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IDENTIFICATION OF VARIABILITY IN VEGETATIVE GROWTH OF SOME WINTER WHEAT VARIETIES UNDER ECOLOGICAL AGRICULTURE WITH NDVI

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Abstract

Early recognizing of plant growth variability can aid in identifying yield-limiting factors such as genotype, soils, nutrient availability and/or environmental limitations.
Normalized Difference Vegetation Index (NDVI) is considered as a potential screening tool for estimation of grain yield in wheat. NDVI has been associated with percent ground cover, leaf area index (LAI), biomass accumulation, and nitrogen use efficiency. In this study we use NDVI to established variability in growth of several winter wheat genotypes and relationships with grain yield under ecological agriculture system. For recording the value of NDVI, Green seeker (Trimble) was used. NDVI values were measured at different stage of vegetations through the growing seasons of 2017-2018 in winter wheat (Triticum aestivum L.) grown at southeast part of Romania (Fundulea) on cambic chernozem soil and 1-2-3-4 years alfalfa stands. Results showed differences in growth of different winter wheat genotypes could be identified with NDVI index. At the stage of tillering, stem elongation and anthesis the relationship between LAI and NDVI is positive and linear while during at grain filling and maturity stage were not correlations. The relationship between NDVI and grain yield was also established. There was the simple correlation between grain yield and NDVI scores at the time of tillering, stem elongation and anthesis, in both seasons, and insignificant association between grain yield and NDVI was also found at grain filling and maturity stage. This demonstrated the opportunity to use this index in characterizing production potential of different winter wheat cultivars under ecological agriculture system.

Key words*: vegetative growth, winter wheat, ecological agriculture, normalized difference vegetative index.*

INTRODUCTION

NDVI is a satellite product that measures the vigour and greenness of vegetation on the earth’s surface. It is calculated as the ratio of visible spectral wave bands to near-infrared spectral wave bands. Healthy, green vegetation has a high presence of chlorophyll pigment, which causes low reflectance in visible wave bands and high reflectance in near-infrared wave bands. The reverse is true in vegetation under stress. NDVI is a unitless index, with values ranging from −1 to 1. Healthy vegetation has the highest positive values, while bare soil, water, snow, ice, or clouds have NDVI values of zero or that are slightly negative (Mkhabela et al., 2005). In present there are many portable instruments which are able to measure NDVI. This could be used as a potential screening tool for estimation of grain yield in wheat and many studies were performed in this sense especially under conventional agriculture system. In this study we use NDVI index to established variability in growth of two winter wheat genotypes in culture pure and two mixtures of these and relationships with grain yield under ecological agriculture system.

MATERIALS AND METHODS

The experiments were carried out at National Agricultural Research and Development Institute Fundulea, Ecological Research Center, during 2017-2018, on cambic chernozem soil. The experiment was with randomized complete block design (RCBD) with split plot arrangement having four replications. The plot size was 15 m × 1.5 m. The experimental variants were: year, cultivar and different year alfalfa stands. We used two cultivars (Glosa and Izvor) as pure culture and two mixtures of these cultivars (50% Glosa + 50 Izvor and 25% Glosa and 75% Izvor) and as previous plants was soybean and 1-2-3-4 years old alfalfa stands.

Normalized Difference Vegetation Index (NDVI) was measured by a spectroradiometer (Green-Seeker Hand Held Crop Sensor, Trimble unit), above the canopy at 50 cm height at different growth stages (tillering, stem elongation, anthesis, grain filling, and maturity - milk).
The leaf area was record with leaf area meter (LAI 2000.).
The yield was determined by weighing the seeds after harvesting

RESULTS AND DISCUSSIONS

The years of experimentation were totally different from the viewpoint of quantity and monthly repartitions of rainfall. In 2017, the cumulated rainfall during April - June exceeded with 55 mm the normal of the zone (180.6 mm), suggesting favourable conditions for winter wheat crop.
But the cumulated rainfall during June exceeded only with 22.1 mm the normal of the zone (74.3 mm), suggesting more little favourable conditions for grain filling than in 2018 (Figure 1).

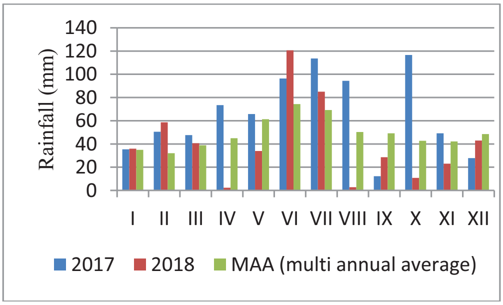

Figure 1. Rainfall during years of experimentations

Concerning temperatures, in 2018, the average of temperature during April and May exceeded the normal of the zone with 4.6°C and 2.5°C respectively, while in 2017 in the same period the temperatures were lower by 0.6 and 0.2°C respectively (Figure 2).
In 2018, the moisture deficits from April up to May created unfavourable conditions during stem elongations and reproductive organs appearance but the cumulated rainfall during June exceeded with 46.3 mm the normal of the zone (74.3 mm), suggesting favourable conditions for grain filling (Figure 1).

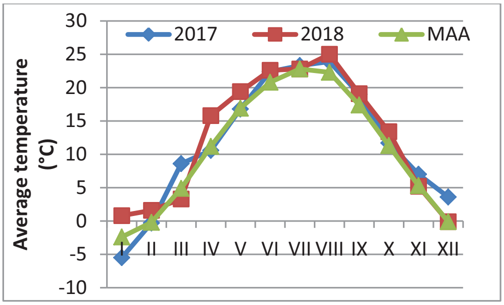

Figure 2. Monthly temperature during years of experimentations and multi annual temperatures (from 1960 to 2018)

The values of leaf area index LAI were the highest in 2018 year for all cultivars. The lowest value was recorded by all cultivar at maturity. The peak LAI was the highest for Glosa cultivar at anthesis in 2018 year conditions and lowest value was recorded by the same cultivar at maturity. During 2017 the highest values was reached by Mixture 2 at all stage of vegetations (except stem elongation) (Table 1).

Table 1. The dynamics of leaf area index for winter wheat cultivars and mixtures at different growth stages during 2017 and 2018 conditions

Winter wheat cultivars and mixtures	Tillering	Stem elongation	Anthesis	Grain Filling	Maturity
2017					
Glosa	1.35	2.75	2.71	2.92	1.31
Izvor	1.25	2.55	2.69	2.15	1.28
Mixture 1 (75% Izvor+25% Glosa)	1.33	2.5	2.75	3.12	1.54
Mixture 2 (50 % iz + 50% Glosa)	1.38	2.49	2.81	3.05	1.51
2018					
Glosa	1.85	2.85	3.21	1.42	0.45
Izvor	1.73	2.65	2.95	0.98	0.82
Mixture 1 (75% Izvor+25% Glosa)	1.8	2.73	2.98	1.51	1.13
Mixture 2 (50 % iz + 50% Glosa)	1.78	2.56	2.98	1.42	0.95

The NDVI reached a maximum during anthesis and started to decline from this date onwards (Table 2).
Many researchers concluded that increases in red reflectance were related to the decreases in chlorophyll content resulting from lower N supply, decreases in NIR reflectance mostly responded to decreases in LAI and green

biomass, as has been widely reported for wheat crops, (Jensen et al., 1990; Fiela et al., 1995).

Table 2. Effect of different wheat cultivars and mixtures on NDVI score at different growth stages

Winter wheat cultivars and mixtures	Tillering	Stem elongation	Anthesis	Grain Filling	Maturity
2017					
Glosa	0.37	0.52	0.53	0.50	0.31
Izvor	0.33	0.47	0.51	0.48	0.28
Mixture 1 (75% Izvor+25% Glosa)	0.42	0.57	0.55	0.50	0.3
Mixture 2 (50 % iz + 50% Glosa)	0.44	0.48	0.56	0.48	0.3
2018					
Glosa	0.6	0.68	0.78	0.42	0.34
Izvor	0.53	0.62	0.76	0.43	0.33
Mixture 1 (75% Izvor+25% Glosa)	0.53	0.58	0.75	0.51	0.22
Mixture 2 (50 % izvor + 50% Glosa)	0.54	0.5	0.72	0.42	0.31

We can observe that at grain filling stage NDVI decreases only with 0.08 in 2017 while during 2018 reached up to 0.42, because crop becomes under stressed and its capacity to absorb PAR is reduced. Fernandez et al. (1994) described that NDVI score reached up to 0.4 in productive environments which have high LAI thus showing the vigorous crop canopy as dark foliage.

At the stage of tillering, stem elongation and anthesis the relationship between LAI and NDVI is positive and linear (r = 0.95, 0.68, 0.92) (Figures 3, 4 and 5) while during the grain filling and maturity stage were not correlations, as Figures 6 and 7 shows.

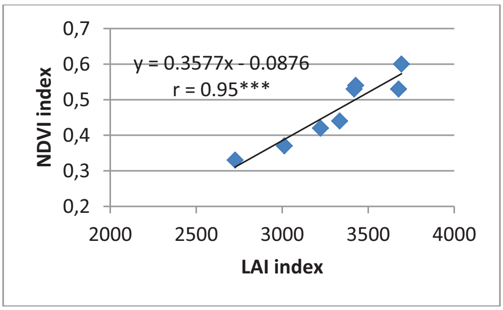

Figure 3. The relationships between leaf area and NDVI index during tillering stage in years of experimentations

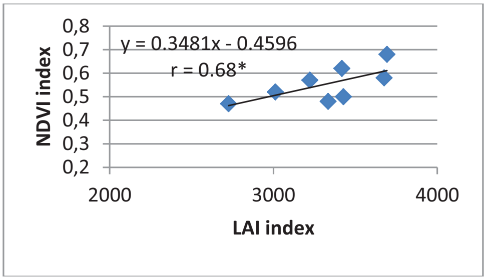

Figure 4. The relationships between leaf area and NDVI index during stem elongation stage in years of experimentations

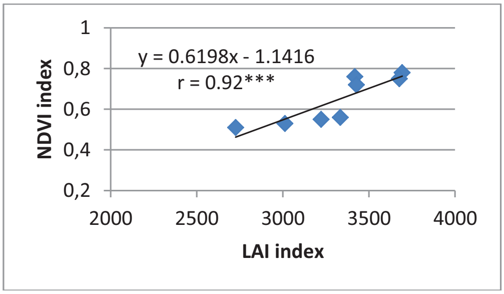

Figure 5. The relationships between leaf area and NDVI index during anthesis stage in years of experimentations

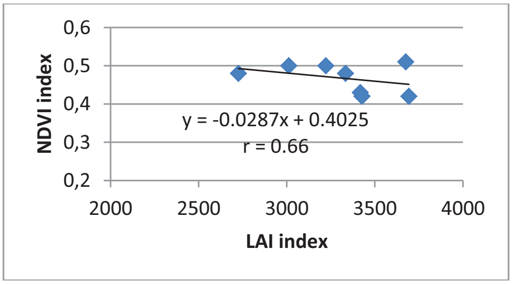

Figure 6. The relationships between leaf area and NDVI index during grain filling stage in years of experimentations

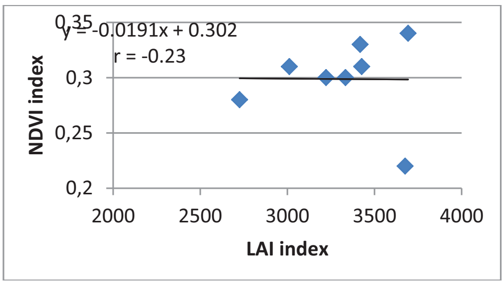

Figure 7. The relationships between leaf area and NDVI index during maturity stage in years of experimentations

Our results are in concordance with onother studies which shown that a variation in LAI implies different intercepted radiation that, according to the Radiation Use Efficiency (RUE), is directly related to the production of biomass that will determine the possible yield (Carcova et al., 2003).
Martin and Heilman (1986) found that spectral vegetation indices were highly correlated with LAI at small research plots.
Other studies at paddy rice also showed that there were statistically sign cant correlations between LAI and spectral vegetation indices derived from the NOAA Advanced Very High Resolution Radiometer (AVHRR) sensors (Lu 1997, Zhao et al. 1993; 1996)
The analysis of variance for NDVI shows the very significant influence of the years, the genotypes but also their interaction on this character. The highest variance being given by factor B (year) (Table 3).

Table 3. Analyses of variance for NDVI

Source of variance	Degree of freedom	Mean square	S2	F factor and significance
Factor A (cultivar)	3	0.01715	0.00571	8.65***
Error	9	0.0059	0.00066	
Factor B (year)	1	0.2182	0.2182	187.27***
A x B	3	0.0275	0.00919	7.89***
Error	12	0.0139	0.00116	

***significant differences for P<0.001

Concerning the yield, analysis of variance revealed the very positive effect of the cultivars in both years, while under moderate stress (2018) there was a significant difference (P<0.001) for yield between studied old alfalfa stands (Table 4).

Table 4. Analysis of variance for the yield

Source of variance	Degree of freedom	F factor and significance 2017	F factor and significance 2018
Factor A (cultivar)	3	5.98***	19.98**
Error	9		
Factor B (old alfalfa stands)	3	2.86	23.80***
A x B	9	0.69	0.12
Error	36		

Glosa in pure culture and mixture 1 and 2 showed higher grain yield in 2018 under 3 years old alfalfa stand (Figure 8).

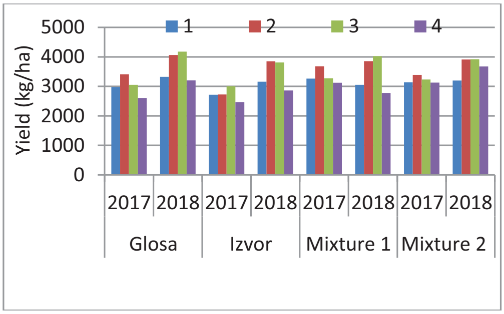

Figure 8. The yield of studied cultivars under 1-2-3-4 year old alfalfa stands. Fundulea 2017 and 2018

Table 5 shows the simple correlation between grain yield and NDVI scores. At the time of tillering, stem elongation and anthesis, these relationships were highly positively correlated in both seasons, and insignificant association between grain yield and NDVI was also found at grain filling and maturity stage.
Other study in conventional agriculture system showed a clear association between grain yield and NDVI measured but at maturity stage correlation between grain yield and NDVI was greater than NDVI values recorded at different growth stages (Syeda Refat et al., 2014).

Table 5. The relationships between NDVI scores at different stage of vegetation and the yield

Stage of vegetation	Coefficient of correlation (r) between yield x NDVI
Tillering	r = 0.93***
Stem elongations	r = 0.68**
Anthesis	r = 0.86***
Grain filling	r = 0.36
Maturity (milk stage)	r = -0.0097

***significant differences for P<0.001
**significant differences for P<0.01

The statistical analysis indicated there was a significant difference (P<0.001) for NDVI index between compared cultivars and previous crop. The variation due to the old alfalfa stands (factor B) was greater than that due to the cultivar (factor A) or the interaction of the two factors in both years of experimentation (Table 6).

Table 6. Analysis of variance for NDVI index at stem elongation

Source of variance	Degree of freedom	F factor and significance 2017	F factor and significance 2018
Factor A (cultivar)	3	20.64***	6.37**
Error	9		
Factor B (old alfalfa stands)	3	47.33***	71.90***
A x B	9	4.79***	1.38
Error	36		

***significant differences for P<0.001
**significant differences for P<0.01

The higher values of NDVI was reached by Glosa cultivar under 2 and 3 years old alfalfa stands in both years of experimentations. The higher temperatures from spring of 2017 (4.6°C over the normal of the zone in April) accelerated the growth of the plants which explains the higher values of NDVI in this year for all studied cultivar. Also, we can have observed that the higher values of NDVI were recorded in 2 and 3 years alfalfa stands as compared with 1 and 4 years old alfalfa stands (Figure 9). This may be in concordance with some studies which suggests that alfalfa 2-3 years long stands have the potential of making significant benefits to soil N status.

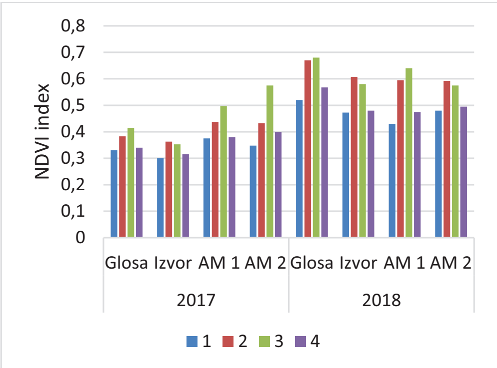

Figure 9. NDVI index of studied cultivars at stem elongation under 1-2-3-4 year old alfalfa stands. Fundulea 2017 and 2018

Also, it is obviously that under 2017 conditions mixture of winter wheat genotypes (especial mixture 2, in proportion of 50:50) have higher values of NDVI than NDVI of pure winter wheat genotypes. Matching with the studies performed by Toncea et al. (2017; 2018) shown that in ecological agriculture, the yield of the mixture of winter wheat genotypes is, often, equal or high, with about 230 kg/ha than yield of pure winter wheat genotypes.

CONCLUSIONS

The potential of NDVI to differentiate wheat cultivars for grain yield under different years and ecological agriculture was demonstrated. The NDVI was able to differentiate cultivars at different growth stages.

Under ecological agriculture system the NDVI scores at the tillering, stem elongation and anthesis stages can be used as yield predictors in wheat; the study showed a clear association between grain yield and NDVI measured at these growth stages.

The highest NDVI values have been obtained where in crop rotation alfalfa was cultivated for 2-3 years.

Under more stressful condition NDVI measurements reveals that wheat varieties mixtures are more intense green coloured.

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