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9. ABSTRACT

Past research has shown that amount of protein and its amino acid modification are genetic traits that are amenable to modification by breeding in food and feed crops. This research team has identified a number of wheat varieties with high potential value as genetic sources of high protein and elevated level of lysine. High protein varieties include Atlas 66 and Atlas 50, U.S. varieties derived from Frondoso (Brazil), Aniversario (Argentina), Nap Hal (India), and Nebraska Male Fertility Restorer. The most promising genetic sources of elevated lysine are Nap Hal (India) and C.I. 13449 (USA). Crosses among these and other varieties have produced experimental lines with levels of protein and lysine significantly higher than the parental varieties and much higher than ordinary varieties of wheat. More than 100 lines under irrigated test conditions at Yuma, Arizona since 1973 have averaged 17% protein and 3.5% lysine. This represents an approximate 40% increase in protein and 20% increase in lysine. Such lines can be expected to possess superior nutritional value.

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Report of Research Findings

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April 1, 1975 - March 31, 1976

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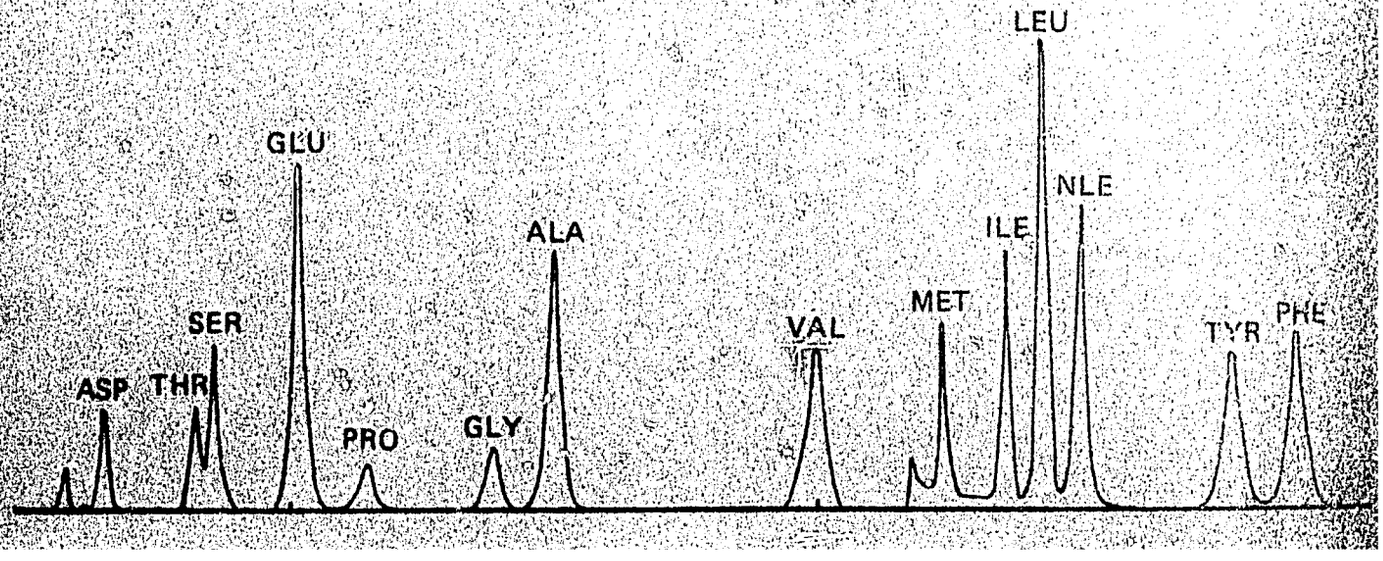
AGRICULTURAL RESEARCH SERVICE

U.S. DEPARTMENT OF STATE
AGENCY FOR INTERNATIONAL DEVELOPMENT

UNIVERSITY OF NEBRASKA - LINCOLN
COLLEGE OF AGRICULTURE



R E P O R T

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R E S E A R C H F I N D I N G S

GENETIC IMPROVEMENT OF PRODUCTIVITY AND NUTRITIONAL QUALITY OF WHEAT

April 1, 1975 - March 31, 1976

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NARRATIVE SUMMARY OF ACCOMPLISHMENTS AND UTILIZATION

Summary Statement

Wheat is a major food throughout the world. It ranks in importance with rice as an efficient provider of both calories and protein. Genetically increasing the content and quality of protein of the wheat grain offers an inexpensive, practical and acceptable way to improve the human diet. For maximum value the improvement in nutritional quality must be accompanied by high grain yield and resistance to production hazards like diseases and insects. Full utilization of available genetic variability for protein and lysine in the world's wheats could provide the protein needs of an additional 400 million people. Coupled with anticipated advances in wheat productivity the number of people accommodated could be substantially higher than 400 million.

Research has shown that amount of protein and its amino acid modification are genetic traits that are amenable to modification by breeding in food and feed crops. The University of Nebraska in cooperation with the Agricultural Research Service, USDA, and with major financial support since 1966 from the Agency for International Development, U.S. Department of State, has identified a number of wheat varieties with high potential value as genetic sources of high protein and elevated level of lysine. High protein varieties include Atlas 66 and Atlas 50, U.S. varieties derived from Frondoso (Brazil), Aniversario (Argentina), Nap Hal (India), and Nebraska Male Fertility Restorer. The most promising genetic sources of elevated lysine are Nap Hal (India) and C.I. 13449 (USA). Crosses among these and other varieties have produced experimental lines with levels of protein and lysine significantly higher than the parental varieties and much higher than ordinary varieties of wheat. More than 100 lines under irrigated test conditions at Yuma, Arizona since 1973 have averaged 17% protein and 3.5% lysine. This represents an approximate 40% increase in protein and 20% increase in lysine. Such lines can be

expected to possess superior nutritional value.

Expanded Statement

Success of research efforts to genetically improve the nutritional quality of wheat depends on existence of genetic variation for protein and lysine. Protein and lysine data were obtained on 13,000 common wheats, 3,400 durums, and 673 spelt wheats in the World Wheat Collection maintained by the USDA, Agricultural Research Service and new accessions to the Collection continue to be analyzed. The information is the best and most comprehensive of its kind available in the world today. Seed of nutritionally promising varieties in the Collection has been made available to most countries in which wheat is an important crop and is of much value to breeders in these countries for genetic improvement of wheat.

Twenty-six high protein lines selected from crosses of Atlas 66 with hard red winter varieties were publically released as elite germplasm. Seed has been distributed for testing and is being used in breeding programs in LDC's. A new high protein variety Lancota (C.I. 17389) also derived from Atlas 66, was distributed in 1975. Lancota combines high protein content with high yield, disease resistance, and excellent agronomic traits. Its production on all of Nebraska's wheat acres could contribute as much as 900 railroad boxcars of additional protein in a single year. In those LDC's where it is adapted Lancota could provide significant additional protein for human consumption.

Transgressive segregation for very high protein and high lysine was demonstrated in crosses involving Atlas 66, Nap Hal, and C.I. 13449. This provides evidence of different genes for high protein in the parent varieties that function additively to produce new high levels of protein and lysine. Two-hundred-eighty high protein-high lysine lines from these crosses were distributed to breeders at 26 different sites in LDC's and other countries in 1974 for local agronomic evaluation and use in breeding programs. Known genetic

variability for protein in wheat suggests that grain protein content can be increased as much as five percentage points. Accumulated performance data from Nebraska and the IWWPN indicate that it should be possible to accomplish this without sacrificing yield.

Seed fractionation studies of Atlas 66, Nap Hal, and C.I. 13449 have shown the high protein effect to reside entirely in the endosperm of Atlas 66 and largely in the endosperm of Nap Hal. The high protein effect, therefore, is transmissable to white flour milled from these varieties and is not lost in the milling process. The high lysine effect was found in the endosperm of C.I. 13449 but in the aleurone of Nap Hal. Research at Nebraska has shown that high quality protein can be extracted with an alkaline solution from the aleurone and its addition to the white milled flour to achieve much elevated nutritional quality may have commercial feasibility. Although much wheat is consumed as whole wheat flour in LDC's, there is a strong trend toward the use of commercially milled white flour by the urban populations of these countries. High protein-high lysine effects that reside in the endosperm provide much more flexibility of utilization than would similar effects in the less digestible bran fraction.

Small animal bioassays conducted at the University of Nebraska have confirmed that increased protein content in wheat grain improves its nutritional value. High protein varieties fed at 56% grain in the diets consistently produced significant higher weight gains and FER values in weanling mice than lower protein varieties. At higher levels of grain in the diets, all varieties produced acceptable weight gains and similar FER's. Somewhat reduced PER values of the protein from the high protein varieties was more than offset by their additional protein when equal quantities of grain were fed. This increased efficiency is expected to be the same for humans. This was tested for selected parental varieties in cooperative small animal and human bioassays conducted at

the University of Nebraska, the British-American Hospital in Lima, Peru, and other locations in 1974. The final report is being prepared.

The International Winter Wheat Performance Nurseries (IWWPN) organized by the University of Nebraska and the ARS in 1969 provide an extremely useful vehicle for rapid and efficient testing of new varieties on a worldwide basis. They have been equally as effective in promoting cooperation, improved communication, and exchange of useful new germplasm among wheat breeders throughout the world. They were grown at 59 sites in 36 countries in 1975 and have served to identify varieties with outstanding adaptation to widely differing conditions of climate and soil. The high yielding Russian variety Bezostaya 1 has become widely established and is contributing to increased wheat production in Turkey and neighboring countries as a result of its superior performance early in the IWWPN. The high yielding variety Bolal, developed in Nebraska, also has become established in Turkey and is contributing to its wheat production.

Bezostaya 1 and other varieties whose performance superiority has been demonstrated in the IWWPN are being widely used in LDC and other breeding programs. They are being utilized prominently by Nebraska in crosses with high protein-high lysine wheats to combine high productivity and broad adaptation with superior nutritional value. Testing of high protein Nebraska varieties in the IWWPN has established the stability and usefulness of high protein genes in a wide array of international wheat production environments.

Atlas 66 derived varieties produce comparable yields of grain with higher protein content than ordinary varieties under low as well as high soil fertility. Their protein advantage in Nebraska and international tests is in the range of 1.5 to 3.0 percentage points or about 20-30 percent more protein than comparably yielding varieties in the same tests. Production of high protein grain (14-17%) can be achieved from these already available Atlas-derived wheats

grown under high soil fertility. Laboratory analyses indicate that, with 17% protein, they will provide more of all of the essential amino acids, including lysine, than an equal amount of Opaque-2 maize with 10% protein.

A rapid *in vivo* laboratory screening test involving nitrate reductase assay is being perfected in the Nebraska laboratory for efficient early identification of cultivars with genetic potential for high grain protein. A highly important spin-off from this research was the discovery of the major mechanism by which most, if not all, herbicides kill plants and the associated development of a rapid efficient laboratory technique for identification of chemicals with herbicidal properties. The method has been public patented. The research may also contribute to elucidation of mechanisms by which fungi and other pathogens damage or kill plants. An added dividend from this research was the discovery that many surfactants used in conjunction with herbicides are plant specific and a key to successful destruction of weeds without damage to the crop specie involved. It is evident that this line of investigation may have important and far reaching beneficial effects on future agricultural development especially in the fields of pest and disease control.

More than 50 publications have resulted from these investigations and have been distributed in the LDC's. High protein-high lysine wheat germplasm has been distributed to geneticists, breeders, and agronomists throughout the world. The staff has organized three international wheat conferences and has participated in numerous other workshops. The Nebraska laboratory has provided important analytical service for many LDC's.

PROJECT OBJECTIVES

Wheat is the most efficient producer of both calories and protein among the food cereals. Wheat, consumed as whole wheat flour, can produce enough protein from an acre of land in one year to satisfy the protein needs of one person for 877 days. This compares with 654 days for rice, only 130 days for beef or hogs, and 185 days for poultry. Development and full use of genetically high protein productive wheats with improved amino acid balance would significantly increase its nutritional value and could provide protein for as many as 400 million additional people. Combined with anticipated advances in yield, the number of additional people accommodated could be substantially more than 400 million.

Because of the encouraging results already achieved from the breeding efforts to date, there is every reason to expect that this project will continue to make highly important contributions to nutritional improvement on a worldwide basis by increasing yield and improving wheat protein both quantitatively and qualitatively. The excellent relationships already established by the Nebraska-ARS group with national research, educational, and extension organizations in a large number of cooperating countries through the IWWPN network provides the necessary vehicle for rapid evaluation and use of improved wheats from the project. This together with effective linkage with international research and development organizations such as CIMMYT, FAO, and IAEA will enable early delivery to and utilization of new improved varieties and related production information by farmers in LDC's.

<u>Itemized Objectives</u>

a. Develop by established genetic and breeding procedures hybrid populations and experimental varieties with genetic potential for high productivity and improved nutritional value for evaluation and selection in national breeding programs and in international performance trials.

b. Characterize the quality properties of nutritionally improved wheats through chemical and physical studies to provide a more reliable basis for prediction of processing value.

c. Identify agronomically and nutritionally superior broadly adapted winter wheat varieties and study the influence of soil and environmental factors on yield and quality of the varieties in the International Winter Wheat Performance Nursery.

d. Study the roles of nitrogen metabolism and photosynthetic efficiency in increased productivity and improved nutritional value of wheat to enable improved efficiency of selection for these complex traits.

e. Determine the potential and limitations of nitrogen-fixing microorganisms for increased nitrogen utilization by wheat and enhancement of its productivity and nutritional value by means of studies of associative symbiotic nitrogen fixation.

f. Verify the biological value of a limited number of promising high protein-high lysine advanced wheat lines by means of rat bioassays.

g. Strengthen wheat research in LDC's through distribution of germplasm, hybrid populations, advanced lines, and research information to the LDC's and international organizations; organize and participate in regional, national, and international wheat workshops and conferences; make on-site inspections of cooperative nurseries and special plantings; encourage and accept qualified students and young scientists from developing countries and the USA for graduate study and special training in wheat genetics, breeding, and production at the University of Nebraska.

RESEARCH ACCOMPLISHMENTS

Genetics and Breeding

Yield and protein data in the table that follows clearly show that the new variety Lancota, while equal or superior to Centurk in yield, produces grain with two percentage points higher than Centurk (Table 1).

Various breeding materials grown at Lincoln in 1975 are summarized in Table 2. Promising winterhardy productive high protein lines grown in observation plots at Lincoln are listed in Table 3. They are moderately short statured with good seed characteristics. Many exhibit acceptable milling and dough mixing properties. All yielded as much as or more than Centurk and Lancota and produced grain with protein content equal to or higher than Lancota. Selections from Favorit/5/Cirpiz/4/Jang Kwang/2/At 66/Cmn/3/Velvet were especially attractive with combined moderately short stature, high yield, very high protein content and good processing characteristics.

Non-hardy winters and springs are propagated each year at Yuma, Arizona. Yuma plantings in 1975 are summarized in Table 4. Highly significant differences in yield, protein and lysine occurred among 330 wheats grown in a high protein-high lysine observation nursery (Table 5). Correlations and particularly outstanding entries are listed in Tables 6 - 9.

Particularly promising selections for protein, lysine, and agronomic type grown in F_3 headrows are listed in Table 10. Several show elevated mean NO_3 reductase activity with evidence of segregation of NO_3 reductase level.

Table 1. Grain yield and protein content of Centurk and Lancota winter wheat varieties in paired plot comparisons at Lincoln, Nebraska, 1975.

CENTURK				LANCOTA			
Protein	Lysine		Yield	Protein	Lysine		Yield
	Adj.	Unadj.			Adj.	Unadj.	
%	%	%	q/ha	%	%	%	q/ha
15.3	3.3	3.1	40.7	16.6	3.0	2.8	45.7
15.6	3.1	2.9	36.2	17.6	2.9	2.7	40.8
16.1	3.1	2.9	37.0	17.8	2.9	2.6	37.7
16.1	3.1	2.9	33.8	17.1	2.9	2.7	38.0
16.1	3.0	2.9	34.1	17.9	2.9	2.7	33.5
15.3	3.2	3.0	36.6	17.9	2.9	2.7	39.2
15.9	2.9	2.7	33.2	17.4	2.9	2.7	38.2
15.4	3.2	3.0	35.2	17.1	2.9	2.7	35.2
16.0	2.8	2.6	35.3	17.7	3.0	2.8	34.9
15.8	3.2	3.0	32.4	17.7	2.9	2.7	28.9
15.3	3.3	3.1	38.3	16.7	3.0	2.8	43.0
15.6	3.2	3.0	35.6	17.7	2.9	2.6	37.3
15.0	3.1	3.0	37.9	17.3	2.8	2.5	40.0
15.6	3.2	3.0	38.8	17.6	2.9	2.7	36.5
14.9	3.0	2.9	37.6	17.8	2.9	2.7	38.7
15.2	3.2	3.1	42.9	17.7	2.8	2.6	39.9
16.2	3.1	2.9	34.7	17.6	2.7	2.5	37.3
15.6	3.2	3.0	25.2	17.5	2.9	2.7	29.9
$\bar{x}$ =15.6	3.1	2.9	35.9	17.5	2.9	2.7	37.5

Table 2. USAID/UN-L wheat breeding program, Lincoln, Nebraska, 1975.

Nursery	No. of Entries	No. of Replications	Plot Size
F_2 bulks	261	1	S4R8'
F_2 bulks	29	1	S2R8'
F_3 bulks	118	1	S2R8'
F_4 bulks	172	1	S2R8'
Headrows - F_3 and F_4	15,000	1	SR4'
Parents - observation purposes	93	1	S4R8'
Headrow progeny - I	4,313	1	S2R8'
Headrow progeny - II	905	2	S2R8'
High protein-high lysine	280	1	SR8'
IWWPN	30	4	S4R8'
Seeding rate study	10	4	S4R8'
Miscellaneous USSR wheats	13	1	S4R8'
Yuma selected headrows - for growth habit classification	2,195	1	SR8'

Note: A total of 587 new crosses were made in the greenhouse in 1975. These consisted of spring x spring, spring x winter, and winter x winter combinations.

Table 3. Promising high protein experimental winter wheats grown in single 2-row plots at Lincoln, Nebraska, 1975.

Pedigree or Name	Plot Number	Plant Height	Seed Rating	Yield	Protein	Mlg. Type	Mixing Characteristics	
							Time	Tolerance
		In.		q/ha	%		Min.	
Lancota	$\bar{x}$ of 18 plots	38	VG	37.5	17.5	G	3 1/3	3
Centurk	$\bar{x}$ of 18 plots	40	G	35.9	15.6	G	3 2/3	4
NE701132/K-43902-Mironof-skaya 808-Akrain	5032	41	VG	36.5	17.4	F	2 2/3	4+
	5037	43	VG	42.0	16.7	F	2 2/3	3+
	5044	41	VG	36.1	17.5	G	2	3
	5047	42	VG	40.2	16.0	-	-	-
NE701134/Aurora	5058	39	Ex	42.4	18.0	F	2 1/3	3
NE701136/Blueboy	5086	37	G	38.6	19.0	P	2	3
	5089	36	G	38.1	17.5	VP	2 1/3	3
NE70654/3/Manella//At 66/Cmn	5136	37	G	37.1	17.2	P	1 1/3	2
Sava/2/Purd. 4930A6-28-2-1/ Fert. F_3 3547-CI13857/3/ ID0032	5198	37	VG	42.5	16.3	F	1 1/3	2-
At 66/Cmn//Nebr. Rest. 3547 /3/Aurora	5225	39	VG	41.2	17.1	-	-	-
	5227	39	VG	38.4	18.0	-	-	-
NE701136/Centurk	5255	36	VG	38.9	16.2	-	-	-
	5266	39	VG	41.7	16.3	-	-	-
MV69-05/5/Cmn/Ot/3/At 66/2/ Cmn/4/NB68437	5279	34	Ex	36.7	18.1	G	2	4
	5296	37	VG	37.0	17.5	-	-	-

Table 3. (Continued).

Pedigree or Name	Plot Number	Plant Height	Seed Rating	Yield	Protein	Mlg. Type	Mixing Characteristics Time	Mixing Characteristics Tolerance
		In.		q/ha	%		Min.	
NE701152/Sort 315-16	5316	36	VG	42.8	17.6	G	2 1/3	2
	5328	42	G	49.9	16.5	G	2 1/2	3
NB68713/3/At 66/Cmn/2/CI13447 /4/Stepnaia	5389	38	VG	36.5	17.8	-	-	-
	5390	40	Ex	38.8	18.8	-	-	-
NE701154/Skorospelka	5410	41	VG	44.7	16.7	-	-	-
NE701154/Jubileinaia	5430	41	VG	37.4	18.0	-	-	-
NB69559/Dacia	5459	41	VG	40.8	18.0	-	-	-
	5462	36	VG	43.4	17.5	VP	1 2/3	3
NB68437/Nebr. Rest. 3584/2/ Bezostaya 1	5496	38	G	45.0	16.5	G	2 2/3	4
NB69559/NE701134	5544	42	VG	41.4	17.4	-	-	-
Excelsior/3/At 66/Cmn/2/ Tx2607-6	5594	35	G	41.0	17.7	P	2 1/3	4+
	5608	39	G	39.7	18.4	-	-	-
	5615	40	VG	40.4	17.3	-	-	-
Roussalka/NE70654	5671	40	VG	37.2	19.1	-	-	-
	5681	38	G	39.3	18.0	-	-	-
Moldova/7/At 66/Cmn/5/Fert. F_3 3547/3/CI13857/9/Zg 5994-66 /8/Aiv/2/CI13857/6/Fert. F_3 3547/4/CI13857	5730	38	G	42.6	18.4	-	-	-

Table 3. (Continued).

Pedigree or Name	Plot Number	Plant Height	Seed Rating	Yield	Protein	Mlg. Type	Mixing Characteristics	
							Time	Tolerance
		In.		q/ha	%		Min.	
Roussalka/NE701154	5797	35	G	51.6	16.7	F	1 2/3	2
At 66/Cmn/2/Wrr/3/NB68709 /4/Rannaya	5808	42	VG	55.1	15.9	-	-	-
NE701136/Lovrin 13	5947	37	VG	40.1	16.8	-	-	-
NE701132/Dacia	6021	36	VG	37.4	19.1	-	-	-
	6026	38	VG	41.4	18.2	VP	2 1/3	2+
	6049	34	VG	38.3	18.7	-	-	-
Rannaya/Lovrin 13	6118	33	G-VG	45.8	17.2	F	1	1+
Skorospelka 35/NE701137	6166	36	VG	39.4	17.5	-	-	-
NE701136/Sort 11-32-1145	6218	37	VG	40.0	18.1	G	2 1/3	2+
NE701132/Dacia	6250	36	G-VG	42.9	18.6	-	-	-
	6253	38	G-VG	39.5	18.5	-	-	-
	6277	37	G	37.4	18.7	VP	3 2/3	3+
NB68513/Moldova	6380	36	Ex	47.2	17.7	-	-	-
Aurora/NE701154	6427	36	G-VG	38.0	17.3	-	-	-
	6440	38	G-VG	44.2	16.5	-	-	-
Rannaya/NE701136	6450	37	VG	37.7	17.5	G	2	3
NB68570/Bolal	6497	40	G-VG	40.8	17.8	P	1 2/3	3
Aurora/NB69565	6531	36	G	38.3	18.2	-	-	-

Table 3. (Continued).

Pedigree or Name	Plot Number	Plant Height In.	Seed Rating	Yield q/ha	Protein %	Mlg. Type	Mixing Characteristics Time Min.	Mixing Characteristics Tolerance
Rannaya 2/Bezostaya 4	6831	35	G	48.8	16.8	F	2 2/3	4-
NB65672/Nebr. Rest. 3547// Aurora	6882	40	G	43.4	18.1	-		-
NB68437/Nebr. Rest. 3954// NE701134	11098	39	G	34.2	18.1	G	2 2/3	3+
	11126	42	G	38.9	17.9	-	-	-
Dwarf Bezostaya//NB68437/ NB68256	11150	33	VG	37.9	16.4	G	3	3+
Centurk/3/At 66/Cmn/2/Tx2607-6	11163	39	M-G	38.6	18.0	G	2 1/2	3-
	11186	38	VG	39.9	17.0	G	2 2/3	4-
ID0033/Purd. 4930 A6-28-2-1// Moldova	11240	42	VG	38.3	18.2	VP	1 1/2	3-
	11250	37	G	36.9	17.3	VP	1 1/2	3
NB66403/5/NB69581/4/NB69565 /3/Jingkwang/2/At 66/Cmn	11340	34	VG	37.0	18.4	G	3 1/3	4
	11343	33	G-VG	36.4	19.1	G	3 1/3	4-
Favorit/5/Cirpiz/4/Jang Kwang /2/At 66/Cmn/3/Velvet	11345	34	VG	39.6	19.1	G	3 2/3	4
	11361	34	G-VG	36.2	18.2	G	3	3+
	11369	34	G-VG	36.7	18.1	G	3	4
	12288	33	VG	41.4	18.9	G	3	4
	12291	32	G-VG	41.0	19.8	G	3 2/3	4
	12293	33	VG	41.1	19.3	G	3 2/3	4
	12297	32	VG	42.0	19.1	G	3	3+
	12303	34	VG	39.9	18.5	G	3 1/3	4

Table 3. (Concluded).

Pedigree or Name	Plot Number	Plant Height	Seed Rating	Yield	Protein	Mlg. Type	Mixing Characteristics	
							Time	Tolerance
		In.		q/ha	%		Min.	
Favorit/5/Cirpiz/4/Jang Kwang /2/At 66/Cmn/3/Velvet	12305	34	VG	41.6	18.5	G	3	4
	12307	37	VG	37.9	17.0	P	2 2/3	3+
	12310	34	G-VG	38.7	18.6	G	3	4
	12312	32	VG	39.0	19.1	G	4	4
	12315	32	VG	39.0	18.6	G	3 1/3	4-
	12318	33	G	37.3	17.3	-	-	-
	12323	34	G-VG	39.8	18.7	G	4	4
	12327	34	VG	41.0	18.7	G	4	4
	12332	33	VG	41.6	18.9	G	4	4-
	12333	33	VG	38.7	18.7	G	4	4
	12335	34	Ex	41.9	18.5	F	4	4-
NB542437//At 66/Cmn	11956	37	G	36.8	17.5	G	1 2/3	1+
	11995	41	G-VG	33.4	19.4	F	2 1/3	3
Backa//Suwon 85/Purd. 4930A6-28-2-1	12106	41	VG	38.9	17.7	G	3	3
Sava/3/At 66/Cmn/2/NB69655	12142	39	VG	36.8	18.5	VP	2 1/3	3+
	12148	40	G	44.3	18.7	VP	2 1/3	4
Zg 5994-66/4/Aiv/CI13857/3/ Fert. F_3 3547/2/CI13857	12228	33	G-VG	37.4	17.2	G	3 2/3	4-
	12230	38	Ex	39.2	16.5	G	2 1/2	3
JinKwang//At 66/Cmn	12556	40	G	30.9	21.1	VP	2	3+
	12582	34	VG	37.3	17.1	VP	2	2
	12592	35	VG	39.3	18.2	VP	1 2/3	2
CI13449//At 66/Cmn	11522	38	G	35.9	17.6	VP	3	3-
Nap Hal/Lancer	11803	37	G	31.2	17.0	P	2 1/3	3

Table 4. USAID/UN-L wheat breeding program, Yuma, Arizona, 1975.

Nursery	No. of Entries	No. of Replications	Plot Size
Large-scale increases for IWWPN	38	1	10' x 275'
Small-scale increases for IWWPN	69	1	4SR20'
F_1 winter	22	1	SR6'
F_1 spring and spring x winter	148	1	SR6'
F_1 spring durum	31	1	SR6'
Parents of F_1's	62	1	SR6'
F_2 spring and spring x winter	770	1	SR20'
F_3 and F_4 spring and spring x winter	56	1	SR20'
Headrows - F_3's and F_4's	6,008	1	SR4.5'
Headrow progeny	2,195	1	SR20'
High protein-high lysine yield trial	330	4	SR10'
High protein yield trial	21	4	SR10'
World collection - durum	93	1	S2R20'
World collection - bread wheats	30	1	SR6'
Spring wheats - Klepper/CIMMYT program	113	1	SR6'

Gametocide Studies

I. High protein - bread wheat, 1974 Yuma source.

II. High yield performance - bread wheat, 1973 Lincoln source.

III. High yield performance - durum wheat, 1974 Yuma source.

Table 5. High protein-high lysine wheat nursery, Yuma, Arizona, 1975. (330 entries, 4 replications)

Trait	Nursery		$LSD_{.05}$
	Mean	Range	
Yield (q/ha)	51.4	12.5 - 87.5	12.4
Protein (%)	13.0	10.2 - 20.3	1.3
Protein (q/ha)	6.5	2.3 - 11.0	1.9
Lysine (% of protein)			
Unadjusted	3.2	2.5 - 3.9	--
Adjusted	3.2	2.9 - 3.6	0.13

Table 6. Correlations: 1975 Yuma high protein-high lysine wheat Nursery. (N = 1320)

	Protein %	Protein (q/ha)	Yield	Unadjusted Lysine	Adjusted Lysine
Protein (%)	100	-0.10	-0.55	-0.71	-0.19
Protein (q/ha)		100	0.87	--	--
Yield			100	0.41	0.17
Unadj. lysine				100	0.77
Adj. lysine					100

Table 7. Performance of Nap Hal/Atlas 66 lines in the 1975 Yuma high protein-high lysine wheat nursery.

Entry		Protein	Lysine per Unit Protein		Yield
			Unadj.	Adj.	
		%	%	%	q/ha
Nap Hal		14.7	3.2	3.3	27.4
Atlas 66		14.9	2.9	3.1	44.5
Centurk		11.7	3.2	3.1	55.0
Nap Hal/At 66	292	19.0	2.9	3.1	35.7
"	297	17.8	3.0	3.2	32.9
"	232	17.8	2.7	2.9	43.1
"	296	17.6	3.0	3.2	34.9
"	285	17.0	3.1	3.2	33.2
"	185	16.1	3.0	3.2	35.7
$LSD_{.05}$		1.3	-	0.1	15.3

Table 8. Performance of Nap Hal/CI 13449 lines in the 1975 Yuma high protein-high lysine wheat nursery.

Entry		Protein	Lysine per Unit Protein		Yield
			Unadj.	Adj.	
		%	%	%	q/ha
Nap Hal		14.7	3.2	3.3	27.4
CI 13449		10.9	3.4	3.3	67.8
Centurk		11.7	3.2	3.1	55.0
Nap Hal/CI 13449	248	13.3	3.2	3.3	63.6
"	245	12.9	3.5	3.6	70.4
"	305	12.7	3.4	3.5	57.2
"	253	12.5	3.4	3.4	87.5
"	247	12.2	3.5	3.5	71.0
"	205	12.2	3.6	3.5	65.5
$LSD_{.05}$		1.3	-	0.1	15.3

Table 9. Performance of miscellaneous lines in the 1975 Yuma high protein-high lysine wheat nursery.

Exp. Line or Variety	Entry No.	Protein	Lysine per Unit Protein		Yield
			Unadj.	Adj.	
		%	%	%	q/ha
K-73	274	14.9	2.9	3.0	53.1
K-75	275	14.3	2.9	3.0	52.1
Nap Hal/CR 8156	257	14.2	3.2	3.3	53.3
Lancota	242	13.9	3.0	3.0	62.5
At 66/Cmn/2/Wrr/3/69655	109	13.1	3.1	3.1	69.1
CI 13449/Centurk	61	12.4	3.2	3.2	79.2
Centurk	---	11.7	3.2	3.1	55.0
CR 8156	---	11.0	3.2	3.0	58.6
$LSD_{.05}$		1.3	-	0.1	15.3

Table 10. F_3 headrows grown at Yuma, Arizona in 1975 with exceptionally high grain protein content.

Pedigree	Plot Number	Seed Rating	Protein	Lysine		NO_3 Reductase Activity	
				Unadj.	Adj.	Mean	Range
			%	%	%		
Atlas 66	$\bar{x}$ of 28 rows	G	13.6	3.1	3.2	13.0	9.0 - 15.0
Nap Hal	$\bar{x}$ of 28 rows	M	13.4	3.3	3.4	12.2	4.0 - 17.0
Centurk	$\bar{x}$ of 28 rows	G	11.7	3.1	3.0	11.1	5.0 - 18.0
F226-68/NE701132//Nap Hal/Lancer	2036	Ex	17.1	2.8	3.0	--	---
	2072	G	14.1	3.1	3.2	--	---
At 66/Nap Hal/Dwarf Bezostaya/NE701132	2162	VG	15.1	2.9	3.0	13.7	10.9 - 16.8
	2210	VG	18.6	2.7	2.9	12.5	8.9 - 14.5
At 66/Nap Hal//NE701134/Centurk	2263	G	15.8	2.9	3.1	11.6	9.4 - 14.3
At 66/Nap Hal//F226-68/Centurk	2390	VG	16.3	2.7	2.9	13.8	10.4 - 17.7
At 66/Nap Hal//NE701136/Centurk	2466	M	16.3	2.9	3.1	--	---
	2547	M	16.6	2.8	3.0	--	---
At 66/Nap Hal//NE701152/Aurora	2575	VG	17.0	2.7	2.9	15.0	11.5 - 17.5
	2584	G	15.9	3.0	3.2	--	---
	2626	G	14.8	3.1	3.3	--	---
	2635	Ex	14.6	3.0	3.1	--	---
	2699	VG	15.2	2.9	3.0	11.1	9.5 - 12.8
	2752	G	17.3	2.9	3.2	12.3	9.0 - 14.9
	2782	G	17.2	2.8	3.0	13.0	10.3 - 18.4
At 66/Nap Hal//Bezostaya	2811	G	16.1	2.8	3.1	9.8	7.3 - 11.9
At 66/Nap Hal//Skorospelka 35/NE701137	2944	G	16.6	2.9	3.1	12.3	10.7 - 15.1
At 66/Nap Hal//Norde Desprez 2	3207	G	14.9	3.0	3.1	--	---

Table 10. (Continued).

Pedigree	Plot Number	Seed Rating	Protein	Lysine		NO_3 Reductase Activity	
				Unadj.	Adj.	Mean	Range
			%	%	%		
At 66/Nap Hal//Bezostaya	3442	G	16.2	2.8	3.0	16.2	13.7 - 18.4
	3474	G	15.2	2.9	3.1	--	---
	3502	G	16.8	2.8	3.0	12.3	9.9 - 15.7
	3558	VG	15.8	2.9	3.1	11.5	9.1 - 14.8
	3584	G	15.0	3.0	3.1	--	---
	3618	G	15.7	2.9	3.0	--	---
	3652	VG	15.7	2.9	3.1	12.6	7.1 - 19.0
At 66/Nap Hal//NE701134/Skorospelka	3706	VG	16.5	2.9	3.0	16.1	14.5 - 17.8
At 66/Nap Hal//NE701154/Skorospelka	3768	VG	15.2	2.9	3.1	15.2	11.1 - 16.9
	3793	VG	15.9	2.9	3.1	13.1	9.2 - 17.7
At 66/Nap Hal/Rannaya//NE701136	3826	G	14.2	3.2	3.4	--	---
	3850	M	14.6	3.1	3.3	--	---
	3909	G	14.9	3.2	3.4	--	---
	3916	G	15.7	3.0	3.2	14.0	11.8 - 16.0
	3945	G	15.2	3.0	3.2	--	---
Nap Hal/At 66//NB68510/Hyslop	4090	VG	14.2	3.0	3.1	--	---
	4181	G	15.9	3.0	3.2	--	---
Nap Hal/At 66//NS11-35	4262	G	14.6	2.9	3.1	--	---
Nap Hal/At 66//Lovrin 12	4316	VG	15.5	3.0	3.1	12.9	11.3 - 14.5
	4342	G	16.2	2.9	3.1	--	---
	4370	G	16.2	3.0	3.2	14.6	12.5 - 16.3
Nap Hal/At 66//Rannaya/Lovrin 12	4436	G	14.5	3.0	3.1	--	---
	4478	G	14.8	3.0	3.1	--	---

Table 10. (Continued).

Pedigree	Plot Number	Seed Rating	Protein	Lysine		NO_3 Reductase Activity	
				Unadj.	Adj.	Mean	Range
			%	%	%		
Nap Hal/At 66//Aurora	4547	G	14.1	3.1	3.2	--	---
	4582	VG	15.9	2.9	3.1	13.7	11.6 - 14.6
	4612	G	16.7	3.0	3.2	12.3	9.9 - 14.3
Nap Hal/At 66//TR535	4672	G	14.1	3.2	3.3	14.3	11.6 - 18.5
	4739	G	14.5	3.1	3.2	--	---
NB68570/Excelsior//At 66/Nap Hal	4795	Ex	15.4	2.9	3.1	--	---
	4805	VG	15.1	2.9	3.1	11.9	10.1 - 16.1
	4812	G	15.7	2.9	3.1	--	---
	4841	Ex	15.2	2.9	3.1	12.9	10.9 - 15.3
	4857	Ex	15.6	2.9	3.1	13.2	9.2 - 16.9
At 66/Nap Hal//NB68570/Centurk	5014	G	15.3	3.1	3.2	12.6	11.2 - 14.1
At 66/Nap Hal//NE701132/Likafen	5346	G	15.3	2.9	3.1	12.9	10.3 - 15.3
At 66/Nap Hal//Tx62A2522-1-4	5419	G	14.6	2.9	3.1	--	---
At 66/Nap Hal//Centurk	6118	G	14.6	2.9	3.1	--	---
	6120	VG	14 9	2.9	3.1	9.5	8.2 - 10.8
	6136	G	15.7	3.0	3.2	12.6	10.3 - 17.7
Nap Hal/3/At 66/5/Likafen/4/At 66/Cmn /2/Hume	6155	G	14.7	2.9	3.1	--	---
	6248	G	15.0	2.9	3.1	--	---
Nap Hal/At 66//Blueboy II	6256	VG	13.1	3.4	3.4	--	---
	6260	G	18.8	2.9	3.0	12.1	9.9 - 13.5
	6280	G	13.9	3.2	3.3	--	---
	6293	VG	14.9	3.0	3.2	10.7	8.8 - 12.5
	6328	Ex	14.4	3.0	3.1	15.1	11.9 - 17.8

Table 10. (Concluded).

Pedigree	Plot Number	Seed Rating	Protein	Lysine		NO_3 Reductase Activity	
				Unadj.	Adj.	Mean	Range
			%	%	%		
Nap Hal/At 66//Blueboy II	6348	VG	14.8	3.0	3.2	11.8	9.0 - 14.1
	6349	VG	15.4	2.9	3.1	13.3	10.5 - 14.6
Nap Hal/At 66//NE701134/Aurora	6357	VG	15.1	2.9	3.1	12.3	10.4 - 14.6
	6394	G	16.6	2.9	3.1	10.9	9.2 - 14.2
	6401	Ex	14.7	3.0	3.1	--	---
	6424	Ex	15.3	2.9	3.0	11.9	9.6 - 14.2
	6439	VG	18.2	2.7	2.9	12.2	9.1 - 14.3
Nap Hal/At 66//Aurora/NE701154	6487	G	14.6	2.9	3.1	--	---
	6529	G	14.7	2.9	3.1	--	---
Nap Hal/At 66//Sort 12-13	6691	G	17.1	2.8	3.0	--	---
	6697	Ex	15.6	2.8	3.0	13.6	11.1 - 15.9
	6723	G	17.3	2.8	3.0	13.3	11.3 - 15.3
	6734	G	16.6	2.8	3.0	11.3	10.5 - 13.1
Nap Hal/At 66//F266-68/NE701132	6846	G	14.8	2.9	3.1	--	---
	6860	Ex	17.5	2.8	3.0	10.9	9.0 - 13.1
	6873	G	16.0	2.9	3.0	13.6	11.1 - 16.5
Nap Hal/At 66//F-22-70	6906	Ex	16.9	2.9	3.1	11.6	9.4 - 14.6
	6907	G	16.5	2.9	3.1	14.2	12.6 - 16.4
	6911	G	17.2	2.9	3.1	--	---
	6928	VG	16.3	2.8	3.0	11.3	8.9 - 14.5
	6934	G	17.3	2.9	3.1	11.4	8.2 - 16.5
	6940	VG	17.9	2.9	3.1	--	---
	6941	VG	16.8	2.9	3.1	11.0	9.6 - 13.1
	6976	VG	16.9	2.9	3.1	--	---

CHEMICAL AND PHYSICAL CHARACTERIZATION OF NUTRITIONALLY IMPROVED WHEATS

A Modified Milling Procedure for Separating Endosperm and Non-Endosperm Portions of the Wheat Kernel for Protein and Lysine Analysis

A modified milling procedure for separating endosperm and non-endosperm components of the wheat (*Triticum aestivum* L.) kernel was developed and evaluated. After milling and sifting, the endosperm adhering to the bran was removed in a washing (Osterizer) procedure, dried, and added to the mill flour to reconstitute the starchy endosperm. Reasonably complete and uniform separation of the endosperm and non-endosperm components were obtained without any appreciable loss of either components for component proteins.

Means and the results of the analysis of variance of the check varieties for kernel weight, milling yield, flour weight, bran flour weight, washed bran weight, sample recovery percent and percent endosperm are listed in Table 11. The check varieties differed significantly for milling yield, flour weight, bran flour weight, washed bran weight, and percent endosperm. Although field replication had some effect on these variables, most of the variation was due to differences among the wheats analyzed. Sample recovery percentage was not affected by variety or field replication. Considering the number of steps in the modified milling procedure, the sample recovery percentages are satisfactory

Whole grain protein and lysine percentages were calculated using endosperm and bran weights and protein and lysine percentages. The means, ranges, and standard deviations for measured and calculated protein and lysine (% of sample) percentages are listed in Table 12. Calculated protein and lysine mean and range values are almost identical to the measured values. These results show that very little if any protein was lost in the washing process by solubilization of the bran and bran flour in the 80:20 ethanol:acetone washing solution.

Table 11. 1973 World Wheat Collection special study nursery.1/

Variables	Mean	Range	Standard Deviation
Test weight (kg/hl)	77.89	70.95 - 83.85	3.279
1000 kernel wt. (g)	40.63	24.95 - 57.94	7.351
Milling yield (%)	71.20	63.10 - 78.80	3.180
Flour weight (g)2/	12.70	11.28 - 14.09	.580
Bran flour wt. (g)2/	1.60	.92 - 2.50	.390
Washed bran wt. (g)2/	3.15	2.56 - 4.77	.309
% endosperm	81.90	72.80 - 85.50	1.770
Sample recovery %	98.10	96.30 - 99.20	.500

1/ Average D.W. = 17.8 g.
2/ Dry weight basis.

On the average, 80% of the protein in wheat grain is endosperm protein while only 68% of the total lysine resides in endosperm proteins. The means, ranges, and standard deviations for these variables are listed in Table 13. The large range values for percent of protein and lysine that is in the endosperm indicates that the distribution of protein and lysine within the wheat kernel varies significantly among wheats. The large range values of endosperm and bran protein and lysine content indicates that there are differences among wheats for endosperm and bran protein and lysine content.

Comparisons of endosperm contents by our blender washing technique and a detergent extraction procedure are listed in Table 14.

Table 12. 1973 World Wheat Collection special study nursery.

Variable	Mean	Range	Standard Deviation
Grain (% protein)	16.39	11.20 - 21.00	2.29
Calculated grain (% protein)1/	16.60	11.36 - 21.16	2.32
Grain lysine (%)	0.47	0.37 - 0.60	0.059
Calculated grain lysine (%)2/	0.47	0.36 - 0.59	0.056

1/ The correlation of calculated grain % protein and grain % protein = r = .98**.

2/ The correlation of calculated grain lysine (% of sample) and grain lysine (% of sample) = r = 0.93**.

Table 13. 1973 World Wheat Collection special study nursery.

Variable	Mean	Range	Standard Deviation
% of kernel protein in endosperm	79.30	70.50 - 84.90	2.47
% of kernel lysine in endosperm	68.00	58.80 - 74.80	2.94
Endosperm, % protein	16.10	10.80 - 21.00	2.43
Endosperm, lysine/protein (%)	2.45	2.14 - 3.08	.166
Bran, % protein	19.00	13.10 - 25.10	2.40
Bran, lysine/protein (%)	4.40	3.23 - 4.97	.286

Table 14. Comparison of endosperm contents % between blender washing procedure and the detergent extraction technique of Moss and Stennert (Aust. J. Agric. Res., 1971, 22:547).1/

Sample	Blender Washing %	Detergent Washing %
1	86.81	86.50
2	85.82	85.78
3	86.69	86.78
4	86.30	87.35
5	86.35	85.76
6	86.66	85.34
7	86.47	86.05
8	87.96	85.96
9	87.81	87.81
10	87.13	88.25
11	86.16	86.58
12	86.70	86.07
13	86.79	85.78
14	86.41	86.04
$\bar{x}$	86.72	86.43
σ	0.59	0.85
S_M	0.16	0.23

1/ Means of duplicate samples.

Protein and Lysine Contents of Whole Grain, Endosperm, and Bran of the Parents and Progenies of High Protein and/or High Lysine Crosses of Common Wheat

Whole kernel, endosperm, and bran protein and lysine values for the parent and selected progeny rows of the Nap Hal x Atlas 66 population are summarized in Table 15. Parent and check variety values are mean values. Coefficients of variation and LSD values were obtained from analysis of variance of the parent and check rows. The listed progeny rows are representative of the protein and lysine segregates obtained from the cross. Protein and lysine values for the parent and selected progeny rows of Nap Hal x CI 13449 and Nap Hal x CIMMYT 8156 crosses are listed in Tables 16 and 17, respectively.

Table 15. Whole kernel, endosperm, and bran protein and lysine values and 100 kernel weights for parent, check, and progeny rows of Nap Hal x Atlas 66. Coefficients of variation and LSD values were obtained from the analysis of variance of the parent and check rows.+

Parental/ Check Lines n=3	Whole Kernel			Endosperm			Bran		100
	P	LP	ALP	P	LP	ALP	P	LP	KWT
Centurk	15.5	3.0	2.8	15.0	2.5	2.4	19.6	4.5	3.7
Atlas 66	19.4	2.8	2.8	19.3	2.5	2.5	19.8	4.4	3.6
Nap Hal	19.6	3.1	3.1	19.0	2.5	2.5	24.5	4.6	2.7
Coefficient of variation %	2.7	1.5	1.5	2.5	2.3	2.2	2.4	7.2	3.3
$LSD_{.05}$	1.0	0.1	0.1	0.9	ns	ns	1.0	ns	0.2
Progeny row no.									
10286	16.3	3.0	2.9	15.7	2.6	2.5	19.4	4.5	2.5
12333	14.4	3.0	2.8	14.1	2.7	2.6	19.2	4.5	3.6
15138	24.2	2.8	3.0	23.6	2.3	2.4	25.8	4.4	2.9
11982	20.0	3.1	3.1	19.1	2.4	2.4	25.4	4.6	2.8
15168	21.0	2.8	2.8	21.3	2.2	2.3	21.9	4.5	3.0
11026	19.6	3.0	3.0	18.7	2.5	2.5	25.2	4.5	3.1
14329	20.7	2.6	2.7	19.9	2.2	2.3	21.8	4.4	2.8
15252	20.0	3.0	3.1	19.6	2.7	2.7	22.7	4.3	3.2
11481	20.5	3.0	3.1	21.0	2.8	2.8	21.8	4.5	3.2
10078	23.3	2.7	2.8	20.9	2.7	2.8	25.5	4.0	2.9
12546	21.6	2.8	2.9	21.3	2.4	2.4	23.1	3.9	2.8
12120	23.6	2.9	3.0	23.2	2.4	2.6	26.7	4.5	3.5

+ Adjusted lysine values obtained by adjusting lysing (% of protein) values to mid-parent protein level using linear regression model for this population. Abbreviations: P = % protein; LP = lysine (% of protein); ALP = lysine (% of protein) adjusted for % protein; KWT = kernel weight (g). LSD values listed only when 'F' ratio from the analysis of variance was significant at the .05 level.

Table 16. Whole kernel, endosperm, and bran protein and lysine values and 100 kernel weights for parent, check, and progeny rows of Nap Hal x CI 13449. Coefficients of variation and LSD values obtained from the analysis of variance of the parent and check rows.+

Parental/ Check Lines n=2	Whole Kernel			Endosperm			Bran			100
	P	LP	ALP	P	LP	ALP	P	LP	ALP	KWT
Centurk	12.8	3.2	3.0	12.0	2.9	2.7	16.2	4.9	4.6	3.5
Nap Hal	16.2	3.2	3.2	15.2	2.9	2.9	21.9	4.8	4.8	2.7
CI 13449	15.6	3.1	3.1	14.6	2.8	2.8	19.6	4.4	4.4	2.2
Coefficient of variation %	6.6	3.4	1.8	6.3	3.8	2.4	6.0	2.1	0.5	7.4
LSD	2.3*	ns	0.2**	2.1*	ns	ns	3.7**	0.3**	0.07**	0.4**
Progeny row no.										
15958	14.5	3.3	3.2	13.7	2.9	2.8	21.4	4.3	4.3	3.0
16551	11.8	3.6	3.4	10.8	3.1	2.9	19.2	4.6	4.5	2.2
16240	19.9	3.1	3.4	19.7	2.7	2.9	25.5	4.3	4.6	2.6
16900	19.4	3.4	3.6	18.5	2.7	2.9	25.4	4.6	4.9	2.9
16593	11.6	3.7	3.4	10.5	3.3	3.0	19.3	5.0	4.9	2.3
18640	16.8	3.4	3.5	15.6	3.0	3.0	24.9	4.7	5.0	2.5
16691	16.1	3.3	3.3	15.3	2.6	2.6	22.4	4.5	4.6	3.2
16686	14.2	3.5	3.4	13.6	3.0	2.9	20.9	5.0	5.0	3.4
16681	14.9	3.5	3.4	14.4	3.0	2.9	21.4	5.1	5.1	3.5
15958	14.5	3.3	3.2	13.7	2.9	2.8	21.4	4.3	4.3	3.0
15986	13.7	3.2	3.1	13.3	2.8	2.8	20.8	4.5	4.5	3.1
16946	16.5	3.2	3.3	15.6	2.6	2.7	22.6	4.6	4.7	3.1
16440	14.4	3.6	3.5	13.4	3.2	3.1	21.3	4.9	4.9	3.7

*,** Indicates significance at the .10 and .05 levels respectively.

\+ Adjusted lysine values obtained by adjusting lysine (% of protein) values to mid-parent protein level using linear regression model for this population.

LSD values listed only when 'F' ratio from the analysis of variance was significant at the level indicated.

Abbreviations: P = % protein; LP = lysine (% of protein); ALP = lysine (% of protein) adjusted for % protein; KWT = kernel weight (g).

Table 17. Whole kernel, endosperm, and bran protein and lysine values and 100 kernel weights for parent, check and progeny rows of Nap Hal x CIMMYT 8156. Coefficients of variation and LSD values obtained from the analysis of variance of parent and check rows.

Parental/ Check Lines n=2	Whole Kernel		Endosperm		Bran		100 Kernel Weight
	P	LP	P	LP	P	LP	(g)
Centurk	13.2	3.2	12.7	2.8	17.0	4.7	3.6
Nap Hal	17.0	3.2	16.3	2.8	22.4	4.7	2.5
CIMMYT 8156	12.8	3.0	12.6	2.7	16.2	4.4	3.9
Coefficient of variation %	1.6	2.5	2.7	3.7	2.2	2.7	2.8
$LSD_{.05}$+	0.8	ns	1.2	ns	1.3	ns	0.3
Progeny row no.							
19165	13.7	3.4	12.6	2.7	19.4	4.8	3.4
19170	14.5	3.2	13.7	2.6	20.2	4.8	3.8
18932	15.2	3.1	14.5	2.8	21.0	4.8	3.4
19010	15.0	3.5	14.5	2.8	20.5	4.9	3.2
19704	16.2	3.2	15.3	2.8	21.8	4.5	2.5
19754	16.6	3.2	15.8	2.8	22.6	4.6	2.6

+ LSD values listed only when 'F' ratio from the analysis of variance was significant at the .05 level.

Abbreviations: P = % protein; LP = lysine (% of protein).

Protein and Lysine Content of Grain, Endosperm, and Bran of Wheats from the USDA World Wheat Collection

Mean protein, lysine (% of protein), and lysine (% of sample) percentages of the bran from the World Collection wheats were much higher than those of the endosperm and whole wheat samples (Table 18). Difference of whole grain and endosperm protein percentages is small.

Endosperm protein was highly correlated with whole grain protein (Table 19).

Endosperm protein had the largest effect on grain lysine content of any of the factors tested (Table 20).

Linear regressions of lysine (% of protein) on percent protein of whole grain, endosperm, and bran samples of the World Collection wheats are presented in Figure 1. The length of the regression lines reflect the range in protein values.

Some endosperm protein values are slightly higher than whole kernel protein, but the differences are within the range of laboratory experimental error.

Table 18. Means, range values and standard deviations for whole grain, endosperm, and bran protein and lysine values of wheat grown in the World Wheat Collection Special Study Nursery at Yuma, Arizona in 1973. + ≠

Variable	Mean	Range	Standard Deviation
% Protein			
Whole grain	16.4	11.2 - 21.0	2.29
Endosperm	16.1	10.8 - 21.0	2.43
Bran	19.0	13.1 - 25.1	2.40
Lysine (% of sample)			
Whole grain	.47	.37 - .60	.059
Endosperm	.39	.29 - .50	.050
Bran	.83	.46 - 1.14	.107
Lysine (% of protein)			
Whole grain	2.90	2.52 - 3.37	.214
Endosperm	2.45	2.14 - 3.08	.166
Bran	4.40	3.23 - 4.97	.286

+ Bran includes the germ.

≠ Results are for 129 World Collection wheats plus 6 checks replicated 4 times.

Table 19. Correlation coefficients for whole grain, endosperm, and bran protein and lysine percentages for 135 wheats grown in the World Wheat Collection Special Study Nursery at Yuma, Arizona, 1973. + #

	Whole Kernel		Endosperm			Bran			%
	LS	LP	P	LS	LP	P	LS	LP	END
Whole kernel									
% protein	.85**	-.49**	.98**	.89**	-.54**	.75**	.55**	-.34**	-.35**
Lysine (% of sample)		.04	.82**	.91**	-.15**	.72**	.59**	-.22**	-.41**
Lysine (% of protein)			-.48**	-.17*	.78**	-.23**	-.07	.28**	-.03
Endosperm									
% protein				.90**	-.55**	.67**	.49**	-.32**	
Lysine (% of sample)					-.14	.64**	.48**	-.30**	
Lysine (% of protein)						-.31**	-.23**	.14	
Bran									
% protein							.87**	-.21**	
Lysine (% of sample)								.29**	

*,** Indicates significance at the .05 and .01 levels of probability, respectively.

\+ Results are for 129 World Collection wheats plus 6 checks replicated 4 times.

\# Abbreviations: P = % protein; LS = lysine (% of sample); LP = lysine (% of protein); % End = percent endosperm.

Table 20. Standardized partial regression coefficients for whole grain protein and lysine content from the regression analysis of wheats grown in the 1973 Yuma World Wheat Collection Special Study Nursery. Results are for 129 World Collections wheats plus 6 check varieties replicated 4 times.

Dependent Variables	Independent Variables	Standardized Partial Regression Coefficients	Coefficient of Determination for Regression Model
Whole grain % protein	1. Endosperm % protein	.8717**	.9792
	2. Bran % protein	.1599**	
	3. % Endosperm	-.0099	
Whole grain Lysine (% of sample)	1. Endosperm % protein	.8866**	.8679
	2. Endosperm lysine (% of protein)	.3961**	
	3. Bran % protein	.2458**	
	4. Bran lysine (% of protein)	.1333**	
	5. % Endosperm	-.1161	

*,** Indicates significance of the partial regression coefficients at the .05 and .01 levels of probability, respectively.

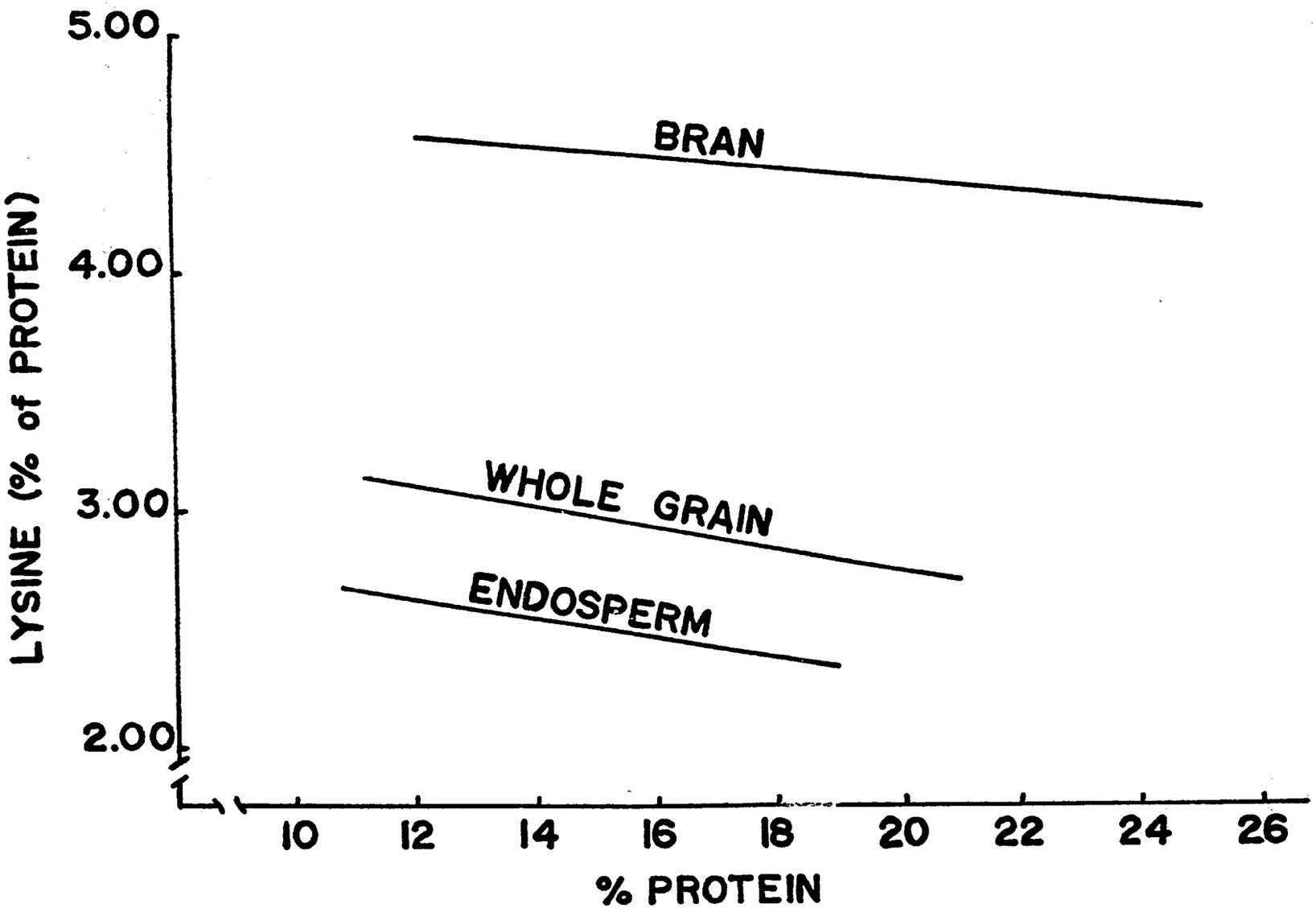


Figure 1. Linear relationship of % protein and lysine (% of protein) for whole grain endosperm, and bran of wheats from the 1973 World Wheat Collection Special Study nursery.

Variation of Phytate Content in Wheat (This research funded by Nebraska Wheat Development Division)

Phytic acid (inositol-hexaphosphoric acid) and its derived salts, the phytates, occur in the seed coats of many cereal grains. In cereals, phytic acid represents 35 to 97% of the total phosphorus and is generally regarded as a poor source of phosphorus to monogastric animals. It is not equally distributed, the pericarp and adherent aleurone layer, together with the germ, containing proportionally 10 to 20 times the level in the endosperm. The importance of phytic acid in nutrition depends upon its property of forming insoluble or nearly insoluble compounds with mineral elements, including calcium, iron, magnesium and zinc, the resultant phytates being excreted in the feces. Consequently dietary calcium, iron, etc. can be rendered unavailable when combined with phytic acid. Diets high in phytic acid and poor in calcium, iron and zinc, produced mineral deficiency symptoms in experimental animals and in children.

Phytic acid and the phytates may be decomposed by the enzyme phytase to produce inositol and phosphoric acid. Wheat and rye are rich in phytase, which is unequally distributed through the grain in somewhat the same manner as phytic acid. The extent to which the phytic acid content of wheat and rye may be harmful in a diet will depend on the conditions under which the cereal has been processed for consumption.

Fortunately, fermentation used in baking partially reduces phytate content and makes trace minerals available. Boiling (cooking) under acid conditions also partially destroys phytates.

Recent research has shown that fiber content interfers with the absorption of essential trace minerals and is probably more important than phytate.

Until this problem is resolved we felt information on phytate content might be useful.

Selected parental and varietal wheats were analyzed for their phytate "P" content. Data from these analyses is shown below.

Phytate Phosphorus Content of Selected Wheat Samples

Variety	% P
"Bread" wheat	0.17 - 0.28
Atlas 66	0.29
Nap Hal	0.28
Bezostaya	0.27
Scout 66	0.26
Buckskin	0.19
Sentinel	0.18
HiPlains	0.22
Lancer	0.18
Lancota	0.18
Centurk[1/]	0.32

1/ This sample at 0 lb. N/acre as well as those to 120 lbs. N/acre were similar in % P.

Quality Evaluation of Selected Germplasm Lines

To this time our efforts are primarily concerned with identifying the nutritional potential of germplasm. Since improved germplasm materials are going into new varieties for food uses it would be useful to know something about potential for particular end uses. With such information improvements could be made in both nutritional and processing quality in a breeding program.

During 1975 approximately 700 lines were micro-milled and the flour evaluated for dough mixing properties with a 10 g. mixograph. Factors such as (kernel color) hardness, milling properties, mixing time and mixing tolerance

can be now listed along with nutritional and agronomic potentials. Selected dough mixing time and tolerance data were made part of the record in Table 3. Selected examples are presented in Figure 2.

Mixograms of Nap Hal, CR 8156, parents and best selected progeny are shown in Figure 3.

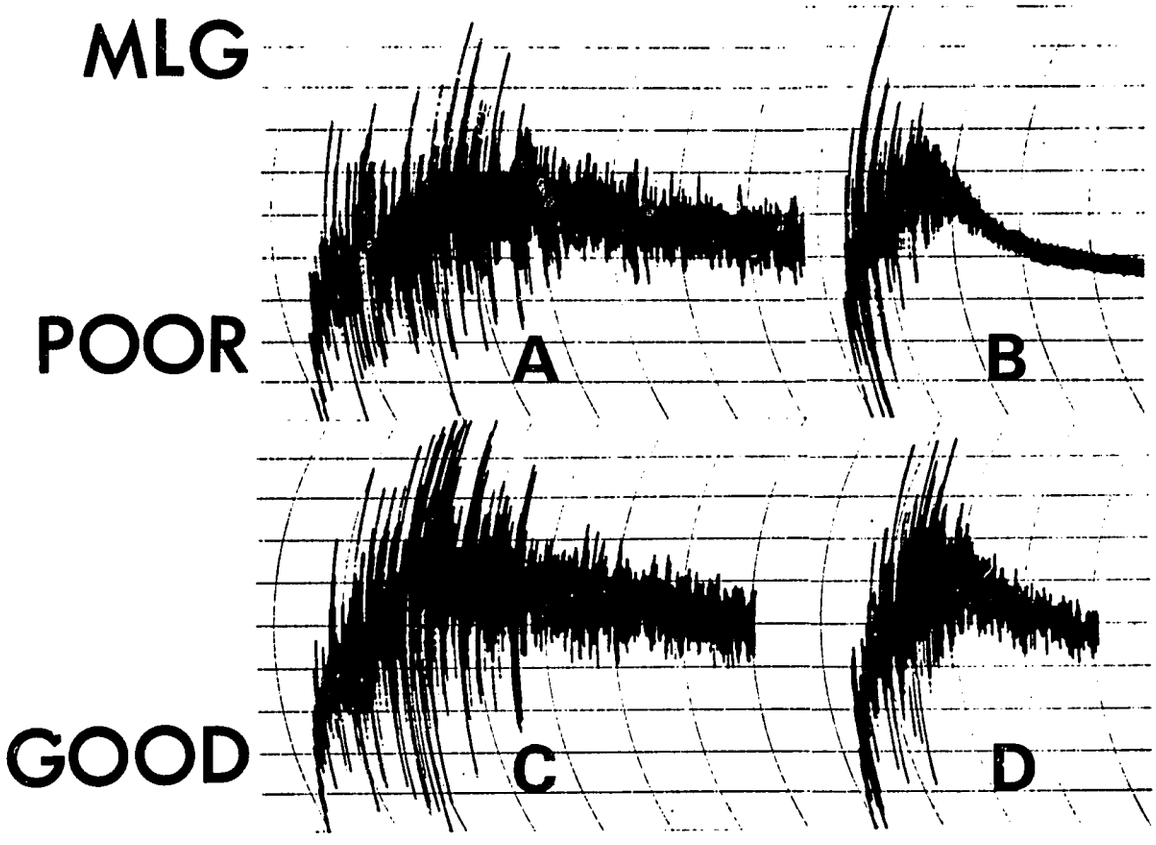


Figure 2. Examples of diverse milling types (soft vs. hard endosperm) exhibiting differences in mixing characteristics.

A, B, C, D samples were plot numbers 6277, 12458, 5496, and 5958 in Table 3 material. (Items missing from Table 3 will be published in the next report.) Protein levels were 18.7, 17.4, 16.5, and 16.9, respectively.

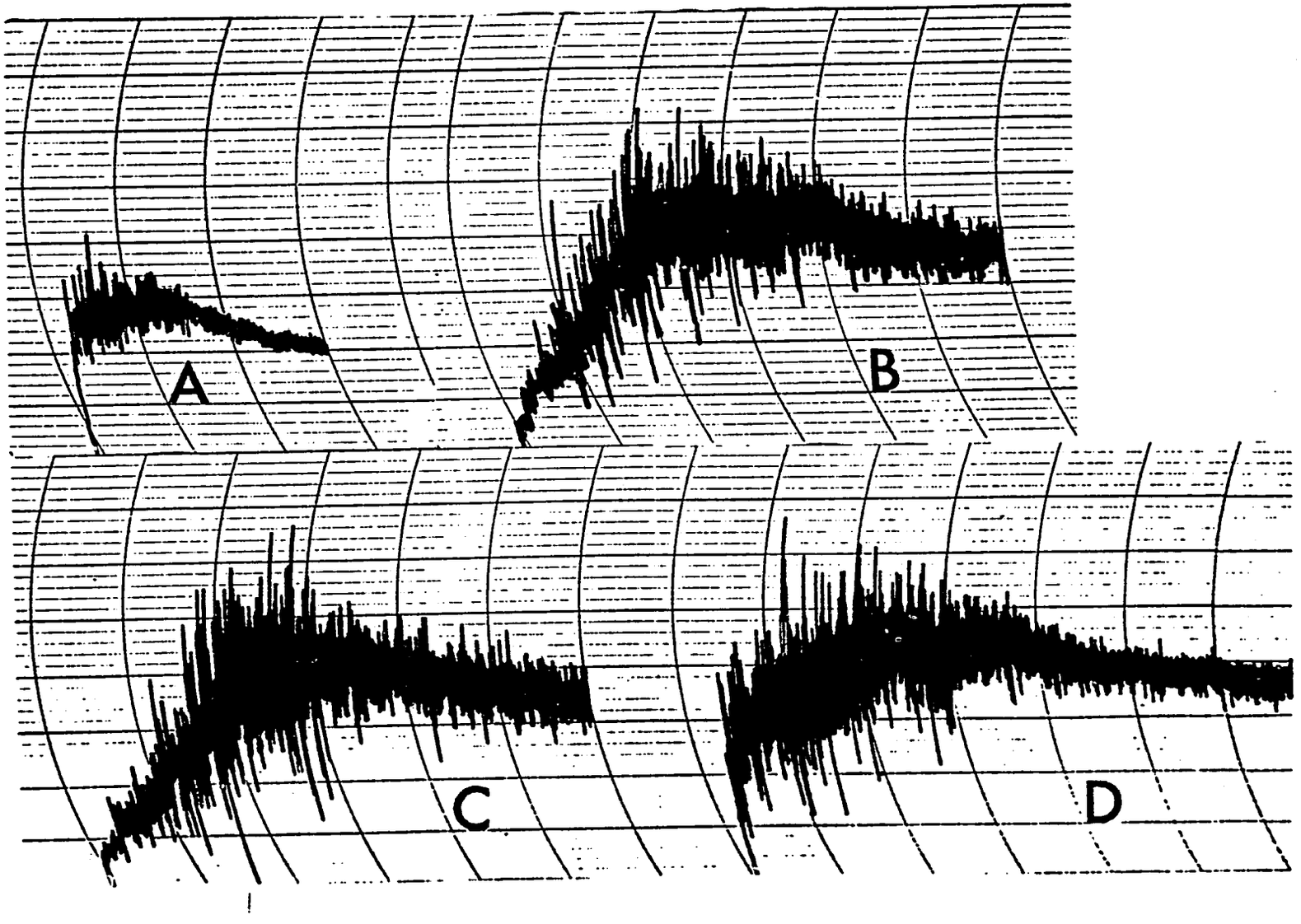


Figure 3. Mixograms of:

A. Nap Hal parent
B. CR 8156 parent
C and D. Quality selections from Nap Hal x CR 8156 progeny

INTERNATIONAL EVALUATION

Ongoing Research

The International Winter Wheat Performance Nursery

The preliminary report of performance results from 1975 has already been distributed. The nursery was grown at 59 sites in 36 countries. A summary of varieties tested in the IWWPN since 1969 and their origin appears in Tables 21 and 22, respectively. Lancota has shown moderately high yield combined with high protein in the IWWPN (Table 23).

Varieties with the highest yield in each year of testing are summarized in Table 24. Similar summaries for varieties with the highest protein, highest test weight, earliest maturity, shortest plant height, and highest winter survival in each year of testing appear in Tables 25 - 29.

Table 21. Summary of varieties tested and the year entered for testing in the International Winter Wheat Performance Nurseries, 1969-1976.

Variety	Country	Year Entered IWWPN
Atlas 66	USA, North Carolina	1969
Arthur (Purd. 5752A1-1P-2)	USA, Indiana	1969
Aurora	USSR	1974
Bezostaya 1	USSR	1969
Bankuti 1201	Hungary	1969
Blueboy	USA, North Carolina	1969
Benhur	USA, Indiana	1969
Backa	Yugoslavia	1971
Bolal	Turkey	1974
Burgas 2	Bulgaria	1974
Blueboy II	USA, North Carolina	1974
Biserka	Yugoslavia	1975
Bordenave Puan Sag	Argentina	1976
Cappelle Desprez	France	1969
Centurk (NB 66425)	USA, Nebraska	1969*
Clarion	Netherlands	1972
Caribo	West Germany	1972
Carifen 12	Chile	1972
CI 15074 (NB 68513)	USA, Nebraska	1971
Dacia	Romania	1972
Diplomat	West Germany	1972
Dwarf Bezostaya (Karlik 1)	USSR	1974
Demar 4	Italy	1974
Dunav 1	Yugoslavia	1975
Felix	Netherlands	1969
Fertodi 293	Hungary	1969
Favorit	Romania	1974
Flavio	Italy	1976
F26-70	Romania	1976
Gaines	USA, Washington	1969
Gage	USA, Nebraska	1969
GKF-2	Hungary	1975
Galiafen	Chile	1976
GKF-8001	Hungary	1976
Heine VII	West Germany	1969
Hokuei	Japan	1971
INIA 66	Mexico	1969
Jyva	Finland	1971
Jubilar	West Germany	1974

* Centurk was grown in the Southern Hemisphere in 1969 in addition to 1971-1973.

Table 21. (Continued).

Variety	Country	Year Entered IWWPN
Kirac 66	Turkey	1972
Kavkaz	USSR	1974
Kitakomi-Komugi	Japan	1975
Kormoran	West Germany	1975
Lancota (NE 701132)	USA, Nebraska	1972
Lancer	USA, Nebraska	1969
Lerma Rojo 64	Mexico	1969
Lilifen	Chile	1972
Likafen	Chile	1974
Lely	Netherlands	1975
Marimp 3	Italy	1972
Maris Nimrod	England	1972
Moldova	Romania	1972
Manella	Netherlands	1974
Martonvasar 2	Hungary	1975
Maris Huntsman	England	1975
Maris Templar	England	1975
Martonvasar 3	Hungary	1976
NB 67730	USA, Nebraska	1969
NS732	Yugoslavia	1971
NE 68719	USA, Nebraska	1976
Odin	Sweden	1969
Oasis	USA, Indiana	1976
Odesskaya 51	USSR	1976
Parker	USA, Kansas	1969
Purdue 4930A6-28-2-1	USA, Indiana	1969
Probstdorfer Extrem	Austria	1971
Priboy	USSR	1976
Riley 67	USA, Indiana	1969
Roussalka	Bulgaria	1972
Rashid	Iran	1975
San Pastore	Italy	1969
Stadler	USA, Missouri	1969
Scout 66	USA, Nebraska	1969
Sturdy	USA, Texas	1969
Shawnee	USA, Kansas	1969
Sava	Yugoslavia	1971
Starke	Sweden	1971
Strampelli	Italy	1971
Sentinel	USA, Nebraska	1975
Sieve	Italy	1975
Sage	USA, Kansas	1976

Table 21. (Concluded).

Variety	Country	Year Entered IWWPN
Timwin	USA, Wisconsin	1969
Triumph 64	USA, Oklahoma	1969
Tamwheat 102 (TX62A4793-7)	USA, Texas	1970*
Talent	France	1975
TRS 237	Australia	1975
Vakka	Finland	1971
Victor I	Italy	1972
Winalta	Canada	1969
Winter Triticale	USA, Nebraska	1971
WWP 7147	Austria	1976
WA 5829	USA, Washington	1976
Yung Kwang	South Korea	1969
Yorkstar	USA, New York	1969
Zlatna Dolina (Golden Valley; Zg 5994/66)	Yugoslavia	1972
Zenith	Switzerland	1972
Zg 5996/66 (Sanja)	Yugoslavia	1974

* Grown in Southern Hemisphere in 1970 in addition to 1971-1973.

Table 22. Summary by country of the number of wheat varieties tested in International Winter Wheat Performance Nurseries, 1969-1976.

Country	Number of Varieties Tested
Argentina	1
Australia	1
Austria	2
Bulgaria	2
Canada	1
Chile	4
England	3
Finland	2
France	2
Hungary	6
Iran	1
Italy	7
Japan	2
Korea	1
Mexico	2
Netherlands	4
Romania	4
Sweden	2
Switzerland	1
Turkey	2
USA	28
USSR	6
West Germany	5
Yugoslavia	7
24 countries	96 varieties

Table 23. Yield and protein characterization of selected varieties grown in the International Winter Wheat Performance Nursery in 1973.

Variety	Yield		Protein	
	q/ha	Rank	%	Rank
a) High yield, ordinary protein				
Sava	45.2	(1)	13.5	(23)
Centurk	42.2	(2)	14.0	(19)
Blueboy	40.8	(5)	12.4	(30)
b) Mod. high yield, high protein				
Lancota	38.2	(12)	15.5	(3)
Moldova	38.3	(11)	15.2	(4)
Dacia	40.7	(7)	14.9	(7)
Probstdorfer Extrem	40.4	(8)	14.7	(6)
c) Low yield, high protein				
Atlas 66	34.7	(21)	16.7	(1)
CI 15074	34.1	(22)	15.7	(2)
d) Low yield, ordinary protein				
Carifen 12	33.7	(23)	12.9	(29)
Hokuei	35.1	(19)	13.3	(27)

Selection of high vs. low yield based on a grand mean over 43 locations of 36.3.

Selection of high vs. ordinary protein based on a grand mean over 31 locations of 14.2.

Table 24. Summary of superior yielding varieties identified in the IWWPN testing network from 1969-1975.[1/]

1969 (16 sites)

Variety	g/ha	Source
Bezostaya	45.2	USSR
Blueboy	43.5	USA, NC
San Pastore	41.1	Italy
Sturdy	40.5	USA, TX
Timwin	39.9	USA, WI

1970 (32 sites)

Variety	g/ha	Source
Bezostaya 1	39.9	USSR
Timwin	36.9	USA, WI
Arthur	35.7	USA, IN
Scout 66	35.4	USA, NE
Parker	34.6	USA, KS

1971 (28 sites)

Variety	g/ha	Source
Sava	41.5	Yugoslavia
Blueboy	40.5	USA, NC
Bezostaya 1	39.8	USSR
Timwin	39.0	USA, WI
Centurk	38.9	USA, NE

1972 (38 sites)

Variety	g/ha	Source
Bezostaya 1	42.6	USSR
Sava	41.9	Yugoslavia
Dacia	41.8	Romania
Probstdorfer Extrem	40.6	Austria
Zlatna Dolina	40.5	Yugoslavia

1973 (43 sites)

Variety	g/ha	Source
Sava	45.0	Yugoslavia
Centurk	42.2	USA, NE
Zlatna Dolina	42.1	Yugoslavia
Blueboy	41.9	USA, NC
Probstdorfer Extrem	40.8	Austria

1974 (38 sites)

Variety	g/ha	Source
Kavkaz	44.5	USSR
Aurora	44.3	USSR
Burgas 2	42.2	Bulgaria
Bezostaya 1	41.8	USSR
Zlatna Dolina	41.6	Yugoslavia

1975 (36 sites)

Variety	g/ha	Source
Talent	47.4	France
Maris Huntsman	44.9	England
Blueboy	44.6	USA, NC
GKF-2	44.6	Hungary
Aurora	44.6	USSR

1/ Varieties listed in descending order of yield performance averaged over all locations reporting complete data.

Table 25. Summary of superior grain protein varieties identified in the IWWPN testing from 1969-1975.1/

1969 (18 sites)

Variety	%	Source
Atlas 66	17.5	USA, NC
Purdue 4930A6-28-2-1	16.6	USA, IN
NB 67730	16.4	USA, NE
Cappelle Desprez	16.0	France
Odin	15.4	Sweden

1970 (25 sites)

Variety	%	Source
Atlas 66	19.3	USA, NC
Purdue 4930A6-28-2-1	18.3	USA, IN
NB 67730	17.2	USA, NE
Cappelle Desprez	16.0	France
Bankuti 1201	15.8	Hungary

1971 (22 sites)

Variety	%	Source
Atlas 66	18.1	USA, NC
NB 68513	16.5	USA, NE
Fertodi 293	16.2	Hungary
Backa	16.1	Yugoslavia
Parker	16.0	USA, KS

1972 (24 sites)

Variety	%	Source
Atlas 66	16.5	USA, NC
Lancota	15.3	USA, NE
CI 15074	15.2	USA, NE
Lilifen	15.0	Chile
Moldova	14.7	Romania

1973 (31 sites)

Variety	%	Source
Atlas 66	16.7	USA, NC
CI 15074	15.7	USA, NE
Lancota	15.5	USA, NE
Moldova	15.2	Romania
Dacia	14.9	Romania

1974 (35 sites)

Variety	%	Source
Atlas 66	16.9	USA, NC
Lancota	16.0	USA, NE
Moldova	15.9	Romania
Dacia	15.6	Romania
Favorit	15.5	Romania

1/ Varieties listed in descending order of protein percentage (d.w.b.) averaged over all locations reporting complete data.

Data from 1975 harvest are not yet available.

Table 26. Summary of superior test weight varieties identified in the IWWPN testing network from 1969-1975.1/

1969 (14 sites)

Variety	kg/hl	Source
Parker	81.7	USA, KS
Bezostaya 1	80.5	USSR
Shawnee	80.4	USA, KS
Triumph 64	80.3	USA, OK
Lancer	79.9	USA, NE

1970 (25 sites)

Variety	kg/hl	Source
Triumph 64	80.4	USA, OK
Parker	80.4	USA, KS
Bezostaya 1	80.0	USSR
Winalta	79.6	Canada
Shawnee	79.5	USA, NE

1971 (13 sites)

Variety	kg/hl	Source
Parker	80.8	USA, KS
Bezostaya 1	80.4	USSR
NB 68513	80.0	USA, KS
Probstdorfer Extrem	79.8	Austria
Centurk	79.6	USA, KS

1972 (14 sites)

Variety	kg/hl	Source
Probstdorfer Extrem	79.2	Austria
Bezostaya 1	78.7	USSR
CI 15074	78.2	USA, NE
Dacia	77.6	Romania
Roussalka	77.6	Bulgaria

1973 (18 sites)

Variety	kg/hl	Source
Bezostaya 1	80.8	USSR
Probstdorfer Extrem	80.7	Austria
Lancota	79.9	USA, NE
Centurk	79.6	USA, NE
CI 15074	79.5	USA, NE

1974 (15 sites)

Variety	kg/hl	Source
Bezostaya 1	78.6	USSR
Aurora	77.9	USSR
Favorit	77.3	Romania
Demar 4	77.2	Italy
Dacia	76.7	Romania

1975 (18 sites)

Variety	kg/hl	Source
Bezostaya 1	78.7	USSR
Favorit	77.9	Romania
Dunav 1	77.7	Yugoslavia
Demar 4	77.6	Italy
Martonvasar 2	77.5	Hungary

1/ Varieties listed in descending order of test weight in kg/hl over all locations reporting complete data.

Table 27. Summary of the five earliest maturing varieties in days to flowering identified in the IWWPN testing network from 1969-1975.1/

1969 (17 sites)

Variety	Days	Source
San Pastore	138.0	Italy
Benhur	138.0	USA, IN
Triumph 64	138.0	USA, OK
Sturdy	140.0	USA, TX
Arthur	141.0	USA, IN

1970 (29 sites)

Variety	Days	Source
Triumph 64	138.0	USA, OK
Benhur	139.0	USA, IN
San Pastore	139.0	Italy
Arthur	140.0	USA, IN
Sturdy	140.0	USA, TX

1971 (20 sites)

Variety	Days	Source
Strampelli	135.1	Italy
NS 732	135.3	Yugoslavia
Triumph 64	135.6	USA, OK
San Pastore	136.5	Italy
Benhur	139.0	USA, IN

1972 (25 sites)

Variety	Days	Source
Roussalka	142.8	Bulgaria
Moldova	143.5	Romania
Strampelli	144.5	Italy
Zlatna Dolina	145.5	Yugoslavia
Sava	146.1	Yugoslavia

1973 (31 sites)

Variety	Days	Source
Roussalka	139.5	Bulgaria
Strampelli	140.4	Italy
Moldova	141.1	Romania
Victor I	142.4	Italy
Marimp 3	143.3	Italy

1974 (26 sites)

Variety	Days	Source
Roussalka	137.9	Bulgaria
NS 732	138.7	Yugoslavia
Moldova	139.3	Romania
Zg 5996/66	141.5	Yugoslavia
Marimp 3	141.9	Italy

1975 (31 sites)

Variety	Days	Source
Biserka	141.5	Yugoslavia
Kitakomi-Komugi	141.8	Japan
GKF-2	143.0	Hungary
Zg 5996/66	143.5	Yugoslavia
Bolal	143.6	Turkey

1/ Varieties listed in ascending order of days from January 1 to flowering over all locations reporting complete data.

Table 28. Summary of the five shortest varieties identified for plant height in the IWWPN testing network from 1969-1975.1/

1969 (18 sites)

Variety	cm	Source
Gaines	76.0	USA, WA
Sturdy	84.0	USA, TX
Timwin	89.0	USA, WI
Cappelle Desprez	93.0	France
Felix	93.0	Netherlands

1970 (25 sites)

Variety	cm	Source
Gaines	74.0	USA, WA
Sturdy	78.0	USA, TX
Timwin	82.0	USA, WI
Felix	85.0	Netherlands
San Pastore	86.0	Italy

1971 (20 sites)

Variety	cm	Source
NS 732	58.7	Yugoslavia
Sava	80.4	Yugoslavia
Sturdy	81.5	USA, TX
Backa	81.6	Yugoslavia
Timwin	86.3	USA, WI

1972 (29 sites)

Variety	cm	Source
Victor I	79.1	Italy
Carifen 12	79.2	Chile
Zlatna Dolina	80.6	Yugoslavia
Roussalka	82.0	Bulgaria
Sava	85.4	Yugoslavia

1973 (33 sites)

Variety	cm	Source
Carifen 12	76.5	Chile
Zlatna Dolina	77.2	Yugoslavia
Victor I	79.4	Italy
Roussalka	79.6	Bulgaria
Sava	83.9	Yugoslavia

1974 (25 sites)

Variety	cm	Source
NS 732	58.8	Yugoslavia
Dwarf Bezostaya	64.7	USSR
Zg 5996/66	71.6	Yugoslavia
Zlatna Dolina	74.9	Yugoslavia
Carifen 12	75.1	Chile

1975 (31 sites)

Variety	cm	Source
Dwarf Bezostaya	64.7	USSR
Zg 5996/66	74.0	Yugoslavia
Dunav 1	80.0	Yugoslavia
Biserka	80.2	Yugoslavia
Talent	80.6	France

1/ Varieties listed in ascending plant height averaged over all locations reporting complete data.

Table 29. Summary of superior varieties identified for winter survival in the IWWPN testing network from 1969-1975.1/

1969 (9 sites)

Variety	%	Source
Triumph 64	89.9	USA, OK
Odin	89.5	Sweden
Winalta	89.5	Canada
Benhur	89.4	USA, ID
Stadler	89.3	USA, MO

1970 (16 sites)

Variety	%	Source
Bezostaya 1	88.0	USSR
Stadler	87.0	USA, MO
Benhur	86.0	USA, IN
Triumph 64	85.0	USA, OK
Arthur	85.0	USA, ID

1971 (11 sites)

Variety	%	Source
Jyva	93.5	Finland
Vakka	93.0	Finland
NB 68513	92.7	USA, NE
Parker	92.4	USA, KS
Hokuei	92.3	Japan

1972 (22 sites)

Variety	%	Source
CI 15074	94.1	USA, NE
Starke	92.9	Sweden
Probstdorfer Extrem	92.9	Austria
Hokuei	92.3	Japan
Vakka	92.1	Finland

1973 (22 sites)

Variety	%	Source
Centurk	94.1	USA, NE
CI 15074	93.8	USA, NE
Vakka	93.3	Finland
Probstdorfer Extrem	92.8	Austria
Lancota	92.5	USA, NE

1974 (11 sites)

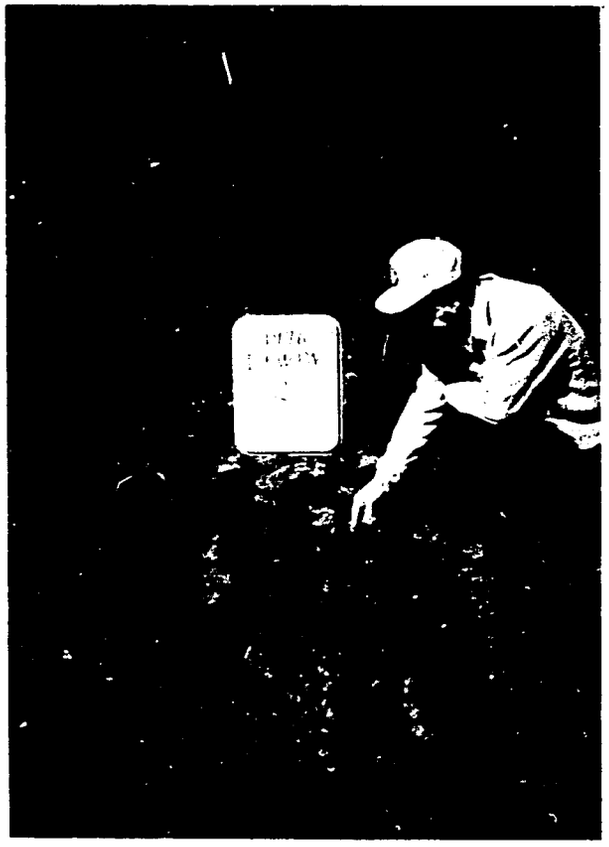
Variety	%	Source
Kavkaz	84.4	USSR
Aurora	82.8	USSR
Bezostaya 1	82.6	USSR
Burgas 2	82.5	Bulgaria
Dacia	80.5	Romania

1975 (12 sites)

Variety	%	Source
Bezostaya 1	93.3	USSR
Martonvasar 2	93.3	Hungary
Kavkaz	93.0	USSR
Sentinel	91.9	USA, NE
Lely	91.1	Netherlands

1/ Varieties listed in descending order of percent winter survival averaged over all locations reporting complete data.

Winterkill in 8th IWWPN, Lincoln, Nebraska, 1976.



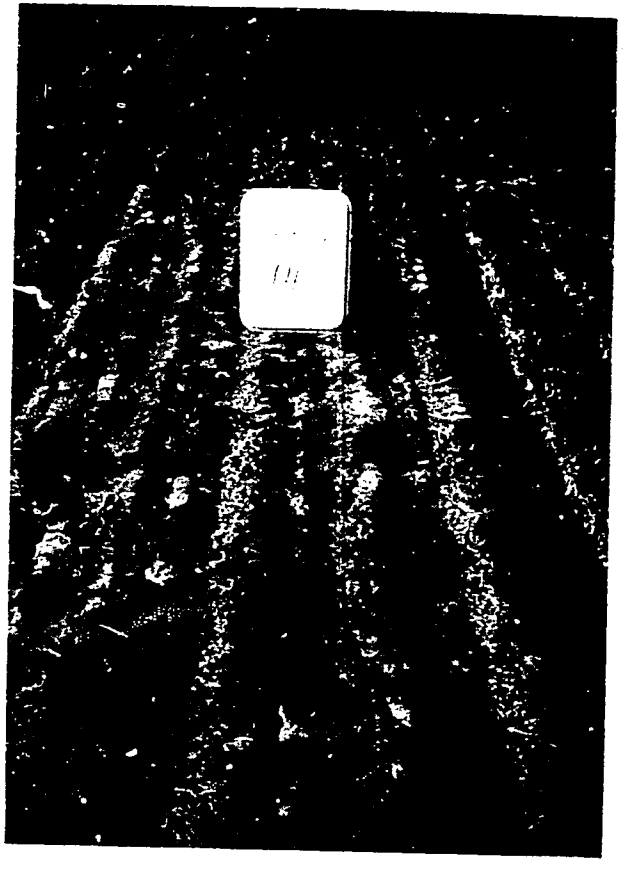
Maris Huntsman

Flavio

Winterkill and survival in 8th IWWPN, Lincoln, Nebraska, 1976.

Biserka

Sentinel



Talent

New Research

Soil and Environmental Factors

Work has been initiated on the influence of soil and environmental factors on the yield and quality of varieties in the IWWPN with the 1976 crop. Profile soil sampling to six feet and site characterization were effected at the following nursery sites in November, 1975: Austria, France, Hungary (Martonvasar), Italy (Rieti), Japan, Korea, Nepal, Pakistan, Romania, Turkey (Erzurum, Eskisehir, Haymana), Yugoslavia (Novi Sad), California, Colorado, New York, North Carolina, and Oklahoma. Conditions in Beirut prevented the scheduled sampling of sites in Iraq, Jordan and Lebanon. Further sample collections were made in the spring (March 20 - April 5, 1976) in Czechoslovakia, England, Germany (West), Netherlands, Norway, Poland, Sweden, and Switzerland. Soil samples for Argentina, Brazil, Mexico, and Peru may possibly be taken during 1976.

Arrangements have been made additionally for plant sampling at heading to be effected on the varieties Bezostaya, Atlas 66, Martonvasar 3, Oasis, and Kormoran which give a full range of early to late maturing types. Locations listed are those from which the individuals responsible expressed interest in participating in this extension of the IWWPN.

The soil profile samples on hand are now being processed and will be analyzed for pH, exchangeable Al (if pH indicates need), free $CaCO_3$, available P, exchangeable Mg and K, total N, available S, organic matter, mineral N, and extractable Fe, Zn and Cu (weak acid or DTPA). The plant samples procured at heading time will be digested and analyzed for the same nutrients. We anticipate equating these data, compounded with factors of weather, with differential varietal performance in yield and quality.

PHYSIOLOGICAL STUDIES OF HIGH YIELD AND HIGH PROTEIN

Nitrogen Metabolism

Intensive research measuring nitrate reductase activity (NRA) has been conducted during the past year. A technique which non-destructively tests *in vivo* NRA of individual wheat seedlings has been tested and utilized. More than 8,000 individual plants from a number of wheat varieties and populations have been analyzed in this manner. Seedlings which demonstrated high NRA are transplanted to greenhouses for seed multiplication and further observation and testing.

Initial studies compared the variety Centurk with certain European varieties such as Biserka, Bezostaya, MV-2, and Zlatna Dolina. It was found that these wheats were similar in mean values but that Centurk had a wider distribution than the others.

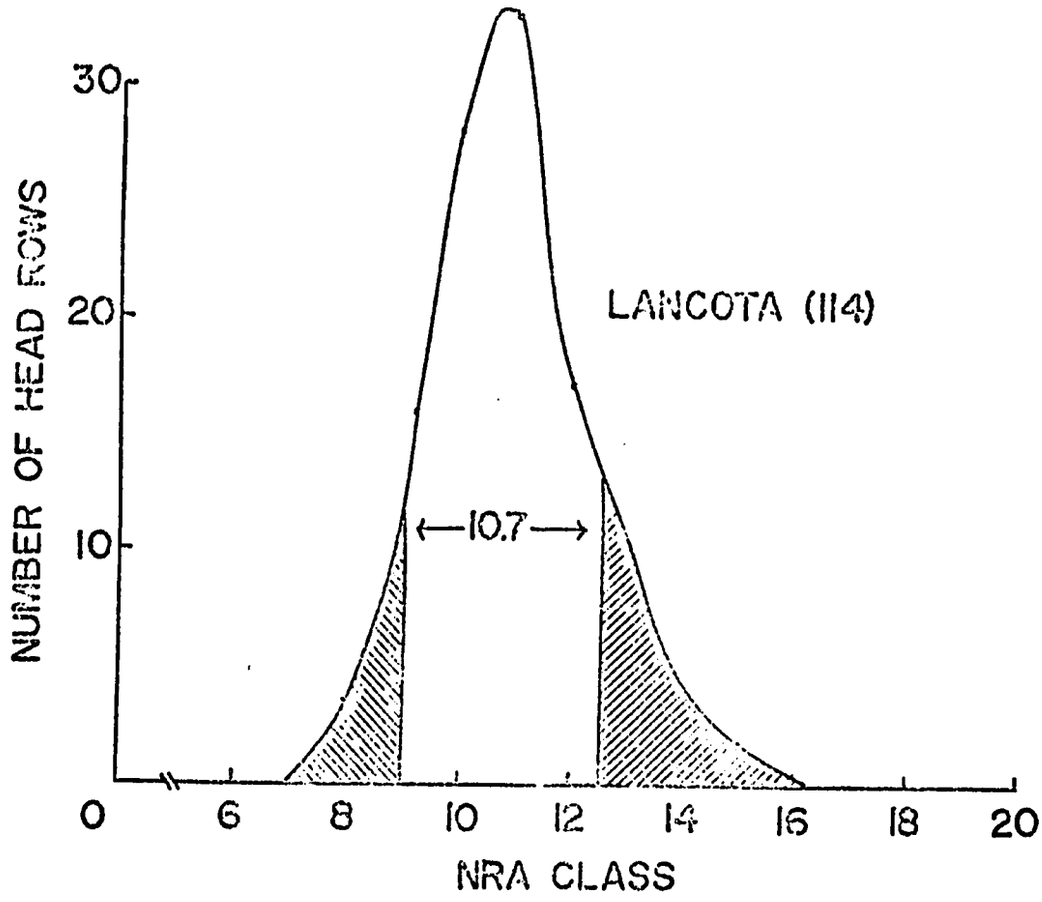
The variety Lancota was tested in a similar fashion. One-hundred-fourteen head row selections grown in Yuma were tested (10 seedlings each). The distribution of the head row mean values are shown on the following page.

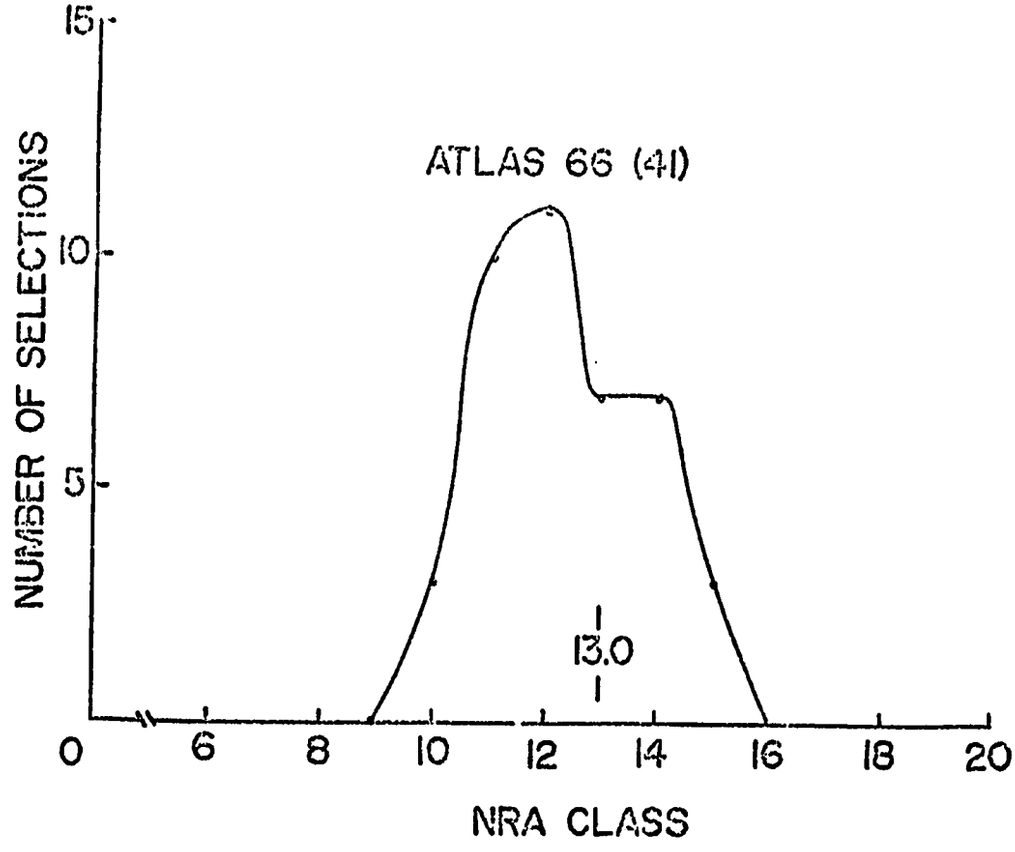
Lancota has a mean NRA of 10.7 and a range of 9 to 15. In comparison with other varieties, Lancota appears to be segregating for *in vivo* NRA. Appropriate plants have been saved.

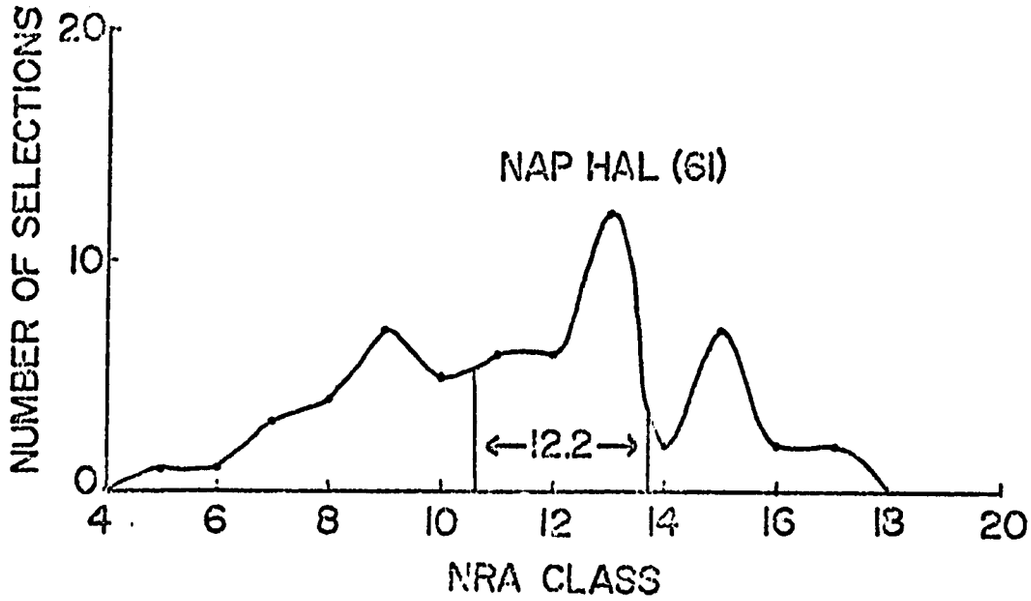
The NRA distribution of 41 random head selections of Atlas 66 (410 observations) yielded a mean of 13.0 with a range of 10 to 15. Atlas 66 is the most uniform, high NRA wheat variety we have tested.

Nap Hal, also used as a high protein progenitor, presented the diverse pattern (page 60) of NRA (based on 610 observations).

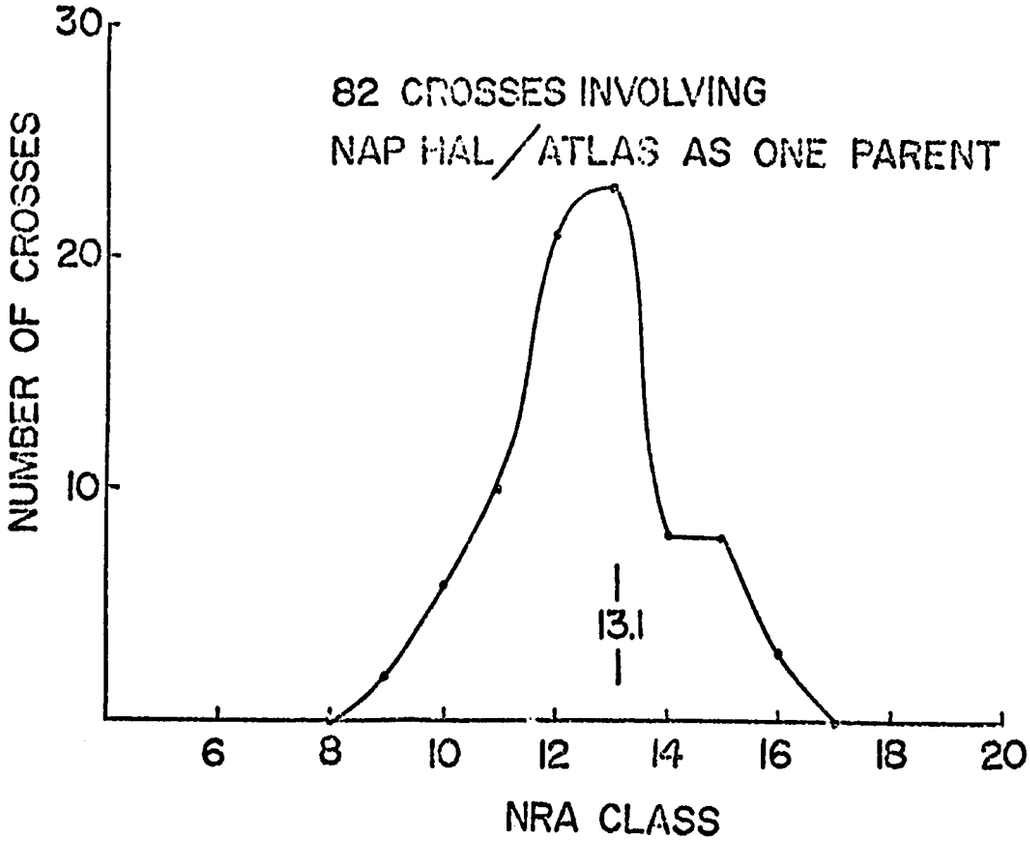
With a mean of 12.2 and a range of 5 to 17, Nap Hal appears to have wide variation for NRA, from extremely low to high. Selections have been made from both ends of this distribution.


30
20
10
0
NUMBER OF HEAD ROWS
LANCOTA (114)
10.7
6
8
10
12
14
16
18
20
NRA CLASS


15
10
5
0
NUMBER OF SELECTIONS
ATLAS 66 (41)
13.0
6
8
10
12
14
16
18
20
NRA CLASS



Crosses involving Nap Hal/Atlas 66 as one parent have been tested. All of these lines were first field selected for desirable agronomic characteristics and high protein content.



This distribution of means (820 observations) had a mean of 13.1 and a range from 9 to 16. Some selections appear to be segregating; other selections appear to be extremely uniform for NRA.

Seed from Nap Hal was among samples sent to the Northern Regional Research Laboratory (USDA) for individual kernel evaluation by sodium dodecyl sulfate-polyacrylamide gel electrophoresis of the glutenins. Five different electrophoretic patterns were noted. Following analysis of the non-germ end of grains, germ ends were returned to Nebraska for propagation and seed multiplication. NRA was determined on 10 seedlings of each of these Nap Hal lines.

NAP HAL STUDIES

Electrophoretic Protein Type	$\bar{x}$ NRA	Range
I (30)	10.2	8.2 - 12.4
II (5)	10.2	8.9 - 12.8
III (1)	13.4	9.2 - 15.8
IV (3)	15.2	13.0 - 17.6
V (1)	21.4	18.7 - 23.8

Type I (300 observations) and Type II (50 observations) had identical mean values and similar ranges. Type III and Type IV appeared to have higher means and different ranges. Type V has the highest range and mean of any winter or spring wheat tested to date. Presently, 11 of these plants have been isolated and are being used for seed multiplication. According to our observations, the population of Nap Hal contain approximately 1 - 2% of Type V plants.

The table on the following page illustrates present levels of NRA in the latest Nebraska-released variety (Lancota) compared to the genetic potential for NRA in future varieties.

	$\bar{x}$ NRA	Based on No. of Observations
Lancota	10.7	1140
Nap Hal	12.2	410
Atlas 66	13.0	610
Nap Hal/Atlas Crosses	13.1	820+
Nap Hal Type IV	15.2	30
Nap Hal Type V	21.4	10

A wheat such as Nap Hal Type V should be extremely useful in crosses to obtain higher grain protein wheat. Wheat has also been shown to be very good for rapid herbicide screening. Type V would double the sensitivity of these tests.

Equipment for the measurement of synthesis of vegetative protein and translocation to the grain is being assembled for testing during the spring and summer.

Plant Loss of Nitrogen

The primary activities to date have dealt with obtaining the specialized equipment for the gaseous N loss experiment and the finding and hiring of a suitable research assistant to conduct the experiments.

With regard to the equipment, four companies were contacted regarding construction of a gas tight growth chamber. The equipment has been ordered and it will continuously monitor NH_3 and NO_2. During these same experiments separate gas samples will be taken periodically and analyzed for NO, various amines, etc. by gas chromatography.

Mark Hooker was employed as a research assistant on March 1, 1976. He was already a member of our research staff and has been active in decision making on this research activity. We are planning to begin experiments by July 1, 1976.

Photosynthetic Efficiency

Light Interception Efficiency and Distribution Patterns -- Light interception equipment especially adapted for measuring photosynthetically active radiation (PAR) in wheat canopies has been assembled. Various semi-dwarf types and normal type in the Southern Regional Performance Nursery at Lincoln will be compared with respect to light interception. Head and seed counts will be determined to provide base information for use in establishing comparable plant populations of non-/or low-tillering dwarf types. Erect dwarf types (60 cm or less) will be selected from the wheat nursery this spring for fall planting and evaluation with respect to light interceptions, populations and row spacings.

Day-Night Temperature Effects -- Three growth chambers providing a total of approximately 9.75 square meters of space (3.25 sq. m. per chamber) are now in the process of being installed. Studies on day-night reactions and photosynthetic efficiency will be initiated as soon as the growth rooms are available.

Dr. Clegg has developed a rapid and simple technique for measuring carbon-dioxide concentrations. This technique will be available and used for carbon-dioxide exchange studies in wheat.

Plant Senescence -- Attempts to start wheat callus for cytokinin bioassays were unsuccessful due to fungi and bacterial contamination. With the installation of the growth facilities, studies using synthetic cytokinin to prevent leaf senescence will be initiated.

ASSOCIATIVE SYMBIOTIC NITROGEN FIXATION

Associative symbiotic nitrogen-fixing relationships were studied by surveying roots of plants in eastern Nebraska for nitrogen fixation (C_2H_2 reduction). The period has been used primarily to learn assay procedures and bacteriological techniques. In general, methods described by Dr. J. Dobereiner have been used but conditions such as O_2 tensions and preincubations have been varied because of the vast difference in climates between Brazil and Nebraska. Surveys were performed mostly on winter wheat but some spring wheats from University of Nebraska nurseries also have been tested to C_2H_2 reduction. Because of the late start in sampling the 1975 winter wheat, the plants were rapidly approaching maturity and thus did not represent vigorously growing plants.

Approximately 125 wheat root samples were tested for acetylene reduction under assay conditions which included preincubations under 0, 0.02 and 0.20 atm. of O_2 for 0, 24, 48, and 72 hrs. and incubations with 0.1 atm. C_2H_2 under 0, 0.02 and 0.2 atm. of O_2. Most (74) of the roots from nursery-grown plants yielded no acetylene reduction. However, roots from Centurk, Lancer and Nebraska 3547 did reduce small amounts of acetylene (30-50 nmoles/g dry weight) after a 1-day preincubation under 0.02 atm. O_2 and then 2 days incubation at 0.02 atm. O_2 and 0.1 atm. C_2H_2.

Samples taken from the Agronomy Research Farm at Mead exhibited much higher rates of acetylene reduction. The maximum observed value was 58 nmoles C_2H_4 formed hr^{-1} (g dry wt)$^{-1}$ after 24 hours preincubation and 3 1/2 hours with 0.1 atm. of C_2H_2 under anaerobic conditions. Subsequent samples taken from the same field yielded acetylene reduction values ranging from 0 to 5.7 nmoles hr^{-1} (g dry wt)$^{-1}$ with the activity decreasing as the plants aged. The highest value (5.7) was obtained with a root sample that was preincubated overnight under air and then C_2H_2 added. The results were encouraging because nitrogen fixation (C_2H_2 reduction) was observed. An extensive survey in the spring of

1976 using vigorously growing plants should result in numerous nitrogen-fixing samples.

Associative symbiotic nitrogen fixation was examined also with isolated roots from forage and grain sorghums. This was undertaken to (a) obtain experience in assay methods, isolation of bacteria and characterization techniques and (b) search for nitrogen-fixing bacteria which might be used to inoculate wheat roots since there is no reason to assume plant specificity for these bacteria. Root samples were obtained from a forage sorghum nursery (compliments of H. Gorz and F. Haskins). Of the 251 lines assayed for acetylene reduction, only 12 exhibited reduction with activities ranging from 0.2 to 17 nmoles C_2H_2 formed hr^{-1} (g dry wt)$^{-1}$. Of these 12 lines, only one exhibited activity when re-assayed at a later date.

Root samples were also obtained from field and nursery (compliments of J. Eastin) grain sorghum plants. Of the 29 lines, 26 exhibited acetylene reductions ranging from 1.7 to 102 nmoles hr^{-1} (g dry wt)$^{-1}$. Subsequent assays on some of the positive lines yielded acetylene reduction but generally lower levels. An apparent lack of consistency among plants within lines and/or activities from day to day was observed which may be true differences or artifacts of the assay.

Randomly selected fields of grain sorghum were also sampled. Samples from three grain sorghum fields gave 1.3 - 8.6 nmoles C_2H_2 formed hr^{-1} (g dry wt)$^{-1}$, whereas samples from four fields exhibited no activity. Sorghum root sections which yielded acetylene reduction have been used for the isolation of the nitrogen-fixing bacteria. Nitrogen-fixing aerobes, facultative anaerobes, and anaerobes have been isolated. Presently, 60 isolates have been characterized on biochemical and morphological bacteria as Klebsiella and 30 isolates have been classified as Spirillium species using Dobereiner's criteria.

Presently, research involves measuring acetylene reduction by winter wheat plants growing in the greenhouse. Plants represent samples obtained from fields as well as from seeds germinated in the greenhouse. Some plants are inoculated with nitrogen-fixing isolates from sorghum. Future work will involve an extensive field survey for N_2 fixation using young vigorously growing winter wheat in Nebraska.

NUTRITIONAL EVALUATION

An important facet of the wheat protein improvement project involves measurement of the nutritive value of experimental high protein wheats.

By slightly modifying the method of M. F. Friedman and J. W. Finley, to satisfy equipment differences between laboratories, we are utilizing chemical derivatives of ethyl vinyl sulfone to estimate the percentage of lysine in wheat grain which is biologically available or readily digestible.

The wheat lines for this study are being selected from the "High Protein and High Lysine Observation Nursery," which was grown at 24 international sites in 1975. This nursery, replicated at Yuma, Arizona, will provide ample seed for analytical procedures and feeding trials with small animals (Table 30). Also, the nursery cooperators are sending grain samples of all of the lines to our laboratory for analyses. We, therefore, have an excellent opportunity to study differences in protein-lysine content and available lysine percentages over many growing conditions.

From the plots grown at Yuma, Arizona, we will determine available lysine by one or more existing procedures, e.g., [methyl acrylate, 1 fluoro-2, 4-dinitrobenzene (FDNB), or 2,4,6-trinitrobenzenesulfonic acid (TNBS)]. This will provide data for comparison of methods and identification of lines to be advanced to feeding studies.

If complete amino acid data indicate that samples vary only in lysine, which is first limiting, then growth should be a good indicator of available lysine.

The WARF Institute, Madison, Wisconsin, will conduct the nutritional evaluations with rat assays.

Kernel fractionations of the experimental lines will enable us to locate the kernel components which may be contributing to either higher protein, higher lysine, or both.

Lines of interest also will be analyzed for amino acid profile and chemical score. If lines appear to be different in available lysine values or nutritional qualities based upon rat performance, electrophoretic techniques will be employed to give us an indication of which protein components may be responsible for the higher nutritive value.

By utilizing kernel fractionations, amino acid profiles, available lysine determinations, rat bioassays, and electrophoretic studies, a very thorough and reliable assessment of the true value of our high protein and high lysine experimental wheat lines should be possible.

Table 30. High protein-high lysine nursery, Yuma, Arizona, 1975.

		Amount of Seed	Weighted Protein	Weighted Lysine
Lancota	2	3243	11.82	2.99
Centurk	81	3185	12.38	3.10
Bezostaya	123	3303	12.83	3.11
CI 13449	163	3287	10.96	3.23
CR 8156	279	3516	11.43	3.13
Atlas 66	300	3011	15.87	3.11
Nap Hal	320	2637	14.47	3.26
Nap Hal/13449	205	3536	12.15	3.51
Nap Hal/13449	247	3827	12.22	3.51
Nap Hal/13449	305	3306	12.74	3.46
At 66/Cmn//NB 69690	113	3142	11.71	3.38
Nap Hal/Atlas 66	292	1502	19.32	3.11
Nap Hal/Atlas 66	232	2522	17.68	2.92
K-13	265	2980	16.09	2.94
K-52	271	2729	15.80	3.10
Nap Hal/Atlas 66	224	1629	17.10	3.37
Nap Hal/CR 8156	257	3182	14.24	3.32

INFORMATION, GERMPLASM EXCHANGE, TECHNICAL ASSISTANCE, AND TRAINING

Cooperators at 25 sites received a high protein-high lysine observation nursery comprised of 280 winter, intermediate and spring types. Seed samples of each harvested entry have been returned to Lincoln for laboratory analyses from 15 sites (Table 31).

A high protein-high lysine winter wheat observation nursery containing 402 entries was distributed to 28 cooperators in the summer of 1975 (Table 32). A similar nursery comprised of 130 spring types went to 16 cooperators for observation and evaluation in 1976 (Table 33).

Experimental wheats with promising high protein and high lysine traits distributed to cooperators on request for breeding purposes are listed in Tables 34 - 37. Approximately 25 breeders throughout the world have received all or a portion of these wheats in 1975.

Reprints of published information from this project were distributed on request to a large number of researchers in many countries.

A list of publications issued since the last project review are attached.

Participants of project personnel in regional, national and international meetings is summarized on pages 79 and 80.

Workshops and conferences are summarized on pages 80 and 81.

Students who received training with our wheat group at the University of Nebraska are identified on page 81.

Table 31. Cooperators at 25 locations in 20 countries who received seed of the 1974-1975 High Protein-High Lysine Observation Nursery (280 lines).

Location	Cooperator	Samples Returned[a]
Afghanistan, Kabul	Food and Agriculture Officer, USAID	
Argentina, Bordenave	Ing. E. F. Godoy	x
Brazil, Herval	Mr. M. A. B. Rocha	
Brazil, Passo Fundo	Dr. Augusto Carlos Baier	
Chile, Temuco	Dr. I. Ramirez	
Egypt, Alexandria	Dr. Ali Salem	x
England, Cambridge	Dr. F. G. H. Lupton	
Hungary, Martonvasar	Dr. S. Rajki	x
India, New Delhi	Dr. M. V. Rao	
Iran, Karaj	Dr. H. Kaveh	x
Jordan, Amman	Mr. Zulfe Ghosheh	
Korea, Suwon	Chang Hwan Cho	x
Lebanon, Tel Amara	Dr. J. P. Srivastava	x
Nepal, Kathmandu	Dr. A. N. Bhattarai	x
Netherlands, Wageningen	Dr. J. Mesdag	x
Pakistan, Islamabad	Dr. Armando Campos	x
Pakistan, Islamabad	Dr. Armando Campos	
South Africa, Bethlehem	Mr. B. Lombard	
Spain, Logrono	Dr. P. de la Hera	
Turkey, Ankara	Dr. Art Klatt	x
Turkey, Eskisehir	Dr. T. Atay	x
USA, Arizona	Dr. V. A. Johnson	x
USA, Nebraska	Dr. V. A. Johnson	x
USA, Oklahoma	Dr. E. L. Smith	x
Yugoslavia, Zagreb	Dr. J. Potocanac	x

a/ x = Seed samples returned to Lincoln, Nebraska for quality analyses.

Table 32. Seed distribution of the 1975-1976 High Protein-High Lysine Winter Wheat Observation Nursery (402 entries).

Location	Cooperator
Afghanistan, Kabul	Food and Agriculture Officer
Afghanistan, Kunduz	Food and Agriculture Officer
Argentina, Balcarce	Ing. R. Bedogni
Argentina, Bordenave	Ing. S. Garbini
Brazil, Passo Fundo	Dr. Augusto C. Baier
Chile, Temuco	Dr. Juan Acevedo
Ecuador, Quito	Ing. Mario Lalama Hidalgo
Hungary, Martonvasar	Dr. L. Balla
India, Shalimar	Dr. M. V. Rao
India, Simla	Dr. M. K. Upadhyay
Iran, Hamadan	Dr. H. Kaveh
Iran, Karaj	Dr. H. Kaveh
Iraq, Sulaimaniya	Dr. M. Aziz
Jordan, Amman	Dr. Zulkifl Ghosheh
Korea, Suwon	Dr. Hyun Ok Choi
Lebanon, Beirut	Dr. J. P. Srivastava
Mexico, Toluca	Dr. N. Borlaug
Nepal, Kathmandu	Food and Agriculture Officer
Peru, Lima	Dr. M. Romero
Republic of South Africa, Pretoria	Mr. T. C. Nel
Spain, Logrono	Dr. P. de la Hera
Turkey, Ankara	Dr. Art Klatt
Turkey, Erzurum	Dr. Fahrettin Tosun
Turkey, Eskisehir	Director of the Experiment Station
USA, Arizona	Dr. V. A. Johnson
USA, Nebraska	Dr. V. A. Johnson
USA, Oklahoma	Dr. E. L. Smith
USA, Oregon	Dr. W. Kronstad

Total of 28 locations in 19 countries.

Table 33. Seed distribution of the 1975-1976 High Protein-High Lysine Spring Wheat Observation Nursery (130 entries).

Location	Cooperator	Number of Sets
Afghanistan, Kabul	Food and Agriculture Officer	1
Afghanistan, Kunduz	Food and Agriculture Officer	1
Algeria, Algiers	Mr. R. Nezzal	1
Brazil, Passo Fundo	Dr. Augusto C. Baier	1
Brazil, Pelotas	Mr. Milton B. Rocha	1
Chile, Santiago	Dr. Ignacio Ramirez	1
India, New Delhi	Dr. M. V. Rao	2
Iran, Karaj	Dr. H. Kaveh	2
Iraq, Sulaimaniya	Dr. Mahesh P. Panth	1
Italy, Rieti	Dr. G. Zitelli	1
Jordan, Amman	Mr. Zulkifl Ghosheh	1
Lebanon, Beirut	Dr. J. P. Srivastava	1
Pakistan, Islamabad	Dr. Armando Campos	1
Spain, Madrid	Ing. E. Sanchez-Monge	1
USA, Arizona	Dr. V. A. Johnson	4
USA, California	Dr. Cal Qualset	1

Total of 16 locations in 13 countries.

Table 34. Spring wheats from ARS-Nebraska program with high protein and/or high lysine potential for breeding purposes. Distributed on request to breeders in 1975.

1975 Yuma No.	Pedigree	Protein	Lysine % of Protein Unadj.	Lysine % of Protein Adjusted	1975 Yield at Yuma, Ariz.
		(%)			(q/ha)
10038	Nap Hal/Atlas 66, F_7	16.0	3.0	3.2	44
10100	"	16.0	3.1	3.3	37
10121	"	17.0	3.0	3.2	59
	Comparative Performance of Parents and Check Varieties				
	Nap Hal	13.0	3.3	3.3	29
	Atlas 66	14.4	3.0	3.1	63
	Centurk	10.5	3.1	2.9	58
10461	Nap Hal/CI 13449, F_6	12.5	3.5	3.6	59
10491	"	12.4	3.6	3.6	52
10699	"	12.4	3.6	3.6	51
10841	"	12.7	3.5	3.6	82
10451	"	10.9	3.8	3.7	56
10642	"	11.0	3.9	3.8	62
10811	"	11.8	3.8	3.7	52
	Comparative Performance of Parents and Check Varieties				
	Nap Hal	13.0	3.3	3.3	25
	CI 13449	10.2	3.5	3.2	62
	Centurk	10.1	3.2	2.9	46
10958	Nap Hal/CIMMYT 8156	13.0	3.3	3.4	61
10961	"	16.9	3.1	3.3	71
10967	"	13.4	3.2	3.3	61
11029	"	12.3	3.4	3.4	69
11074	"	12.6	3.3	3.3	68
11507	"	13.6	3.3	3.4	75
11511	"	12.2	3.3	3.3	67
11513	"	13.1	3.3	3.4	63
11522	"	12.1	3.3	3.3	66
11524	"	12.9	3.3	3.4	64
	Comparative Performance of Parents and Check Varieties				
	Nap Hal	13.0	3.3	3.3	42
	CIMMYT 8156	10.2	3.3	3.0	59
	Centurk	10.7	3.3	3.1	40
11564	Nap Hal/CB113	12.9	---	3.3	58
11574	"	13.0	---	3.3	62
11593	"	14.1	---	3.4	45
11847	Nap Hal/Justin	13.1	---	3.4	40

Table 35. Winter and intermediate type wheats from the ARS-Nebraska program with high protein and/or high lysine potential for breeding purposes. Distributed on request to breeders in 1975.

1975 Yuma No.	Pedigree	Protein	Lysine % of Protein		1975 Yield at Yuma, Ariz.
			Unadj.	Adjusted	
		(%)			(q/ha)
21061	CI 13449/Centurk	12.6	3.2	3.2	85
10486	Nap Hal/CI 13449, F_6	12.9	3.6	3.6	55
10521	"	12.5	3.5	3.5	59
10661	"	13.0	3.4	3.5	77
10768	"	12.0	3.5	3.5	66
10185	Nap Hal/Atlas 66, F_7	16.2	3.1	3.3	48
10600	Lancota	13.1	3.1	3.1	84
	Comparative Performance of Parents and Check Varieties				
	Nap Hal	13.0	3.3	3.3	25
	CI 13449	10.2	3.5	3.2	62
	Centurk	10.1	3.2	2.9	46

Table 36. Winterhardy high protein and/or high lysine winter wheats from the ARS-Nebraska program, 1974. Distributed to selected breeders in 1975.

Source	Protein	Adjusted Lysine (% of Protein)	1975 Lincoln Yield	Ht.	Quality		
					Seed	Mix	
						Time	Tol.
	(%)			(In.)			
75L10014	14.9	3.1	34	37	Ex	2	3
10035	14.7	3.2	42	35	VG	2 2/3	3
10174	14.7	3.3	38	33	G	2 1/3	2
10309	13.8	3.5	35	40	Ex	2 2/3	3
10330	17.1	3.2	35	38	G	2	3
10393	16.0	3.0	36	37	G	2	3
10591	16.2	---	36	41	G	3	4
10624	17.1	3.0	41	39	Ex	2	2-
10824	14.3	3.4	37	37	Ex	3	3
10831	16.2	3.2	33	38	G	2 1/3	4

Table 37. Pedigrees of the experimental lines shown in Table 36.

Source	Pedigree
75L10014	Tx1682/3/Sel. 14-53/2/Atlas 66/Cmn
10035	Centurk/3/Aiv/1385/2/Sel. 14-15
10174	NE69633/4/Suwon 85/3/Atlas 66/Cmn/2/Hume
10309	Sel. 14-50-3/Centurk
10330	Sel. 14-53/3/Lancer/2/Atlas 66/Cmn
10393	Sel. 14-53//Atlas 66/Cmn
10591	Atlas 66/Cmn//NE69690
10624	Atlas 66/Cmn//NE69655
10824	NE69566/Sel. 14-50-3
10831	Atlas 66/Cmn//Centurk

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Stroike, J. E., V. A. Johnson, J. W. Schmidt, P. J. Mattern, and K. D. Wilhelmi. 1974. Results of the fourth international winter wheat performance nursery. Nebr. Res. Bul. 265, 159 pages.

Johnson, V. A., P. J. Mattern, and K. P. Vogel. 1975. Cultural, genetic, and other factors affecting quality. Bread (358 pages), Applied Science Publishers Ltd., London, England. pp. 127-140.

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Klepper, L. A. 1975. Nitrate reductase and its role in the accumulation of protein in the grain of wheat. Proc. Latin American Wheat Conf., Porto Alegre, Brazil. pp. 337-343.

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Mattern, P. J. 1975. Laboratory methods for protein evaluation. Proc. Latin American Wheat Conf., Porto Alegre, Brazil. pp. 332-336.

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Johnson, V. A. Opportunity to improve the nutritional value of wheat through breeding. Proc. 9th National Conf. on Wheat Utilization Research, Seattle, Washington, 1975. (In press).

Johnson, V. A., P. J. Mattern, J. E. Stroike, and K. D. Wilhelmi. 1976. Breeding for improved nutritional quality in wheat. Proc. 2nd International Winter Wheat Conf., Zagreb, Yugoslavia, June, 1975. pp. 316-333.

Klepper, L. A. 1976. Nitrate assimilation enzymes and seed protein in wheat. Proc. 2nd International Winter Wheat Conf., Zagreb, Yugoslavia, June, 1975. pp. 334-340.

Klepper, Lowell A. 1976. Nitrite accumulation: An explanation for synergistic combinations of herbicides. Weed Sci. (In press).

Klepper, Lowell A. 1976. Nitrite accumulation within herbicide-treated leaves. Weed Sci. (In press).

Mattern, P. J. 1976. Processing and nutritional quality of high protein wheats. Proc. 2nd International Winter Wheat Conf., Zagreb, Yugoslavia, June, 1975. pp. 305-316.

Stroike, J. E. and V. A. Johnson. 1976. The international winter wheat performance nursery. Proc. 2nd International Winter Wheat Conf., Zagreb, Yugoslavia, June, 1975. pp. 501-510.

Participation in Meetings

V. A. Johnson. Invited speaker at Midwest Assoc. of State Departments of Agriculture Conf., June 17, 1974, Lincoln, Nebraska.

V. A. Johnson and J. W. Schmidt. Invited speakers at 24th Annual North Central States Meeting of Seed Certification Officials, August 15, 1974, Lincoln, Nebraska.

V. A. Johnson. Invited speaker at International Symposium on Bread, September 1-6, 1974, London, England.

V. A. Johnson. Invited speaker at Regional Briefing on Protein Enrichment for Better Foods, September 18, 1974, Peoria, Illinois.

V. A. Johnson, L. Klepper, P. J. Mattern, R. A. Olson, J. W. Schmidt, and K. D. Wilhelmi. Participants Latin American Wheat Conference, October 21-28, 1974, Porto Alegre, Brazil.

V. A. Johnson. Presented seminar at Agricultural University, October 9, 1974, LaMolina, Peru.

V. A. Johnson and P. J. Mattern. Presented seminar at AID, U. S. Department of State, January 27, 1975, Washington, D.C.

P. J. Mattern. Invited speaker at Symposium, New York Section of American Assoc. of Cereal Chemists, April 7-8, 1975, New York City.

V. A. Johnson. Presented seminar to Faculty of Agriculture, University of Alexandria, May 21, 1975, Alexandria, Egypt.

V. A. Johnson, L. Klepper, P. J. Mattern, R. A. Olson, J. W. Schmidt, and J. E. Stroike. Participants 2nd International Winter Wheat Conference, June 9-19, 1975, Zagreb, Yugoslavia.

V. A. Johnson. Invited speaker at Symposium on Genetic Vulnerability, Germplasm Resources, and Plant Breeding Strategies, American Soc. Agron., August 24-30, 1975, Knoxville, Tennessee.

V. A. Johnson. Presented seminar to Agronomy Department, Washington State University, October 6, 1975, Pullman, Washington.

V. A. Johnson. Invited speaker at 9th National Conference on Wheat Utilization Research, October 8-10, 1975, Seattle, Washington.

V. A. Johnson. Invited participant, International Conference on Crop Productivity Research Imperatives, October 20-24, 1975, Harbor Springs, Michigan.

V. A. Johnson. Participant, National Wheat Improvement Committee Meeting, November 17-18, 1975, Beltsville, Maryland.

V. A. Johnson. Presented seminar to Department of Plant Genetics and Agronomy, University of Minnesota, January 26, 1976, St. Paul, Minnesota.

V. A. Johnson. Presented seminar to Plant Breeding and Poultry Departments, Cornell University, February 9, 1976, Ithaca, New York.

V. A. Johnson. Invited speaker, International Symposium on Genetic Control of Diversity in Plants, March 1-7, 1976, Lahore, Pakistan.

Workshops and Conferences Organized

A Latin American Wheat Conference was organized and held at Porto Alegre, Brazil, October 21-28, 1974. One-hundred-thirty-one researchers and research administrators from 12 countries participated in the conference. The Proceedings of the conference has been published and distributed by the University of Nebraska. The Ministry of Agriculture of Paraguay has invited the next Latin American Wheat Conference to be held in Asuncion in 1977.

The Second International Winter Wheat Conference was organized and held at Zagreb, Yugoslavia, June 9-19, 1975. This followed by three years the First

International Wheat Conference held in Ankara, Turkey. The Conference Proceedings has been published and distributed. An invitation to hold the third conference at Fort Collins, Colorado, in 1979 has been extended by Colorado State University. Dr. Sosinov, Director of the Wheat Institute at Odessa, USSR, has indicated interest in inviting the third conference to Odessa in 1978, if Ministry approval can be obtained.

Training Activities

Melaku Worede from Ethiopia completed the Ph.D. degree at the University of Nebraska in July, 1974 and returned to his country.

Tobar Danakasuma from Indonesia began study with us for the Ph.D. degree in September, 1975.

Plans are underway for two scientists from Latin America (Columbia and Brazil) to join us next summer for advanced degree study.

Allen Diehl (Nebraska) and Kenneth Vogel (Nebraska) completed Ph.D. degrees in 1974. Steven Kuhr (Nebraska) completed the M.S. degree in 1974 and is currently working toward the Ph.D. degree as a full-time member of our group.

Kenneth Wilhelmi is nearing completion of the Ph.D. and has replaced J. E. Stroike as supervisor of the international winter wheat performance nursery.

New graduate students on the wheat nutrition project at the University of Nebraska in 1975 include Douglas Hartmann (Nebraska) and David Worrall (Michigan). Stanley Kowalski (Pennsylvania) will join us next summer.

Syed Md. Ifzal, and IAEA Fellow from the Nuclear Institute for Agriculture and Biology, Lyallpur, Pakistan, is spending six months in the Wheat Laboratory to become proficient in operation of automatic amino acid analyzers (January 1, 1976 - July 1, 1976).

PLAN OF WORK

April 1, 1976 - March 31, 1977

A. Genetics and Breeding

New hybrid combinations involving the most recently identified genetic sources of improved nutrition will be made. The best spring and winter wheats from foreign countries and the USA will serve as recipient genotypes.

Appropriate selection criteria and field and laboratory evaluation techniques will be utilized to identify populations and lines with best agronomic and nutritional potential.

Screening and selection will be made at production sites in Nebraska and Arizona under favorable and unfavorable conditions of soil moisture, soil fertility, temperature, and other production factors.

Large scale enforced genetic recombinations will be induced in composite populations using chemical male gametocides.

Yield tests of promising nutritionally improved lines will be conducted and selected lines will be advanced to the International Winter Wheat Performance Nursery for international evaluation of their productivity and adaptation.

B. Chemical and Physical Characterization of Nutritionally Improved Wheats

Identify differences in kernel components and protein fractions of varieties with improved nutritional value.

Utilize available procedures to measure chemically available lysine in high protein-high lysine varieties and subject those with high and low values to small animal feeding trials for correlation of chemical data with bioassay data as quantity of grain becomes available.

Use standard selection tests to identify high protein and/or high lysine lines with acceptable milling and baking potential.

Obtain wheats from LDC's that represent extremes in processing acceptability for food use, analyze for hardness, and determine protein and starch properties associated with acceptable processing quality in these countries.

C. International Evaluation

Evaluate new winter wheats from the Nebraska program and from other countries in the International Winter Wheat Performance Nursery and identify varieties and lines with superior agronomic and quality characteristics. Obtain analytical data for protein on all samples and for lysine on selected samples.

Analyze and summarize performance data from all test sites and disseminate to cooperators and wheat scientists in appropriate reports and publications.

Collect soil and plant samples from selected IWWPN test sites and study the influence of soil and environmental factors on the yield and quality of varieties in the IWWPN.

Correlate soil chemical and physical factors that may influence the yield and quality of wheat with the performance, quality, and plant analysis data to uncover useful relationships and interactions between varieties and production factors.

D. Physiological Studies of High Yield and High Protein Nitrogen Metabolism

Identify wheats that are most efficient in taking up and reducing nitrate under optimal and suboptimal nitrate environments and elucidate the processes involved using established techniques for measuring nitrate content and nitrate reductase activity in leaf and stem tissue.

Identify wheats capable of synthesizing large amounts of vegetative protein.

Identify wheats with greatest capacity for translocating large amounts of vegetative protein to the grain for final protein synthesis using newly developed instrumentation for measurement of true protein in vegetative tissue and in the grain.

Plant Loss of Nitrogen

Assemble necessary equipment to maintain environmental control and monitor nitrogen. Initiate research to determine, how, when, and where nitrogen escapes from the wheat plant and what factors influence the magnitude of this loss.

Photosynthetic Efficiency

Characterize photosynthetically active radiation (visible light) interception efficiency and distribution patterns by wheat canopies that vary phenotypically and utilize this information for more efficient genetic selection of productive new wheats and development of improved management systems.

Evaluate photosynthetic efficiency as influenced by different combinations of day-night temperature effects on night respiration and the balance between photosynthesis and photorespiration during the day.

Investigate wheat plant senescence in relation to phytohormone changes to establish the opportunity for extending the period of active photosynthesis in the wheat plant to make it more productive.

E. Associative Symbiotic Nitrogen Fixation

Collect soil and plant samples from Nebraska and other U.S. field locations and assay for associative nitrogen-fixing microorganisms.

Isolate nitrogen-fixing microorganisms from those samples exhibiting nitrogen fixation.

Analyze roots for the site(s) of the nitrogen-fixing microorganisms. If nitrogen-fixing bacteria are found and available by the fall of 1976, they will be used to inoculate test plots of wheat.

F. Nutritional Evaluation

Selected advanced lines with high protein and/or high lysine capabilities will be evaluated with rat bioassay and results correlated with chemical laboratory data to identify the most promising nutritionally superior lines.

G. Information, Germplasm Exchange, Technical Assistance, and Training

Make available to developing countries, genetic stocks, populations, wheat varieties, and lines with improved productivity and nutritional value.

Exchange genetic stocks, experimental lines, and research information with other organizations engaged in international activities, such as CIMMYT, FAO, IAEA, Oregon State University, and Purdue University to insure most rapid progress in the nutritional improvement of wheat.

Make on-site inspections of International Winter Wheat Performance Nurseries and consult with AID Mission, FAO, and CIMMYT personnel in developing countries.

Publish research results in appropriate reports, bulletins, and scientific journals.

Organize and participate in national and international workshops and conferences on wheat as an effective means of communication and information exchange.