Wheat Nitrogen Fertilizer Management Using GreenSeeker Handheld Crop Canopy Sensor

Mohammed A. Naser
Department of Combating Desertification,
College of Agriculture, Al-Muthanna University, Al-Samawah 66001, Iraq;
mohammed.naser@mu.edu.iq
DOI: 10.56201/ijaes.vol.11.no3.2025.pg12.22

Abstract

One of the essential factors in increasing agricultural yields of cereal crops is increasing the grain yield without increasing production costs. Wheat (Triticum aestivum L.) is the main crop in the food basket of the entire world. Therefore, it is necessary to determine the appropriate nitrogen (N) requirements to obtain the optimal production of wheat crops by investigating the impact of different N levels on the wheat crop yield in the Al-Muthanna region, as well as determining the possibility of predicting grain yield using the GreenSeeker handheld proximal crop canopy sensor-based differences vegetative difference index (NDVI). Thus, there is a need to re-evaluate the previous recommendations using remote sensing techniques. The experimental treatments were five levels of N fertilizer including (0 Kg N ha^{-1}, 50 kg N ha^{-1}, 100 kg N ha^{-1},150 kg N ha$^{-1,}$ and 200 kg N ha$^{-1,}$ and each N level was divided into 100%, 70%, 50% percentages, respectively. This study was conducted at the Experiment Station and Agriculture Research of the College of Agriculture-Al-Muthanna University. The NDVI measurements were obtained at FK5, FK7, and FK9 according to the Feekes scale growth stage. The results indicated significant differences in grain yield between different levels of N fertilizer and a 70% percentage outperformed on the 100% and 50% treatments for each of the two N levels of 200 and 150 kg ha^{-1}. The results also show significant differences between NDVI values for different N fertilizer levels. The NDVI readings and wheat yield values increased and followed a similar pattern with increasing N fertilizer levels. This suggests that NDVI can predict wheat grain yield when the NDVI is not saturated. This study showed the potential of using GreenSeeker proximal crop canopy sensor-based NDVI readings as a useful tool to predict wheat grain yield.

Keywords: *Wheat crop, N fertilization, NDVI, GreenSeeker, Proximal sensor.*

Introduction

Wheat (*Triticum aestivum* L.) is one of the essential cereal crops in terms of cultivated areas and global consumption. The importance of this crop is increasing due to its strategic role in food security (Naser, 2012; Ali et al., 2020). The cultivated area in Iraq reached 8,177 dunums with a productivity of 5,234 tons (Directorate of Agricultural Statistics, 2024). Most of the world's population depends on the wheat crop due to its importance in human nutrition, as it contains proteins, carbohydrates, amino acids, vitamins, and dietary fiber (Wali, 2010).

The low production issue is not limited to Iraq only. Still, it affects a majority of countries that already suffer from the increasing population in contrast to the big shortage in providing food materials, specifically cereal crops, including wheat, whose production meets more than 30% of the real requirements of the people. Therefore, researchers continuously investigate and study possible scientific means that increase wheat productivity and improve quality (Al-Baddrani and Al-Romy, 2013). Thus, the growth and production of this crop are affected by many factors, including environmental and biological factors. The most important factors are organic and mineral nutrients, including nitrogen (N). Therefore, N is considered the most important nutrient for enhancing wheat production, as it plays a critical role in plant development and is needed in large quantities. There is no nutrient as important as N for plants compared to all other nutrients, as it contributes to most physiological functions and the formation of chlorophyll, nucleic acids (RNA, DNA), carbohydrates, and proteins (Al-Badrani, 2010).

Nitrogen is the first element that determines the productivity of crops in general and cereal crops in particular, including wheat, which works to increase the quantitative and qualitative components of the wheat crop (Al-Baddrani and Al-Romy, 2013; Pandey et al., 2001). Thus, there is a great and crucial need to use N fertilizer to increase and enhance vegetation growth by speeding up many essential processes in organic materials production, including increasing dry matter and improving the quality and quantity of the crop (Peltoman, 1995; Al-Jubouri, 2011). Thus, the consumption of chemical fertilizers, including N fertilizers, has increased in recent years. However, there are negative environmental impacts and a serious risk to human health in addition to the direct effect on microorganisms in the soil due to the low efficiency of N use, which was estimated at 33% of total N applied to the soil, which translated to lose hundreds of thousands of tons nitrogen fertilizer annually (Johnson and Raun, 2003). As a result, numerous research were conducted on this crop to examine how varying N fertilizer rates affected the development and productivity of wheat crops in different parts of Iraq. Al-Badrani (2010) indicated that wheat growth and production significantly increased at 200 kg N ha^{-1} in a field experiment in the Anbar region. Likewise, Al-Bakka (2015) also showed in his study of several wheat varieties and their response to N fertilizer, as grain yield increased significantly at 400 kg N ha^{-1} in the Kufa region. Adnan et al., (2016) also point out that wheat yield improved at the levels of N fertilization of 150 kg ha^{-1}. Therefore, we see a difference in the extent of the wheat response to N fertilizer application through previous experiments, in addition to missing studies to investigate different rates of N fertilizers on the wheat yield in the Al-Muthanna region using remote sensing techniques. Also, the farmers still relied on N fertilizer recommendations produced by the Ministry of Agriculture in Iraq, but from different parts than the Al-Muthanna region. Therefore, it has become important to study the effect of N fertilizer for each region separately to know the optimal N fertilizer recommendation to increase the efficiency of N use, improve yield, and increase farmers' profits while reducing environmental pollution by using hand-held remote sensing devices, including the GreenSeeker handheld crop sensor.

This study aimed to investigate the impact of varying N fertilizer levels on wheat grain yield in the Al-Muthanna region and to identify the possibility of predicting grain yield using a GreenSeeker handheld canopy crop sensor.

Materials and Methods

Study Site

This study was carried out during the 2022-2023 agricultural winter season in silt loam soil at the Experiment Station and Agriculture Research of the College of Agriculture - Al-Muthanna University, Al-Bandar, where the soil was prepared by plowing, smoothing, and amending. Soil sampling was conducted at 0-30 cm depth and randomly from different places. Then, the soil samples were combined to obtain a single sample from each block to conduct soil physical and chemical analyses at the College of Agriculture, Al-Muthanna University laboratory as shown in Table 1.

Table 1. Summarized soil characteristics for the study experiment.

Soil Characteristic	Value	Unit
pH	7.5	-
EC	3.2	dS m^{-1}
Available N	2.15	mg Kg^{-1}
Available P	0.53	
Available K	179	
Soil particles	**Percentage (%)**	**Soil texture**
Clay	20.8	Silt loam
Silt	60.7	
Sand	18.5	

Experimental Design and Treatments

A field experimental study used a randomized complete block design (RCBD) with three replications (figure 1) and 15 experimental units for each block, totaling 45. This experiment was conducted to test five levels of nitrogen fertilizer (urea fertilizer 46% nitrogen) as a source of nitrogen fertilizer thus the nitrogen treatments were: 1- without N fertilizer (0 kg N as comparison treatment), 2- 50 kg N ha^{-1}, 3- 100 kg N ha^{-1}, 4- 150 kg N ha^{-1}, and 5- 200 kg N ha^{-1}, which symbolized by (F0, F1, F2, F3, and F4), respectively and each N fertilizer level was applied with three different percentage as 1- complete N recommendation 100%, 70%, and 50%, which symbolized by (L1, L2, and L3), respectively. The dimensions of each experimental unit were 2 m * 2 m and were divided into ten lines with an equal distance of 20 cm between lines, Moreover, a distance of 50 cm was applied cm between units to ensure that the N fertilizer does not move from one experimental unit to another as shown in Figure 1. Wheat crop (Baghdad variety) was planted on 11/24/2022 using the dry cultivation method by manually scattering the seeds directly on the planting lines and covering them with soil, with a population of 120 kg seeds ha^{-1}.

Figure 1. Field experimental plots for the wheat crop.

The field was irrigated whenever necessary, and the period between one irrigation and another varied depending on the wheat growth stages, as determined according to the Feekes scale

(Large, 1954). Moreover, weeds growing in the wheat field were manually controlled as necessary. Fertilization operations were done by applying a triple superphosphate form at a rate of 100 kg ha^{-1} as a phosphorous source and potassium as a potassium sulfate with a rate of 60 kg ha^{-1} and for one dose of both fertilizers before planting. For N fertilizer, urea was used as a source of N fertilizer, and it was spread on the surface of the field soil in two doses, the first dose after two weeks of planting and the second dose forty days after the first dose. The percentage of vegetation cover was obtained by a GreenSeeker proximal handheld canopy sensor (Trimble Navigation Limited, CA, USA) based on normalized difference vegetation index (NDVI), which was calculated using the equation as follows:

NDVI= (NIR - Red) / (NIR + Red) ------------------- (1)

Where NIR is the near-infrared wavelength light reflectance at 770 nm, and Red is the red wavelength light reflectance at 660 nm.

A GreenSeeker handheld sensor has its source light and ambient radiation does not impact it. Thus, the sensor emits light on the wheat vegetation cover, part of this light is absorbed by the vegetation cover (wheat leaves), and the other part is reflected, the sensor receives reflected light from the vegetation cover to obtain NDVI, which indicates the density of the vegetation cover and the content of chlorophyll (Naser et al., 2021). NDVI readings were measured three times during the season after 44 days of planting (FK5 growth stage according to Feekes scale), which was at the branching stage. The second NDVI readings were measured at the FK7 growth stage, which was at the emergence of the second node as presented in Figure 1. The third NDVI readings were measured at the FK9 wheat growth stage, which represented the beginning of the appearance of the flag leaf. The manual harvesting process was done on 4/29/2023 after the appearance of signs of physiological maturity, yellowing, and drying of all parts of the plant to obtain the total yield of the wheat crop.

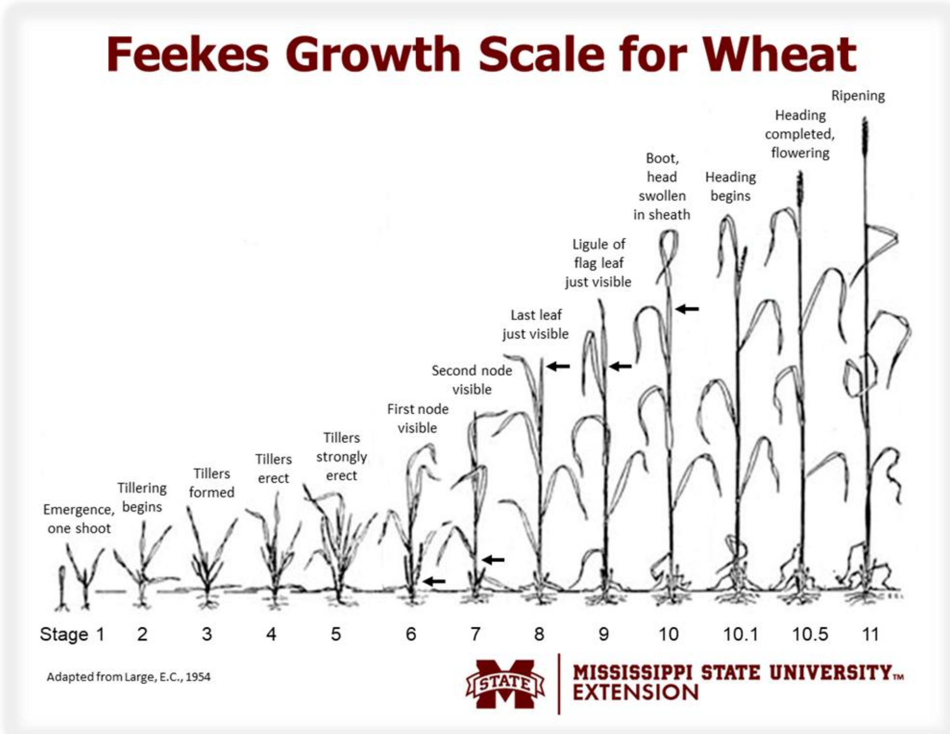

Figure 2. Shows wheat growth stages according to the Feekes scale as adapted from Large, (1954) and Mississippi State University Extension.

Statistical Analysis

An analysis of variance (ANOVA) for grain yield values and NDVI readings was statistically done using the GenStat program (Al-Rawi and Khalaf Allah, 1980). The mean of treatments was selected based on a probability level 0.05 and the least significant difference (LSD).

Results and discussion

Different N Levels Effect on Grain Yield

Figure 3 shows the results of grain yield statistical analysis that indicated significant differences in the grain yield between the different N fertilizer levels, with the 70% treatment outperforming the 100% and 50% treatments for both fertilizer levels of 200 and 150 kg ha^{-1} with a 5.77 and 5.67 Mg ha^{-1} compared to comparison treatment, which reached to 0.94 Mg ha^{-1}. Moreover, it was noted that grain yield increased, which was attributed to the increased nitrogen fertilizer level, which agrees with Al-Badrani (2010) and Al-Omari (2003) who indicated that the best grain yield was obtained when fertilizing at the highest fertilizer level.

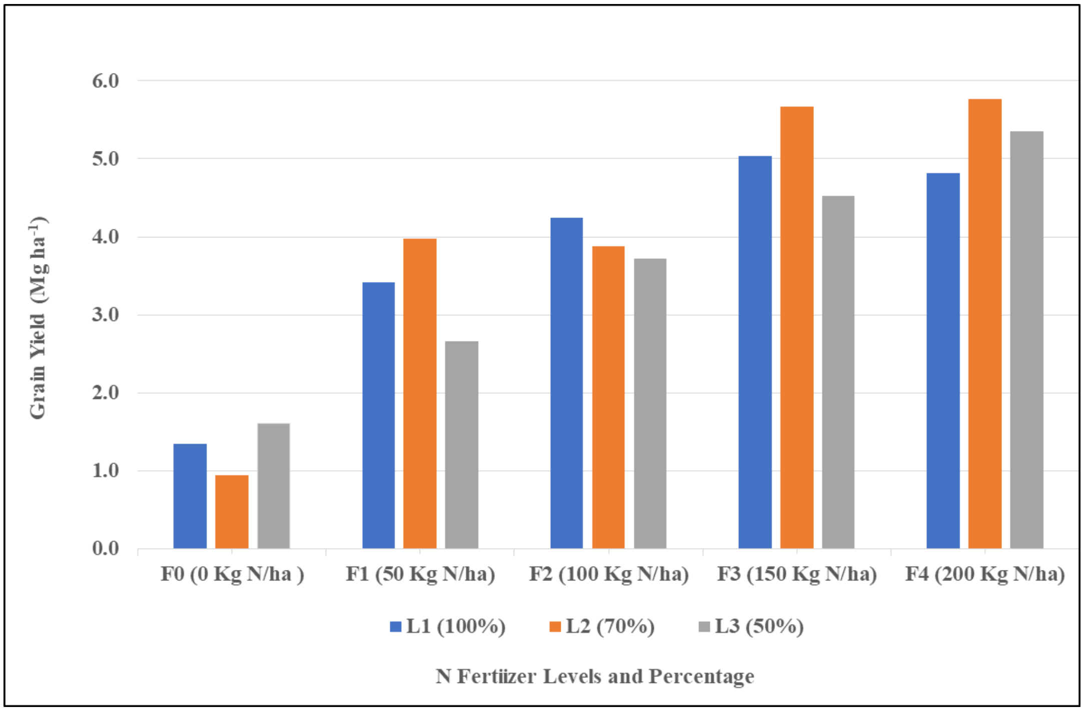

Figure 3. Relationship between grain yield and different N fertilizer levels and percentages.

Different N Levels Effect on NDVI

Figures 4, 5, and 6 display the results of NDVI statistical analysis at different levels of N fertilizer, and they indicated significant differences in the NDVI values between different N fertilizer levels. Furthermore, it was noted that the values of the vegetative difference index increased with the increased rate of N applied because the quantity of additional N added led to increases in the wheat biomass. As a result, the percentage of chlorophyll content increases with increasing wheat biomass and N fertilizer levels.

This result agrees with Orlloff et al. (2012) who indicated that the N accumulation increases with the progress of the growth stage and the highest N accumulation at the FK7-FK8 growth stages which is the best stage for predicting yield compared to other growth stages because the values of the vegetative index are recorded at the highest values and may be highly correlated with growth and yield (Samborski, 2009).

The study results also showed that the values of the vegetative difference index and yield at different levels of N fertilizer for the early vegetative growth stages followed a similar pattern. Therefore, it is possible to predict grain yield using the NDVI before plant biomass reaches a very high density, when the NDVI loses sensitivity (Naser et al. 2020; Naser et al. 2014).

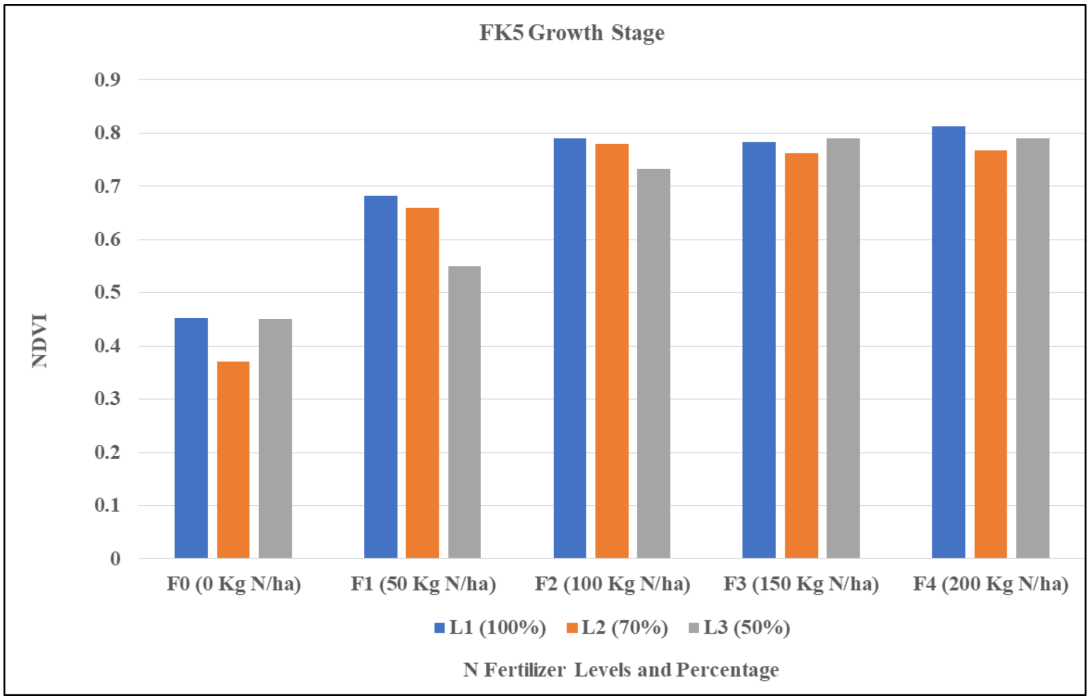

Figure 4. Relationship between the vegetative growth difference index and different levels of nitrogen fertilizer at the branching stage.

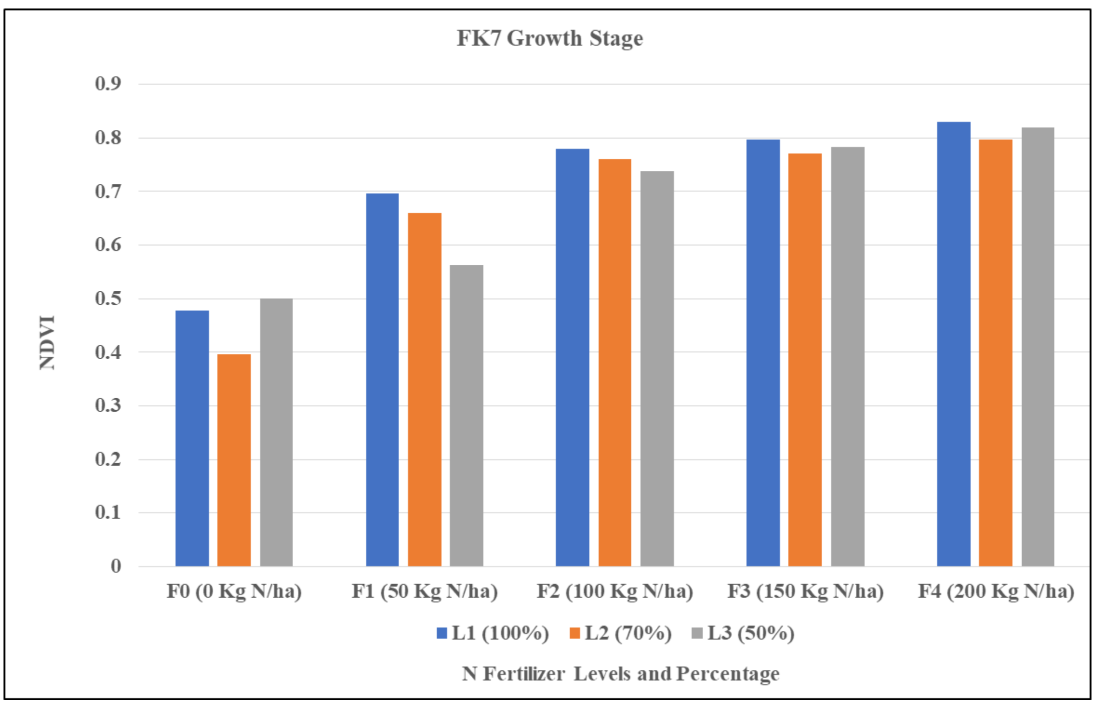

Figure 5. Relationship between the vegetative growth difference index and different levels of nitrogen fertilizer at the second node emergence stage.

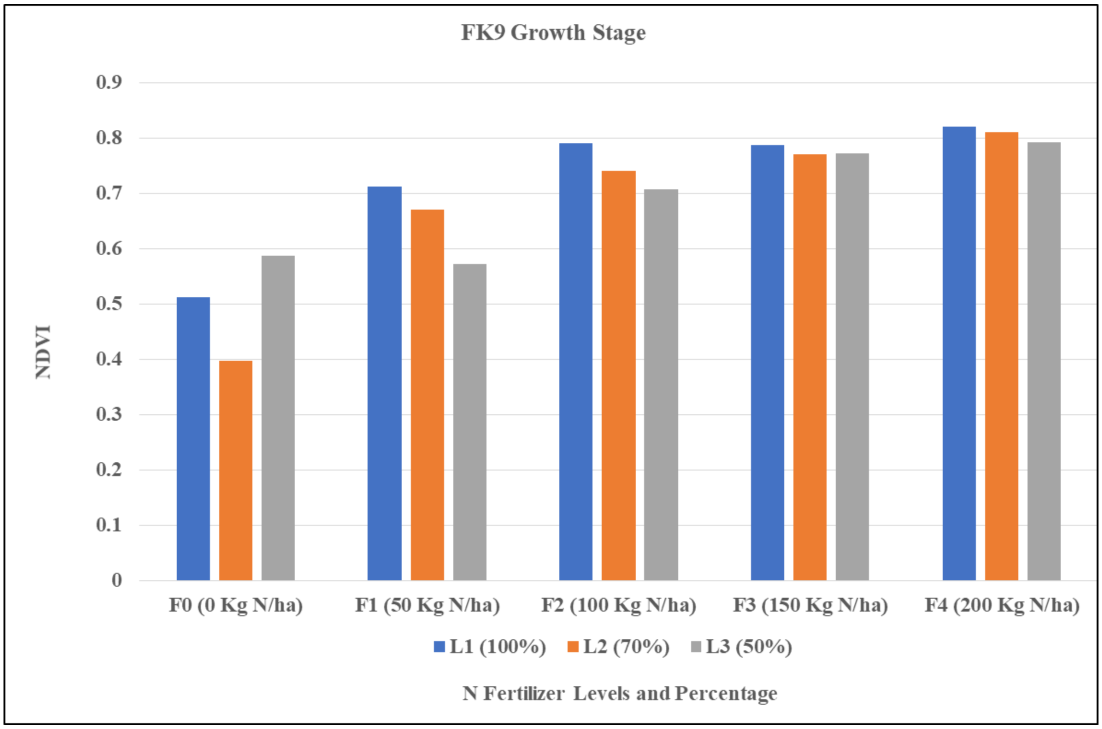

Figure 6. Relationship between the vegetative growth difference index and different levels of nitrogen fertilizer at the beginning of the emergence of the flag leaf stage.

Conclusions

GreenSeeker proximal sensor-based NDVI could be a useful tool to predict wheat grain yield, as NDVI and grain yield values increased with increasing N fertilizer levels. The results indicated that NDVI readings and grain yield values with different N levels followed a similar pattern. Therefore, there is a great potential to predict grain yield through the NDVI before the plant biomass reaches a very high density when the NDVI will lose its sensitivity to predict growth and grain yield. This field experiment showed how determining the N requirements is significant for each region due to the differences in the soil properties. Therefore, studying and analyzing the soils of the Al-Muthanna region to recommend the amount of N fertilizer is necessary to reach the best yield at the lowest cost. The study suggested conducting more studies on the wheat crop in Al-Muthanna Governorate using manual optical sensors according to the available capabilities.

References

Al-Baddrani, Wahida Ali Ahmed and Ibrahim Ahmed Al-Romo. 2013. Effect of different levels of nitrogen fertilization (urea) on some growth characteristics of wheat (Triticum spp.), *Journal of Basic Education Research*, Volume (12), Issue (3).

Al-Badrani, Imad Mahmoud Ali. 2010. Effect of nitrogen levels on growth and yield characters of two bread wheat cultivars. *Anbar Journal of Agricultural Sciences*, 3 (8) 98 – 107.

Al-Bakka, Hussein Mahsen Murtadha. 2015. Wheat cultivars evaluation by agronomic traits, application of three nitrogen levels and nitrogen efficiency parameters. *Kufa Journal of Agricultural Sciences,* 7(4) 244-255.

Adnan Muhammad, Zahir Shah, Hidayat Ullah, Bushra khan, Muhammd Arshad, Ishaq Ahmad Mian, Gohar Alikhan, Mukhtar Alam, Abdul Basir, Inayat-Ur- Rahman, Murad Ali and Wasif Ullah khan. Yield response of wheat to nitrogen and potassium fertilization. Pure and Applied Biology. *Pure Appl. Biol. http://dx.doi.org/10.19045/bspab.2016.50109*.

Al-Jubouri, Anas Nayef Jassim. 2011. Effect of seed size and plant density on the growth and yield of some wheat varieties. *Master's thesis. College of Agriculture and Forestry. University of Mosul*. 723-732

Ali, Ali, S. Ibrahim, and Bijay-Singh. 2020. "Wheat Grain Yield and Nitrogen Uptake Prediction Using AtLeaf and GreenSeeker Portable Optical Sensors at Jointing Growth Stage." *Information Processing in Agriculture* 7 (3): 375–83. https://doi.org/10.1016/j.inpa.2019.09.008.

Al-Omari, Mohammed Ragheb. 2003. Effect of using organic fertilizer on the productivity of local wheat varieties. *Master's thesis. College of Graduate Studies. An-Najah University*

Alrawi, Khashi Mahmoud and Khalaf Allah Abdul Aziz. 1980). Design and analysis of agricultural experiments. Dar Al-Kutub for Printing and Publishing, Ministry of Higher Education and Scientific Research, University of AlMosul, Iraq.

Directorate of Agricultural Statistics. 2024. https://cosit.gov.iq/ar/agri-stat/veg-prod.

Johnson, G.V. and W.R. Raun. 2003. Nitrogen response index as a guide to fertilizer management. *Journal of Plant Nutrition*, 26: 249–262.http://www.mississippi-crops.com/wpcontent/uploads/2015/02/Wheat_FeekesScale_graphic.png.

Large, E. C. (1954) Growth stages in cereals-illustration of the Feekes scale. Plant Pathology, 3, 128-129.

Naser, M. A., R. Khosla, L. Longchamps, M. Moragues, S. Haley, R. Reich, G. S. McMaster, and G. W. Buchleiter. 2014. "Can Active Sensor Based NDVI Consistently Classify Wheat

Genotypes?" *International Society of Precision Agriculture – ISPA*.

Naser, Mohammed A. 2012. "Active Sensing: An Innovative Tool for Evaluating Grain Yield and Nitrogen Use Efficiency of Multiple Wheat Genotypes." *Master Thesis, Colorado State University, Fort Collins.*

Naser, Mohammed A., Raj Khosla, Louis Longchamps, and Subash Dahal. 2020. "Using NDVI to Differentiate Wheat Genotypes Productivity under Dryland and Irrigated Conditions." *Remote Sensing* 12 (5). https://doi.org/10.3390/rs12050824.

Pandey, R.K., J.W. Maranville, and Y. Bako. 2001. Nitrogen fertilizer soil response and use efficiency for three cereal crops in Niger. *Journal Communications in Soil Science and Plant Analysis*, 32/100: 1465-1482.

Peltomen, J. 1995. Grain yield and quality of wheat as affected by nitrogen fertilizer application timed according to apical development. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science*, Volume 45, Issue 1, 2-14.

Orloff, S., Wright, S., Ottman, M., 2012. Nitrogen management impacts on wheat yield and protein. 11-12pp. In: Proceedings, California Alfalfa & Grains Symposium, Sacramento, CA, December.

Samborski, S.M., N. Tremblay, and E. Fallon. 2009. Strategies to make use of plant sensors, based on diagnostic information for nitrogen recommendations. *Agron. J.* 101(4): 800–816.

Wali, Arul Mohsen Anwar. 2010. Response of growth and yield of five wheat varieties to different methods of nitrogen fertilizer application, *Kirkuk University Journal of Agricultural Sciences*, 1 (2) 95-105.