

National Infrared Reflectance Project on Forages

I. Background, Current Status, and Future Plans

A. Background

Following progress made in evaluating quality of grains and oilseeds through near-infrared reflectance spectroscopy (NIRS) at the Instrumentation Research Laboratory (Karl Norris, Chief), Beltsville Agricultural Research Center, a Specific Cooperative Agreement was established June 25, 1975, between USDA/ARS and The Pennsylvania State University (PSU). The resulting research project initiated in-depth studies on infrared for the nutritional evaluation of crops and miscellaneous feedstuffs. Project leaders were R.F Barnes (USDA/ARS) and J.S. Shenk and B.R. Baumgardt (PSU).

An instrument was designed and assembled for the project by Lemont Scientific, Inc., State College, PA. Encouraging progress was made in rapidly evaluating the quality of forages for feeding animals. Shortly after assuming the duties of Director, U.S. Regional Pasture Research Laboratory (USRPR) April 10, 1977, William C. Templeton, Jr. began reviewing the status of NIRS research at University Park and other locations. Following discussions with a number of people, he called a meeting October 12 and 13, 1977, on "Statistical Considerations in Forage Evaluation by Infrared Reflectance Spectroscopy." Another meeting was held December 16, 1977, involving five chemists and a statistician from the Eastern Regional Research Center, Philadelphia, PA, a plant breeder from Beltsville, MD, and four persons from University Park, PA. Comments and discussions during and following these meetings resulted in a consensus that the utility of NIRS in forage-crops and animal-nutrition research and its potential for wide use in ration formulation, hay grading and marketing, and Extension programs warranted a major research thrust.

B. Planning and Formative Period, 1978-1980

During 1978 several meetings were held to develop plans, secure funds, and procure equipment for a National Infrared Reflectance Project on Forages. Abbreviated highlights of those activities are given in Appendix I.

The original proposal for a national project included the following five broad objectives, formulated and agreed upon in the series of planning meetings:

1. To develop and test computer programs which provide continuing advances in data processing and mathematical treatment of infrared data to maximize prediction accuracy;
2. To further define and measure plant, environmental, and other factors contributing to variation in infrared prediction of chemical composition and animal response;
3. To relate chemical and physical properties of forages to infrared reflectance spectral properties;

4. To test the usefulness of infrared reflectance in forage breeding, forage-management, and animal-utilization research programs; and
5. To produce, analyze, assemble, and maintain selected forage samples in a reference library for use in IR instrument calibration and other forage-evaluation studies.

It was agreed from the outset that the six locations (Appendix II) would address problems of relevance to each location's specific mission and goals, taking into account the needs and expertise at the individual locations. Thus, work plans and individual projects were developed for each location during late 1978 and early 1979, keeping in mind overall objectives of the national project. Through the location work plans and interaction with project leaders, the Project Coordinator was kept appraised of anticipated research which would contribute to achievement of national-project objectives.

Following discussion of instrumentation needs, with primary inputs from Karl H. Norris and John S. Shenk, John Espenschade, AOD, Hyattsville, MD circulated to prospective suppliers June 19, 1979 a Request for Proposals to supply six computerized high-precision, near-infrared reflectance spectrophotometers. The proposal of Neotec Corporation, Silver Spring, MD was eventually accepted, and delivery of equipment was initiated November 19, 1979, with shipment of an instrument to University Park, PA. Shipment of the last unit, was made January 30, 1980 to Athens, GA. A 3-day training short course to familiarize instrument operators at the locations and provide hands-on experience was held at the Royal Pines Motel, College Park, MD, December 12-14, 1979, with USDA/SEA/FR, The Pennsylvania State University, and Neotec Corporation cooperating. Through efforts of the University Park group, an outstanding software package and operating procedures had been developed and were distributed at the short course. Instrument hardware configuration is given as Appendix III.

C. Progress and Current Status of Research

CY 1980 was a year of intense activity, although instrument delivery, familiarization, and some hardware problems allowed less than a full year's research time for some locations. A set of 30 forage samples was used to compare chemical and spectral assays within and among the six locations. Both cool-season and warm-season species were included. Each laboratory conducted standard laboratory analyses of the forages. In addition, each collected reflectance data for each of the samples on three consecutive days.

Average spectral curves from the six instruments were noticeably different in reflectance level and in amplitude of absorption bands, but a simple normalization of the data resulted in curves essentially alike except for the water regions. Differences in the normalized curves were caused primarily by differences in sample moisture at the six locations.

The errors associated with NIRS analysis compared favorably with those obtained by routine chemical and biological procedures. Moreover, between-lab variation was no greater for NIRS than for the standard procedures.

Near the end of the year it was clear that a group meeting to discuss progress, operating problems, and future plans was essential. The first annual NIRS Workshop was held at the Southwestern Livestock and Forage Research Station,

El Reno, OK February 11-13, 1981. A copy of the minutes is attached (Appendix IV).

In response to a request from the Project Coordinator, Status of Research and Projected Needs reports were prepared by project leaders at each location in late summer 1981. Highlights of accomplishments to date follow:

1. St. Paul, MN -

a. Accomplishments -

- (1) Based on assays of 700 small-grain forages, NIRS gave quality evaluations to a degree of accuracy similar to that reported for chemical and biological assays.
- (2) From studies encompassing over 1,000 corn-stover samples it was concluded that NIRS can evaluate acid detergent fiber (ADF) of such materials to a degree of accuracy close to that reported for other forages. NIRS prediction of acid detergent lignin (ADL) was less successful; however, the corn breeder was sufficiently satisfied with overall results that NIRS was used to predict ADF and ADL on 350 samples of unknown composition for use in his breeding program.
- (3) Using 190 samples of small-grain forage to study effects of fineness of grinding and type of mill used for grinding samples, it was found that quality estimates are influenced by both variables. Thus, predictive equations should be developed using materials processed in a manner similar to that to be used for the samples to be assayed.
- (4) Samples of cool-season grasses of several species from diverse growth environments were used to ascertain the utility of NIRS in breeding and management studies. Results indicated that predictive equations developed from use of samples in a given trial were, in general, not sufficiently accurate for use with samples from another trial at another location.
- (5) Based on results with birdsfoot trefoil-grass-weed mixtures, it was concluded that NIRS can evaluate forage quality of such mixtures as accurately as that of other forages.

- b. Operating/Maintenance Problems - Lamp and encoder replacements required within six months and one year, respectively, Extensive computer problems during first year, but none of consequence later.

2. Athens, GA _

a. Accomplishments - Calibrations have been developed for bermudagrass hays dried under different regimes and for bahiagrass and other warm-season grasses. Fiber analysis and other laboratory procedures have been tested and evaluated. The Fiber-Tec system was found to be more reliable and two units have been procured. (Research Leader was on duty at El Reno July 1980-81).

b. Operating/Maintenance Problems - None

3. El Reno, OK -

a. Accomplishments -

(1) Recognized problems associated with wet-chemistry analyses and determined them to be related to problems of water content and inability to appropriately conduct moisture analysis by oven drying.

(2) Calibration equations were developed for crude protein (CP), neutral detergent fiber (NDF), ADL, and in vitro dry matter disappearance (IVDMD) using 100 "Old World" bluestem samples. Narrow (12mm) and wide (18mm) derivative segments were tested, with neither found to be consistently superior.

(3) NIRS was used to predict IVDMD of 76 producer alfalfa samples in the first alfalfa and machinery exhibition in Oklahoma.

(4) Extensive testing showed the Tecator Fiber-Tec instrument gives reduced standard errors in fiber analyses and, compared to conventional fiber-analysis procedures, improves the calibration equations in NIRS work.

b. Operating/Maintenance Problems - Considerable hardware problems in start-up and early operation.

4. Logan, UT -

a. Accomplishments -

(1) Alfalfa samples from USU testing laboratory were used to develop predictive equations. Correlations between NIRS predicted values and crude fiber, ADF and estimated total digestible nutrients were +0.91, +0.95, and +0.94, with standard errors of the difference (SED) of 1.1, 1.5, 1.5, respectively. Samples from alfalfa variety trials showed lower correlations but low SEDs.

- (2) NIRS was used to assay total N, soluble N, ADF ADL, and NDF of crested wheatgrasses from a breeding project. Values of r were +0.98, +0.87, +0.91, +0.62, and +0.93, with corresponding SEDs of 0.04, 0.04, 1.01, 0.53, and 0.96.
- (3) Tests of NIRS for predicting carotene of alfalfa and grass samples dried with different methods resulted in high correlations, but SEDs were relatively high.
- (4) NIRS prediction of digestible organic matter from fecal samples of elk showed a correlation of +0.84, with SED of 2.8, while values for organic matter intake were +0.74 and 8.06, respectively.

b. Operating/Maintenance Problems - Considerable difficulty with the computer early, then with monochromator and some other hardware. Repair of floppy-disk drive (cost \$1,000) and lamp replacement were required.

5. Beltsville, MD -

a. Accomplishments -

- (1) Participated in network-wide evaluation of 30 forage samples to compare wet-chemistry and NIRS results at the six locations.
- (2) Scanned several hundred alfalfa samples for determination of effects of harvest date on crude protein, P, and K predictions.
- (3) Scanned over 200 tall fescue samples to predict perloline levels.
- (4) Scanned several hundred corn samples to verify usefulness of NIRS in predicting protein of corn.
- (5) Two hundred alfalfa samples were analyzed by NIRS to determine protein level prior to initiation of a breeding program.
- (6) The derivative ratio data treatment for NIR spectra was developed to minimize effects of sample temperature, particle size, and interfering absorbers.
- (7) The curve fitting data treatment for NIR spectra has been developed to provide a more robust calibration where an adequate number of samples are available.
- (8) The effect of sample temperature on NIR spectra has been defined and procedures have been developed to minimize temperature effects in predicting sample composition.

b. Operating/Maintenance Problems - No significant problems.

6. University Park, PA -

a. Accomplishments -

- (1) Developed a complete software package for operation of Neotec 6100/PDP 1103(1134) spectrocomputer system. The programs have been in use at the six locations since initiation of the national effort. Work continues on up-dating and improving the software, with suggestions and operator experiences being evaluated continuously and incorporated if deemed desirable.
- (2) Assisted in establishment of a number of new installations using the network instrumentation and software, including units at Edmonton, Alberta, Canada; Aberdeen, Scotland; Sydney, Australia; Ona, FL; Forage Testing Laboratory, University Park, PA; Eastern Laboratory, York, PA; and Cotton Genetics Research Laboratory, USDA/ARS, College Station, TX.
- (3) Analyzed forage samples from the University of Minnesota, forage and fecal samples from New Mexico, alfalfa hays from California, alfalfa breeding samples from Cornell University, and forage samples for researchers at The Pennsylvania State University and the U.S. Regional Pasture Research Laboratory.
- (4) Developed a mobile NIRS van which has been driven over 34,000 miles to test utility of the equipment in assessment of hay quality in common marketing/ sale environments and in testing of forages used, primarily, in dairy cattle rations. The instrumentation and associated software allow "on-the-spot" analysis of forages and feedstuffs and formulation of rations based on the forages analyzed. The van has been used and demonstrated in 10 states and Canada, through cooperative efforts of Extension Specialists, County Agents, Vocational Agriculture Teachers and other groups.
- (5) Three graduate students have completed thesis research with NIRS, and a fourth utilized NIRS extensively in analyzing samples from two forage-management experiments.
- (6) A study of the effects of plant species and drying methods on spectral properties and quality assessment of forages is partially completed. Preliminary results confirm the importance of having a range of materials in the calibration samples which are truly representative of those for which values are to be predicted.
- (7) Sixty Pennsylvania hays, with 30 produced each of two years, were fed to sheep in digestion trials. The forages represented various cuttings, maturities and species and provided a wide range in nutrient composition. Except for lignin, the fit of NIR spectra to forage

composition, as estimated by standard laboratory procedures was excellent. Prediction of sheep intake and digestion measurements by NIRS was superior to that obtained from standard laboratory measurements.

b. Operating/Maintenance Problems - No significant problems.

D. Research Plans for CY 1982

Work plans are developed on an annual or more frequent basis, with discussion and coordination of plans accomplished in large measure at the Annual NIRS Workshops. The goal, objectives, and research approaches of the national project were reviewed and discussed at length during the 2nd Workshop at Athens, GA December 3-4, 1981 (see Appendix V, VI).

The goal of the project is to establish an improved near-infrared reflectance analytical system for forage and feedstuff quality evaluation. Objectives are to:

1. Relate chemical and physical properties of forages to their infrared reflectance spectral properties,
2. Test and validate NIRS for determination of forage quality,
3. Establish standards for the conduct of NIRS analyses,
4. Establish and maintain a library of reference forage samples for use in NIRS instrument calibration, and
5. Facilitate transfer of NIRS technology.

Abbreviated work plans for CY 1982 are given below by location:

1. St. Paul, NN -
 - a. Ascertain influence of amount of birdsfoot trefoil in mixture with grasses and weeds on NIR measurement of CP, NDF, and IVDMD.
 - b. Determine whether and to what extent cutting management/harvest method influence equation development for NIR prediction of quality.
 - c. Use equations developed previously for corn stover to ascertain whether maize breeders have changed stover quality in developing hybrids for improved stalk strength during the past 50 years.
 - d. Estimate heritability of fibrous constituents of reed canarygrass and breed for improved quality using equations previously developed. Attempts will also be made to develop and verify equations for predicting IVDMD of reed canarygrass.
 - e. Participate in national program to obtain and evaluate with NIRS forage samples from the U.S. to be used in an effort to develop "universal equations" for CP and ADF.

Athens, GA -

- a. Test and validate usefulness of NIRS for "Old World" bluestems and eastern gamagrass (in cooperation with El Reno and Woodward, OK).
- b. Evaluation by chemical analysis and NIRS of tall fescue breeding lines (cooperative with Joe Bouton, University of GA).
- c. Fundamental studies aimed at elucidating relation of chemical and physical properties of forages to their digestion. Both warm- and cool-season grasses will be studied using NIRS, wet-chemistry, and nuclear magnetic resonance.
- d. Continue studies of wet-chemistry methodology.
- e. Assist in collection and analysis of samples to develop universal equations.

3. El Reno, OK -

- a. Implement routine use of NIRS predictive equations for assessing quality of alfalfa and "Old World" bluestems.
- b. Develop equations for use with weeping lovegrass and eastern gamagrass (cooperative with Woodward, OK and Athens, GA).
- c. Investigate utility of NIRS for detecting progressive changes in forage composition as it is consumed and passed through the gastro intestinal tract.
- d. Assist in sample collection for universal equation study.

4. Logan, UT -

- a. Further test and analyze alfalfa samples from 1980 and 1981 harvests to improve existing NIR predictive equations.
- b. Investigate chemical composition of forage carbohydrates and test usefulness of NIRS in determining composition.
- c. Cooperate with two forage-plant breeders (Asay and Rumbaugh) in testing applicability of NIRS in screening breeding materials.
- d. Assist national effort to develop universal equations by supplying 47 alfalfa hays produced under different climatic conditions and fed to sheep in a digestion trial.

5. Beltsville, MD -

- a. Continue testing, as time permits, application of NIRS for determination of quality factors in alfalfa forage and corn grain.
- b. Assist in collection of samples for reference library and universal equation development.

- c. Develop procedure for standardizing the photometric scale of NIR spectrophotometers using a calibrated ceramic standard in combination with a calibrated standard of plastic beads.
 - d. Develop programs to allow application of factor analysis to NIR data to permit evaluation of this data treatment in calibrating instruments.
6. University Park, PA -
- a. Continue testing and validation of NIRS for determination of forage and feedstuff quality, including further work and possible release of an improved software package for the Neotec 6100/PDP 1103(1134) system and completion of software to operate the Neotec 51.
 - b. Facilitate NIRS technology transfer by assisting personnel engaged in or interested in application of the technology to areas where its use is indicated.
 - c. Establish a library of reference forage samples and serve as leader in collection and preparation of samples for use in testing whether satisfactory universal equations for CP and ADF can be developed.
 - d. Initiate efforts to establish guidelines for use of NIRS in forage research, utilization, and marketing, giving consideration to instrument standardization, protocol for calibration and verification of predictive equations, and procedures for sample preparation and presentation of samples to NIR instruments.

II. Potential Applications of NIRS

Research results continue to indicate that NIRS is a valid and useful technique for assessment of forage quality. The advantages of the technology, compared to conventional procedures, are that it is non-consumptive, i.e. the materials analyzed are not changed/destroyed; only small quantities of materials are required; it is very rapid; less labor is required; and, finally, use of spectro-computer systems such as the Neotec 6100/PDP 1103 allows incorporation of other associated routines for performing such chores as ration balancing, determination of feed-replacement values of various feedstuffs, etc.

A. Forage-Related Areas in Which Usefulness of NIRS is Indicated

1. Plant Breeding -

To achieve significant improvement in traits of economic importance, forage-plant breeders normally must deal with very large numbers of plants. NIRS facilitates this, and allows extensive screening in early phases of improvement programs. Only small quantities of materials are required for testing and single plants or even a portion of a plant may suffice.

2. Forage Management -

As in plant breeding studies, most forage-management trials normally result in only small quantities of experimental forages for study. Also, in the past most management practices have been imposed on an empirical basis. The time required to determine forage quality was so great that it could not be assessed prior to harvest or imposition of desired treatments. NIRS allows evaluation of 20 to 40 samples per hour, making possible "readouts" of quality parameters before final action is required. Thus, forage quality can be monitored on a daily basis, with decisions made and actions taken to impose desired treatments on forages of defined quality traits. For example, alfalfa could be harvested on specific dates to provide forages of chosen digestibilities. Then, combining information on digestibility and predicted forage yield, yields of digestible nutrients could be estimated prior to harvest.

3. Forage-Utilization Research -

Potential usefulness of NIRS in forage-utilization studies appears to be very great. As indicated previously, quality of forages could be monitored on a daily basis. Experimental diets could be formulated and feeding trials initiated or changed as forage quality changes, or is varied experimentally. Changes in feedstuffs as they undergo digestion and passage through the digestive tract could be more easily monitored, and estimation of quantity and quality of ingested forages from feed:fecal relationships would be facilitated.

4. Ration Formulation -

Producers have long insisted that the time required for analyses of forage quality are a primary deterrent to efficient utilization of those feedstuffs. Forages supply very large proportions of the feed for dairy cattle (60-65%), beef cattle (80-85%), and sheep (~90%), thus inefficiencies in their utilization resulting from inappropriate supplementation, markedly increase production costs of livestock and livestock products. NIRS, employing the mobile-van concept, for example, allows forage and other feedstuff analyses to be performed rapidly on large numbers of samples. The same computer and appropriate software can be employed for least-cost ration balancing based on quality and quantity of available home-grown feeds and costs of purchased supplement. Availability of NIR technology in mobile, as well as fixed-station, units will provide livestock producers many options in their approaches to improving feed efficiency.

5. Quality Assessment of Commercial Hays -

Approximately 20% of the hay produced in the U.S., some 30 million tons per year, is sold once or more before it is fed. Although federal hay-grade standards, organoleptic in nature, have been in place for a long time, they are not employed with any appreciable portion of the commercial crop.

Objective assessment of the nutritive value of hays would provide useful information to all segments of the industry. Market transactions

would be based more on real worth of the product, and the final purchaser would be able to appropriately supplement the hay, if required, to achieve optimum utilization efficiency in livestock feeding. The NIRS van has been demonstrated to meet the needs for rapid, on-the-spot assessment of hay quality in several marketing environments.

6. Education -

Rapidity and accuracy of NIRS technology make its use extremely attractive for many applications. These attributes, coupled with the mobility of a van installation, provide a powerful teaching aid for use with students, livestock producers, hay growers, and other groups. Relationships between physical attributes and subjective judgments of forages to actual nutritive properties, whether real or imagined, can be determined almost instantaneously. Observations to date indicate the resulting discussions and interaction which follow such tests are exceptionally enlightening to most participants.

B. Need to Aid Technology Transfer -

NIRS is a good example of a new technology which has much to offer forage/livestock producers, among others. However, transfer of the technology presents several unique facets.

Unlike many products, forages, normally do not enter into commercial channels. To great extent they are utilized on farms where produced, with no income to the producer until they are converted into animal products which are sold. Moreover, in many systems of livestock production forages do not constitute the sole diet.

Chemically, forages are far more complex than are cereal grains and oilseed meals and other supplements. Traditionally, especially in the U.S., they have been looked upon as "cheap" sources of feed, worthy of relatively little attention. More recently, forages are receiving increased attention as the demand for cereal grains for human consumption increases and as energy costs mount. Producers are operating under a severe cost/price squeeze, with great pressure to reduce costs.

Thus, there is need to reassess the role of forages in livestock production and to seek means of reducing costs of producing livestock products. Feed makes up a large proportion of the costs of producing livestock and their products, with forages constituting from 60 to 90% of the feed fed to cattle and sheep. Reducing costs of forage production, improving forage nutritive value, or utilizing forages more efficiently would lower total costs of livestock production.

Owing to the complex chemical nature of forages, determination of their value as feedstuffs is considerably more difficult than is that of concentrates. To the present, fairly sophisticated hardware and custom-made software packages are required to achieve reliable results. Moreover, a set of reference (calibration) samples, representative of the forages to be analyzed, is required for use in instrument calibration. Scarcely any private and public testing laboratories have such samples in hand or ready access to them.

With relation to the forage-related areas in which NIRS is indicated to be useful, four fairly discrete opportunities emerge. They relate primarily to research, education, ration formulation, and hay marketing.

1. Research -

Interaction and cooperation of a number of research personnel involved in plant breeding, forage management, and forage utilization are underway. Interest appears to be increasing and is likely to proceed in the years ahead. Instrumentation capabilities are such that diverse groups at a given institution, for example, can effectively utilize the same instrument in a number of different projects. It is visualized that, as knowledge of NIRS becomes more widely available, local arrangements will be made to effect purchase and use of appropriate equipment for use in these programs. Eventually, reference forage samples for instrument calibration should be available through the present National Project.

2. Education -

There appears to be great opportunity to use NIRS technology in Extension and other educational programs. However, most effective exploitation will require assistance from specialists, provision of training, hands-on learning experiences, and appropriate coordination. Obviously, funding will be required to purchase equipment and initiate such efforts. In one state, at least, a stationary instrument and a van unit have been purchased for extension efforts, primarily with dairymen.

3. Ration Formulation -

Efficient utilization of the nation's forage resources requires accurate assessment of their nutritive properties, consideration of the nutrient requirements of specific classes of animals at desired levels of production, and provision of appropriate supplements. Traditionally, producers have received assistance, including analytical work, from both the public and private sectors.

Integration of NIRS technology into current advisory programs appears feasible and appropriate. At least one private analytical laboratory utilizes NIRS and in the same state forage testing is currently being done by a public laboratory with NIRS equipment.

In such instances there is particular need to have close coordination and working relations between analytical laboratories and specialists who are familiar with the technology and who have appropriate samples and expertise. Otherwise, frustration, disenchantment with the technology, and wasted time and money may result.

4. Hay Marketing -

The process of marketing hay varies greatly throughout the country. No one approach toward objective quality evaluation is likely to serve all areas and clientele satisfactorily. In hay marketing, as in ration formulation, there likely will be need for both private and public efforts, at least until a firm procedure(s) can be established and the technology can be more thoroughly tested in "real-world" marketing situations.

In summary, potential applications of NIRS technology in forage/livestock research and production are many and varied. Lack of adequate assistance with technology transfer from the research arena to potential users is the primary factor delaying exploitation of NIRS at this time, especially in ration formulation and hay marketing. There is real need for increased interaction between research, extension, hay grading and marketing groups, and industry to assure that the technology is appropriately tested. Otherwise, its potential usefulness may not be realized, at least not in the near future.

Appendix 1

Meetings and Planning Activities Related to
a National Infrared Reflectance Project
on Forages

1. February 9, 1978, University Park, PA--Meeting with J. S. Shenk and other University Park personnel.
2. March 13, 1978, University Park, PA--Meeting with PSU personnel to consider statistical aspects, development of predictive equations, etc.
3. March 16, 1978, Beltsville, MD--Meeting concerning research on use of NIRS for predicting forage quality (R. F Barnes and Wilda Martinez, National Program Staff; L.L. Jansen, Program Analysis and Coordination Staff; Horace Puterbaugh, Program Planning and Review Staff, Northeast Region; K. Norris, BARC; and J.S. Shenk and M. Westerhaus, PSU, W.C. Templeton, Jr., USRPRL).

At this meeting it was agreed that Templeton and Shenk would draft a research proposal for a cooperative project to include a central laboratory and satellite laboratories at strategic locations. It was further agreed that USRPRL-PSU would continue to serve as the focal point for NIRS research on forage crops, close coordination being maintained with the research program of K. Norris at BARC.

Assessment by the BARC group of commercial NIRS instruments for their applicability to predict forage quality was encouraged. It was urged that, to the extent possible, any such effort should include all instruments available at the time of testing.

4. March 30, 1978--Proposal for establishment and development of a National Infrared Forage Research Project sent to R. F Barnes.
5. April 12, 1978--Sent to R. F Barnes a list of objectives, proposed budget for each satellite location and University Park, list of additional personnel required at University Park, and justifications.
6. May 8, 1978, Beltsville, MD--Meeting to discuss further the proposal for establishment and development of an Infrared Information System. (Attendance roster not available, but apparently included K. Norris, Wilda Martinez, G.C. Marten, SEA-AR, St. Paul, MN; J.S. Shenk, J.B. Poweli, R.F Barnes and W.C. Templeton, Jr.)

Norris indicated he had tested Neotec Model 6100, the Gary 14 instrument in his lab, and the two instruments at University Park. It was pointed out that the Neotec 6100 was the only commercial monochromator instrument available. It was decided that USRPRL would try to lease and further test a Neotec 6100 to determine its suitability for use in the kind of research to be undertaken.

7. May 22-23, 1978, University Park, PA—Infrared workshop on use of NIRS in quality evaluations of grains, forages, and other food and agricultural products. Announcement letters and discussion outline mailed May 4 to a large number of potential participants. Twenty-four people attended, with representation from industry, PSU, USDA/AMS, and USDA/ARS.
8. August 1, 1978—Lease of Neotec Model 6100 Instrument initiated for testing and evaluation of potential usefulness in National Research Project.
9. September 7, 1978, Beltsville, MD—Meeting attended by: D. Burdick and F.E. Barton, II, USDA/ARS, Athens, GA.; G.C. Marten, USDA/ARS, St. Paul, MN; T. Schatzki, USDA/ARS, Berkeley, CA; R.F. Barnes and Wilda Martinez, NPS; H. Puterbaugh, PPPS, NER; L.L. Jansen, PACS; K. Norris and J.B. Powell, BARC; J.S. Shenk and R. Hoover, PSU, and W.C. Templeton, Jr., USRPRL.

In-depth consideration was given to procedures to expedite initiation of the proposed coordinated research. Norris reviewed instrument testing, indicating three instruments essentially equal in performance: Cary 14 in his lab, HRS-2 at University Park, and Neotec 6100.

Discussion of criteria for selecting Cooperating Labs, lead time required, procurement procedures, budget requirements, source of funds, etc.

10. September 15, 1978—Templeton sent to R. F. Barnes a first draft outlining need, background, and justification of intensified effort on NIRS research (to be used in presentations to appropriate administrators).
11. November 8-9, 1978, University Park, PA—Work Group Meeting on the Application of NIRS Analysis to Forages.

Meeting attended by 16 persons, representing eight locations. Consensus reached as to feasibility of approach and expressions of interest in participation voiced by representatives from each of the locations. Templeton elected to serve as Project Coordinator.
12. December 6, 1978, Chicago, IL—Meeting to discuss developments to date and coordinate planned research and related matters. Attended by Barnes, Marten, Powell, Shenk, and Templeton. The latter visited later with K.H. Asay (Logan, UT).
13. February 14, 1979—Formal request for Deputy Director's Temporarily Uncommitted Program Funds, FY 1979, made to Steven C. King, Acting Regional Administrator for Agricultural Research, NER, to purchase NIRS equipment for use at BARC; Athens, GA; El Reno, OK; Logan, UT; St. Paul, MN; and University Park, PA

14. April 9, 1979—Templeton notified appropriate personnel at six Locations that the request for Deputy Director's Temporarily Uncommitted Program Funds had been approved.
15. May 1, 1979, College Park, MD.—Meeting to consider items to be dealt with in the Panel Discussion at Southern Pasture and Forage Crops Improvement Conference, Beltsville, Md., on May 3, and to get an update on purchase of equipment and other matters related to national project.

LOCATIONS AND PROJECT LEADERS
National Infrared Reflectance Research
Project on Forages

<u>Locations</u>	<u>Personnel</u>	<u>Addresses</u>
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	M.R. Hoover	do
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HARDWARE CONFIGURATION

(Individual Site)

NEOTEC 6100 Monochromator	Digital Equipment Corp, PDP-11/03L Computer	RX02 Dual Density <u>Floppy Disks</u> RL01 Cartridge Disk 5MB
	LA120 Hardcopy <u>Terminal</u>	

Itemized List;

Neotec 6100 Monochromator with special interface unit for PDP-11 plus cables

Digital Equipment Corp (DEC)

PDP-11/03 with 64KB Mos Memory and Bootstrap/Diagnostic Board

DLV11-J 4-port RS-232 Interface

RXV21 Dual Density Floppy Disk Drives

RL01 Removable 5 MB Cartridge Disk

DRV11 16-Bit Parallel Interface

LA-120 DEC writer III Hardcopy Terminal

RT-11 Operating System

FORTTRAN IV

USDA Pasture Lab, University Park, PA

IR Network Software Program Package

- Notes:
- 1) All PSU/USDA IR software will run on other PDP-11 family systems (11/23, 11/34, etc.)
 - 2) The minimum configuration required for system operation is the above system without the RL01 Disk.
 - 3) The NEOTEC 6100 requires that the computer system be dedicated to instrument operation. Therefore, multi-user operating systems such as RSX-11M cannot be used during data collection.