقاء (٠.٤٥ – ٠.٥٢ ميكرومتر:TM1) ، الخضراء (٠.٥٢ – ٠.٦٠ ميكرومتر: TM٢) ، الحمراء (٠.٦٣ – ٠.٦٩ ميكرومتر: TM٣) ، تحت الحمراء (٠.٧٦ – ٠.٩٠ ميكرومتر: TM٤)، كذلك تم حساب NDVI .

تم قياس دليل المساحة الورقية، تركيز الكلوروفيل بالأوراق فى نفس مراحل النمو السابقة للمحصولين وكان من أهم النتائج التى تم الحصول عليها:

١- أختلفت الأنعكاسات الطيفية فى النطافات المختلفة للتباين عند جميع مراحل النمو المختلفة. كانت هذه الأختلافات واضحة وغير منتظمة فى مراحل النمو المختلفة وخلال موسمى الزراعة.

٢- كانت قيم الأنعكاس الطيفى من الطيف الكهرومغناطيسى فى المجالين الطيفيين الأزرق والأحمر عند أقل مستوى الا أنه أرتفع قليلا فى المجال الطيفى الأخضر.

٣- زاد الأنعكاس الطيفى فى مجال الأشعة تحت الحمراء بشكل كبير وملحوظ – الا أن الزيادة لم تكن منتظمة خلال مراحل النمو المختلفة وكذلك خلال موسمى الزراعة.

٤- لوحظت علاقة أرتباط معنوى بين كل من نسبة الكلوروفيل ودليل مساحة الورقة (LAI) مع أنعكاس الجزء من الطيف المميز لـTM٤ – لوحظ أيضا وجود ارتباط معنوى بين كل من TM1, TM2, TM3 مما يعنى ان استخدام أى منهم مع TM٤ سيكون قادرا على تمييز مواقع ومساحات المحاصيل باستخدام Supervised Classification فى أى دراسات مستقبلية قد تجرى على نطاق واسع.

٥- أوضحت الدراسة أن أنسب فترات النمو التى يمكن منها تمييز القمح عن الفول يمكن ترتيبها تنازليا كالتالى: II < IV < III , وذلك باستخدام معالجة منظومة من النطاقات الطيفية تتكون من TM٤ مع أى من TM1, TM2, TM3 .

أخيرا توصى الدراسة بالآتى:

أولا: تعميم هذه الدراسة على باقى المحاصيل الأستراتيجية المنزرعة فى الموسم الشتوى والصيفى بالأراضى المصرية كأحد الفعاليات المستقبلية لانتاج خرائط التركيب المحصولى باستخدام معالجة مرئيات الأقمار الصناعية.

ثانيا: حتمية عمل المعاينات الحقلية للمساحات الأرشادية المنزرعة بالمحاصيل المختلفة طبقا للمنهجية العلمية المتبعة فى هذا الشأن بالتزامن مع التقاط المرئية الفضائية ذات القدرة التوضيحية المناسبة لطبيعة الدراسة.

ثالثا: بأخذ الجدوى الأقتصاديه فى الأعتبار (فى تقدير المساحة المحصولية باستخدام التقانات الحديثة ومعالجة المرئيات الفضائية) فان هذه العملية هى عالية التكاليف. وللحصول على الأحصاءات الزراعية بمصداقية عالية فى مثل هذه التطبيقات – فانه يوصى بتنفيذ هذه التقانات تحت ظروف الزراعات المجمعة (فى دورات زراعية) وايضا تحت ظروف الزراعة الحديثة بالاراضى المستصلحة حديثا– حيث تكون مساحات الحقول كبيرة ومنزرعة تحت ظروف رى متماثلة لأستخدام موحد– وفى الجانب الأخر فان استخدام هذه التقانات تحت ظروف تفتت الملكية الزراعية وصغر مساحة الحقول والمنزرعة بخليط من محاصيل متنوعة مع اختلاف ظروف الرى (رطوبة التربة) ونظام الخدمة . هذه الظروف مجتمعة تؤثر سلبا على دقة الأحصائيات المتحصل عليها وذلك لصعوبة الفصل الكامل لقيم البصمة الطيفية للمحاصيل.