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Reflectance Measurement of N, P and K Content of Wollypod Vetch under Different N, P and K Fertilization

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The objective of this study was to determine the relationships between nitrogen, phosphorus and potassium content of wollypod vetch (*Vicia villosa* ssp dasycarpa (Ten.) Cav) and spectral reflectance. Visible near-infrared reflectance spectroradiometer (VNIR) was used to predict the N, P and K content of wollypod vetch under different N (0, 20, 40, 60 and 80 kg ha), P (0, 30, 60, 90 and 120 kg ha) and K (0, 20, 40, 60 and 80 kg ha) fertilization. An experiment was conducted in the 2006 growing season in the Mediterranean region conditions of Turkey. Increasing N fertilization decreased spectral reflectance from 1.18 to 0.78 %. The highest spectral reflectance was obtained from control plot (1.19 %), while the least spectral reflectance was obtained from 60 kg ha P dose (0.82 %) in P fertilization. In K fertilization, the highest spectral reflectance was obtained from control plot (1.19 %), while the least spectral reflectance was obtained from 40 kg ha K dose (0.90 %). Woolypod vetch N, P and K content had high correlation with spectral reflectance. In N fertilization, the r^2 of predicted and measured N, P and K were high (0.935, 0.797 and 0.884, respectively). In P fertilization, the r^2 of predicted and measured N, P and K were (0.800, 0.886 and 0.928). In K fertilization, the r^2 of predicted and measured N, P and K were (0.911, 0.851 and 0.859, respectively). Present results suggest that spectral reflectance in VNIR can be used for non-destructive prediction of forage N, P and K content in wollypod vetch under different fertilizations.

Key Words: Visible near-infrared reflectance spectroradiometer, Reflectance, Fertilization.

INTRODUCTION

Reflectance measurements offer a more rapid and less expensive assessment of growing conditions than traditional chemical analysis using leaf tissue or plant sap. Reflectance measurements to quantify plant growth and nutrient stress at the field level during a growing season may be an

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appropriate tool to decide on fertilization application and timely correction of nutrient shortages before irreversible growth damage occurs[1]. Near infrared reflectance spectroscopy (NIRS) has been proposed as a method for the rapid evaluation of the chemical composition, associated quality attributes and physiological properties of forages[2]. Nitrogen, phosphorous and potassium are mainly responsible for plant development and health; therefore they determine nutritional quality of forage for herbivores[3]. A relationship between spectral reflectance, particularly visible absorption and macronutrients such as phosphorous, potassium, magnesium and calcium is expected due to their effect on the photosynthetic process in plants[4,5]. For example, phosphorous is fundamental to tissue composition as well as one of the components of the nucleic acids and enzymes. Potassium is also important, both for activating enzymes responsible for the metabolism of carbohydrates and in the apical dominance[6]. These elements are therefore responsible for both the photosynthetic process and the tissue composition of plants[7]. Nitrogen exhibits specific absorption features in the shortwave infrared[8] and is also responsible for the metabolic function of the chlorophyll. The objective of this study was to determine the relationships between nitrogen, phosphorus and potassium content of wollypod vetch and spectral reflectance under different fertilizations.

EXPERIMENTAL

This study was conducted at Isparta (37º 45' N, 30º 33' E, elevation 1035 m) located on the Mediterranean region of Turkey in 2006. The monthly rainfall for March through June was 105.5, 38.9, 43.8 and 32.3 mm (total 220.5 mm), respectively. The 30 year mean for the same months is 219.9 mm. Wollypod vetch (*Vicia villosa* ssp dasycarpa (Ten.) Cav) (Baydurbey cv) seed was obtained from Field Crops Central Research Institute of the Ankara.

The major soil characteristics, based on the method described by Rowell[9] were found to be as follows. The soil texture was clay; organic matter was 1.2 %; total salt was 0.2 %; lime was 7 %, sulphur was 11 mg kg^{-1}, extractable P was 3.7 mg kg^{-1}; exchangeable K was 109 mg kg^{-1}; pH was 7.1.

The experiment was established in a randomized block design with 3 replicates. Fertilizer applications were randomly assigned to 39 plots within each of 3 blocks. Each treatment plot was 2.1 × 5 m. In the N experiments, ammonium nitrate (33 %) was applied at 0, 20, 40 and 80 kg ha. In the P experiments, triple super phosphate (45 %) was applied at 0, 30, 60, 90 and 120 kg ha. The K experiments received potassium sulphate (50 %) at 0, 20, 40, 60 and 80 kg ha. All fertilizers were broadcast on the surface. When the plots had 50 % flowers (in June) the plots were harvested for forage yield.

Measurements: In 50 % flowering stage of wollypod vetch, spectral reflectance measurements were obtained during clear days from all plots. A portable ASD Hend Held spectroradiometer was used to collect the spectral reflectance data. The ASD measures spectral reflectance in the 325-1150 nm wavelength range with a 1 nm sampling interval. The optical sensor of the spectroradiometer was mounted on a boom 1.5 m above and perpendicular to the soil surface. The radiometer had 10° field of view, producing a view area with a 0.89 m diameter. A Spectralon reference panel (white reference) was used to optimize the ASD instruments for taking canopy reflectance measurements at each sampling plot. The canopy reflectance data were expressed as relative values by dividing them by the white reference panel reflectance readings[10].

All plots were clipped within 1 cm of the ground surface in 50 % flowering stage after canopy reflectance measurements. Wollypod samples were immediately dried, weighed and ground for determinations of N, P and K content according to standard laboratory producers. The N analysis was made according to the kjehldal method. The analysis of P and K were made in the samples extracted by fresh-burn method[11,12].

Data analysis: The reflectance values measured by VNIR spectroradiometer in different fertilization applications were recorded *via* ASD ViewSpect® software. The highest reflectance per cent was determined as 762 nm wavelength. Reflectance values at this wavelength were separately recorded for each fertilization application. Then regression analysis applied to plant N, P and K content between reflectance values (%) and laboratory analysis. Predicted values for N, P and K content were obtained by using regression equations. In conclusion, r^2 values were estimated as a result of the regression analysis between measured and predicted values.

RESULTS AND DISCUSSION

Nitrogen content ranged between 2.24 and 3.15 %, P was between 0.12 and 0.15 % and K between 1.09 and 1.16 % by N fertilization (Table-1). N ranged between 2.24 and 2.81 %, P was between 0.12 and 0.17 % and K between 1.09 and 1.41 % by P fertilization. N ranged between 2.24 and 3.01 %, P was between 0.12 and 0.15% and K between 1.09 and 1.45 % in the 50 % flowering stage by K fertilization in wollypod vetch. In the N fertilization, the highest N, P and K content was determined in 60 kg ha N dose (3.15, 0.15 and 1.16, respectively). 60 kg ha P dose application gave higher N, P and K contents more than other P doses applications (2.81, 0.17 and 1.41%, respectively). In the K fertilization, the highest N, P and K content was obtained from 40 kg ha K dose (3.01, 0.15 and 1.45%, respectively) (Table-1).

TABLE-1
DESCRIPTIVE STATISTICS OF N, P AND K CONTENT OF WOLLYPOD VETCH IN DIFFERENT NITROGEN, PHOSPHORUS AND POTASSIUM FERTILIZATION

Fertilization	N (%)	P (%)	K (%)
N fertilization (kg /ha)			
0	2.24	0.12	1.09
20	2.44	0.13	1.12
40	2.83	0.14	1.16
60	3.15	0.15	1.16
80	3.08	0.14	1.15
Std. Deviation	0.39	0.01	0.03
CV (%)	14.50	8.40	2.70
P fertilization (kg /ha)			
0	2.24	0.12	1.09
30	2.46	0.16	1.27
60	2.81	0.17	1.41
90	2.41	0.16	1.31
120	2.34	0.14	1.15
Std. Deviation	0.22	0.02	0.13
CV (%)	8.80	13.30	10.20
K fertilization (kg /ha)			
0	2.24	0.12	1.09
20	2.39	0.12	1.31
40	3.01	0.15	1.45
60	2.44	0.13	1.39
80	2.63	0.14	1.35
Std. Deviation	0.29	0.01	0.14
CV (%)	11.70	9.90	10.40

The wide range in wollypod vetch variables resulted from a wide variation in N rates (0-80 kg ha), P rates (0-120 kg ha) and K rates (0-80 kg ha). Application of N rates of 0 and 80 kg ha decreased reflectance from 1.18 to 0.78 % at visible near infrared wavelength (762 nm) (Fig. 1). In P fertilization, spectral reflectance varied from 0.82 to 1.19 in wollypod. The highest spectral reflectance was obtained from control plot (1.19 %), while the least spectral reflectance was obtained from 60 kg ha P dose (0.82%) (Fig. 2). In K fertilization, the highest spectral reflectance was obtained from control plot (1.19%), while the least spectral reflectance was obtained from 40 kg ha K dose (0.90%) (Fig. 3).

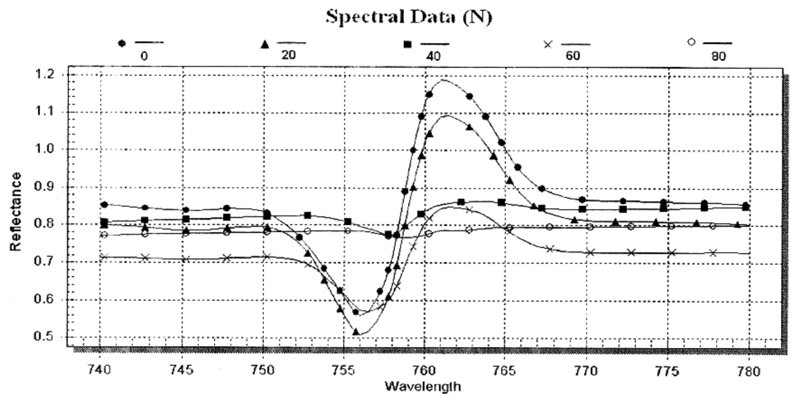


Fig. 1. Percentage reflectance (%) of wollypod vetch in nitrogen fertilization (kg ha)

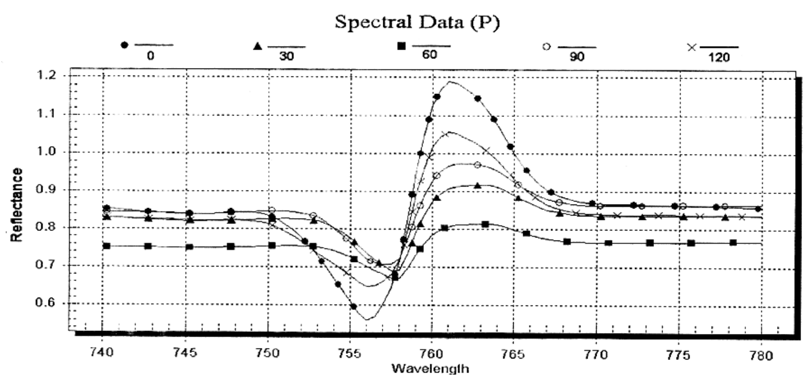


Fig. 2. Percentage reflectance (%) of wollypod vetch in phosphorus fertilization (kg ha)

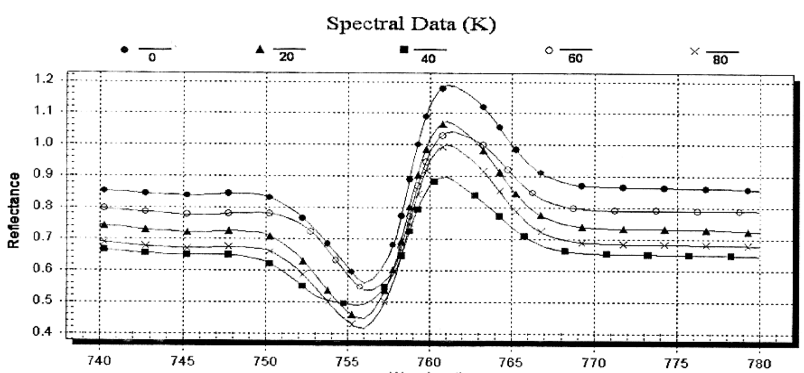


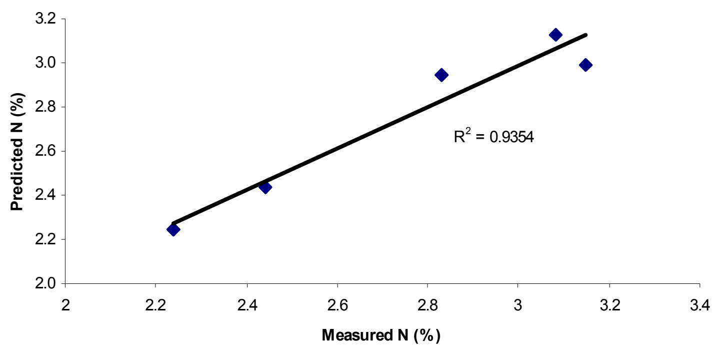
Fig. 3. Percentage reflectance (%) of wollypod vetch in potassium fertilization (kg ha)

Forage N, P and K content in the test data set were predicted by the corresponding equations of the 762 nm wavelength reflectance in Table-2. These forage variables were also predicted by the models of the regression in Table-2 on the basis of the reflectance data. Regression equations developed from the test data set were applied to the test data set for all five spectral reflectance. In N fertilization, the r^2 of predicted and measured N and K were high (0.935 and 0.884, respectively), P had low r^2 (0.797). In P fertilization, the r^2 of predicted and measured K and P were high (0.928 and 0.886, respectively), N had low r^2 (0.800). In K fertilization, the r^2 of predicted and measured N, P and K were high (0.911, 0.851 and 0.859, respectively) (Table-2; Figs. 4-6).

TABLE-2
LINEAR RELATIONSHIPS WITH FORAGE QUALITY VARIABLES OF N, P AND K CONTENT ON THE BASIS OF THE CALIBRATION DATA SET IN DIFFERENT N, P AND K FERTILIZATION

Quality parameter	Equation	Std. error	r^2
Nitrogen fertilization			
N (%)	N = 4.84-2.20 R	0.12	0.935
P (%)	P = 0.19-0.06 R	0.006	0.797
K (%)	K = 1.29-0.16 R	0.011	0.884
Phosphorus fertilization			
N (%)	N = 3.69-1.23 R	0.11	0.800
P (%)	P = 0.27-0.12 R	0.008	0.886
K (%)	K = 2.03-0.78 R	0.039	0.928
Potassium fertilization			
N (%)	N = 5.31-2.66 R	0.10	0.911
P (%)	P = 0.25-0.11 R	0.006	0.851
K (%)	K = 2.57-1.19 R	0.059	0.859

The green colour of plant canopies is generally associated with leaf chlorophyll which is positively correlated with N concentration[13]. In present studies the application of N rates of 0 and 80 kg ha decreased reflectance from 1.18 to 0.78 % at visible near infrared wavelength (762 nm). Light reflectance in the visible wavelengths (400-700 nm) increases with N deficiency[14,15] because of chlorophyll reduction. Nguyen and Lee[16] reported that leaf N and chlorophyll concentration and content increased by N application. These results are consistent with present results. Several publications[6,17,18] have shown a strong relationship between the concentration of N and the concentrations of chlorophyll a and b. Nitrogen is related



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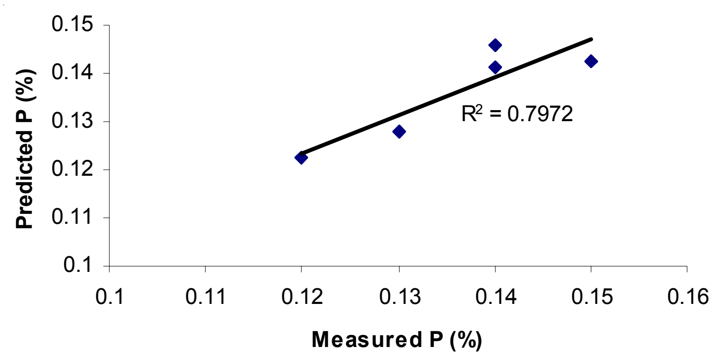

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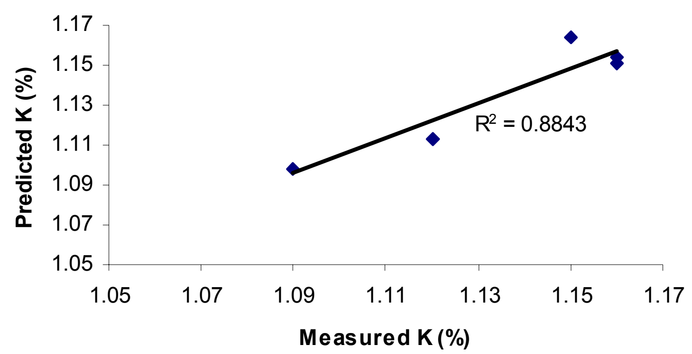

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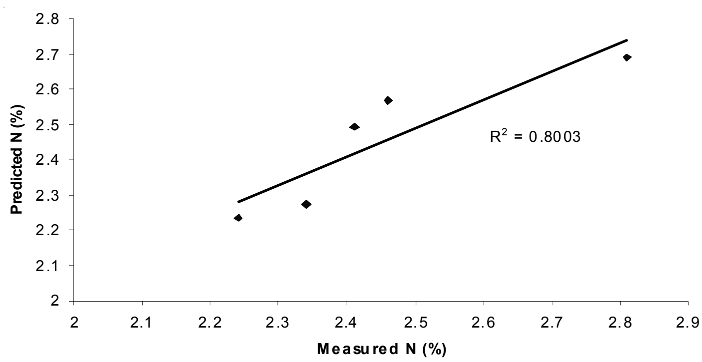
Fig. 4. Comparison of laboratory measured forage N, P and K content in the test data set with their predicted values based on the equations developed with spectral reflectance in nitrogen fertilization



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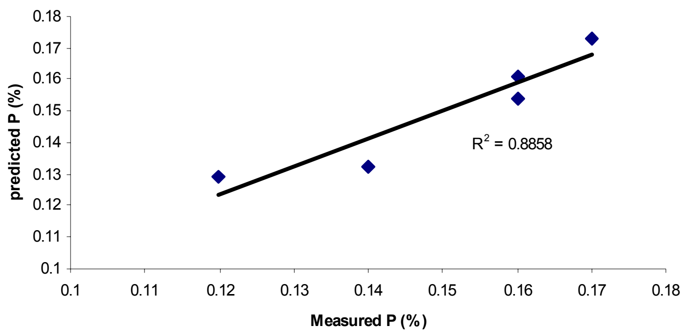

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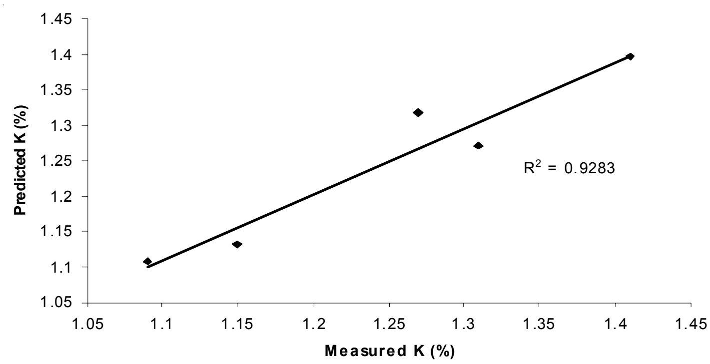

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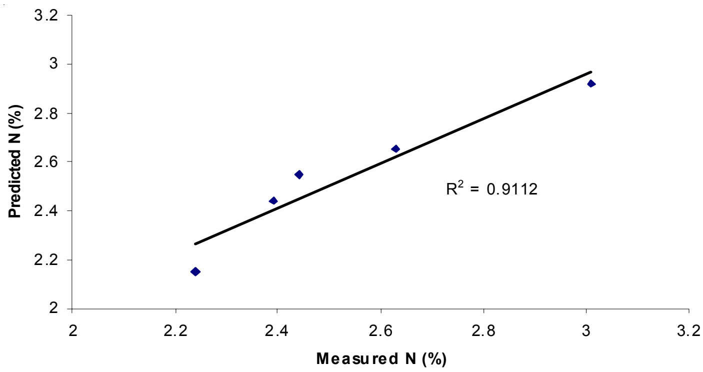
Fig. 5. Comparison of laboratory measured forage N, P and K content in the test data set with their predicted values based on the equations developed with spectral reflectance in phosphorus fertilization



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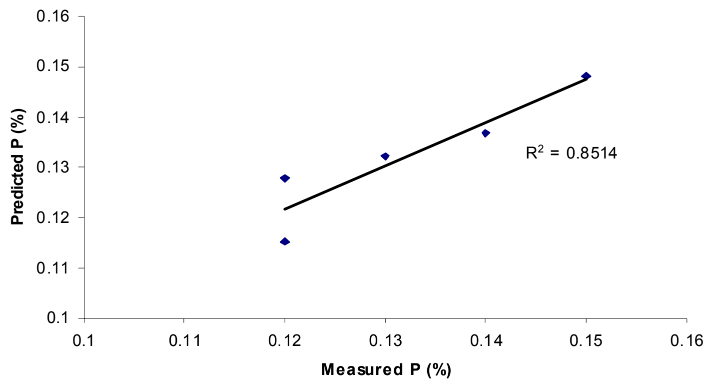

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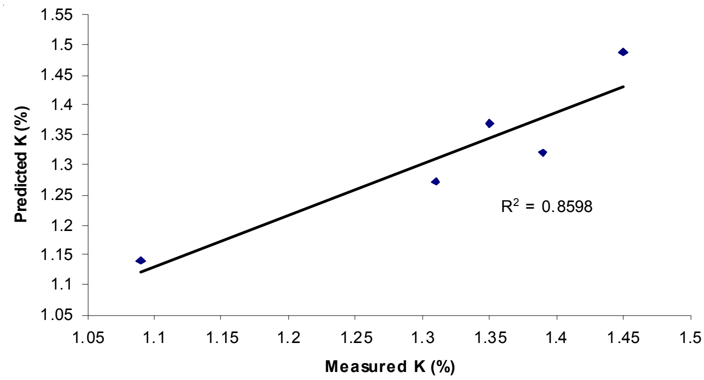

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Fig. 6. Comparison of laboratory measured forage N, P and K content in the test data set with their predicted values based on the equations developed with spectral reflectance in potassium fertilization

to the protein synthesis that promotes the photosynthetic process. Therefore, nitrogen deficiency disturbs the metabolic function of the chlorophyll, which is the photosynthetic element responsible for the absorption of electromagnetic energy at specific wavelengths in the visible region[6]. Since chlorophyll largely determines spectral reflectance in the visible region, a strong relationship between visible absorption bands and nitrogen concentration is also expected. The same applies to other biochemical such as phosphorous and potassium which are also responsible for both the photosynthetic process and tissue composition in plants.

In present study, the P was between 0.12 and 0.17% and spectral reflectance varied from 0.82 to 1.19 in wollypod in P fertilization. Vazquez de Aldana *et al.*[19] reported an r^2 of 0.53 of 0.31% P tissue for predicting P in grasses with NIRS. Similarly, Ramos *et al.*[20] reported that r^2 values between 0.49 and 0.77 in the range of 0.17 to 0.26 % P tissues for predicting P concentration in grasses. On comparison to these previous studies, most of present r^2 values were higher and present equations had higher r^2 values. Studies have shown that K deficiency in wildlife results in muscle weakness cardiac as well as respiratory failure[21,22]. In present study, the highest spectral reflectance was obtained from control plot (1.19 %), while the least spectral reflectance was obtained from 40 kg ha K dose (0.90 %) in K fertilization. Al-Abbas *et al.*[4] found that absorption at 830-1100 nm was lower for P deficient corn leaves, whereas leaves deficient in K had higher absorption in these wavelengths, this result is consistent with present results for K.

Conclusion

Increasing N fertilization decreased spectral reflectance from 1.18 to 0.78 %. The highest spectral reflectance was obtained from control plot (1.19 %), while the least spectral reflectance was obtained from 60 kg ha P dose (0.82 %) in P fertilization. In K fertilization, the highest spectral reflectance was obtained from control plot (1.19 %), while the least spectral reflectance was obtained from 40 kg ha K dose (0.90 %). Woolypod vetch N, P and K content had high correlation with spectral reflectance. In N fertilization, the r^2 of predicted and measured N, P and K were high (0.935, 0.797 and 0.884, respectively). In P fertilization, the r^2 of predicted and measured N, P and K were (0.800, 0.886 and 0.928). In K fertilization, the r^2 of predicted and measured N, P and K were (0.911, 0.851 and 0.859, respectively). Our results suggest that spectral reflectance in VNIR can be used for non-destructive prediction of forage N, P and K content in wollypod vetch under different fertilizations.

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