AC 2011-382: ACTIVE LEARNING PROJECTS IN A MINORITY SERVING LAND GRANT UNIVERSITY ADDRESS ENGINEERING CHALLENGES IN SUSTAINABLE AGRICULTURE AND ENVIRONMENTAL STEWARDSHIP

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Active Learning Projects in a Minority Serving Land Grant University Address Engineering Challenges in Sustainable Agriculture and Environmental Stewardship

Abstract

This paper provides an overview of student activities during 2010 summer and beyond in projects titled *Aerial Imaging and Remote Sensing for Precision Agriculture and Environmental Stewardship (AIRSPACES)* and *Environmentally Conscious Precision Agriculture: A Platform for Active Learning and Community Engagement* led by the primary author. The paper highlights the kite aerial photography (*KAP*), remote controlled/autonomous instrumented boat (*Aquabot*), and optical sensor based nitrogen management efforts. *Kite Aerial Photography (KAP),* and the *Remote Controlled Boat (Aquabot)* endeavors were inspired by the remote sensing and environmental run-off monitoring facets of the ongoing "Precision Agriculture (PA)" project. The *KAP* and *Aquabot* projects were initiated by the NASA support for the Minority Serving Institute Partnership (MSIP) program in 2009 summer. Sustained involvement of students to address engineering challenges for sustainable agriculture and environmental stewardship has been facilitated by continued support from Maryland Space Grant Consortium/NASA and United States Department of Agriculture (USDA). The faculty and staff from programs in Natural Sciences, Agriculture, Aviation Sciences, Engineering, and Technology have partnered effectively in these multi-disciplinary undertakings. Active collaborations and campus visits of scientists and engineers at the USDA and NASA have not only promoted project goals, but also opened pathways for career opportunities and professional development for participating students and faculty respectively.

1.0 INTRODUCTION

Sustained support from Maryland Space Grant Consortium/ NASA and United States Department of Agriculture (USDA) for the remote sensing and precision agriculture related efforts since 2004 fall have provided an active platform for experiential learning and research for a multi-disciplinary team of faculty, student, and staff at University of Maryland Eastern Shore (UMES). These efforts were initiated by a pilot project with the acronym AIRSPACES: **A**erial **I**maging and **R**emote **S**ensing for **P**recision **A**griculture and **E**nvironmental **S**tewardship that provided support for a graduate student to work on his master's thesis under the supervision of the primary author, by Maryland Space Grant Consortium(MDSGC/NASA). A few undergraduate STEM majors were also supported by MDSGC. MDSGC/NASA has renewed their support annually till date. The scope of the project has been refined and integrated with multi-year project (2006-2009, extended to August 2011 through no-cost extension) funded by USDA with the title "Environmentally Conscious Precision Agriculture (ECPA): A Platform for Active Learning and Community Engagement" for which the primary author serves as the principal investigator (PI). These efforts have drawn strong student participation and the results and activities have been disseminated through websites, outreach activities, conference presentations and publications [1-5]. Some of the new directions integrated with the broad scope of these projects at UMES includes (i) Kite Aerial Photography(KAP), (ii) design of a remote controlled boat for water quality monitoring (Aquabot) and (iii) optical sensor based nitrogen management for cereal crops, provide the basis for this paper. The *KAP* and *Aquabot* efforts were initiated by the NASA support for the Minority Serving Institute Partnership (MSIP) program in 2009 summer [6,7].

2.0 KITE AERIAL PHOTOGRAPHY

Remote sensing and precision agriculture related efforts at UMES have utilized a variety of platforms including manned airplanes, robotic helicopters, as well as, small remote controlled unmanned aerial vehicles for remote sensing and aerial imaging. Under suitable wind and other weather conditions, kite aerial photography (KAP) could provide another low cost option for precision agriculture and variety of other applications involving earth sciences, disaster surveillance, and natural resource management. The downtime associated with the Cessna 172 and robotic helicopter based aerial imaging platforms at UMES, as well as some of the difficulties associated with training individuals to use remote controlled fixed wing airplanes for aerial imaging prompted the "AIRSPACES" team and the NASA collaborator to explore kite based aerial imaging efforts. A preliminary study involving lift and drag characterization of several kite configurations likely to be utilized for aerial imaging applications, and, laboratory and field investigations of *Picavet* and *Aeropod* platforms for *KAP*, were initiated during summer of 2009 at UMES under the auspices NASA MSIP endeavor[6]. While *KAP* has primarily been used by hobbyists for recreational purposes, there is a growing body of literature documenting scientific investigations with KAP[8,9]. Relevance to ongoing efforts in remote sensing for precision agriculture, recreational value, technical support from NASA engineers at Wallops Flight Facility(WFF) of NASA GSFC, and most importantly continued funding for STEM students for the AIRSPACES project have sustained student interest in the project. Figures 1 through 11 are photographs that document KAP related efforts at UMES. Several kite configurations have been tested by UMES students under varying load conditions. Simulation tools provided on the NASA website[10] gave students a feel for the kite performance with regard to lift and stability under varying wind conditions. The Delta (Figure 1) and the Coneye (Figure 2) kites were determined to be best suited for the UMES project. UMES students also helped NASA engineers test the Twin Delta-Coneye kites for low wind conditions (Figure 3). Figures 4 through 6 are various arrangements that have been used for camera systems on kite aerial imaging by UMES students

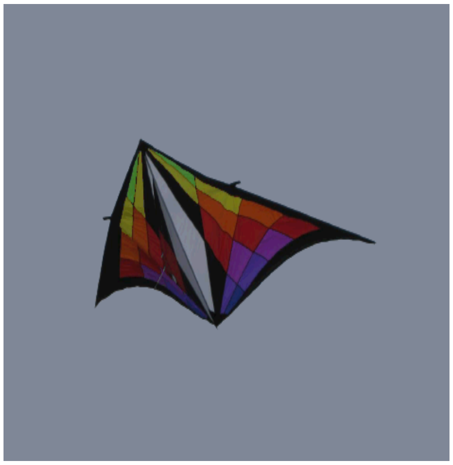

Figure 1 : Delta Kite

Figure 2 : Delta-Coneye

Figure 3 : Twin Delta-Coneye

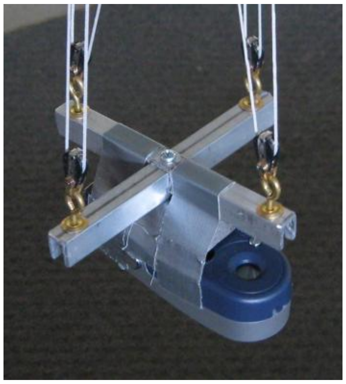

Figure 4: UMES Picavet

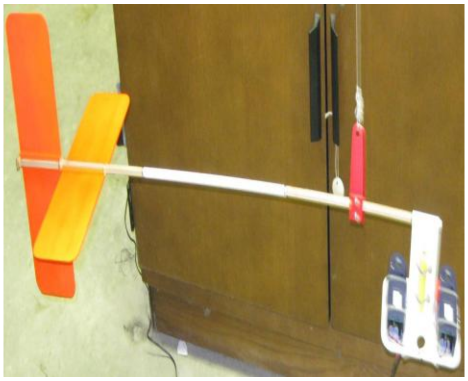

Figure 5 : NASA-Aeropod

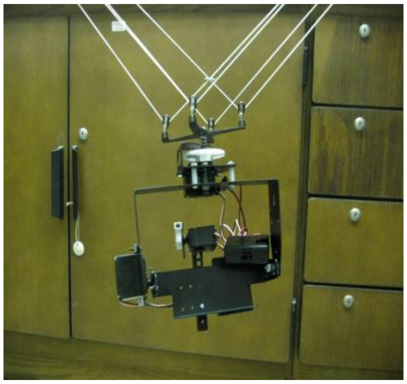

Figure 6: Picavet and Aurico

Figure 7: Kite Image of UMES field

Figure 8 : Kite Image of Corn Crops

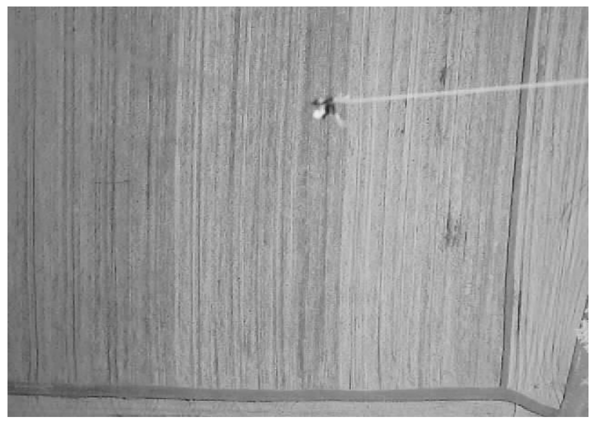

Fig 9: Aeropod image of wheat field (RGB)

Fig 10 : Aeropod image of wheat field (NIR)

Figure 11 : Mosaic of three images acquired with Aurico system and camera rig

for the project. Figures 7 and 8 are images of UMES cornfields acquired by the *Picavet* system for a single camera built by UMES students (Figure 4). Figures 9 and 10 are images of UMES wheat fields acquired with the Aeropod dual camera system designed by NASA engineers, the left and right camera on the Aeropod captures RGB and Near- Infra-Red (NIR) imagery in pairs. Figure 11 is a mosaic of three images acquired from a kite using Aurico camera rig on a *Picavet* system of a portion of the UMES campus in 2010 winter/spring time by a group of UMES students. The Aurico is an automated system that can allow the camera to pan, tilt, and shoot at pre-programmed intervals. KAP hobbyists use this system for recreational aerial imaging. The information for the camera rig (*Picavet* based) and Aurico system is available at the URL http://www.brooxes.com. It may be noted while *Picavet* systems are popular among KAP hobbyists, *Aeropods* are aerodynamically stabilized platforms developed by NASA engineers for kite or balloon based remote sensing efforts, that avoid complex arrangement of threads characteristic of a *Picavet* system.

Although kites have proven to be reliable remote sensing platforms for moderate wind conditions it is difficult to work with these in mild and low wind situations. AIRSPACES and ECPA project team members are exploring the use of tethered helium balloon platforms for remote imagery on days when there is little to no wind. Also significant efforts are underway to safely fly lightweight Far InfraRed (FIR) and Color Infra Red (CIR) digital cameras on kite and balloon platforms to support research efforts in multispectral imaging for applications in precision agriculture and natural resource management. Students are also learning to use software environments such as ArcGIS 9.3, MATLAB, and Multispec[11] for post processing, georeferencing, mosaicking, and other image analyses. Fieldwork complimented by design efforts and software use in laboratory environment is providing rich learning experience for the students involved in the project.

3.0 REMOTE CONTROLLED BOAT (AQUABOT)

The Kolb model suggests that balance among the four stages as shown in Figure 12 leads to optimal learning, deeper understanding of concepts and applications, and longer retention of information. It is achieved through reflective observation (RO), and active experimentation (AE). However, a necessary condition for such construction of knowledge is that this knowledge should be grasped first. Knowledge depiction occurs through Concrete Experience (CE) and Abstract Conceptualization (AC). The *Aquabot* project exemplifies how the Kolb model provides the framework for improving the original prototype for the experimental prototype for the automated water quality platform[6]. The team members for the boat project have chosen the same acronym as the original project from which it drew inspiration. The new acronym AIRSPACES: **A**ir-propelled **I**nstrumented **R**obotic **S**ensory **P**latform for **A**ssateague **C**oastline **E**nvironmental **S**tudies captures the goal and scope of this new, but integral dimension of the ongoing venture. Figure 13 shows the original platform that was developed by an exchange student in 2009 summer. A LEGO-NXT system with adaptors for Vernier-sensors (salinity, pH, temperature) and

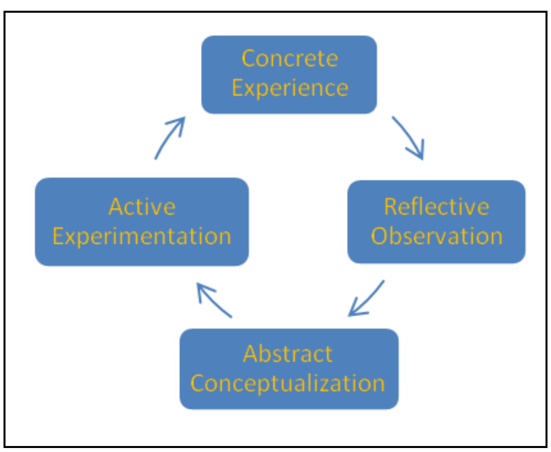

Figure 12: Kolb Model

a Global Positioning System(GPS) unit were integrated and mounted on a remote controlled boat platform that was acquired from a hobby shop. At the conclusion of the summer (2009) some UMES students led by Mr. Xavier Henry decided to look into improving the platform while continuing to work on other aspects of the AIRSPACES project. The remote controlled boat for the original platform used two propellers immersed in the water and driven by two independent servo-motors. The turning action was provided by differential thrust. However, it was noted that while collecting sensor data in bays, rivers and lakes, the propeller had a propensity to be entangled with seaweeds, other vegetation and debris common in shallow waters. Students in the AIRSPACES project had experience working with remote controlled airplanes. They decided to use the parts from a single propeller small RC-airplane with a damaged body to build an air-propelled boat. The same joystick controller was used with the same power and communication system. The wind thrust from the back of the boat was manipulated with remote controlled rudders designed by the students to move the airflow for turning action. The body of the boat was built out of styro-foam and the location of the NXT system, sensors, and GPS unit were determined taking into consideration fundamental factors such as buoyancy, center of gravity, and moment balance. Figure 14 shows refined model of the first re-designed air-propelled boat prototype. While the problem of entanglement with shallow water vegetation was eliminated, the drag on the boat surface and limited power of the thrust made the motion and turning action sluggish. Though the automated sensing and GPS performed well, the battery power did not last long enough to cover a significant area of the water bodies that were to be studied. Students experimented with the pitch of the propeller blades to improve thrust, obtained larger propellers, improved battery system and ampere-hour capacity, the rudder manipulation mechanism and some of the aesthetic aspects for the current form shown in Figure 15.

Figure 13: Original form

Figure 14: 1st Iteration

Figure 15: Current form

In the current form the system works well in moderate wind and water currents and can collect data for 30-45 minutes in the bays, rivers, and lakes where it has been deployed. The thrust power is adequate to maintain adequate velocity of the boat to cover 10 to 20 ft/s. The rudder system allows quick turning action and a bumper in front of the boat protects it against collision with underwater rocks and debris. The NXT based system has also allowed students to use the platform to learn and implement software tools such as ROBOTC and LABVIEW, over and above the NXT code that came with the LEGO-NXT system. Current and future efforts with the boat project involve replacing the NXT system with LABQUEST which will be easier interface with GPS and Vernier sensors. Students are also developing a low cost fully autonomous platform that will eliminate the need for remote controller. The boat platform has provided avenues for project work for courses in Instrumentation(ENGE 380) and Marine Botany (BIOL 202) offered by Dr. Nagchaudhuri (primary author) and Dr. Mitra (one of the co-authors) respectively.

4.0 OPTICAL SENSOR BASED NITROGEN MANAGEMENT

As part of the project titled *Environmentally Conscious Precision Agriculture: A Platform for Active Learning and Community Engagement* a multi-instructor team taught course has been developed that is open to all seniors and graduate students in the STEM majors. The course *(Advanced Technologies in Agriculture and Environmental Sciences)* is typically offered in the spring semester and incorporates significant field based project and learning activities that are subsequently integrated with paid summer internship efforts for selected students[2]. In spring 2010, a new project was introduced in the course that initiated the students to the extensive research activity with optical sensor based nitrogen management efforts at several universities in the United States and other developed and developing nations throughout the world [12]. In recent years large production agriculture facilities have started adopting this technology. In view of this the project leaders decided to incorporate field activities with hand-held optical sensors and GPS unit(Figure 19, on loan from USDA collaborator) with agronomy fundamentals, remote sensing, and, the ArCGIS 9.3 software based geospatial information technology related activities that were already part of the course. The objective was to determine normalized difference vegetation index (NDVI) for calculating optimal application of nitrogen during mid season for winter wheat. A field experiment was set-up on a winter wheat field at UMES to allow students to collect spatially located NDVI data and use the information to estimate net profit and amount and cost of nitrogen (N) fertilizer applied to a winter wheat crop using four management methods listed below:

Method 1: No N application in mid-season.
Method 2: N-rate applied uniformly across field based on yield goal for winter wheat.
Method 3: Variable rate using mean NDVI for the entire N-Rich strip.
Method 4: Variable rate using maximum NDVI for the entire N-Rich strip.

Some of the results obtained by the students using equations provided in reference[13]are outlined below:

	Method	Yield (bu/ac)	Total Yield (bu)	Gross Value ($)	Net Value ($)
1	No N (Ypo)	14.46	88.06	427.10	427.10
2	Flat Rate N	30.00	182.70	886.10	818.86
3	Ypn Max NDVI	30.87	188.00	911.79	886.24
4	Ypn Mean NDVI	21.88	133.25	646.26	636.50

TABLE 1: Results from the pilot project conducted by students in spring 2010 course

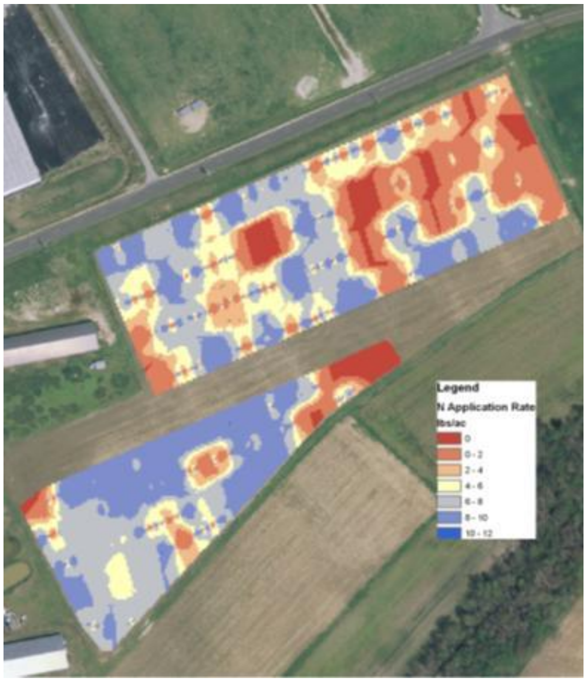

Figure16 :N prescription map using Method 3

Figure17 :N prescription map using Method 4

Figure 18: Student Design

Figure 19: Crop circle (Optical Sensor)

Figure 20: Field use

Figures 16 and 17 are prescription maps created by spatial interpolation of point data on ArcGIS 9.3 for mid season (Feekes 4 / 5 growth stage [14]) nitrogen application for winter wheat based on NDVI data collected by the students registered in the course. The NDVI data were collected using the hand-held Crop Circle optical sensor with GPS attachment by walking appropriate regions and transects in the chosen field. The pilot project provided the students with a keen insight on the philosophy behind the modern approach of fertilizer application in mid-season for cereal crops using advanced on-the-go sensing using optical sensors and variable rate application. During the summer internship following the course the students designed a unicycle based platform (Figure 18) for ease of field data collection with the hand-held optical sensor and GPS attachment. For the summer a follow –up project was outlined for pilot investigation with corn crop. Figure 20 shows some of the students collecting field data with the Crop Circle sensor in a corn field using the unicycle platform during summer of 2010.

Actual implementation of variable rate nitrogen application at UMES in the future using prescription maps or on-the-go sensing and actuation will involve significant effort in developing information specific to eastern shore. However, the experience provided the students preliminary insight in this active research area with projected wide field applications in the near future.

5.0 CONCLUSION AND FUTURE PLANS

The projects highlighted in this paper have generated considerable enthusiasm among UMES students, the project investigators and the USDA and NASA collaborators. These projects provide a foundation of learning experiences and research initiation that enhance classroom lectures. Project assignments in several courses offered by the investigators have incorporated aspects of these endeavors. Maryland Space Grant Consortium/NASA and United States Department of Agriculture have committed to continue to fund these efforts in the near future. In this regard, MDSGC has approved the annual funding for the AIRSPACES project for 2011. In recognition of the success of "Environmentally Conscious Precision Agriculture (ECPA)" project, NIFA/USDA has recently approved a three-year proposal(2010-2013) titled "Bio-Fuel, Sustainability, and Geospatial Information Technologies to Enhance Experiential Learning Paradigm for Precision Agriculture Project" developed by the primary author. The effort will build on the success of the AIRSPACES and ECPA projects, as well as address the additional dimensions of sustainability and renewable energy with particular emphasis on "biofuels". Involved faculty and students have initiated efforts that will synergize aspects of these projects. Furthermore after a hiatus of a year Maryland Space Grant Consortium/NASA have assured continued funding for the exchange program among UMES, Morgan State, and UMCP for 2011 summer and beyond. The projects combine the UMES undertaking to serve the underserved, as well as the 1890 land grant mission. Since their inception the projects have involved more than 50 students at UMES in experiential learning and research activities outlined; more than 75% of these students have been women or minority. The projects have also promoted agriculture as a modern high tech field and advanced aspects of environmental stewardship and bio-energy consistent with broader mission related to the land grant status of the campus.

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BIBLIOGRAPHY

1. Nagchaudhuri, A., Morris, A., Mitra, M., and Henry, X., "Simplified Management Zones from Analyses and Mapping of Multiple Years of Spatially Distributed Harvest Data," *Proceedings of 2008 Annual Conference of American Society for Engineering Education*, Austin, Texas, June 2009.
2. Nagchaudhuri, A., Mitra, M., Daughtry, C., Marsh, L., Earl, T.J, and Schwarz, J. " Site- Specific Farming, Environmental Concerns, and Associated Advanced Technologies Provide a Platform for Active Learning and Research at a Land Grant University", *Proceedings of 2008 Annual Conference of American Society for Engineering Education*, Pittsburgh, PA , June 22-25, 2008.
3. Nagchaudhuri, A., Mitra, M., Stoakley, R., Turner, T., Cherinet, S., Ladd, G., Chalyam, H., Hartman, C., Burrow- Mcelwain, J, "Rich Learning Experiences for Minority Undergraduate Students Through Inquiry based Project Activities in the Field and Laboratory Settings", *Proceedings of 2007 Annual Conference of American Society for Engineering Education*,June 24-27, Honolulu, Hawaii, 2007.
4. Nagchaudhuri, A., Mitra, M., Brooks, C., Earl, T.J., Ladd, G., and Bland, G., "Integration of Mechatronics, Geospatial Information Technology, and Remote Sensing in Agriculture and Environmental Stewardship", *Proceedings of 2006 International Mechanical Engineering Congress and Exposition* (IMECE'06), , Nov 5-10, Chicago, IL., 2006
5. Nagchaudhuri, A., Mitra, M., Brooks, C., Earl, T.J., Ladd, G., and Bland, G., "Aerial Imaging and Remote Sensing at University of Maryland Eastern Shore", *Proceedings of 2006 ASEE Annual Conference, June 18-21, Chicago, IL, CD ROM*
6. Nagchaudhuri, A., Green, D., Mitra, M., and Henry, X." Experimental Prototype of a Remote Controlled Platform to Monitor Water Quality Data," *Proceedings of 2010 Annual Conference of American Society for Engineering Education*, Louisville, KY, June, 2010
7. Nagchaudhuri, A., Teays, T., Chen, G., Bowden, M., and Henry, R.C., "Broadening Student Research Experiences through a Summer Exchange Program across Campuses", *Proceedings of 2010 Annual Conference of American Society for Engineering Education*, Louisville, KY, June,'10
8. Aber, J.S., Aber, S.W. and Leffler, B. 2001. Challenge of infrared kite aerial photography. *Kansas Academy Science, Transactions* 104(1/2), p. 18-27.
   Available online @ http://www.kansasacademyscience.org/TKAS/trans104/aber1/aber1.htm
9. Oh, P.Y., and Green, W.E., " Mechatronic Kite and Camera Rig to Rapidly Acquire, Process and Distribute Aerial Images", IEEE/ASME Transactions of Mechatronics, Vol.9 (4) pp. 671-678, December 2004.
10. NASA Glenn Research Center, Interactive Kite Modeler, http://www.grc.nasa.gov/WWW/K-12 /airplane/ kiteprog.html
11. Multispec: Available online at http://cobweb.ecn.purdue.edu/~biehl/MultiSpec/
12. Sensor Based Nitrogen Rate Calculator, Available online at http://www.soiltesting.okstate.edu/SBNRC/SBNRC.php
13. Raun, W.R., Solie, J.B., Stone, M.L., Martin, K.L., and Freeman, K.W., "Optical Sensor Based Algorithm for Crop Nitrogen Fertilization, Communications Soil Science Plant Analysis, 36, pp. 2759-2781, 2005.
14. Miller, T.D., "Growth Stages of Wheat: Identification and Understanding for Improved Crop Management", Texas Agricultural Extension Service (Texas A&M), SCS-1999-16.
    Available Online : http://www.soiltesting.okstate.edu/SBNRC/SBNRC.php