PROJECT NO. RU-5

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
January 1, 2004 - December 31, 2004

PROJECT TITLE: Defining the Forage Variability in Rice Straw

PROJECT LEADER:
Glenn Nader - Livestock Farm Advisor for Butte/Sutter/Yuba Counties (530) 822-7515
142-A Garden Hwy. Yuba City, Ca. 95991 ganader@ucdavis.edu

PRINCIPAL INVESTIGATORS :
Peter Robinson - Department of Animal Science Extension Dairy Nutritionist
Mike Connor – UC Sierra Foothill Research & Extension Center Superintendent

COOPERATORS:
Agland Industries Inc., Arborg, Manitoba, Canada

LEVEL OF 2OO2 FUNDING: $19,600

OBJECTIVES:

1. Maceration to improve rice straw forage quality.
   A. Macerate straw at one location.
   B. Collect samples from macerated and un-macerated rice straw.
   C. Conduct wet chemistry and biological analysis to determine forage quality.
   D. Evaluate the impact of maceration on forage quality by feeding it to 40 head of cattle.

2. Coordinate with researchers in other countries working on rice straw forage utilization.
   A. Design a plan of work and supervise a student to research and summarize work on forage rice straw studies.
   B. Facilitate publication of a review of rice straw forage research.

EXPERIMENTS CONDUCTED:

Objective 1- Evaluation of in-field maceration of rice straw.

2003 Results

The low digestibility of rice straw has been a limiting factor to its use as a feed for cattle, although rice straw has been used as a dry matter supplement for cattle. Previous studies by Zinn et al. indicate that maceration can greatly increase the digestibility of rice straw.

Agland Industries of Manitoba (Canada) provided a field macerator for our project and rice straw was treated at the time of harvest, at 60% moisture. Half each of the rice check was divided into macerated and un-macerated sections. The straw was allowed to dry and then baled. Samples were collected from each macerated and unmacerated field treatment and assayed by wet chemistry and by biological analysis. Results were:

Rice Straw Maceration Study - Organic Components (2003)

Sample	*Treatment*	*DM*	*OM*	*Fat*	*CP*	*ADICP*	*NDF*	*dNDF*	*ADF*	*TDN*	*ME*
		%	%DM	%DM	%DM	%CP	%DM	%NDF	%DM	%DM	Mcal/kg DM
1	Macerated	94.8	85.0	2.0	4.5	14.0	68.2	42.8	48.9	45.0	0.71
	Unmacerated	94.4	82.2	2.2	5.1	12.5	66.7	42.7	48.6	43.2	0.67
2	Macerated	94.9	84.2	1.8	4.4	16.7	69.0	43.5	50.2	43.9	0.68
	Unmacerated	94.1	84.2	2.3	4.9	15.2	65.8	43.9	47.7	46.5	0.74
3	Macerated	93.9	83.3	1.9	4.7	13.6	67.8	39.3	49.8	41.0	0.62
	Unmacerated	93.5	83.4	2.1	5.3	12.0	63.0	41.5	46.1	45.6	0.72
4	Macerated	94.9	82.6	2.1	4.6	9.1	68.5	40.4	49.9	41.2	0.63
	Unmacerated	93.9	82.2	2.0	5.5	15.4	64.9	43.8	48.5	44.5	0.70
5	Macerated	94.3	83.7	2.1	4.9	17.4	67.9	43.8	49.0	44.5	0.70
	Unmacerated	93.7	82.9	2.0	4.9	13.0	66.3	43.3	48.3	44.4	0.69
6	Macerated	93.9	85.4	2.4	5.4	11.8	67.2	44.0	48.3	47.2	0.75
	Unmacerated	91.7	86.2	2.6	5.0	13.0	64.9	39.2	47.8	46.3	0.73
7	Macerated	93.1	84.7	2.7	4.9	13.0	67.5	39.7	48.5	43.9	0.68
	Unmacerated	92.6	85.4	2.7	4.6	16.3	66.3	33.8	48.6	41.2	0.63
8	Macerated	92.9	85.6	2.6	4.8	17.8	68.1	39.1	48.8	43.6	0.68
	Unmacerated	90.6	85.7	2.5	5.1	15.2	65.2	35.6	46.7	43.1	0.67
9	Macerated	91.7	84.8	2.3	4.8	15.9	67.6	38.4	48.3	42.4	0.65
	Unmacerated	93.1	83.9	2.0	4.6	14.0	72.3	38.0	49.9	38.2	0.57
10	Macerated	91.7	83.4	2.0	4.7	16.3	71.1	37.9	49.8	38.2	0.57
	Unmacerated	93.9	84.2	2.0	4.8	15.6	71.7	38.8	50.7	39.4	0.59
11	Macerated	92.8	86.7	2.0	5.3	18.3	68.9	35.3	49.4	40.7	0.62
	Unmacerated	93.3	84.6	1.9	4.5	17.9	70.4	36.9	51.5	39.0	0.59
12	Macerated	93.6	88.2	1.7	5.4	16.1	69.0	37.4	48.5	43.4	0.68
	Unmacerated	93.5	84.5	2.1	4.2	19.2	69.6	38.3	50.8	40.5	0.62
13	Macerated	93.5	84.7	2.1	4.6	18.6	69.8	40.5	50.2	42.1	0.65
	Unmacerated	93.0	84.5	2.1	4.8	18.2	66.5	37.9	49.0	42.1	0.66
Average	Unmacerated	93.2	84.1	2.2	4.9	15.2	67.2	39.5	48.8	42.6	0.66
Average	Macerated	93.5	84.8	2.1	4.8	15.3	68.5	40.2	49.2	42.9	0.66

Summary	**Control**	**Macerated**	**SEM**	***P***
DM, %	93.2	93.5	1.06	0.39
OM, % DM	84.1	84.8	1.37	0.24
Fat, % DM	2.2	2.1	0.28	0.58
CP, % DM	4.9	4.8	0.34	0.86
ADICP, % CP	15.2	15.3	2.56	0.94
NDF, % DM	67.2	68.5	2.17	0.14
dNDF, % NDF	39.5	40.2	3.00	0.59
ADF	48	49.2	1.24	0.40

Rice Straw Maceration Study - Inorganic Components (2003)

Sample	*Treatment*	*Ca* %DM	*P* %DM	*Mg* %DM	*K* %DM	*S* %DM	*Na* %DM	*Cl* %DM	*Cu* ppm	*Fe* ppm	*Zn* ppm	*Mo* ppm	*Se* ppm
1	Macerated	0.34	0.084	0.200	2.1	0.065	0.028	0.53	2.8	170	35	0.43	nd
	Unmacerated	0.41	0.089	0.180	1.9	0.066	0.032	0.59	3.2	210	31	0.44	nd
2	Macerated	0.35	0.089	0.190	2.1	0.059	0.015	0.62	3.1	170	39	0.47	nd
	Unmacerated	0.33	0.087	0.191	1.9	0.066	0.091	0.74	3.5	200	29	0.34	nd
3	Macerated	0.28	0.100	0.181	2.1	0.063	0.044	0.61	3.4	200	32	0.29	nd
	Unmacerated	0.35	0.140	0.182	2.0	0.073	0.036	0.57	5.0	250	35	0.41	nd
4	Macerated	0.31	0.081	0.179	2.1	0.050	0.046	0.60	3.1	200	33	0.26	nd
	Unmacerated	0.32	0.098	0.213	2.0	0.077	0.094	0.70	4.8	210	37	0.34	nd
5	Macerated	0.38	0.100	0.201	2.1	0.068	0.032	0.64	9.3	200	43	0.43	nd
	Unmacerated	0.35	0.096	0.171	2.0	0.065	0.043	0.58	5.4	170	33	0.28	nd
6	Macerated	0.35	0.130	0.213	1.7	0.072	0.220	0.61	3.8	280	22	0.45	nd
	Unmacerated	0.36	0.130	0.207	1.6	0.069	0.220	0.49	3.9	210	24	0.44	nd
7	Macerated	0.37	0.120	0.226	1.7	0.059	0.210	0.52	4.8	890	26	0.41	nd
	Unmacerated	0.39	0.120	0.216	1.7	0.070	0.260	0.52	4.4	290	25	0.38	nd
8	Macerated	0.38	0.120	0.215	1.7	0.060	0.270	0.59	3.2	240	24	0.34	15
	Unmacerated	0.42	0.130	0.210	1.7	0.070	0.220	0.52	4.3	300	25	0.41	15
9	Macerated	0.31	0.120	0.218	1.9	0.071	0.210	0.56	2.5	240	22	0.31	15
	Unmacerated	0.26	0.100	0.204	2.1	0.067	0.160	0.52	3.7	240	21	0.28	14
10	Macerated	0.27	0.110	0.196	2.0	0.073	0.200	0.57	3.3	250	21	0.48	10
	Unmacerated	0.27	0.096	0.202	2.0	0.069	0.190	0.59	2.3	200	22	0.22	12
11	Macerated	0.58	0.140	0.324	1.6	0.140	0.370	1.10	6.4	300	22	1.35	7
	Unmacerated	0.53	0.094	0.300	1.3	0.079	0.160	0.69	5.7	340	22	0.90	nd
12	Macerated	0.51	0.091	0.294	1.1	0.086	0.250	0.79	6.1	300	19	1.60	nd
	Unmacerated	0.45	0.089	0.300	1.3	0.074	0.160	0.60	5.1	285	21	0.93	nd
13	Macerated	0.48	0.089	0.294	1.2	0.080	0.160	0.54	4.2	235	16	1.07	nd
	Unmacerated	0.52	0.111	0.290	1.4	0.075	0.190	0.70	4.9	250	16	0.74	nd
Average	Unmacerated	0.38	0.106	0.220	1.8	0.071	0.143	0.60	4.3	243	26	0.47	
Average	Macerated	0.38	0.106	0.225	1.8	0.073	0.158	0.64	4.3	283	27	0.61	

2004 Research

To be certain that maceration is evaluated correctly, relative its impact on the nutritional value of rice straw, it is currently being tested in a cattle feeding study that started on October 1, 2004. Forty heifers were divided into four groups with two receiving a diet of macerated rice straw and two groups receiving unmacerated straw. Heifers were weighed on Day 0 and assigned to blocks by weight and then randomly assigned to one of the four groups. Each group will be fed a 60% alfalfa 40% rice straw diet by weight, with each forage fed in the long stem form straight from the 3 twine bale twice a day. The flakes are being broken up by hand and mixed in the concrete bunk. Each group will fed to the same refusal (or waste) rate, and daily consumption will be recorded. Heifer consumption is being recorded daily, and weight gains, body scores and fecal samples will be collected on Days 13, 28, 42, 56, 70 and 84.

Products

Body scores, consumption and weight gains of beef heifers fed macerated vs. un-macerated rice straw will be compared. Findings will be reported next year.

Objective 2 - Coordinate with other researchers in other countries working on rice straw forage utilization.

The 2004 UC Davis Recommended Rice Straw Forage Energy Prediction Equations

The fundamental characteristic of rations for cattle, around which all other nutrients are structured, is its energy content. Expressed variably as TDN (total digestible nutrients) or ME (metabolizable energy), the level of energy in a ration is the sum of the energies of its component feeds. And therein lies the rub since, unlike chemical components such as crude protein (CP) or acid detergent fiber (ADF), the energy content of a feedstuff cannot be chemically analyzed, as energy only represents the potential of a feed's chemical components to do work as biological products, such as meat or milk, or as heat. Nevertheless, an accurate knowledge of the energy content of feeds is central to formulation of cattle rations that maximize the animal's output of usable products.

It has long been recognized that the two key factors that determine the energy value of a forage for cattle are its content of fat, due to its high energy value, and the digestibility of its total structural fiber (i.e., neutral detergent (ND) fiber; NDF), due to its high level in forages. The former can be dealt with by chemical analysis, although the latter has proven to be more difficult. The most common approach to estimate the energy value of feedstuffs has been to calculate its TDN value using an equation based on analyzable components of feedstuffs. Although the TDN equation has changed over the past 120 years, as feedstuff analyses have improved, the principles have remained unchanged. TDN is calculated based on digestible CP, digestible fat, digestible NDF, and digestible non-fiber carbohydrate (NFC), all corrected for a metabolic cost of digestion by the animal. The TDN value can then be used to estimate the metabolizable energy (ME) value of individual feedstuffs. This UC Davis approach has been validated and published (Robinson et al. 2004; Animal Feed Science and Technology, 114: 75-90).

However the package of chemical and biological characteristics of feeds that is required to calculate TDN, and/or ME, costs up to $70 with a turnaround time of 3 to 14 days. Cattle feeders require faster response times and lower costs. Over the past 3 to 4 years a number of California rice hays have had their TDN and ME values estimated at UC Davis by this expensive, and time consuming, approach that includes numerous analyses on each sample. Fortunately, the number of forage samples with these analyses is now sufficiently large to allow simpler equations to estimate the TDN and ME values, based upon a much smaller number of chemical assays, to be recommended. This simpler predictive approach relies upon the basic similarity in the chemical and biological structure of these forages within California, and surrounding areas with similar climates, to allow the actual TDN and/or ME, calculated from the complete set of chemical and biological assays, to be estimated from a much smaller number of assays.

However, as in all cases where corners are cut to save time and money, some predictive accuracy is lost. Thus the equations are presented from best to worst with the r^2 value indicated, where r^2 is a statistical value that describes the ability of the equation to predict the calculated energy values (where an r^2 of 1.00 is perfect prediction and 0.00 is no prediction at all). Since both NDF and ADF are used extensively in the industry, equations are presented based upon both, with or without the addition of CP or organic matter (OM; which is all the DM except ash), but only if they provide substantive improvements in predictability over NDF or ADF alone.

The 2004 UC Davis Recommended Forage Energy Prediction Equations

As rice straw samples arriving in commercial California forage testing laboratories vary in terms of requested assays, the laboratories require the ability to predict TDN from assays such as ADF, NDF, OM and/or CP. Thus it is the decision of each laboratory to decide which equation to use, based upon available assays and the relative accuracy (i.e., the r^2 value) of the equations, since each of the equations predicts TDN.

All values of NDF, ADF, CP, OM, as well as TDN, are as a % of DM. Both NDF and ADF are expressed with residual ash, and NDF is assayed with the inclusion of sodium sulfite in the ND and the use of a heat stable alpha amylase during ND extraction. Although wet chemical analysis is very popular in California, values based upon near infrared (NIR) procedures are acceptable if they have been calibrated based upon appropriate wet chemical assay sets. TDN is estimated at 1xM (i.e., low feed intake), as this is the most common usage of TDN when we use it amongst ourselves.

Rice Straw

Recommended equations to predict the TDN value of California rice hays are:

$$TDN = -12.13 - (0.61931 * NDF) + (1.13472 * OM) \qquad r^2 = 0.61$$

$$TDN = 37.85 - (0.98864 * ADF) + (0.62155 * OM) \qquad r^2 = 0.60$$

$$TDN = 108.88 - (1.37413 * ADF) \qquad r^2 = 0.53$$

Within rice hay, there is very little difference in the predictive ability of NDF vs. ADF if OM is included. However if OM is unavailable, then ADF, but not NDF, is acceptable.

International Study Group Summary

Reports that rice straw fed directly from the field (i.e., prior to field drying) results in higher voluntary intake, and digestibility, than field dried and baled rice straw suggests that the drying process causes sharp reductions in its nutritive value. As previous nutritional upgrading approaches have focused on the rice straw after drying, it is likely that they could more appropriately be called ‘nutritional recovery’ rather than nutritional upgrading.

Drying of straw appears to reduce its nutritive value, at least partly due to depletion of soluble sugars by aerobic fermentation, although this loss may not be substantial unless the drying process is prolonged over several days due to poor drying conditions. Thus faster drying may tend to conserve sugars, thereby decreasing the proportion of structural fiber in the rice straw dry matter, which would increase its energy value to the animal. However, it is also possible that the slow drying process may cause structural changes in the biogenic silica crystals, which may slow ruminal digestibility of cell wall, possibly by interfering with bacterial attachment and/or enzyme binding to substrate. In growing rice straw, silica is in a hydrated form and the drying process likely causes it to lose free water molecules which results in increased coarseness of the texture of the straw. This could reduce palatability and/or increase animal chewing power requirements for particle size reduction in the rumen. Loss of water molecules from biogenic silica may also lead to its binding with secondary cell wall carbohydrates, and this may strengthen the cell wall thereby making it more resistant to ruminal digestion. If a disruption of this process were to occur soon after harvest, the strengthening of the cell wall structure by binding of silica with it may be minimized, resulting in retention of the fermentable structural fiber, which are the ones that have been shown to be more likely to become even more fermentable due to application of microbial and/or enzyme mixtures.

Maceration of grasses and legumes in the Midwestern and Northeastern states of the US has resulted in increased drying rates, at least partially due to the physical abrasion and shredding of stems and leaves. The success of this technology has resulted in commercial development of field scale maceration machines that that are used to lift, macerate and replace windrows of forages in the field. This technology has not, to date, been applied to rice straws in the US, although research is currently underway at the University of California to evaluate its impact on the digestibility of rice straw. Since maceration will likely increase the drying rate of rice straw, it may increase its digestibility by limiting the negative effects of dehydration of silica on fermentability of rice straw cell wall, thereby making it a better possibility for positive effects of direct fed microbials and/or enzyme cocktails.

As silica is precipitatable at acid pH, acidification at the time of maceration may further prevent binding of silica with cell wall components leading to even lower losses of digestibility during drying. Other harvest technology possibilities that may be associative with direct fed compounds remain to be identified.

While much is known about the reasons why rice straw has such a low nutritive value, much remains to be determined. A better understanding of the interactions of silica with cell wall digestibility is critical to allowing development of practical strategies and methods to increase the nutritional value of rice straw.

This is not the first time that the low nutritional value of rice straw has been recognized, the substantial economic benefits that would result from its nutritional upgrading, or identified a potential course of action to achieve rice straw with a higher nutritive value. In fact, previous attempts of nutritional upgrading of rice straw have largely been successful, within their objectives, but practical nutritional upgrading technologies have not been the result. The potential for associative effects of rapid post harvest desiccation and use of direct fed microbials and/or enzymes within a commercially practical technology is the goal. However, the intellectual and structural resources provided by several persons and groups will be required to achieve it.

Rice Straw Variability

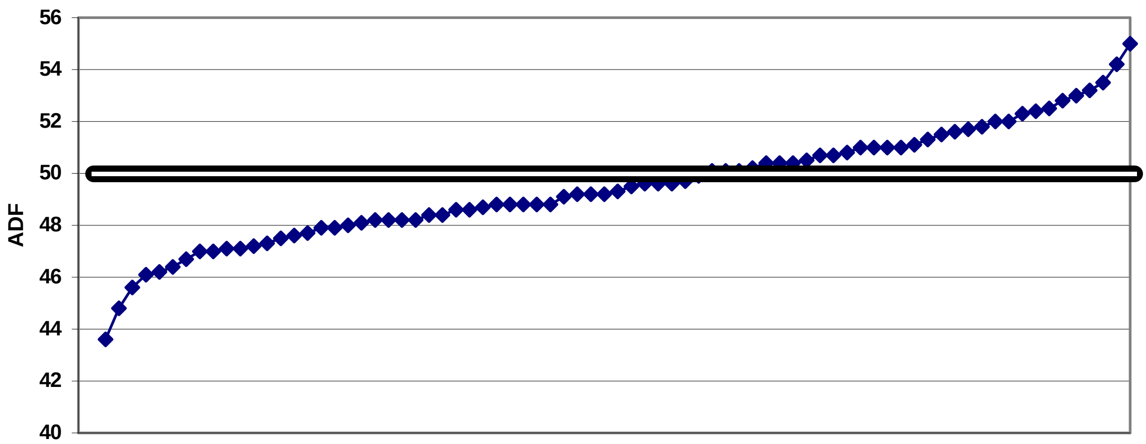
In 2002, 37 random samples of rice straw stacks were sampled and analyzed by wet chemistry for there constituents. This was repeated again in 2003 and 40 samples were collected and analyzed. Core samples were collected using a Penn State probe and analyzed by University of California Animal Science Department. The wet chemistry included total N by Kjeldahl analysis, that is used to calculate crude protein (CP), fiber content determinations by acid detergent fiber (ADF) and neutral detergent fiber (NDF), fat content by Ether Extract (EE) and dry matter determination by oven drying at 105^{o}C. The biological evaluation predicts the energetic value of rice straw was conducted at the UC Dept. of Animal Science.

This data (below) illustrates to rice growers and cattlemen that not all rice straw should be fed to cattle. In 2001, we established guidelines for purchasing rice straw for feeding to cattle. The intent of these guidelines were to decrease the variability of the performance of cattle fed rice straw by making sure only the best forage quality product is used. This will help erase the negative stigma of past failures in feeding rice straw to cattle. The guidelines are as follows:

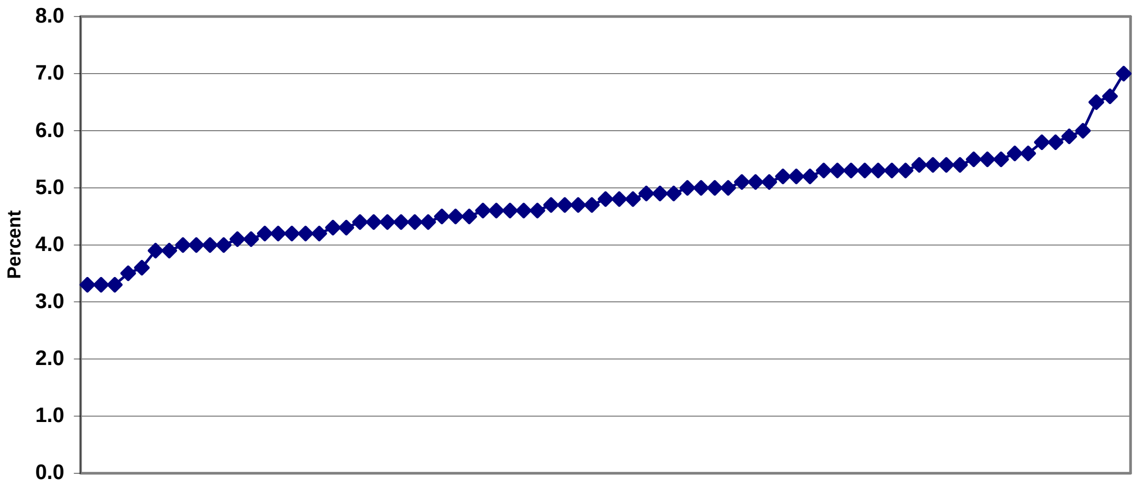
Lab Test	Minimums
•Crude Protein	4.5 or higher
•Fiber (ADF)	50 or lower

The comparison of the variation in the wet chemistry of the straw can be in the graphs below. This impacts forage quality and other uses of rice straw.

Rice Straw Variability Study (2002/2003)
77 samples



Crude Protein



Raw Data Sets – Rice Straw Variability Study (2002/03)

Organic Components

Year	Sample	DM	OM	Fat	CP	ADICP	NDF	dNDF	ADF	TDN	ME
		%	%DM	%DM	%DM	%CP	%DM	%NDF	%DM	%DM	
2002	3	93.4	84.0	2.0	4.2	10.3	67.3	39.0	49.6	42.3	0.65
2002	4	93.2	86.4	2.0	4.7	11.4	65.3	34.0	47.1	42.4	0.65
2002	5	93.7	83.6	2.1	5.0	10.6	67.7	39.1	48.1	41.6	0.64
2002	6	93.5	85.1	2.1	4.5	11.9	67.7	34.9	48.7	40.2	0.61
2002	7	93.0	87.3	2.6	5.5	9.8	69.5	39.1	48.2	44.7	0.70
2002	8	93.6	83.4	2.0	4.4	12.2	67.3	39.6	49.1	41.9	0.64
2002	10	94.5	84.2	2.1	4.0	10.5	69.5	39.9	48.8	41.8	0.64
2002	11	94.2	85.0	2.2	4.9	10.9	69.0	40.1	48.4	43.0	0.67
2002	13	93.6	82.8	2.0	4.6	11.6	64.7	36.9	48.2	41.0	0.63
2002	14	94.0	83.8	2.0	4.4	12.2	64.6	41.1	47.3	44.8	0.70
2002	15	93.4	85.9	2.7	4.9	10.9	66.2	37.4	47.0	44.3	0.69
2002	16	93.9	85.6	2.2	4.4	12.2	69.2	38.9	49.9	42.7	0.66
2002	17	94.6	85.5	2.2	5.0	10.6	68.6	32.9	48.6	38.8	0.58
2002	18	94.0	86.0	2.2	4.1	10.3	66.2	47.2	47.7	50.5	0.82
2002	19	92.9	84.5	2.2	5.4	10.0	67.7	43.8	49.3	45.7	0.72
2002	20	93.8	84.2	1.9	3.5	12.1	71.3	42.3	51.0	42.3	0.65
2002	21	94.2	85.0	2.1	3.3	12.9	71.3	39.7	51.1	41.5	0.64
2002	22	92.7	82.0	0.9	4.2	10.3	69.3	45.8	50.4	42.5	0.65
2002	23	92.7	80.3	2.5	5.3	10.2	66.0	37.0	51.0	38.6	0.57
2002	24	93.3	80.7	2.0	5.3	14.3	64.1	34.0	49.2	37.2	0.55
2002	25	93.7	81.9	1.8	4.4	9.8	64.9	35.2	50.4	38.8	0.58
2002	26	93.6	82.8	1.4	4.1	13.2	67.1	37.9	50.1	39.5	0.60
2002	27	94.1	85.1	1.7	4.3	10.0	66.2	39.5	46.2	43.9	0.68
2002	28	93.9	79.1	1.5	7.0	7.6	68.8	39.7	52.3	36.1	0.52
2002	29	93.9	82.1	2.2	5.5	9.6	66.3	35.6	47.9	38.7	0.58
2002	30	93.8	85.8	1.4	3.3	16.1	70.6	34.4	50.7	38.0	0.56
2002	31	94.4	84.3	2.1	5.4	9.8	70.0	35.0	50.1	38.0	0.56
2002	32	94.1	84.2	2.1	4.7	11.4	71.3	36.0	52.0	37.9	0.56
2002	33	93.1	83.4	2.3	4.8	13.3	71.5	34.3	52.8	35.9	0.52
2002	34	94.3	85.9	1.8	4.2	10.0	60.0	33.1	44.8	44.6	0.70
2002	35	94.1	82.8	1.6	4.0	15.8	71.5	38.3	51.5	37.4	0.55
2002	36	94.2	83.2	1.5	5.6	11.3	71.3	37.3	52.5	36.9	0.54
2002	37	93.5	85.9	1.7	3.6	11.8	60.7	31.2	43.6	42.9	0.66
2002	38	93.7	84.3	1.8	4.6	14.0	67.4	30.9	48.2	36.5	0.53
2002	39	92.2	85.1	1.6	3.3	13.3	69.7	39.7	49.6	41.9	0.64
2002	40	93.8	83.9	1.8	5.0	10.6	72.5	30.0	52.0	32.1	0.44
2002	41	94.0	83.8	1.8	5.1	10.4	71.2	29.3	51.6	32.4	0.45
2003	1	93.5	85.2	1.8	4.8	11.1	63.6	42.7	47.0	47.5	0.76
2003	2	93.3	84.7	1.9	5.1	14.6	65.6	42.7	48.8	45.8	0.72
2003	3	91.7	84.4	1.5	4.7	16.3	67.5	38.0	50.5	40.9	0.62
2003	4	94.2	82.6	1.8	4.4	12.2	61.4	38.0	46.7	43.3	0.67
2003	5	94.5	84.4	1.9	5.1	12.5	68.3	45.5	47.1	46.1	0.73
2003	6	93.5	85.7	2.2	5.2	14.3	66.6	35.2	47.6	41.6	0.64
2003	7	94.9	82.6	2.0	5.6	11.3	66.2	37.7	48.8	40.3	0.61

2003	8	93.9	83.2	2.3	4.9	15.2	69.8	36.3	51.0	38.1	0.57
2003	9	93.9	84.9	2.6	4.7	13.6	71.9	39.8	50.8	41.4	0.63
2003	10	94.1	84.6	2.6	5.4	11.8	66.7	43.5	47.5	46.5	0.74
2003	11	94.6	86.3	2.5	5.5	11.5	69.7	40.7	49.5	44.5	0.70
2003	12	94.1	86.5	2.9	5.8	10.9	68.5	44.2	48.8	48.2	0.77
2003	13	94.0	83.7	2.1	4.6	16.3	70.2	31.8	51.0	35.0	0.50
2003	14	93.5	83.2	2.1	5.2	10.2	67.3	42.3	48.0	43.6	0.68
2003	15	94.3	83.6	2.1	4.5	16.7	66.3	41.8	49.2	44.0	0.69
2003	16	93.7	83.2	2.1	5.9	12.7	60.9	41.9	45.6	46.7	0.74
2003	17	93.9	84.0	1.9	5.8	11.1	67.2	40.6	50.1	42.9	0.66
2003	18	92.9	84.2	2.2	5.3	12.2	65.6	40.5	48.4	44.3	0.69
2003	19	94.3	82.5	1.9	4.8	15.6	65.0	45.1	49.2	45.6	0.72
2003	20	94.7	86.6	1.9	4.4	16.7	66.4	38.8	47.2	44.7	0.70
2003	21	93.3	82.1	2.3	6.0	14.3	65.1	35.4	48.2	39.1	0.59
2003	22	94.4	79.0	1.5	4.6	14.0	69.0	40.9	53.5	36.8	0.54
2003	23	94.0	83.6	1.9	5.0	19.1	71.0	37.9	51.8	38.2	0.57
2003	24	93.5	86.0	1.9	3.9	13.9	65.9	34.4	48.6	41.8	0.64
2003	25	94.1	80.0	1.9	5.3	14.0	65.2	35.3	50.2	36.6	0.54
2003	26	95.3	82.0	2.1	4.6	13.6	69.6	40.5	51.3	39.8	0.60
2003	27	94.2	76.5	1.8	5.3	12.0	66.8	37.5	51.7	33.7	0.48
2003	28	93.9	85.7	1.8	4.3	15.0	64.0	38.3	46.4	44.9	0.70
2003	29	94.9	78.7	1.5	4.0	13.2	71.7	40.0	55.0	34.4	0.49
2003	30	94.5	83.9	1.7	6.5	13.1	69.0	37.6	50.7	39.2	0.59
2003	31	94.1	81.6	1.6	6.6	12.9	63.2	34.7	47.9	38.5	0.57
2003	32	95.0	79.8	1.5	5.3	12.0	69.2	39.8	52.4	36.6	0.54
2003	33	94.7	82.9	2.0	4.2	12.5	67.7	44.6	50.4	44.6	0.70
2003	34	94.1	79.4	1.6	5.4	11.8	70.1	33.2	54.2	31.1	0.42
2003	35	94.8	79.3	1.5	4.2	15.0	69.5	39.1	53.2	35.5	0.51
2003	36	93.9	87.5	1.6	3.9	13.5	63.8	39.5	46.1	47.5	0.76
2003	37	95.0	84.8	1.6	5.2	16.3	68.0	41.0	49.7	43.0	0.66
2003	38	94.9	79.2	1.6	4.5	16.3	69.7	34.6	53.0	32.2	0.45
2003	39	94.8	84.7	1.6	4.0	15.8	69.0	39.2	49.6	41.3	0.63
2003	40	95.2	84.7	2.0	5.3	12.0	66.9	40.8	48.8	44.0	0.68

Raw Data Sets – Rice Straw Variability Study (2002/03)

Inorganic Components

Year	Sample	Ca	P	Mg	K	S	Na	Cl	Cu	Fe	Zn	Mo
2002	3	0.24	0.100	0.16	1.6	0.072	0.100	0.43	6.2	340	27	0.25
2002	4	0.27	0.120	0.20	1.3	0.090	0.190	0.43	3.9	490	47	0.54
2002	5	0.41	0.087	0.22	2.1	0.078	0.064	0.44	4.3	180	60	0.66
2002	6	0.37	0.075	0.16	1.8	0.068	0.100	0.56	3.8	240	39	0.49
2002	7	0.31	0.084	0.18	1.7	0.080	0.300	0.64	1.9	140	46	0.25
2002	8	0.30	0.075	0.23	1.7	0.062	0.180	0.66	2.3	180	35	0.64
2002	10	0.38	0.065	0.13	1.6	0.069	0.026	0.44	2.7	220	21	0.52
2002	11	0.21	0.061	0.14	1.7	0.086	0.020	0.47	3.5	200	22	0.37
2002	13	0.25	0.100	0.23	1.7	0.120	0.076	0.10	3.0	160	28	0.42
2002	14	0.27	0.100	0.25	1.5	0.150	0.130	0.10	4.2	340	31	0.42
2002	15	0.33	0.130	0.22	1.5	0.062	0.100	0.46	4.1	210	29	1.20
2002	16	0.33	0.069	0.25	1.4	0.060	0.270	0.49	3.0	400	21	1.20
2002	17	0.33	0.100	0.16	1.8	0.088	0.016	0.50	3.4	180	27	1.20
2002	18	0.33	0.093	0.21	1.9	0.079	0.020	0.38	3.9	220	33	2.00
2002	19	0.34	0.120	0.22	2.0	0.078	0.035	0.23	4.2	250	29	3.70
2002	20	0.33	0.100	0.18	1.5	0.080	0.026	0.23	2.3	190	19	0.37
2002	21	0.31	0.100	0.18	1.6	0.086	0.024	0.19	3.4	610	21	0.44
2002	22	0.28	0.110	0.16	1.6	0.110	0.390	0.90	2.8	190	21	0.29
2002	23	0.27	0.110	0.19	1.7	0.065	0.045	0.35	2.5	150	57	1.50
2002	24	0.29	0.100	0.21	1.9	0.071	0.034	0.51	4.2	270	36	0.76
2002	25	0.26	0.100	0.21	1.8	0.086	0.049	0.14	3.2	160	32	0.47
2002	26	0.26	0.093	0.18	1.7	0.098	0.023	0.10	4.2	140	32	0.38
2002	27	0.35	0.110	0.14	1.8	0.100	0.068	0.35	2.6	270	42	0.68
2002	28	0.23	0.170	0.19	2.7	0.110	0.047	1.00	5.4	360	23	0.72
2002	29	0.30	0.089	0.15	2.0	0.088	0.046	0.56	4.3	170	25	0.48
2002	30	0.22	0.088	0.12	1.7	0.067	0.190	0.48	4.7	320	28	0.30
2002	31	0.35	0.088	0.20	1.6	0.087	0.340	0.54	2.3	200	22	0.74
2002	32	0.31	0.086	0.18	1.9	0.100	0.340	0.85	4.0	300	36	0.36
2002	33	0.30	0.058	0.17	2.0	0.088	0.230	0.75	3.0	210	23	0.25
2002	34	0.24	0.094	0.16	1.3	0.069	0.150	0.53	3.0	200	24	0.35
2002	35	0.25	0.056	0.22	2.1	0.086	0.190	0.92	4.9	130	31	0.34
2002	36	0.27	0.100	0.22	2.0	0.110	0.300	1.10	6.2	240	25	0.25
2002	37	0.23	0.076	0.16	1.3	0.065	0.170	0.54	2.7	230	18	0.35
2002	38	0.28	0.140	0.22	1.8	0.150	0.260	0.38	5.6	240	41	2.50
2002	39	0.33	0.051	0.29	1.5	0.100	0.430	1.20	5.4	230	20	0.36
2002	40	0.23	0.087	0.21	1.9	0.091	0.230	0.54	3.0	210	25	0.84
2002	41	0.22	0.099	0.18	1.7	0.090	0.310	0.52	3.2	230	26	0.90
2003	1	0.25	0.060	0.19	1.5	0.065	0.15	0.46	2.5	460	13	0.70
2003	2	0.31	0.076	0.28	1.8	0.100	0.31	0.91	3.8	300	19	0.32
2003	3	0.32	0.083	0.22	1.5	0.080	0.20	0.37	6.0	800	23	0.35
2003	4	0.23	0.071	0.20	1.6	0.063	0.03	0.32	3.0	820	18	0.26
2003	5	0.33	0.081	0.19	1.8	0.067	0.11	0.35	2.9	240	23	0.57
2003	6	0.34	0.099	0.19	1.6	0.078	0.21	0.50	1.5	250	16	0.41

2003	7	0.37	0.092	0.21	2.0	0.066	0.07	0.70	3.2	220	23	0.41
2003	8	0.39	0.080	0.20	1.5	0.056	0.30	0.56	2.0	330	23	0.58
2003	9	0.31	0.086	0.24	1.6	0.060	0.34	0.82	2.2	460	17	0.34
2003	10	0.38	0.110	0.16	1.7	0.064	0.01	0.29	2.1	200	22	1.50
2003	11	0.31	0.082	0.18	1.8	0.079	0.12	0.69	3.1	190	30	0.38
2003	12	0.33	0.085	0.19	1.8	0.080	0.20	0.68	3.1	200	27	0.33
2003	13	0.26	0.086	0.19	1.9	0.057	0.16	0.50	2.6	670	21	0.32
2003	14	0.50	0.090	0.14	1.7	0.056	0.02	0.47	5.7	300	28	0.33
2003	15	0.36	0.075	0.17	1.7	0.043	0.04	0.47	6.6	330	37	2.40
2003	16	0.38	0.170	0.26	2.2	0.083	0.02	0.44	8.4	350	35	1.60
2003	17	0.32	0.097	0.24	1.8	0.068	0.28	0.40	6.2	330	27	0.82
2003	18	0.42	0.140	0.200	1.7	0.066	0.110	0.34	7.4	240	40	1.00
2003	19	0.31	0.088	0.240	1.7	0.055	0.110	0.60	4.6	240	24	0.45
2003	20	0.27	0.120	0.169	1.1	0.089	0.500	0.46	5.2	550	27	0.51
2003	21	0.40	0.140	0.247	1.9	0.080	0.160	0.43	5.5	600	35	1.10
2003	22	0.23	0.120	0.233	2.3	0.067	0.092	0.53	13.0	610	33	1.10
2003	23	0.31	0.100	0.245	1.6	0.071	0.440	0.85	4.6	670	31	0.32
2003	24	0.27	0.094	0.182	1.5	0.060	0.190	0.49	4.2	250	28	0.26
2003	25	0.31	0.140	0.202	2.0	0.065	0.091	0.38	8.1	460	31	1.30
2003	26	0.33	0.073	0.189	1.8	0.054	0.017	0.51	6.9	290	30	0.76
2003	27	0.28	0.092	0.287	1.7	0.037	0.021	0.35	12.0	3400	40	1.80
2003	28	0.24	0.084	0.192	1.2	0.060	0.330	0.44	5.2	890	27	0.30
2003	29	0.21	0.099	0.211	2.0	0.062	0.041	0.70	7.5	460	32	2.30
2003	30	0.33	0.130	0.234	1.7	0.088	0.230	0.56	6.0	980	33	2.20
2003	31	0.33	0.120	0.190	1.9	0.074	0.087	0.32	5.8	740	35	0.75
2003	32	0.25	0.097	0.295	1.6	0.055	0.260	0.87	9.2	1800	33	0.84
2003	33	0.38	0.082	0.190	1.8	0.049	0.040	0.44	5.0	450	35	1.60
2003	34	0.29	0.078	0.202	1.7	0.063	0.170	0.57	4.0	720	24	0.89
2003	35	0.19	0.085	0.179	2.1	0.058	0.120	0.61	3.2	350	23	1.80
2003	36	0.27	0.086	0.181	1.1	0.059	0.310	0.52	2.8	400	29	0.29
2003	37	0.26	0.120	0.200	1.9	0.047	0.036	0.55	4.1	280	25	2.20
2003	38	0.19	0.089	0.190	2.1	0.061	0.120	0.75	2.5	270	22	1.20
2003	39	0.31	0.074	0.169	1.7	0.046	0.027	0.37	3.1	210	33	1.40
2003	40	0.32	0.089	0.200	1.8	0.070	0.018	0.32	2.8	190	34	1.50