

RELATIONSHIPS OF NDVI AND CHLOROPHYLL CONTENT WITH YIELD COMPONENTS OF DIFFERENT ACCESSIONS OF *Phaseolus vulgaris* L. AND VIGNA (*Vigna unguiculata* L. Walp.)

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Abstract

The aim of this study was to investigate the relationship between NDVI, Chlorophyll and Nitrogen content in leaves with yield components of different *Phaseolus vulgaris* L. and *Vigna* (*Vigna unguiculata* L. Walp.) genotypes. Field experiment was conducted in 2024 year in the experimental field in Institute of Plant Genetic Resources, Sadovo, Bulgaria. The normalized difference vegetation index (NDVI), leaf chlorophyll content (Multy pigmentometer MPM - 100) and Nitrogen content (N-Pen) were measured on leaves directly in the field. The various plant characteristics in addition were measured such as plant height, plant weight, plant weight without pods, pod length, number of pods per plant, number of beans per pod, weight of beans per plant of cowpea (*Vigna unguiculata* L. Walp.) and common beans (*Phaseolus vulgaris* L.). It was found that NDVI index has positive significant correlation with Chlorophyll ($r = 0.69$) and higher between N and chlorophyll ($r = 0.75$). It was also found the morphological traits studied characteristics as days to flowering, plant weight, number of seeds in pod showed higher correlation with chlorophyll index in compare to NDVI and N content.

Key words: NDVI, chlorophyll, cowpea, yield.

INTRODUCTION

There is a growing interest in the search for rapid, non-destructive and efficient methods to assess plant physiological and biophysical parameters, plant health and food quality (Tores et al., 2020). Different types of vegetative indices based on spectral information in the visible and near-infrared regions are being compiled and searched for in order to monitor vegetation quickly and easily remotely such as normalized vegetative index (NDVI), Chlorophyll Absorption in reflectance index (CARI), Chlorophyll Index at red edge (CI green), Pigment index (PI), Photochemical reflectance index (PRI) (Veleva et al., 2022; Weiss et al., 2004) NDVI has also been shown to be related to a number of other plant parameters such as leaf area index (LAI), biomass, photosynthetic activity (Mahlein et al., 2013; Mahlein et al., 2012; Baghzouz et al., 2010; Bell et al., 2004). Leaf chlorophyll content is an important physiological parameter that can serve as an indicator of nutritional status, plant stress or senescence. The amount of chlorophyll and nitrogen in leaves provides extremely

valuable information about plants, the parameters of which have been used to assess the total photosynthetic capacity and productivity of plants. Within precision agriculture, data from different vegetation indices are used to monitor the vegetation process during different seasons. Rapid estimation of chlorophyll and nitrogen content in foliage is critical for determining the optimum fertilization requirement of crops to improve the efficiency of precision agriculture (Haboudane et al., 2004). *Phaseolus vulgaris* L. and *Vigna* (*Vigna unguiculata* L. Walp.) are grain legumes, high protein crops, and beans are one of the main traditional legumes on our table in our country and in the world. (Abebe & Alemayehu, 2022; Hall et al., 2003) *Vigna unguiculata* L. Walp. as known as cowpea is characterised by smaller seeds, a rough or smoother surface and a well coloured hilum. *Vigna* is known for its tolerance to high temperatures and drought, characterising it as highly adaptable to global climate change with pronounced warming and drying during the growing months (Tzanova et al., 2023; Barros et al., 2021). Although spectral reflectance indices have been used to assess yield in cereals such as wheat,

barley, rice information on the performance of these indices for bean and cowpea is needed.

MATERIALS AND METHODS

Field experiment was conducted in the experimental field in Institute of Plant Genetic Resources, Sadovo, Bulgaria in 2024 year. 24 genotypes of cowpea (*Vigna unguiculata* L. Walp.) and 20 common bean (*Ph. vulgaris* L.) with different geographical origins were included in the study (Tsanova et al., 2023). Sowing was carried out manually, with a row spacing of 70 cm, an intra-row spacing of 5 to 10 cm depending on the seed size, a sowing depth of 5-6 cm (bean) and 4-5 cm (cowpea). The studied legumes were grown without irrigation. Weed control is brought out by several hand hoeing of the row spacing and weeding inside the row. Harvesting of beans and vigna was done manually at the stage of full maturity of the beans (90-95%). At the beginning of the growing season, a representative plant was marked from the germinated plants for each of the genotypes studied. The normalized difference vegetation index (NDVI) with Plant Pen 310 (PSI, Czech Republic), leaf chlorophyll content (Multy pigmentometer MPM - 100) and Nitrogen content (N-Pen, PSI, Czech Republic) were foliar measured directly in the field. (Figures 1 and 2) Field measurements of leaves from tagged plants were carried out at the following phenophases: pre-flowering, flowering and pod formation. The various plant characteristics in addition to grain yield were measured such as number of days to full flowering, plant height (cm), plant weight (g), plant weight without pods (g), pod length (cm), number of pods per plant, number of beans per plant, number of beans per pod, weight of beans per plant (g) of cowpea (*Vigna unguiculata* L. Walp.) and common beans *Phaseolus vulgaris* L.



Figure 1. Portable spectral device multipigmentometer MPM - 100 (Opti-science, USA)



Figure 2. Portable spectral device N-Pen (PSI - Photon Systems Instruments, Czech Republic)

RESULTS AND DISCUSSIONS

It was found that NDVI values between 0.33 and 0.77 for bean genotypes, with a mean value of 0.77. According to cowpea plants, NDVI values were between 0.62 and 0.77, with a mean of 0.73. The vegetative index varied very narrowly in the leaves of cowpea samples with SD = 0.03, in contrast to the bean samples with SD = 0.10. The histogram (Figure 3) presents a more detailed reading of the NDVI variations in the different phases of the studied legumes. The highest NDVI index was recorded during the pre-flowering period of both legumes, after which it started to decrease until pod formation, as NDVI decreased to 0.62 in cowpea leaves and twice as low as 0.33 for bean leaves. (Figure 4)

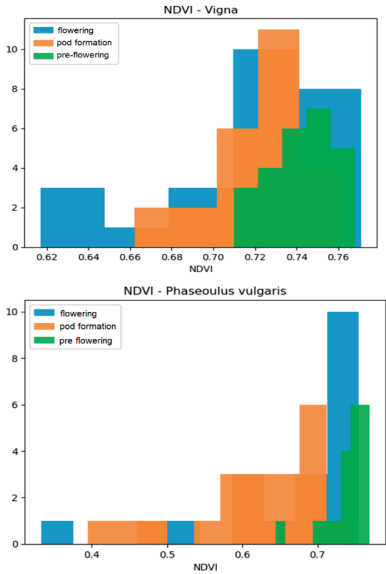


Figure 3. Histogram for NDVI in leaves of *Ph. Vulgaris* and *V. unguiculata*

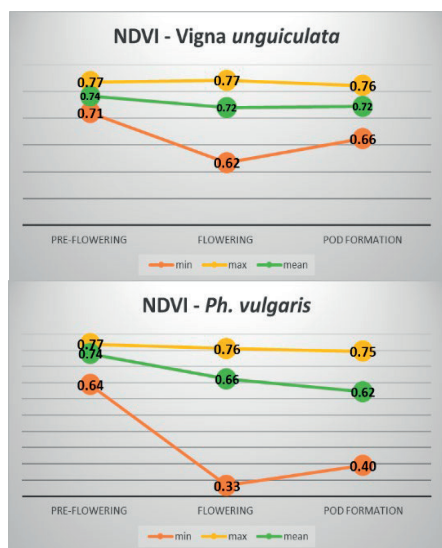


Figure 4. Trends of min., max. and mean NDVI values in leaves of *V. unguiculata* and *Ph. vulgaris*

Table 1. Discriptive statistics of yield components in *Phaseolus vulgaris* L. and *Vigna unguiculata*

Yield components	range	mean	SD
<i>Vigna unguiculata</i>			
Days to full flowering	13-15	13.7	0.98
Plant height, cm	28.0-88.0	44.0	14.7
Plant weight, g	28.0-269.8	95.2	63.9
Plant weight without pods, g	22.2-234.1	80.4	58.2
Pod length, cm	8.5-14.1	11.6	1.6
Number of pods per plant	5.0-20.0	9.6	4.1
Number of beans per pod	5.0-15.0	7.6	2.7
Weight of beans per plant, g	4-25.5	10.2	5.8
<i>Phaseolus vulgais</i>			
Days to full flowering	30-45	43.5	4.8
Plant height, cm	28.0-92.0	52.8	19.4
Plant weight, g	16.0-42.7	24.6	8.6
Plant weight without pods, g	4.4-34.5	20.9	9.1
Pod length, cm	4.5-11.0	6.5	1.9
Number of pods per plant	2.0-7.0	3.8	1.7
Number of beans per pod	1.0-5.0	2.8	1.2
Weight of beans per plant, g	0.5-7.7	2.2	2.3

Chlorophyll values by a portable device showed that the range of chlorophyll units was higher between 0.21 and 1.92 in cowpea plants while the range in bean leaves was smaller between 0.15 and 1.37 (Figure 5). The chlorophyll content of bean leaves decreases from the beginning of vegetation - flowering till pod formation. For instance, the mean value for chlorophyll at the beginning of leaf petal measurement was 0.80, decreased to 0.52 during flowering and reached to 0.47 during to the pod

formation. While in cowpea plants, an increase in the maximum values at the beginning of the vegetation from 1.38 to 1.92 during pod formation and a slight decrease in the minimum values from 0.44 to 0.19 during flowering to 0.15 in the last phase of cowpea development was observed.

Several studies have shown that cowpea is able to maintain high leaf water potential or high relative leaf water content during water stress by closing stomata and thus reducing dehydration (Souza et al., 2010). Studies based on chlorophyll fluorescence estimates in *Vigna unguiculata* the photosystem in these plants is quite resistant to water deficit. Only under extreme dry conditions inhibition of the photosynthetic apparatus can be reported. According to the authors, the reduction of CO₂ assimilation levels in water-stressed cowpea plants is largely dependent on stomata closure, which reduces available internal CO₂ and limits water loss by transpiration. This response appears to be effective in preventing a large reduction in leaf water potential and therefore appears to be the basis or avoiding dehydration in *V. unguiculata*.

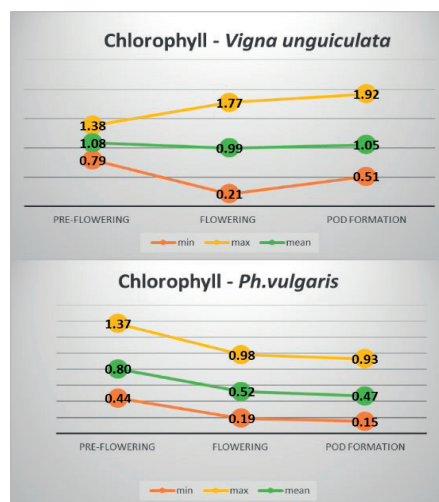


Figure 5. Trends of min., max. and mean Chlorophyll values in leaves of *V. unguiculata* and *Ph. vulgaris* during the three monitoring stages

For the both legumes, a decreasing trend in nitrogen content was observed during plant development. In the case of cowpea, a lesser decrease was recorded, with the mean values decreasing from 12.88 during pre flowering to

10.05 at the flowering period and reaching 9.16 at the pod formation. While in beans the decreasing trend is more from 11.39 to 5.89 to 3.94 - the decrease is 75% while in cowpea it is only 40%. The data presented on yield components found that there were relatively large differences in the measured components in different samples of the two legumes. (Table 1) Pearson's correlation coefficient was calculated to establish the relationship between the components measured by the portable devices and the yield components (Table 2).

Table 2. Pierson's coefficient between chlorophyll, NDVI and N contents and yield components of common bean *Ph. vulgaris* L. and cowpea (*V. unguiculata*)

	<i>N</i>	<i>NDVI</i>	<i>ChlM</i>
N	1.00		
NDVI	0.69	1.00	
ChlM	0.75	0.62	1.00
Days to full flowering	0.39	0.32	0.57
Plant height, cm	-0.02	0.01	-0.13
Plant weight, g	0.33	0.24	0.52
Plant weight without pods, g	0.34	0.23	0.52
Number of pods per plant	0.22	0.23	0.44
Weight of beans per plant (g)	0.23	0.23	0.42
Pod length (cm)	0.27	0.31	0.45
Number of beans per pod	0.28	0.28	0.51
Weight of beans per plant (g)	0.20	0.19	0.40

The highest correlation was found between nitrogen and chlorophyll content with $R = 0.75$, followed by nitrogen and NDVI with $R = 0.69$. A significant correlation was observed between chlorophyll and NDVI with $R = 0.62$.

As can be seen from the presented data on field components, there were relatively large differences in the measured indicators of the representatives of the two types of legumes. For example, plant height in cowpeas varied between 28.0 and 88.0 cm, while in beans the range was larger, between 28.0 and 92.0 cm. At optimal plant density, grain yield depends on the value of its structural components. The structural elements of yield, such as number of pods and seeds per plant, weight of pod and seeds per plant are indicators of type and varietal characteristics and as such are relatively constant values. A difference was found in the weight of the plant and the weight of the plant without pods, with data on the weight of the plant without pods varying between 22.2 and

234.1 g for cowpea and between 4.4 and 34.5 g for *Ph. vulgaris*. The number of pods per plant was between 5 and 20 for cowpea and between 2 and 7 for common bean. The aim of our study was to establish the relationship between morphological components obtained with spectral data of chlorophyll, NDVI and nitrogen values. In this regard, the large range between the values of the components of interest was obtained from different bean and cowpea samples, which is important for the higher precision of the study.

According to the obtained correlation coefficients, it was found that chlorophyll values a direct correlation with most of studied yield components. For example, a positive correlation was observed between chlorophyll content and days before mass flowering where $R = 0.57$. According to morphological parameters, such as plant weight and plant weight without pods the values of $R = 0.52$. For the reproductive organs, such as pods and beans, their number and weight, the correlation was found with the chlorophyll and the number of beans per pod with $R = 0.51$. Similar results were by reported Ramesh et al. (2002) for rice yield, the leaf chlorophyll content at 79 days after sowing correlated well with the grain yield of rice. Multiple regression models also indicated the dependence of rice yield on leaf chlorophyll content before and after flowering. The study of Islam et al. (2014) demonstrated also the importance of using SPAD mater for chlorophyll content in determining wheat yield under variable fertilizer management under field conditions.

CONCLUSIONS

The highest NDVI index in both legumes was recorded during the pre-flowering, after which there was a decline to the pod formation phase. The chlorophyll content in the leaves of the *Ph. vulgaris* accessions decreased from flowering to the pod formation, while the chlorophyll content in the leaves of cowpea (*V. unguiculata*) accessions was relatively stable with average values ranging from 1.08 to 1.05 from pre flowering to pod formation.

In both legumes, a decreasing trend in nitrogen content from the pre flowering to pod formation and maturation was observed, with a much

greater decrease of 75% in beans, while only 40% in cowpea. The results obtained for the relationship between the measured vegetative indices and yield components of the two legumes revealed that chlorophyll index was more significant compared to NDVI.

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