Phyton-
International Journal of
Experimental Botany

Tech Science Press

http://doi.org/10.32604/phyton.2026.087910

ARTICLE

# Using Chlorophyll Content and Spectral Vegetation Indices for Modeling Wheat Yield Grown under Arid Conditions in Saudi Arabia

**Khalid A. Al-Gaadi[1,2], Rangaswamy Madugundu[1], Ahmed M. Zeyada[2,*], Elkamil Tola[1] and Haroon F. Edrees[1]**

[1]Precision Agriculture Research Chair, Deanship of Scientific Research, King Saud University, Riyadh, Saudi Arabia
[2]Department of Agricultural Engineering, College of Food and Agriculture Sciences, King Saud University, Riyadh, Saudi Arabia
*Corresponding Author: Ahmed M. Zeyada. Email: azeyada@ksu.edu.sa

Received: 24 June 2026; Accepted: 29 September 2026; Published: 19 October 2026

**ABSTRACT:** Early prediction of crop yield is a key element in understanding the productivity of agricultural fields. In this context, integrating spectroscopy and plant biophysical parameters with multivariate statistical methods can improve crop growth monitoring and yield prediction, contributing to more effective agricultural management. Therefore, this study was conducted to investigate the effectiveness of leaf chlorophyll content (SPAD readings) and spectral vegetation indices (VIs) in developing yield prediction models at early growth stages of wheat with reference to actual harvested yield. VIs such as the normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), soil-adjusted vegetation index (SAVI), and the normalized difference water index (NDWI) were computed at different crop growth stages. Simple and multiple regression analyses were conducted to assess the relationships among the generated VIs and $Y_A$ for the development of predictive models for early wheat yield estimation. In contrast, the heading stage exhibited a strong and highly significant relationship between wheat yield and SPAD readings in all fields, with $R^2$ values of 0.96 (field 71), 0.65 (field 77), and 0.92 (field 81), along with the lowest RMSE values and $p \leq 0.001$, demonstrating high predictive accuracy. Using SPAD readings, heading stage provided the best prediction accuracy, with the lowest MBE (0.32 t ha$^{-1}$) and RMSE (1.59 t ha$^{-1}$), while the highest $R^2$ (0.83) occurred at the jointing stage. Using vegetation indices, the booting stage showed the most consistent performance (mean $R^2$ = 0.91; RMSE = 0.34 t ha$^{-1}$). Overall, combining SPAD readings and vegetation indices, the heading stage provided the best yield prediction performance (mean $R^2$ = 0.97; RMSE = 0.35 t ha$^{-1}$). Overall, the findings demonstrate that integrating SPAD readings with vegetation indices improves wheat yield prediction accuracy, particularly when using multi-variable models. Among the indices, EVI and SAVI performed better under dense canopy conditions, while NDWI contributed by capturing crop water status. Overall, the results showed that multivariate approaches provide more stable and accurate wheat yield predictions, with optimal performance varying across growth stages.

**KEYWORDS:** Spectroscopy; yield prediction; multivariate analysis; arid climates

## 1 Introduction

Wheat (*Triticum aestivum*) is one of the most widely cultivated cereal crops in the world because it is a staple food and the most important food security crop, contributing to global food security and providing a substantial proportion of dietary calories and protein worldwide [1]. Sustainable wheat production can be achieved through the optimal application of crop inputs and the adoption of precision farming practices, which manage different areas of the field according to spatially and temporally varying growing conditions to maximize production potential [2]. Marino [3] also pointed out that remote sensing methods, which use

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