United States
Department of
Agriculture

Statistical
Reporting
Service

**Statistical
Research
Division**

**SRS Staff Report
Number AGES840426**

1981-82 Sunflower Objective Yield Research

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1981-82 SUNFLOWER OBJECTIVE YIELD RESEARCH. By Michael E. Craig; Statistical Research Division, Statistical Reporting Service, U.S. Department of Agriculture; Washington, D.C. 20250; May 1984. SRS Staff Report No. AGES840426.

ABSTRACT

This report summarizes two years of sunflower objective yield research conducted in North Dakota. The objectives of this research were to develop operational procedures for the at-harvest estimation of sunflower yield and to investigate regression models for early season forecasts. Results from the two year analysis give objective yield estimates that are significantly larger than the Crop Reporting Board's published values. Reasons for these differences are investigated and recommendations are made for future research. Data collection and summary procedures are documented. Forecasting models are investigated for both heads per acre and seed weight per head.

ACKNOWLEDGMENTS

The author wishes to thank Dick Coulter, the office personnel, and the Enumerator staff in the North Dakota State Statistical Office for their comments and suggestions as well as their data collection efforts. Thanks are also expressed to Mary Ann Cummins (Systems Branch) and Jim Lawson (Data Collection Branch) for their support and assistance with processing and data collection throughout the project. Special thanks are also extended to Dr. Jerry Miller, jointly with the Agricultural Research Service and the Department of Agronomy, North Dakota State University for his guidance in the use of the NDSU laboratory equipment and his comments and suggestions for the project as a whole.

Washington, D.C. May 1984

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By Michael E. Craig

INTRODUCTION

The purposes of this two-year study conducted in North Dakota were to develop objective yield procedures for estimating sunflower yield at harvest and to investigate forecasting models to predict yield during the growing season. The procedures were to be developed and documented in such a manner as to be directly applicable to an operational program. Currently, plans are to conduct an operational Sunflower Objective Yield Program for at-harvest yield estimation in 1984 based on this research. The states included for the sunflower program under the 1984 funding request being considered by Congress are North Dakota, South Dakota, and Minnesota. This program only considers sunflower for oilseed harvest and does not include confectionery sunflower. A program for early season forecasts would follow in each state as soon as data and funding for estimation of forecasting equation parameters are available.

The Statistical Reporting Service's (SRS) operational acreage and production program for sunflower as it now stands estimates four quantities: planted acreage, harvested acreage, yield per harvested acre, and production. These estimates are made for oilseed, non-oilseed, and all sunflower. Acreage estimates released in late June are derived from a probability-based June Enumerative Survey and a non-probability June Acreage Survey. Harvested acreage estimates are updated and forecasts of yield and production for all sunflower are made in October based on Monthly Farm Report data. Final yield estimates are made in mid-January based on Fall Acreage and Production (A & P) Survey data. The Fall A & P Survey is a large, non-probability mail survey with a telephone followup for non-response. Production is derived from the estimated yield and the updated harvested acreage.

Prior research in estimating sunflower yield comes from two main sources: experiments in phenology modeling and National Performance Trials by variety. These two approaches are not intended to produce statewide yield estimates. Also, both approaches use controlled growing conditions, such as over-planting and later thinning plots to get a standard plant population for purposes of comparison. The objective yield procedures described in this report are based largely on the SRS

operational program (8) for corn, which of the crops in the operating program is the most comparable in plant characteristics to sunflower.

The North Dakota State Statistical Office (ND SSO) collected field data for two years (1981 and 1982) in support of this research. Weather (12) for the two years played an important part in the final yields obtained by farmers. In 1981, planting began in earnest in late April, about one week behind the five year average. In 1982, cold and wet conditions delayed planting about two weeks behind the pace of 1981. The 1981 sunflower crop caught up to the average in late June, while the 1982 crop lagged throughout the growing season. Harvesting activity began in mid-September 1981 but was slowed by wet, cool weather until a hard frost in late October began the drying process. November 1981 was close to ideal for harvesting with harvest complete by the end of November. Excessive moisture in the late season affected both year's crops, but had a greater effect in 1982. Harvesting activity in 1982 lagged considerably behind the average and was not completed until late December. Other problems in 1982 included a mid-season drought and a damaging frost in late August. Mechanical drying was necessary for much of the 1982 crop. Both year's yields were lower than expected with reports of low oil content common.

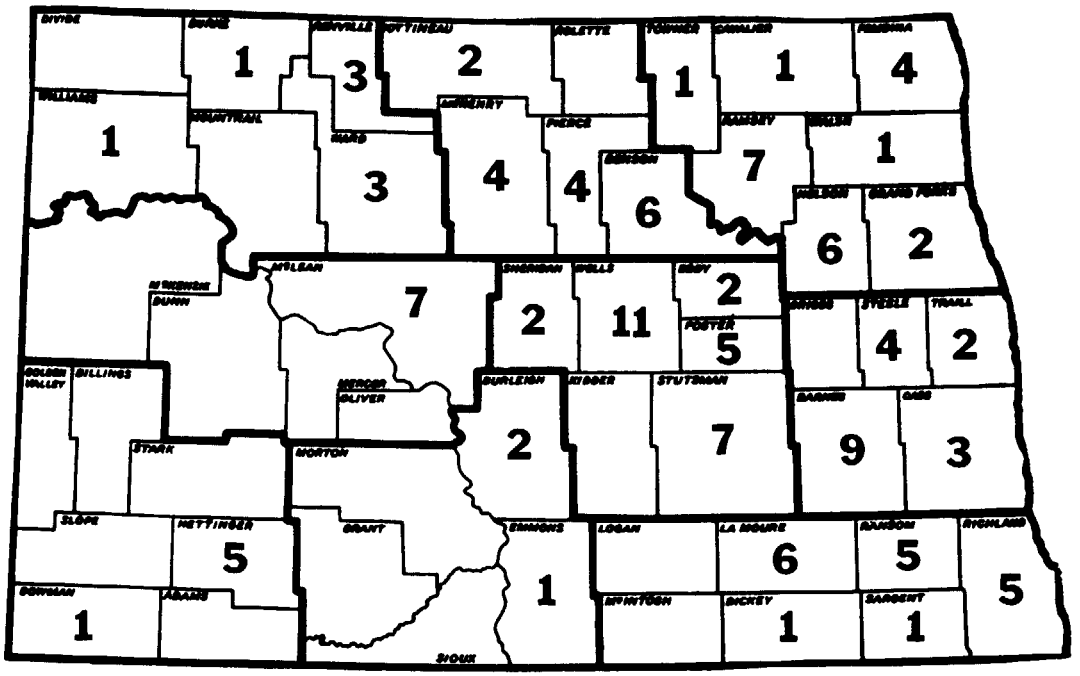
DATA COLLECTION

Sample Design

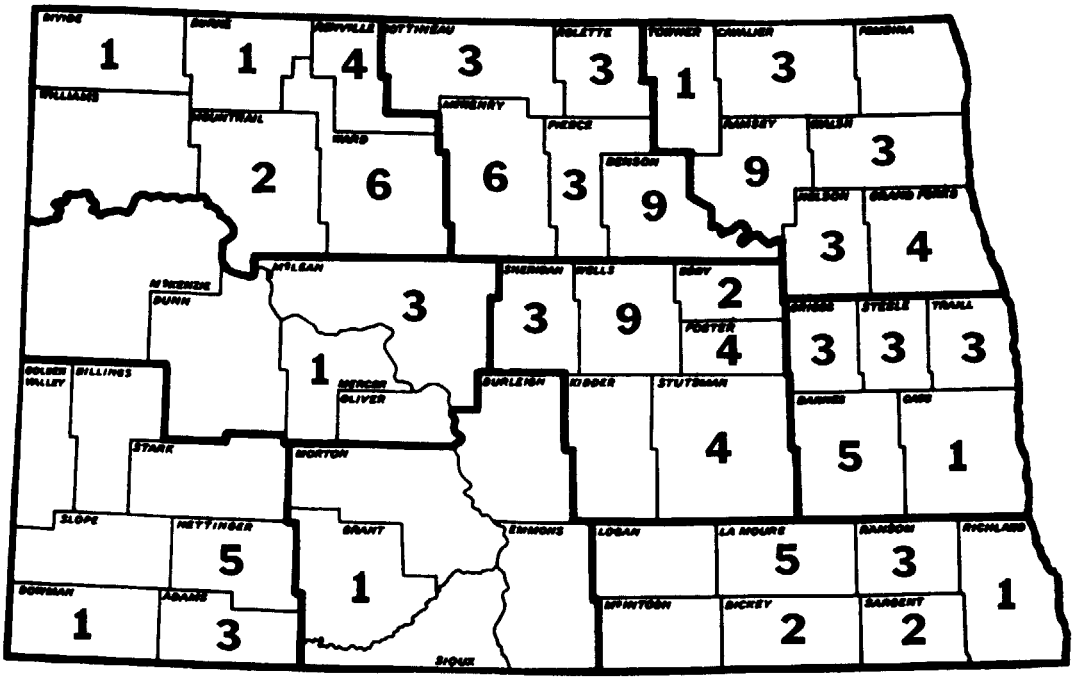
Sunflower objective yield samples were selected in the normal manner, that is a subsample of June Enumerative Survey (JES) fields planted and to be planted to sunflower was selected with probability proportional to expanded acreage. JES item code 697 (acres planted to 'all sunflower') was used for the selection. The sampling procedure allows a field to have more than one sample, which happened both years.

For each of the study years, 125 samples were originally selected. Figure 1 shows the geographic distribution of samples by county for both years. Table 1 shows the distribution of the original samples as determined by the enumerators in the initial interview with the farmer. All mention of samples in the following sections of this report refer to the 'usable' samples (those selected fields found to be sunflower for oilseed harvest and where the farmer gave permission to enter the field). This table shows that 99 samples were 'usable' each year. Table 2 shows data collection costs in North Dakota for the two years.

FIGURE 1: Distribution of Sunflower Samples by County



(a) 1981



(b) 1982

Table 1: Breakdown of Samples by Initial Interview

Description	1981	1982
Oilseed, Row Planted	99*	98*
Oilseed, Broadcast	3	1*
Refusal, Form A	10	4
Confectionery or Abandoned	10	11
No sample field available	1	5
No sunflower in Tract	2	6
Total Samples	125	125

* 'Usable' Samples, note that in 1982 broadcast fields were usable due to special procedures.

Table 2: North Dakota Data Collection Costs (In Dollars)

Description	1981 Total	1981 Per 'Usable' Sample	1982 Total	1982 Per 'Usable' Sample
NASDA Out-of-Pocket	25,101	254	20,703	209
Other non-NASDA	4,416	--	5,289	--
Total Cost	29,517	--	25,992	--

The samples were divided into two groups based on sample number. Odd-numbered samples were used only for yield estimation at harvest and visited only once prior to harvest. Even-numbered samples were used for at-harvest estimation and to develop forecasting models. Enumerators visited even-numbered samples at regular intervals throughout the growing season. Both odd and even-numbered samples were used to estimate harvest loss. The following sections describe enumerator training, timing of data collection, forms used, field and laboratory work, edit procedures, and summary procedures.

Training and Timing

Each year the state training schools for enumerators were held in mid-July. Enumerators learned procedures in a classroom environment and then went to sunflower fields nearby to practice unit layouts and measurements.

Enumerators began initial farmer interviews during the first week of August. These interviews obtained acreage, planting date, and variety information. Enumerators screened samples to determine if selected fields were in fact planted to oilseed sunflower and intended for harvest. Variety information was sometimes used for confectionery screening.

Enumerators visited fields in even-numbered samples semi-monthly from August until the first week in October and monthly thereafter until maturity of the crop. All samples were visited just prior to harvest for the final clippings and field weights. After harvest, a post-harvest interview with the farmer (for production information) and a "gleanings" visit to measure harvest loss were conducted. This interview also provided harvest date and information on reported damage to the fields. Weather, field conditions, and late harvest in both years prevented gleanings visits to some fields. Data collection ended during early December in 1981 and late December in 1982.

Field Enumeration

Each sunflower sample consisted of two clipping units, randomly located in the sample field. Each unit was two rows by 15 feet. Location of the units followed the randomization procedure used in the corn operational objective yield program. During each visit to these units enumerators made plant and head counts, observations on crop maturity, head diameter measurements (if the unit was sufficiently mature), and row spacing measurement. If an even-numbered sample had reached a certain maturity category, three heads were clipped from outside one of the units and mailed to the laboratory. Enumerators visited all samples just prior to harvest, the final pre-harvest visit, and recorded counts and head measurements as before. In addition, enumerators clipped and weighed all heads with seed from Row 1 of each unit. A subsample of the clipped heads (the third through fifth heads in Row 1 of each unit in 1982 and the third and fourth heads only in 1981) was mailed to the laboratory for analysis.

Several fields with no discernible rows were encountered in the 1981 data collection. Samples in these fields (called broadcast fields) were treated as refusals and no further data was collected. A special procedure was developed for the 1982 data collection in broadcast fields utilizing a 6x6 foot square for the clipping unit.

Associated with each clipping unit was a gleaning unit. Gleaning units were visited immediately after harvest to collect data for estimating harvest loss. In 1981 the design for gleanings measurement originally called for picking up all loose seed or partially destroyed heads found in a two row by 15 foot unit. Loose seed gleaning was reduced to the first five foot section because of the time involved. Also, tire tracks or spillage from harvesting equipment complicated gleaning in some units. In 1982 the gleaning layout was changed to be a one foot by six row unit to facilitate data collection and to avoid variability caused by harvesting equipment. A special procedure was also developed for gleaning in broadcast fields.

Laboratory Procedures

On each field visit during the growing season, enumerators determined the maturity category of the sample. If the maturity had reached a given stage, the enumerator clipped three heads from outside Unit 2 and mailed the heads to the ND SSO laboratory. In 1981, both sterile and fertile seeds were counted in the laboratory from a 'pie-section' of these three heads. Separating fertile seeds, sterile seeds, and chaff proved to be very time consuming and subjective, especially for heads not fully mature. In 1982, the laboratory counted only fertile seed for

the entire head. Heads were not sent to the laboratory until a higher maturity category was reached in 1982, which enabled machine separation of fertile seed and reduced the subjectiveness of fertile/sterile determination. For both years, laboratory measurements of head diameter were recorded. These counts and measurements gave information for building weight per head forecasting equations.

Just before harvest, enumerators clipped and weighed all sunflower heads with seed from Row 1 of each unit. In addition, enumerators mailed specified clipped heads in sealed plastic bags to the ND SSO for laboratory measurements. In 1981, the design specified two heads per unit, while in 1982 three heads were mailed. Laboratory measurements included head weights before threshing, seed weights after threshing, and moisture content. Also, seed counts per head and diameter measurements were obtained at this time to allow comparison of heads sent to the laboratory with field measurements to determine if there was any bias in selecting heads for the laboratory.

Laboratory determinations for sunflower closely resembled the procedures for corn in the operational objective yield program. Laboratory work for both years was done at the sunflower laboratory facilities of the North Dakota State University (NDSU). Costs of the laboratory work, excluding equipment, totaled 1,740 dollars in 1982. Of this total, 44 percent of the cost was for C-1 work; and 56 percent for C-2 work. Approximately one and one-third hours were spent on each C-1 form, while each C-2 form took just under two hours.

Forms and Changes

The forms used for data collection and laboratory work were very similar each year and resembled those used with the corn operational program. Enumerators interviewed farmers initially in August and again after harvest and recorded acreage and production information on Forms A and D. Forms B and E contained information from visits to the sunflower field before and after harvest. Laboratory counts and measurements corresponding to preliminary field visits, final pre-harvest clippings, and gleanings were contained in Forms C-1, C-2, and E. This section discusses the changes in forms used between the two years. Appendix I contains a copy of the forms used for 1982 and a copy of the 1981 Form B, which was the form changed most between years.

The initial interview, Form A, was changed for 1982 to aid in the identification of confectionery sunflower fields and to make sure that their acreage was not included under oilseed for harvest. The only change to the Form D post-harvest interview was that detailed information on reported damage was obtained in 1982.

Laboratory forms C-1 and C-2 were changed significantly between the two years. These changes mainly involved the counting of sterile seeds as mentioned in the earlier section on laboratory work. The 1982 laboratory forms included only counts of fertile seeds because of the difficulty of separating sterile seeds from the chaff. The pie-section approached used in the 1981 C-1 laboratory was also dropped. The 1982 C-2 laboratory analyzed three heads per unit (six per sample) while in 1981 only two heads per unit were sent to the laboratory.

Form B, used for pre-harvest field counts and measurements, was the most changed form between the two years. The major changes involved the redefinition of maturity categories (5) or stages. Appendix II gives a description of each year's maturity categories. After the 1981 survey, enumerators stated that some of the categories were very hard to distinguish. For 1982, the categories were simplified into non-technical terms and a code added for units found in blank areas. Also in 1982, the Yield Assessment Section (YAS) provided the enumerator with a color insert showing examples of the various categories. This insert was adapted for our purposes from Extension Folder 541-1980 obtained from the University of Minnesota Agricultural Extension Service.

Changes to maturity category definitions were reflected in revisions made on the Form B counts of stalks, flowers, and heads within the units. These revisions included more intermediate counts in 1982 and a place for counts of total stalks and total heads. These new counts provided a place for enumerators to record counts at each step and to check totals. Also, this took care of the problem of multiple heads per stalk. The addition of intermediate counts allowed a check on reported maturity category in the machine edit.

More detailed information on the forms and instructions for their use were provided in an Enumerator's Manual (9) and in a Supervising and Editing Manual (10) created each year for this research.

Edit and Summary

The YAS wrote and documented procedures for both edit and summary of the survey data. The edit procedure for both years used the Generalized Edit (GE) system, the objective yield reformat program (SOY001), and the objective yield records keeping program for sunflower (SOY301). Parameters for the GE system were written and maintained by the YAS while those for the latter two programs were maintained and updated for each visit by the Enumerative Survey Support Group of Systems Branch. The ND SSO was responsible for keying and loading raw survey data to the Martin Marietta Data System (MMDS). The ND SSO initiated edit runs, reviewed error listings, and updated the data where necessary. The YAS transferred the final 'clean' data tape to its library and created an update master for the next visit edit run. The YAS summarized the data by visit, using the Statistical Analysis System (SAS) on MMDS.

Copies of edit parameters, flowcharts, job streams, and summary programs are available from the YAS. Table 3 gives some descriptive statistics taken from the summaries for the field data collection in 1982. Form B data is shown for visit six only.

Table 3: Descriptive Statistics from 1982 Field Data

Form	Variable	n	Mean	Std. Err.	Min.	Max.
A	Interview Time (Min)	121	17.8	1.02	4	90
	Field Size (Acres)	102	114.8	10.82	16.4	520
	Planting Date (M/D)	102	6/2	--	4/10	6/29
B	1 Row Width (ft)	188	2.5	0.03	1.0	3.5
	4 Row Width (ft)	188	10.5	0.12	4.7	14.6
	Stalks/Row	376	14.5	0.23	1	32
	Heads/Row	376	14.3	0.23	1	28
	Head Diam. (cm)	93	17.3	0.33	9.2	25.0
	Whole Head Wgt (gm)	93	142.0	6.55	25.2	345.1
	Time in Field (min)	94	81.4	2.44	35	165
D	Harvest Date (M/D)	98	11/6	--	10/17	12/12
	Farmer Yield (lb/ac)	98	1198	35.45	300	2118
	Moisture Content (%)	98	15.8	0.31	10	26
	Harvested Sample Acres	98	116.8	11.17	16.4	520
	Interview Time (Min)	98	19.3	1.44	5	105
	Plant to Harvest (Days Elapsed)	98	161.4	1.28	137	193
E	1 Row Width (ft)	87	2.5	0.01	1.3	3.5
	5 Row Width (ft)	87	12.6	0.13	6.4	16.0
	Wgt Seeds - Heads (gm)	87	46.9	6.18	0.0	279.9
	Wgt Seeds - Loose (gm)	87	9.5	1.25	0.1	72.3
	Moisture Content (%)	87	9.2	0.24	5.8	17.9
	Field Time (min)	87	68.5	2.65	15	165

ANALYSIS ASSUMPTIONS

Throughout the following analysis, two assumptions are made with respect to yield estimates and their variances. First, it is assumed that there are no characteristic differences between data on completed forms and missing data. Second, variances are computed under the assumption of simple random sampling. This section discusses these assumptions.

There were several reasons for missing data. Since participation in these surveys was voluntary, some data was lost due to a farmer's unwillingness to cooperate (note Table 1, Form A Refusals). In other cases, data may be lost due to inaccessible fields, incomplete forms, forms lost in mailing, or early or late harvesting of fields. The assumption was made that there was no characteristic difference between completed data and missing data. This assumption may introduce biases in the final estimates, with the amount of bias depending on both the proportion of samples with missing data and the actual differences between the two groups.

One alternative to this assumption is to impute averages for the various missing yield components based on JES land use stratum. Due to time limitations this alternative was not used. However, it is unlikely that yield estimates differ greatly among land use strata since production

practices are essentially the same. Management differences within strata probably introduce more variability than differences across strata.

All variances in this analysis were computed by assuming simple random sampling (2). This is the procedure used in all operational objective yield programs. A criticism of this assumption is that it disregards the actual sampling design. This criticism is currently being investigated in a separate study (13) and is not addressed here.

For reference purposes, the distribution of samples for both years across JES land use strata is given in Table 4. The columns labelled 'Usable' reflect those samples containing sunflower for oilseed harvest where the farmer was willing to cooperate in the survey. The columns labelled 'Complete' reflect the subset of usable samples where all B, C-2, and E Forms were completed for a specific sample with no missing items. Samples that were usable but incomplete generally were missing Form E data from gleaning visits, especially in 1982. Gleaning visits were hampered in some cases by snow cover or by fields harvested after the survey period.

Table 4: Sample Distribution by JES Stratum

	1981			1982		
JES Stratum	Total	Usable	Complete	Total	Usable	Complete
75-100% Cultivated	77	62	59	82	63	54
50-74% Cultivated	35	25	24	34	27	22
15-49% Cultivated	13	12	12	9	9	8
State Total	125	99	95	125	99	84

AT-HARVEST ESTIMATION

Acreage and yield are the two components used in forecasting and estimating production. Forecasts relate to an expected future occurrence and are made prior to the actual harvest of the crop. Estimates generally refer to an accomplished fact after the crop is harvested. Estimates of acreage, yield (per harvested acre), and production for sunflower are published in the Crop Production Annual Summary in mid-January of the year following harvest. Objective yield programs produce end-of-season estimates of harvested acreage and yield per harvested acre to be used as indicators for input into the Crop Reporting Board's published figures.

Harvested Acreage

The estimates of planted acres of sunflower provided by the JES each year were revised to estimate the acres for harvest as oilseed. The revised estimates were based on two interviews with the farmers. The initial interview, recorded on Form A, is intended to remove non-oilseed acreage (for example, confectionery fields) from the JES acreage planted to all sunflower. The post-harvest farmer interview (recorded on Form D) reflects changes occurring after the Form A interview, such as a field abandoned or plowed-up before harvest.

The Form A revision computes the mean ratio by sample of the acres of sunflower for oilseed to the JES acres planted and to be planted. The mean ratio is used to adjust the State total JES acres planted to acres for oilseed harvest. Form A mean ratios for 1981 and 1982 were .8868 and .8561. The Form D revision computes in a similar manner the ratio of Form D acres actually harvested to the Form A acres intended for harvest. The mean of this second ratio is applied to the Form A estimated acreage for the final end-of-season harvested acreage estimate. Form D mean ratios for 1981 and 1982 were .9938 and .9690. Table 5 show acreage estimates and their standard errors for the two years. The published Board estimates for acreage harvested for oilseed were within one standard error of the Form D revised estimates.

Table 5: North Dakota Sunflower Acreage by Calendar Year
(in Thousands of Acres)

	1981		1982	
Source	Estimate	Std. Err.	Estimate	Std. Err.
JES Planted for All purposes	2,536	203	3,826	285
Form A Harvested for Oilseed	2,249	194	3,275	284
Form D Harvested for Oilseed	2,235	193	3,174	281
Board Harvested for Oilseed	2,400	---	3,339	---

Yield per Acre

The estimate of yield per acre is the most important product of an objective yield survey. For our purposes, sunflower yield is defined to be the pounds of fertile seed (with hulls) per harvested oilseed acre, adjusted to 10 percent moisture content. The sunflower objective yield estimates provide an indication, based on probability surveys, of the yield actually realized by the farmers. Discussions with ND SSO and NDSU personnel (5) led to the 10 percent moisture standard. Each state currently has its own standard and there is no nationally defined standard moisture content.

Objective yield surveys employ the concept of net yield. Net yield is defined as the gross (biological) yield minus the loss due to harvesting. Gross yield was calculated from the final pre-harvest field visit (Form B) and laboratory work on samples of mature heads (Form C-2). Data for harvest loss comes from the post-harvest field visit and corresponding laboratory work (Form E). Detailed formulas of estimates and standard errors for gross yield, harvest loss, and net yield are given in Appendix III. The formula for net yield in general terms follows:

Net Yield = Gross Yield - Harvest Loss, where
Gross Yield = (Heads per Acre) x (Seed Weight per Head)

Originally, the net yield per acre was to be computed for each sample and averaged. However, since some of the 99 usable samples each year were missing data for one of the forms involved (B, C-2, or E), two approaches (13) to estimating net yield were used. The first method

expressed the estimate of the net yield as the difference between average gross yield and the average harvest loss, using all available information. This approach is used in most operational surveys because gleanings are usually obtained on a subset of the samples. In the second method, those samples containing complete information for all three forms (95 in 1981 and 84 in 1982) were used in the original manner to compute average net yield across samples. Later references to net yield in this report refer to the first method.

In order to assess the accuracy of the net yield estimates, the farmer's estimate of yield per acre (adjusted to 10 percent moisture) was calculated from production information obtained on the post-harvest interview (Form D). The farmer determined production for the sample field from one of the following sources: pounds held by combine bins (on about 50 percent of the reports), wagon or truckloads (on about 30 percent of the reports), and capacity of storage bins (on most of the remaining reports). Table 6 summarizes the yield estimates by year for the objective yield surveys and includes the farmer reported yields and Crop Reporting Board (CRB) published values for comparison. All yields except the CRB value are corrected to 10 percent moisture.

Table 6: Summary of Yield Estimates
(Yield in pounds per acre)

	1981			1982		
Variable	n	mean	Std. Err.	n	mean	Std. Err.
Gross Yield	97	1915	86	93	1952	94
Harvest Loss	96	152	21	87	221	26
Net Yield (1)	97	1763	90	93	1731	95
Net Yield (2)	95	1766	89	84	1768	106
Reported Yield	93	1210	27	98	1126	35
CRB Yield	--	1200	--	--	1140	--

(1) Calculated as the average gross - average harvest loss.
(2) Calculated on a sample basis and then averaged.

Although the acreage estimates from the objective yield surveys were close to the CRB published values, the net yield estimates differ statistically from the CRB values in both years. These discrepancies (47 percent larger in 1981 and 52 percent larger in 1982) cannot be explained by biases in sample selection of fields. This is shown by the closeness of the farmer reported yields to the CRB values. A within-field bias (in the location of the unit or selection of heads for laboratory analysis) could have been present if the procedures stated in the manual were not followed. Further discussions in this report assume that the CRB yield values were correct, or at least closer to the truth than the objective yield estimates.

Evaluation of the components used to calculate net yield gives further insight into the yield discrepancies. Discussions with NDSU (5,6)

sunflower researchers indicated some reasonable levels for seed weight per head, head population, and harvest loss. Reasonable plant population per acre for sunflower fields ranged from 16,000 to 20,000 (with head population slightly less). Threshed seed weight per head (at 10 percent moisture) indications gave a range of 42 to 47 grams per head. A range of 100 to 200 pounds per acre of seed lost due to harvesting seemed reasonable. Table 7 shows the estimates obtained by the objective yield surveys for the gross yield components (harvest loss estimates are shown in Table 6). Comparison of these estimates with the NDSU ranges indicates that the cause of the yield discrepancies could lie in the estimated seed weight per head.

Table 7: Components of Gross Yield

	1981			1982		
	n	mean	Std.Err.	n	mean	Std.Err.
Heads per acre	97	15647	374	94	16139	481
Seed weight* per head	97	56.8	2.52	93	56.5	2.50

* in grams at 10% moisture

Calculations of estimated seed weight per head are based on field weights made during the final pre-harvest visit and on measurements made in the laboratory using heads clipped from each unit. Appendix IV investigates these weights and measurements and shows some of the attempts made to explain the yield discrepancies. However, no major problem was uncovered to explain the discrepancies.

Reported Damage

On the 1981 post-harvest interview, farmers were asked if there was significant damage to their sunflower fields from drought, flooding, insects, disease, lodging, hail, or other causes. Thirty-nine percent of the responding farmers reported significant damage from one or more of these factors. In 1982, farmers reporting significant damage were asked to identify the major cause. Table 8 summarizes the distribution of the responses to this question by percent of total respondents and by percent of total (unexpanded) harvested acres. Table 9 shows selected variables for the major damage causes. Note that the 'other' causes category is predominately frost damage from an August freeze.

Table 8: Distribution of Reported Damage (1982)

Major Damage	Total Respondents n	Total Respondents Percent	Total Harv. Acres Sum	Total Harv. Acres Percent
None Rept'd	27	27.6	2910	25.5
Birds	23	23.5	3501	30.6
Drought	7	7.1	540	4.7
Flood	2	2.0	139	1.2
Insect	8	8.2	2003	17.5
Hail	5	5.1	701	6.1
Other	26	26.5	1651	14.4
TOTAL	98	100.0	11445	100.0

Table 9: Summary of Selected Variables by Damage Source (in Pounds per Acre at 10% Moisture, 1982 Reports)

Source	Variable	n	Mean	Std. Err.
None Rept'd	Farmer Yield	27	1210	56
	Net Yield	24	1454	114
	Harvest Loss	24	213	39
Birds	Farmer Yield	23	1245	53
	Net Yield	22	2161	217
	Harvest Loss	22	117	26
Insects	Farmer Yield	8	1281	19
	Net Yield	8	2683	449
	Harvest Loss	8	81	26
Other	Farmer Yield	26	1023	79
	Net Yield	22	1462	191
	Harvest Loss	22	420	68

A brief discussion of Table 9 may be helpful to clear up some seeming conflicts in the data. First, the term 'significant damage' was very subjective and its definition varied from respondent to respondent. For example, reports of bird damage were widespread throughout the state. However, the actual damage due to birds is relatively light when compared to frost or wind damage. Also, bird damage was probably less in fringe areas which may be lower yielding. Thus some damaged fields may seem to be higher yielding. Another evidence of this seeming conflict is seen when insect damaged fields are compared to non-damaged fields. However, the 8 insect damaged fields were concentrated in the better yielding areas of eastern North Dakota. The 'other' damage category looks as expected with respect to the undamaged fields. The increased harvest loss in this category seems reasonable with seeds not filling completely due to frost damage and heads laying on the ground due to wind breakage or other problems.

FORECASTING MODELS

The investigation of regression models for early season forecasts of sunflower yield was another objective of this research. Enumerators collected data for even numbered samples during the growing season to be used as input to these models. This data collection included stalk and head counts within the units for all maturity categories. When the units reached a certain maturity stage, enumerators clipped heads from an area just outside one of the units for laboratory analysis. This data supported model building for two of the components of the objective yield estimates: heads per acre at maturity and weight per head at maturity. An historic average for the third component (harvesting loss) would be used in the operational procedure. Forecast model building was complicated by two factors: the change in maturity category descriptions between the two years and the overestimate of net yield found in the end-of-season analysis.

Assumptions

Relationships between early season and late season variables should be dependent on the growth stage of the plants. It has been assumed here that these relationships are not dependent on JES stratum or on the size of the sample field. No adjustments in the regression equations were made due to sampling design. Estimates of regression coefficients and variances may be biased if these assumptions are not correct (1,2).

Enumerators collected variety information during the initial farmer interview (recorded on Form A). This variety information was intended for use as a stratification variable in building forecasting models. However, the large number of varieties found (33 in 1981 and 36 in 1982) made this impractical. Discussions with NDSU sunflower researchers indicated that no groupings of these varieties exist that would currently be appropriate for stratification.

Separate models were built by 1982 maturity category definitions. Since the 1981 categories do not match exactly, some additional assumptions were necessary to make use of the 1981 data. The 1981 categories for pollen exposed and seed filling (codes 3 and 4) were combined and associated with the 1982 category for open flower (code 3) for further analysis. The category for 75 percent florets abscising (code 5) in 1981 was used to represent the 1982 category of flower wilting (code 4). Categories for back of heads yellow with bracts green to brown (codes 6 and 7) in 1981 represented the 1982 category mature and wet (code 6).

Forecasting equations regress values found at maturity (from the final pre-harvest clipping and associated laboratory work) on counts and measurements found during the growing season. If we have no confidence in the at-maturity values, this will carry over to the forecasted values. In the case of sunflower forecasting, values for weight per head at maturity seem out of line and values for heads per acre acceptable. Therefore, most of the forecasting analysis done involves heads per acre although some work was done with weight per head.

Heads per Acre

The heads per acre component of gross yield comes from the multiplication of total heads per sample by a per acre adjustment. The

per acre adjustment comes from the current visit row width measurements. The forecasting equations discussed here for heads per acre use, as the dependent variable, the number of heads found in the sample on the final pre-harvest visit having maturity stage flower wilting or beyond (called HPSM).

Independent variables considered include: total stalks (TS); stalks in prebud stage (PS); stalks with buds, flowers, or heads (SB); total buds, flowers, or heads (TBFH); number of buds (BD); number of heads with open flower or seedfill (FL); and number of heads with flower wilt or beyond (HD). Only two of these variables, TS and HD, were enumerated in 1981. Also in 1982 two more independent variables were considered: number of buds plus number of heads with open flower or seedfill (called BDFL) and number of heads with open flower or seedfill plus number of heads with flower wilt or beyond (called FLHD). Table 10 shows the correlations, for each 1982 maturity category, between the dependent variable (HPSM) and the various independent variables. These correlations are given by year and combined across years where possible.

Table 10: Correlations of HPSM with Independent Variables

Maturity Code (1982)	Variable	1981 n	1981 r	1982 n	1982 r	Combined n	Combined r
2	TS	40	.959	48	.892	88	.908
	PS		--		.137*		--
	SB		.749		.815		--
	TBFH		--		.867		--
	BD		--		.822		--
	FL		--		.263		--
	HD		.147*		.000*		.074*
	BD+FL		--		.867		--
	FL+HD		--		.263		--
3	TS	67	.931	57	.953	124	.943
	PS		--		.110*		--
	SB		--		.953		--
	TBFH		--		.953		--
	BD		--		.134*		--
	FL		--		.786		--
	HD		.331		.006*		.135
	BD+FL		--		.902		--
	FL+HD		--		.812		--
4	TS	33	.976	60	.960	93	.964
	PS		--		.076*		--
	SB		--		.960		--
	TBFH		--		.965		--
	BD		--		-.044*		--
	FL		--		.034*		--
	HD		.980		.957		.963
	BD+FL		--		.024*		--
	FL+HD		--		.969		--
5	TS	67	.984	50	.954	117	.965
	PS		--		.000*		--
	SB		--		.954		--
	TBFH		--		.953		--
	BD		--		.000*		--
	FL		--		-.017*		--
	HD		.983		.980		.980
	BD+FL		--		-.017*		--
	FL+HD		--		.953		--

* not signficant at α =.20

Two approaches (1) to obtaining the 'best' forecasting equation for each maturity category (ignoring months) were used. The first approach was to select the minimum Mean Square Error (MSE) from all possible regressions (deleting from consideration those with high collinearity). The second approach used the SAS stepwise regression algorithm to select the 'best' regression from some combination of five variables PS, SB, BD, FL, or HD. 1981 data was combined with 1982 data where indicated. No outlier observations were deleted. The following

paragraphs discuss the forecasting equations selected by maturity category.

For maturity category 2 (Budding), both approaches selected the same equation, using only the variable TS to forecast HPSM. Since this variable was obtained in 1981, the possibility of combining data from both years was considered. The slope coefficients from each of the two years were compared, using a t-statistic (2), and found to be not significantly different (the calculated t= 1.386 with 84 degrees of freedom). The combined regression, based on a sample of 88, had an r-square of .8242 and a MSE of 40.92. The 'best' equation for maturity 2 was:

HPSM = 5.816 + 0.858(TS).

A similar result was found with maturity category 3 (Open Flower). The regression using only variable TS was selected as the 'best' regression. The test of slope coefficients between the two years was again not significant, with a calculated t = 0.545 with 120 degrees of freedom. Combining the data from both years (a sample size of 124), gave an r-square of .8884 and a MSE of 25.49. The 'best' equation for maturity 3 follows:

HPSM = 3.461 + 0.921(TS).

Maturity category 4 (Flower Wilting) was a little more complicated. The two approaches selected two different regressions, neither of which involved solely variables obtained in the 1981 analysis. The minimum MSE approach selected a regression involving four independent variables (PS, BD, FL, HD) to estimate HPSM. This regression, based on a sample of 60, had an r-square of .9464 and a MSE of 16.86. The equation for maturity 4 using minimum MSE follows:

HPSM = 0.753 + 3.299(PS) - 1.243(BD) + 0.709(FL) + 0.967(HD).

The stepwise algorithm selected a regression with two independent variables, FL and HD, for maturity 4. This regression, based on the same data, had an r-square of .9418 and a MSE of 17.68. The equation for maturity 4 using the stepwise approach was:

HPSM = 0.542 + 0.716(FL) + 0.969(HD).

The two approaches gave different results for maturity category 5 (Mature, Wet) also. However, the regression selected by the stepwise algorithm invovled only the independent variable HD, which was obtained in both 1981 and 1982. Combining the data from both years gives a MSE of 7.38, which is less than the minimum MSE found using all possible regressions of 1982 data. The regression using the combined data (a sample of 117) had an r-square of .9604, while the slopes between the two years were again not significant, with t = -0.387 and 113 degrees of freedom. The 'best' equation for maturity 5 was:

HPSM = 1.697 + 0.959(HD).

Maturity category 1 (Prebud) had only three observations in 1982 and none in 1981 and was not analyzed. This category could probably be combined with category 2 if necessary. Maturity category 6 (Harvest Mature) had no observations in either year, but it is felt that at this stage the actual count of heads would be sufficient for forecasting purposes.

Weight per Head

Estimated weight per head at maturity was calculated in two different manners for this analysis. The standard operational procedure, explained in detail in Appendix III, uses both field weights obtained on the final Form B visit and laboratory weights from the C-2 form. The estimated weight per head using this method is referred to as WPHM. A second approach, mentioned in Appendix IV, calculated weight per head at maturity as the average seed weight obtained on the C-2 heads, ignoring the field weights. Estimated weight per head at maturity using the second method is referred to as WC2M. All weights per head are corrected to 10 percent moisture. Forecasting equations used both WPHM and WC2M as the dependent variable. As mentioned earlier, the large yield discrepancies indicate that the estimated weight per head at maturity values are suspect.

Four data items were available as independent variables in forecasting weight per head at maturity. These variables were heads per acre (HPA), Form B average head diameter (BDM), Form C-1 average seeds per head (CSD), and Form C-1 average head diameter (CDM). Calculations involved 1982 data for maturity categories 4 and 5. Regressions using these variables on 1982 data to forecast WPHM and WC2M gave r-square values ranging from .0521 to .4215. Regressions with several extreme head weights deleted had r-squares ranging from .1338 to .4800. Table 11 shows some descriptive statistics for the independent variables, and Table 12 shows MSE and r-square values for 'best' regressions as selected by the SAS stepwise algorithm (with extreme weight deleted). More detailed analysis of these regressions was not attempted because of the lack of confidence in the dependent variables, WPHM and WC2M.

Table 11: Descriptive Statistics for Head Weight Forecasting
(Correlations with Extreme Weights Deleted)

Variable	Unit	Mean	Std. Err.	Correlations to: WPHM	WC2M
		--- Maturity = 4, n = 60 ---			
B to C1	Days	7.1	0.5	-.16	-.20
HPA	Hds/Ac	16245	703	-.23	-.22
BDM	Cm/hd	16.8	0.5	.36	.55
CSD	Seed/hd	1023	54	.48	.54
CDM	Cm/hd	15.5	0.4	.55	.57
		--- Maturity = 5, n = 50 ---			
B to C1	Days	3.0	0.3	-.11*	-.07*
HPA	Hds/Ac	15718	663	-.28	-.18*
BDM	Cm/hd	17.2	0.5	.49	.62
CSD	Seed/hd	1121	44	.46	.35
CDM	Cm/hd	15.3	0.4	.59	.53

* not significant at α =.20.

Table 12: 'Best' Regressions for Head Weight at Maturity

Variables		Maturity			
Dependent	Independent	Category	n	r^2	MSE
WPHM	HPA,CSD	4	53	.37	287.95
WC2M	CDM	4	55	.20	302.42
WPHM	HPA,CDM	5	48	.48	222.13
WC2M	BDM	5	48	.24	231.86

SUMMARY AND RECOMMENDATIONS

It should be restated here that several assumptions were made throughout this analysis. First, it was assumed that land use stratum or field size have no effect on estimates or forecasts when dealing with nonresponse. Second, all variances shown were computed under the assumption of simple random sampling. These assumptions are not new, and are used throughout the operational programs for all crops. Validity and effect of these assumptions is being investigated by the Yield Research Branch. It is recommended that this analysis be reconsidered, if necessary, based on the results of that investigation.

Based on the 1981 and 1982 sunflower objective yield surveys in North Dakota, the following statements can be made:

(1) The estimates of acres harvested for oilseed sunflower based on objective yield adjustments to the JES planted acreage compare favorably to CRB published values for both years.

(2) The objective yield estimates for sunflower do not compare well with published CRB values, showing a 47 percent larger value in 1981 and a 52 percent larger value in 1982. Since the objective yield estimates have coefficients of variation of approximately 5 percent, these differences are definitely outside sampling error and indicate a bias somewhere in the procedure.

(3) Evaluation of objective yield components indicates that some of the bias may be found in the estimates of weight per head, while the estimates of heads per acre seem reasonable.

(4) The bias does not appear to be in the field sample selection procedure based on the farmer reported yields for the same fields, which are only about 1 percent different from the CRB values.

(5) Forecasting equations for heads per sample (and heads per acre) perform very well under the assumption that the bias in the overall estimate of yield is not found in this component.

(6) Forecasting equations for weight per head do not perform very well. Whether this performance is related to the possible bias of the final estimate or is inherent in sunflower is not known.

(7) Variety information is not currently useful as a stratification variable. However, this may change in the future as use of the dwarf varieties increases (currently they are only in the research stage). Variety information can be useful as an aid to identifying confectionery fields.

(8) Farmer yields in fields which reported significant bird or insect damage are not significantly different from those yields in fields with no reported damage. Reported damage from frost may be significant based on farmer yields but this factor is confounded with other causes.

Recommendations for 1983 data collection based on the 1981 and 1982 research are:

(1) Continue data collection effort at the same level (125 samples) in North Dakota.

(2) Do not extend the program to other states until the source of the bias in the final estimates is found.

(3) Continue field data collection procedures used in 1982, specifically maturity categories and field counts. One exception to this would involve the final pre-harvest visit. Heads for laboratory analysis should be clipped from specific subsection of the row (all those heads within the subsection) rather than selecting the third through fifth heads as was done in 1982. This could help eliminate enumerator bias in selecting heads but would involve a slight change in the C-2 form and to the GE parameter (allowing for a variable number of heads from each sample). A three foot

subsection would average approximately the same number of heads as were analyzed in 1982.

(4) Set up a validation experiment on a very small number of fields similar to the validation studies being conducted for corn and wheat. This could be accomplished through a cooperative agreement and based on research fields outside the sample.

(5) Seeds counted and weighed in the laboratory as part of the objective yield program should be run through a harvester and reweighed to determine if there is some invisible loss (such as seeds separated as chaff or crushed) that is not accounted for by our procedures.

(6) Introduce formal quality control for both field enumeration and laboratory procedures.

(7) A study of the laboratory procedures should be undertaken to check for biases there.

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APPENDIX I. Forms

FORM A:	Initial Interview
FORM B:	Counts (1982)
FORM B:	Counts (1981)
FORM C-1:	Laboratory Determinations
FORM C-2:	Pre-Harvest Lab
FORM D:	Post-Harvest Interview
FORM E:	Post-Harvest Gleanings

UNITED STATES DEPARTMENT OF AGRICULTURE
STATISTICAL REPORTING SERVICE

Form Approved
O.M.B. Number 535-0088
C.E. 12-0035A

FORM A: SUNFLOWER YIELD SURVEY – 1982
INTITAL INTERVIEW

MONTH CODE

Aug. 1..... 1
Aug. 15..... 2
Sept. 1..... 3
Sept. 15..... 4
Oct. 1..... 5
Nov. 1..... 6

YEAR, CROP, FORM, MONTH (1-4)	
251__	

About the first of June a representative from our office obtained information about your farming operations. We are now interested in estimating the production of sunflowers and updating information about your sunflower fields. Your response to this survey is voluntary and not required by law. However, we need and appreciate your cooperation.

Date (_____)..... 170

Starting Time (Military Time)..... 171

JES PLANTED TRACT ACRES 101

(Do Not Change)

1. **Around June 1, you planted or intended to plant..... acres of sunflower in _____ fields in this tract.**
SHOW operator his tract and fields on PHOTO. VERIFY the fields and the acreages of sunflowers planted in the tract and entered in the shaded areas of Table A. OUTLINE and label on the photo all acres reported in Column 5. MAKE necessary corrections and new entries in non-shaded areas of Table A.

If no sunflowers planted in tract, correct Table A and return all forms.

RECORD the acreages of sunflowers to be harvested for oil in Column 6 and ADD to a total.

TABLE A

FIELD NUMBER *(Sample field number is circled.)*	TOTAL ACRES IN FIELD	ACRES PLANTED TO SUNFLOWERS	Acres in USES or CROPS other than sunflowers to be harvested for oilseed. *(For example: waterways, confectionary, other crops, etc.*		ACRES OF SUNFLOWERS FOR OILSEED
			USE	ACRES	
1	2	3	4	5	6

2. **The total sunflower acreage *(Column 6)* to be harvested for oilseed in this tract is.....Acres** 102

IS THAT RIGHT? — *NO – Review all fields, RE-ADD Column 6.* / *YES – Continue.*

IF ITEM 2 HAS — *A ZERO entry – Return all forms.* / *An ACREAGE entry – TURN PAGE.*

All questions on this page apply to the SAMPLE FIELD ONLY'

If no sunflowers were planted in the designated sample field, BUT a NEW field to be harvested for oilseed is listed in Table A, this new field then becomes the sample field to enter in Item 3.

3. Copy acres of sunflower for oilseed in Sample Field Number _____ from Table A . . . . *Record acres or "0"* . . . . . .Acres 103 •

4. What variety of sunflower did you seed in this field _____ *(Name and Number)* 106

5. On what date was this sunflower field planted? _____ *(Month and Day)* 104

6. Was this field sown by: Air ☐ =1 Drill ☐ =2 . . . . . ENTER CODE 107

7a. Even Numbered Samples

"With your permission I will now go out to the field and mark off two small units to be used in making stalk and head counts."

"I will return to the units each month until harvest to make counts and clips a few heads to determine their weight and size. Would that be all right?". YES☐ NO☐ *If "NO", conclude interview and return all forms.*

b. Odd Numbered Samples

"With your permission I will return shortly before harvest and mark off two small units. I will make counts and clip a few heads to determine their weight and size. Would that be all right? YES ☐ NO ☐

8. Where should I leave the heads picked from the units? _____
(Copy onto the sample kit envelope the location where the operator wishes you to leave the heads.)

9. "After you have finished harvesting this field, I will return to ask you about production. It will be appreciated if you can keep a record of the total amount of oilseed harvested from this field."

IMPORTANT:	*Review this form for completness. Record ending time and sign name. Transfer necessary data from Table A to Form D, Item 1.*

Ending Time *(Military Time)* 172

STATUS CODE 180

ENUMERATOR: _____ ENUMERATOR CODE 190

UNITED STATES DEPARTMENT OF AGRICULTURE
STATISTICAL REPORTING SERVICE

Form Approved
O.M.B. Number 535-0088
C.E. 12-00358

FORM B–SUNFLOWER YIELD SURVEY–1982
COUNTS

MONTH	CODE
August 1	1
August 15	2
September 1	3
September 15	4
October 1	5
November 1	6
December 1	7

YEAR, CROP, FORM, MONTH (1–4): 253_

Has operator applied pesticides with organophosphorous content since last field visit? YES ☐ NO ☐

If YES, enter latest application date _____ *and name of pesticide* _____

Date (_____) 370
Starting Time *(Military Time)* 371

UNIT LOCATION

	UNIT 1	UNIT 2
Number of rows along edge of field		
Number of paces into field		

ROW SPACE MEASUREMENTS

1. Is this the same unit that was laid out last month? *Check NO if this is the first visit to lay out the unit or if unit is relocated. For unit(s) checked: YES – skip to Item 3. NO – complete Item 2.*

UNIT 1	UNIT 2
YES ☐ NO ☐	YES ☐ NO ☐

2. a. Measure distance from stalks in Row 1 to stalks in Row 2 ..... Feet and Tenths

UNIT 1	UNIT 2
303 .	304 .

b. Measure distance from stalks in Row 1 to stalks in Row 5 ..... Feet and Tenths

UNIT 1	UNIT 2
305 .	306 .

COUNTS WITHIN 15-FOOT UNITS

	UNIT 1		UNIT 2	
	Row 1	Row 2	Row 1	Row 2
3. a. Number of stalks (Total)	321	322	323	324
b. Number of stalks in prebud stage	325	326	327	328
c. Number of stalks with buds, flowers, or heads (Note: 3a should equal 3b + 3c).	329	330	331	332

	UNIT 1		UNIT 2	
	Row 1	Row 2	Row 1	Row 2
4 a. Total number of buds, flowers and heads	341	342	343	344
b. Number of buds	345	346	347	348
c. Number of heads with open flower or seedfill	349	350	351	352
d. Number of heads with flower wilt or beyond (Note: 4a should equal 4b + 4c + 4d)	353	354	355	356

GENERAL COMMENTS: _____

FORM B–SUNFLOWER YIELD COUNTS (Cont'd)

5. STAGE OF MATURITY *(Circle one stage code per unit)*

	Prebud or Earlier	Budding Visible	Open Flower and Seed Fill	Flower Wilting	Mature, Wet	Harvest Mature	Blank
UNIT 1	300 1	300 2	300 3	300 4	300 5	300 6	7
UNIT 2	302 1	302 2	302 3	302 4	302 5	302 6	7
	If either code = 1, 2, or 3 Enter Time and Sign Name			If lowest code for either unit is 4, 5, or 6 continue.			

MEASUREMENTS WITHIN UNIT 2, ROW 1

6. **Measure diameter of all heads counted in Question 4d, Unit 2, Row I. (Box #355)**

Do **NOT** *remove head. Record to nearest 1/10 centimeter using cloth tapes.*
If more than 30 heads, use blank space on right.
(For oddly shaped heads, take two cross-ways measurements and average them)

1.	____ .	7.	____ .	13.	____ .	19.	____ .	25.	____ .
2.	____ .	8.	____ .	14.	____ .	20.	____ .	26.	____ .
3.	____ .	9.	____ .	15.	____ .	21.	____ .	27.	____ .
4.	____ .	10.	____ .	16.	____ .	22.	____ .	28.	____ .
5.	____ .	11.	____ .	17.	____ .	23.	____ .	29.	____ .
6.	____ .	12.	____ .	18.	____ .	24.	____ .	30.	____ .

Total Diameter 308 ____ .

Total Heads 309 ____

Is Harvest planned within 7 days?

☐ YES→ Complete questions 8 and 9 only (skip7)
☐ NO→ Complete question 7 only (skip 8 and 9)

7. Clip first 3 head beyond Row 1 of Unit 2 which are maturity code 4, 5, or 6. Mail these heads to State Office.

HEAD	1	2	3
Maturity Code			

– If harvest not within 7 days, then stop.

8. Clip and tag 3rd, 4th and 5th heads *(approximately 2 inches below head)* from Row 1 of both units. Then clip remaining heads.
Number of heads clipped with seeds *(Include tagged heads)* .....

Unit 1 Row 1	Unit 2 Row 2	
		310

9. Weight of heads with seed from Row 1 of each unit.
Both units weighed together *(Include tagged heads)* .....Pounds & Tenths 311 ____ .

NOTE: This is final preharvest visit if questions 8 and 9 are completed. Place 3rd, 4th and 5th heads of row 1 in separate bags for each unit and mail to office.

Ending Time 372

Status Code 380

Enumerator Code 390

Enumerator _____

UNITED STATES DEPARTMENT OF AGRICULTURE
STATISTICAL REPORTING SERVICE

FORM B–SUNFLOWER YIELD SURVEY–1981
COUNTS

Form Approved
O.M.B. Number 535-0088
C.E. 12-00358

MONTH	CODE
August 1	1
August 15	2
September 1	3
September 15	4
October 1	5
November 1	6

YEAR, CROP, FORM, MONTH (1–4)

153_

Has operator applied pesticides with organophosphorous content since last field visit? YES ☐ NO ☐

If YES, enter latest application date _____ *and name of pesticide* _____

Date (_____) 370

Starting Time 371

UNIT LOCATION

	UNIT 1	UNIT 2
Number of rows along edge of field		
Number of paces into field		

ROW SPACE MEASUREMENTS

1. Is this the same unit that was laid out last month? *Check NO if this is the first visit to lay out the unit or if unit is relocated For unit(s) checked: YES — skip to Item 3. NO — complete Item 2.*

	UNIT 1	UNIT 2
	YES ☐ NO ☐	YES ☐ NO ☐

2. a. Measure distance from stalks in Row 1 to stalks in Row 2 ..... Feet and Tenths — 303 . | 304 .

   b. Measure distance from stalks in Row 1 to stalks in Row 5 ..... Feet and Tenths — 305 . | 306 .

COUNTS WITHIN 15-FOOT UNITS

	Row 1	Row 2	Row 1	Row 2
3. Number of stalks	331	332	333	334
4. Number of stalks with unopened buds *(Item 4 cannot exceed Item 3 for any row)*	341	342	343	344
5. Number of heads with evidence of seed fill or kernel formation	361	362	363	364

6. STAGE OF MATURITY *(Circle one stage code per unit)*

MATURITY STAGE	Unopened Bud	Pollen Exposed	Seed Filling	75% Florets Abscissing	Back of Head Yellow Bracts Green	Back of Head Brown Bracts Yellow
UNIT 1	300 2	300 3	300 4	300 5	300 6	300 7
UNIT 2	302 2	302 3	302 4	302 5	302 6	302 7

—— If Lowest Maturity Code = 2 or 3 skip Items 7–10.
—— If Lowest Maturity Code = 4, 5 or 6 Continue.

FORM B–SUNFLOWER YIELD COUNTS (Cont'd)

MEASUREMENTS WITHIN UNIT 2, ROW 1

7. Measure diameter of all heads counted in Item 5 for Unit 2, Row 1.

Do **NOT** *remove head. Record to nearest 1/10 inch.*
If more than 30 heads, use blank space on right.

1. ____	7. ____	13. ____	19. ____	25. ____	
2. ____	8. ____	14. ____	20. ____	26. ____	
3. ____	9. ____	15. ____	21. ____	27. ____	
4. ____	10. ____	16. ____	22. ____	28. ____	Total Diameter 308 ____
5. ____	11. ____	17. ____	23. ____	29. ____	Total Heads 309 ____
6. ____	12. ____	18. ____	24. ____	30. ____	

— If Lowest Maturity Code 4 or 5 or 6 Complete Only Item 8.

— If Lowest Maturity Code = 7 Go to Item 9.

8. Clip first 3 heads beyond Row 1 of Unit 2 which are maturity code 4 or 5 or 6.

HEAD	1	2	3
Maturity Code			

— **If Lowest Maturity Code = 7** Complete Items 9 and 10.

9. Clip and tag 3rd and 4th heads *(approximately 2 inches below head)* **from Row 1 of both units. Then clip remaining heads in Row 1 of both units. Number of heads clipped with seeds**	Unit 1 Row 1	Unit 2 Row 1	310

10. Weight of heads with seed from Row 1 of each unit. Both units weighed together ..... Pounds & Tenths 311 ____

Place 3rd and 4th heads of Row 1 in separate bags for each unit.

Ending Time 372

Status Code 380

Enumerator _____

UNITED STATE DEPARTMENT OF AGRICULTURE
STATISTICIAL REPORTING SERVICE

Form Approved
O.M.B. Number 535-0088

C. E. 12-0035C1

FORM C:-1: SUNFLOWER YIELD SURVEY -1982
STATE LABORATORY DETERMINATIONS

MONTH CODE

Sept. 1 3
Sept. 15. 4
Oct. 1. 5
Nov. 1. 6

YEAR, CROP, FORM, MONTH (1-4)
254

Date Processed 401

	HEAD 1	HEAD 2	HEAD 3
1. From ID Tag Maturity Code	402	403	404
2. Diameter in centimeters (Tenths)	405 .	406 .	407 .
3. Number of fertile seeds	408	409	410

Lab Technician _____

UNITED STATES DEPARTMENT OF AGRICULTURE
STATISTICAL REPORTING SERVICE

Form Approved
O.M.B. Number 535-0088

C.E. 12-0035-C-2

FORM C–2: SUNFLOWER YIELD SURVEY–1982
PRE–HARVEST LAB DETERMINATIONS

MONTH CODE
Sept. 1 3
Sept. 15 4
Oct. 1. 5
Nov. 1 6
Dec. 1 7

YEAR, CROP, FORM, MONTH (1-4)
255___

1. Date sample taken . . . . . (Month & Day - Julian Date) — 571 / 570

Date Analyzed (_____) Code

HEADWEIGHT (BOTH UNITS COMBINED)

2. Weight of heads in sealed bags . . . . . (Tenths) Grams — 501 . / 502 .

3. Weight of same number of new bags and rubber bands . . . . . (Tenths) Grams

You may now remove the heads from the poly bags, but be sure to keep tagged and separated. If heads are too wet to thresh easily, heads can be dried for a short period.

4. Weight of heads at time of threshing . . . . . (Tenths) Grams — 505 .

SEED COUNTS AND HEAD DIAMETER

	UNIT 1			UNIT 2		
5. HEAD DIAMETER IN CENTIMETERS . . . . . (Tenths)	512 .	513 .	514 .	515 .	516 .	517 .
6. NUMBER OF FERTILE SEEDS	522	523	524	525	526	527

C–2: SUNFLOWER (Cont'd)

SEED WEIGHT AND MOISTURE DETERMINATIONS

7. Weight of filled seed threshed from Unit 1 heads . . . . . Grams (Tenths) 506 .

8. Weight of filled seed threshed from Unit 2 heads . . . . . Grams (Tenths) 511 .

9. Weight of filled seed from both units at time of moisture test . . . . . Grams (Tenths) 507 .

10. Moisture Content of filled seed from both units 1/ . . . . . Percent(One Decimal) 508 .

1/ If sample weight is too small for moisture test, sufficient seed of known moisture content will be added so that a moisture test can be made. The moisture content of the small sample can then be derived using the followint formula:

$$E = \frac{(A+B)D-(B \cdot C)}{A}$$

Where:

A = Weight of small sunflower sample (Item 9 above),

B = Weight of additonal seed added for moisture test,

C = Known moisture content of B seed (in percent),

D = Moisture content of A and B combined,

and then

E = Moisture content (in percent) of small sunflower sample (enter in Item 10).

Lab Technician: _____

UNITED STATES DEPARTMENT OF AGRICULTURE
STATISTICAL REPORTING SERVICE

Form Approved
O.M.B. Number 535-0088
C.E. 12-0035D

FORM D: SUNFLOWER YIELD SURVEY – 1982

POST–HARVEST INTERVIEW

MONTH CODE

Sept. 15 4
Oct. 1 5
Nov. 1 6
Dec. 1 or later . . 7

YEAR, CROP, FORM, MONTH (1-4)	
256___	

"Earlier this year, I *(or a representative from our office)* contacted you and made some counts and head measurements on small units in one of your sunflower fields. I would like to know how your crop turned out in this field."

Date (_____) 670

Starting Time *(Military Time)* 671

1. *Enter from (Form A, Table A)*

   Sample Field Number (_____) **Acres for Oilseed (_____)**

2. **How many acres of sunflower were** *(or will be)* **harvested for oilseed from this field** . . . . . Acres 606

   If Item 2 is different from Item 1, ask Item 3. If not, skip to Item 4.

   DO NOT CHANGE ITEM 1.

3. **Earlier in the crop year** *(Item 1)* **_____ acres was recorded as being intended for harvest as oilseed. Can you give me a reason for the difference?**

   _____

   _____

4. **How many pounds were harvested from these** *(Item 2)* **_____ acres?**
   Include seed harvested when opening the field and hand gleaning if any . . . . . Total Pounds 607

   If operator indicated yield per acre, multiply by acres in Item 2 to determine total pounds. Show your work. YIELD PER ACRE (_____)

5. **How many pounds do you still expect to harvest from this field?**
   Include hand gleaning . . . . . Total Pounds 608

6. **Then the total pounds harvested** *(or expected from this field is Items 4 + 5)* . . . . . Total Pounds 612

7. **How was this production determined?**

   Pounds Held by Combine Bins 1
   Number of Wagon or Truckloads 2
   Weight at Elevator 3
   Capacity of Storage Bins 4
   Field Not Harvested - Estimated 5
   Other _____ 6

   610

8. **On what date was or will harvest be completed in this field?** _____ . . . . . OFFICE USE 604
   (Month and Day)

FORM D: SUNFLOWER YIELD SURVEY
POST—HARVEST INTERVIEW (Cont'd)

9. What was the moisture content of these seeds when they were harvested? ..... 611 .

10. Was there any significant damage in this field due to birds, drought, flooding, insects, disease, lodging, hail or other causes?

NO . . . . . ☐= 1
YES, Bird . . . . . ☐= 2
YES, Drought . . . . . ☐= 3
YES, Flooding . . . . . ☐= 4
YES, Insects . . . . . ☐= 5
YES, Hail . . . . . ☐= 6
YES, Other - Specify . . . . . ☐= 7

Enter Code 609

"I would like to thank you for your cooperation this season. Before I go, I would like to go into the field in which we made our counts to check on harvesting losses."

ENDING TIME 672

STATUS CODE 680

ENUMERATOR CODE 690

ENUMERATOR _____

UNITED STATES DEPARTMENT OF AGRICULTURE
STATISTICAL REPORTING SERVICE

Form Approved
O.M.B. Number 535-0088

C.E. 12-0035E

FORM E: SUNFLOWER YIELD SURVEY – 1982
POST-HARVEST GLEANINGS

MONTH CODE
Sept. 1 3
Oct. 1 5
Nov. 1 6
Dec. 1 or later ... 7

YEAR, CROP, FORM, MONTH (1–4)
257_

The post-harvest field gleanings should be completed as soon after harvest as possible, preferably within three days after harvest. If the sample field has been plowed or disced since harvest, select an alternate field for gleaning if one is available in the tract.

Date (_____)	770
Starting Time	771
Enumerator Code	790

Enumerator _____

UNIT LOCATION

	UNIT 1	UNIT 2
Number of rows along edge of field	45	45
Number of paces into field	45	45

	UNIT 1	UNIT 2
1. *Measure distance from stalks in Row 1 to stalks in Row 2* ..... Feet & Tenths	703 .	704 .
2. *Measure distance from stalks in Row 1 to stalks in Row 6* ..... Feet & Tenths	705 .	706 .

GLEANING–1-FOOT BY 5–ROW UNITS

Check each box as completed.

	UNIT 1	UNIT 2
3. Pick up all heads attached to stalks and all heads and pieces of heads with seeds in middle. Thresh and deposit all in bags. Identify bag as "Threshed seed"	( )	( )
4. Pick up all loose seeds in middle for each unit. Deposit in a separate bag. Identify bag as "loose seeds"	( )	( )

5. Was an alternate field used for making post-harvest observations? YES ☐ NO ☐

If post-harvest observations cannot be made, give reason here:

_____

Ending Time	772
Status Code	780

POST-HARVEST LAB DETERMINATIONS

6. Weight of filled seeds from heads. ..... (Tenths) Grams	707 .
7. Weight of loose filled seed from ground ..... (Tenths) Grams	708 .
8. Moisture Content. ..... Percent (One Decimal)	709 .

If samples combined for moisture test, show sample numbers combined: _____

Date Analyzed (_____) . . Code 710

DO NOT *show combined sample weights in Item 6 or 7.*

Lab Technician _____

1/ Try threshing seeds from the heads in the field. If this is a problem, place the entire head in the bag to be sent to the lab for threshing.

APPENDIX II. SUNFLOWER MATURITY CATEGORIES (7)

A. 1981 Codes, Categories, and Descriptions

CODE 2: Unopen Bud	When viewed from directly above, the bracts (which surround the bud) give a many pointed star-like appearance. Also the bud is separated from the leaves by a distinctly longer stem distance than the leaf to leaf distance.
CODE 3: Pollen Exposed	The flower opens, the ray flowers are fully extended, and all disk flowers are visible at this time. Flowering begins from the outside, progressing towards the center of the head. Where flowering actually is occurring the reproductive parts are extruded with evidence of yellow pollen on the surface.
CODE 4: Seed Filling	Flowers will still be attached but carefully separate and look down under the flowers to where the seed are forming. Examine the seeds towards the outside of the head. If the seeds are filling they will not look flat, but will appear rounded.
CODE 5: 75 Percent Florets Abscising	Flowers in the sunflower head will become dry and eventually fall off (abscise). It is important to make this determination on a total head basis.
CODE 6: Back of Head Yellow, Bracts Green	First sign of approaching maturity is evident when the back of the sunflower head begins to turn a light yellow color.
CODE 7: Back of Head Brown, Bracts Yellow	Maturity is reached when the back of the head is yellow or brown and the bracts are yellow.

B. 1982 Codes, Categories, and Descriptions

CODE 1: Prebud	Vegetation stage, from seeding until leaf formation ceases and a visible bud has emerged from the leaves.

CODE 2: Budding	From the time the unopened bud is clearly separated from the leaves (with bracts visible and giving a pointed star-like appearance) until ray flowers form and begin to extend. Some interior (disk) area is still hidden.
CODE 3: Open Flower and Seed Filling	Ray flowers have completely extended, uncovering all interior area. Extends through the period of seed filling (seeds become rounded instead of flat). Seeds at the outer edge become dark in color.
CODE 4: Flower Wilting	Ray flowers wilt, darken and begin to fall off. Head inversion (drooping) begins. Note that the back of the head is still mostly green or light green/yellow and that seed filling may still be occuring increasingly toward the middle.
CODE 5: Mature, Wet (Physiological Maturity)	Backs of heads have turned yellow; bracts are yellow or brown; and seeds are dark, hard, and mature. Stems and leaves may begin to dry, but moisture content still too high to harvest.
CODE 6: Harvest Mature	Plants almost totally brown and brittle. Harvest expected at any time.
CODE 7: Blank	Sample unit has no plants. No further counts are expected for this unit unless blank due to harvest. Explain in comments area reason blank.

APPENDIX III. FORMULAS FOR OBJECTIVE YIELD ESTIMATION (8,10,13)

SAMPLE GROSS YIELD (in pounds per acre at 10% moisture)

= (Heads per acre) (Seed Weight per Head)

A. Heads per Acre = (Total Sample Heads) (per Acre Adjustment)

1. Total Sample Heads = All heads in both units with evidence of seedfill or kernel formation.

2. Per Acre Adjustment $\frac{(43560)\ (8)}{(2)\ (2)\ (15)\ (8 \text{ row widths})}$

with:

43560 = Square feet per acre,
8 = Number of Row widths measured,
2 = Number of Units,
2 = Number of rows per unit,
15 = Length of 1 row in feet, and
8 row width = Unit 1 4 row width Unit 2 4 row width

B. Seed Weight per Head (in pounds at 10% moisture)

= (field wgt.) (head wgt. loss) (threshing fraction) x
(Seed wgt. loss) (10% C2 adjustment)

1. Field wgt. = Weight in pounds per head from row 1 of both units measured at field clipping.

2. Head wgt. loss = Ratio of (weight of heads at threshing) to (weight of heads in bags - bag weight)

3. Threshing Fraction = Ratio of (weight of seed threshed from both units) to (weight of heads at threshing)

4. Seed wgt. Loss = Ratio of (weight of seed at moisture test) to (weight of seed threshed from both units)

5. 10% C2 Adjustment = $\frac{1 - (\text{C2\% moisture content}/100)}{.90}$

NOTE: With cancellation of terms,

Seed weight per head =

$$\frac{(\text{field wgt.})\ (\text{wgt. of seed at moisture test})\ (10\%\ \text{adjustment})}{(\text{Wgt. of heads in bags} - \text{bag wgt.})}$$

SAMPLE HARVEST LOSS

(in Pounds per acre at 10% moisture)

= (weight of seed gleaned) (10% E Adjustment) (Pounds per Acre Adjustment)

A. Weight of Seed Gleaned = (weight in grams of seed from heads) + (weight of loose seed from ground)

B. 10% E Adjustment = $\frac{1 - (\text{E\% moisture content}/100)}{.90}$

C. Pounds per acre adjustment = $\frac{(43560)\ (10)}{(2)\ (5)\ (1)\ (453.6)\ (10\ \text{row widths})}$

with:

43560 = Square feet per acre
10 = Number of row widths measured
2 = Number of units
5 = Number of rows in unit
453.6 = Grams per pound
10 Row widths = (Unit 1 5 row width) + (Unit 2 5 row width)

STATE NET YIELD

(in pounds per acre at 10% moisture)

= (Average Gross Yield) - (Average Harvest Loss)

A. Average Gross Yield

$$= \frac{1}{n} \sum_{i=1}^{n} (\text{Sample i Gross Yield})$$

Where

n = number of samples with both B and C2 complete.

B. Average Harvest Loss

$$= \frac{1}{m} \sum_{i=1}^{m} \text{(Sample i Harvest Loss)}$$

where

m = number of samples with E complete.

VARIANCE OF YIELD ESTIMATES

As mentioned earlier in the text, variance computations assume a simple random sample at the state level. Since most items shown in the tables throughout the paper are means, the standard error (or variance of the mean) is reported.

A. Standard Error of the Mean (Assuming a simple random sample)

$$= \left(\frac{\text{Var}(x)}{n}\right)^{\frac{1}{2}} \qquad = \left(\sum_{i=1}^{n} \frac{(X_i - \bar{X})^2}{n(n-1)}\right)^{\frac{1}{2}}$$

where

X_i = sample i value of item X,
n = number of samples with item X available, and

$$\bar{X} = \frac{1}{n} \sum_{i=1}^{n} X_i$$

B. Variance of Net Yield (Gross Yield - Harvest Loss)

The variance for the difference of two statistics which are not independent is:

$$\text{Var}(X - Y) = \text{Var}(X) + \text{Var}(Y) - 2\,\text{Cov}(X,Y)$$

where

$$\text{Cov}(X,Y) = \rho_{x,y}\, s_x s_y, \text{ and}$$

$\rho_{x,y}$ is estimated by sample correlation $r_{x,y}$.

ACREAGE FOR OILSEED

This estimate adjusts the JES estimate of acres (JES Ac) planted to sunflower to reflect acres planted for oilseed harvest (AO) based on Form A interviews. A similar procedure is followed to adjust oilseed harvested acres based on Form D interviews.

Acreage Estimates

$$AO = (\bar{R})\,(JES\ Ac)$$

Where

$\bar{R}$ = Average ratio of tract acres for oilseed (C102) to JES tract planted acres (C101).

$$= \frac{1}{n} \sum_{i=1}^{n} \frac{C102_i}{C101_i}$$

B. Variance of Acreage Estimates (4)

$$Var\ (AO) = (JESAc)^2\ Var(\bar{R}) + (\bar{R})^2\ Var(JES\ Ac) + 2(\bar{R})(JES\ Ac) \cdot Cov(\bar{R}, JES\ Ac)$$

Where

$$Cov(\bar{R}, JES\ Ac) = Var(\bar{R})\ Var(JESAc)\ (\rho_{\bar{R}, JES\ Ac})$$

and

$\rho_{\bar{R}, JES\ Ac}$ is estimated by sample correlation between

$(\frac{C102}{C101})$ and C101.

APPENDIX IV. INVESTIGATIONS OF YIELD DISCREPANCIES

INTRODUCTION

This appendix shows the results of several investigations into the discrepancies between CRB published yield for sunflower and the objective yield estimates for both 1981 and 1982 in North Dakota. Comparisons were made with an independent data set obtained for phenology modeling by researchers at NDSU during 1981. The investigations looked at several possible causes for the discrepancies. The major causes detailed in this appendix consider possible head selection bias by enumerator and moisture loss in plastic mailing bags. Additionally, this appendix includes correlations between selected items and gross yield, farmer reported yield, and the difference net yield minus farmer reported yield. Properties of the larger objective yield estimates were explored using similar correlations.

Other investigations considered but not reported in detail include differences between individual enumerators, effect of time lapse from clipping of heads to harvest or to laboratory analysis, and inaccuracy of moisture meter. None of these investigations showed anything significant.

1981 NDSU Sunflower Phenology Research

The Yield Research Branch obtained a SAS data set under a cooperative agreement with the Agronomy Department at NDSU (6). This data set included results from phenology research performed by the Agronomy Department at two locations in North Dakota during 1981. In this research, sunflower plots were planted following an experimental design format. The sample design had four replicated samples at each location, with each replication having five varieties and from 4 to 6 planting dates. Several plots were lost at one location due to insect damage. The basic plot for a specific planting date and variety was three rows by 25 feet, with 30 inch spacing between rows. Plants were thinned after emergence to approximate a population of 20,000 heads per acre (about 10.5 inches apart). Five heads from the center row were used for laboratory measurements. Sunflower heads used in the laboratory were dried in large ovens and threshed. Table IV-1 shows descriptive statistics for selected items from this research. Table IV-2 shows similar statistics from the objective yield laboratory analysis (Form C-2) for comparison purposes.

Table IV-1: Descriptive Statistics from NDSU Research Plots
(Weights in Grams, Diameters in Centimeters)

Variable	Avg.	Std. Err.	Min	Max
--- Carrington Location, n = 120 ---				
Head with Seed Weight	84.26	2.16	43.70	167.66
Head Diameter	16.59	0.17	12.24	21.39
Seed Count per Head	1103	41.85	163	2526
Seed Weight per Head	49.41	1.34	22.12	97.38
--- Fargo Location, n = 77 ---				
Head with Seed Weight	83.37	2.94	49.56	188.36
Head Diameter	16.48	0.28	11.38	24.74
Seed Count per Head	916	38.26	224	1585
Seed Weight per Head	46.97	2.12	13.18	114.4

Table IV-2: Descriptive Statistics from Object Yield Samples
(Weights in Grams, Diameters in Centimeters)

Variable	Avg.	Std. Err.	Min	Max
--- 1981 C-2 Data, n = 97 ---				
Head with Seed Weight	89.0	3.56	17.25	199.50
Head Diameter	16.48	1.67	7.68	26.09
Seed Count per Head	1172	43.0	98	2511
Seed Weight per Head	54.9	2.51	6.52	141.96
--- 1982 C-2 Data, n = 96 ---				
Head with Seed Weight	119.3	6.41	19.18	359.03
Head Diameter	16.55	0.32	7.88	24.66
Seed Count per Head	1220	35.8	216	2112
Seed Weight per Head	52.5	2.19	4.23	111.37

Comparing Tables IV-1 and IV-2, we see major differences in two items, seed counting per head and seed weight per head. Both items were somewhat larger in the objective yield analysis. One possible explanation for this difference could be that our laboratory procedure allowed some blank (non-fertile) seeds to be counted as fertile seeds in estimating yields. This explanation would imply that the weight per seed from the objective yield analysis would be less. A weighted average from the two NDSU locations gave an average weight per 1000 seed as 47.3 grams, while the objective yield analysis gave average weights of 46.6 and 42.0 for 1981 and 1982. The reader is cautioned to remember that these comparisons were for idea development only. since no statistical measurement of differences could be made.

While this approach would not account for the entire difference between the objective yield and published values, it should be considered as a possible source of bias in the future. Recommendations in the Summary and Recommendations Sections of the main text address this problem.

Head Selection Bias in the Clipping Unit

The discrepancy between the objective yield estimates and the published CRB value was seen after the analysis of the 1981 final month data. A sample by sample check of the final pre-harvest Form B data versus the corresponding Form C-2 laboratory data showed one possible source of bias in the estimates. Enumerators measured head diameters of all heads with seed in Row 1 of Unit 2. Instructions in 1981 were to clip and tag the third and fourth heads with seed in Row 1 of each unit, then clip the remaining heads in each Row 1. Clipped heads from each unit were weighed in the field, then the tagged heads mailed to the laboratory. Upon arrival at the laboratory, head diameter measurements were taken on the four heads. The manual questionnaire check showed some differences between field and lab measurements of head diameters for the Unit 2 heads (which should be the third and fourth on the Form B). In some cases, the laboratory heads were larger than any measured in the field. However, this difference could have been due to mislabelling of the unit numbers.

Heads were expected to shrink slightly due to moisture loss while in the mail or awaiting analysis. In addition to the manual checks, analysis of head diameter means showed an increase rather than a decrease in laboratory heads for 1981. Table IV-3 shows means and standard errors for head diameters in 1981. Although not statistically comparable, the average head diameter gives an indication that enumerators were possibly selecting heads non-randomly.

Table IV-3: 1981 Head Diameter Statistics
(in Centimeters, n = 97 samples)

Form	Unit	Mean	Std. Err.	Min	Max
C-2	1	16.39	0.37	7.62	25.91
C-2	2	16.56	0.41	5.72	26.29
C-2	1,2	16.48	0.33	7.68	26.10
B	1	15.32	0.32	8.22	26.10

In order to make use of the 1981 data under the possibility that the laboratory heads were not a random sample of the head population, I attempted to use the field diameter measurements to correct the bias. I calculated a simple linear regression using the number of fertile seed per head as the dependent variable and the area of the head (from the measured diameter and assuming a circular head) as the independent variable. Both C-2 and C-1 (visit 6, maturity 6) heads were used for calculation of the regression coefficients. This regression, based on 399 heads, had an r-square of 0.59 and estimated the following equation:

(number fertile seeds) = 251.131 + 25.480 x (head area)

Discussions with NDSU researchers indicated that average weight per seed should not change much between heads of the same variety. Substituting the head area calculated from the Form B average head diameter, I obtained an estimated number of fertile seed per head for each sample. This number was then multiplied by the average weight per seed as measured by the laboratory analysis of the C-2 heads, to get an estimated weight per head for each sample. Using this calculated weight per head in the usual estimating formula for yield, I obtained an average gross yield estimate of 1640 pounds per acre (with standard error = 91 pounds per acre). The average net yield based on this method was 1484 pounds per acre (with standard error = 96 pounds per acre). Both of these were statistically different (at the .05 level) from their respective estimates using the C-2 data. This difference indicated a possible head selection bias by enumerators in 1981.

The possible effect of selecting heads in a non-random manner was discussed at the 1982 Sunflower Objective Yield Enumerator School. Enumerators were cautioned to follow the procedures outlined in the Enumerators Manual exactly. The only change between the two years was to take three heads (the third, fourth and fifth) in 1982 instead of two. For the 1982 data collection, the Form B average head diameter was 17.26 versus the Form C-2 average of 16.48 (both with standard errors = .32). Allowing for slight shrinkage of heads due to moisture loss, the two head diameters were not significantly different. Following the same regression procedure for 1982 as shown above for 1981, the regression estimated gross yield was 1942, just 10 pounds per acre different from the gross yield using the normal procedure. Thus, there was no reason to believe that there was any head selection bias in 1982, at least as measured by diameter. The number of seeds per head selected could still have been biased but there was no way to test this.

Moisture Loss in Plastic Mailing Bags

Another source of bias in estimating weight per head could be in not accounting for moisture lost during mailing. This bias would inflate the ratio of seed weight to head-with-seed weight (from laboratory heads) which is multiplied by the field weight per head to obtain yield per head. To investigate this source of bias, I calculated seed weight per head using only the heads mailed to the laboratory. This approach ignores both field weights and weights of heads in plastic bags. Table IV-4 contrasts the average head weights and yield for both years using C-2 weights only versus using the field weights from the Form B. Using only C-2 weights reduced the yield estimates both years, though not significantly.

Table IV-4: Selected Items With and Without Field Weights
(Yields in lbs/acre, Head Weights in grams)

Year	Item	From:	n	Mean	Std. Err.
1981	Seed Wgt/Head	C-2 only	97	54.9	2.5
	Seed Wgt/Head	B and C-2	97	56.8	2.5
	Gross Yield	C-2 only	97	1872	95
	Gross Yield	B and C-2	97	1915	86
	Net Yield	C-2 only	95	1718	100
	Net Yield	B and C-2	95	1766	89
1982	Seed Wgt/Head	C-2 only	96	52.5	2.2
	Seed Wgt/Head	B and C-2	93	56.5	2.5
	Gross Yield	C-2 only	94	1828	85
	Gross Yield	B and C-2	93	1952	94
	Net Yield	C-2 only	84	1641	94
	Net Yield	B and C-2	84	1768	106

Correlations of Selected Items

This section considers sample correlations of selected items with three quantities: gross yield, farmer reported yield, and the difference net yield minus farmer reported yield. The items selected are sample level yield estimates or factors involved in calculating the yield estimates, and descriptions of the variables were given previously in Appendix II. Table IV-5 shows the correlations over all samples of the selected items. Seed weight per head (using field weights) is seen to be the most highly correlated estimating factor to both gross yield and to the difference net minus farmer yield. The correlations go down when seed weight per head is considered using only the laboratory (C-2) weights. The other major factor, heads per acre, is much less correlated to the gross yield or difference in yields. Also of interest is the difference in correlations between the two estimates of average head diameter, with the C-2 estimates being higher even though both should be estimating the same quantity.

Table IV-5: Selected Correlations - All Available Samples

Variable	Correlations with: Gross Yield 1981	Gross Yield 1982	Farmer Yield 1981	Farmer Yield 1982	Net - Farmer 1981	Net - Farmer 1982
Farmer Reported Yield	.212	.479	1.000	1.000	-.065*	.199
Net Yield	.629	.969	.231	.498	.956	.949
Gross Yield	1.000	1.000	.212	.479	.931	.929
C-2 Gross Yield 1/	.629	.867	.288	.433	.547	.755
C-2 Net Yield 1/	.598	.857	.294	.502	.588	.809
Harvest Loss	.056*	-.117*	-.069*	-.250	-.156	-.298
Heads per Acre	.276	.347	.066*	.084*	.200	.320
Heads per Sample	.408	.477	.158	.236	.387	.497
Field Weight	.527	.412	.283	.180	.471	.376
Head Wgt. (in bags)	.234	.216	.306	.106*	.197	.153
Head Wgt. (at thresh)	.488	.215	.301	.042*	.442	.179
Seed Wgt. 1 Head	.821	.845	.212	.403	.766	.804
C-2 Seed Wgt./Head	.529	.682	.301	.364	.482	.591
Head Wgt. Loss	.196	.059*	.196	-.108*	.221	.114*
Threshing Fraction	.369	.378	.135	.372	.359	.307
Seed Wgt. Loss	-.032*	.178	.121	.160	-.069*	-.036*
Dry Matter Fraction	.356	.423	-.066*	.316	.364	.375
Lab Percent Moisture	-.093*	-.232	.032*	.052*	-.067*	-.220
Seeds per Head	.515	.582	.272	.359	.500	.497
Wgt. per Seed	.213	.536	.170	.290	.161	.423
Avg. Head Diam. (B)	.194	.286	.420	.093*	.130*	.250
Avg. Head Diam. (C-2)	.525	.562	.390	.240	.472	.487
Days: Clip to Harvest	-.259	-.306	-.297	-.357	-.140	-.238

* not significant at $\alpha = .20$

1/ Using C-2 weights only, ignores field weight

Another approach considers the correlations when samples were stratified based on their estimated gross yield (either above or below 2900 pounds per acre). Table IV-6 shows correlations of the selected items with gross yield by year and by stratified size. Table IV-7 shows correlations of the same items with the difference between estimated net yield and farmer corrected yield by year and stratified size. Unfortunately, the sample size in the strata for samples greater than 2900 pounds per acre for gross yield is not great enough and many correlations are not significant. One correlation is interesting. Heads per acre showed a higher correlation to gross yield and the difference net minus farmer yield in the larger stratum for both years. Seed weight per head and dry matter fraction are the most correlated variables for both years and size strata.

Table IV-6: Correlations with Gross Yield - By Year and Size 1/

Variable	1981		1982	
	<2900	>2900	<2900	>2900
Farmer Reported Yield	.252	-.030*	.456	.240*
Net Yield	.951	.989	.911	.995
C-2 Gross Yield 2/	.596	-.155*	.769	.763
C-2 Net Yield 2/	.565	-.265*	.729	.781
Harvest Loss	.035*	.842	.053*	-.515
Heads per Acre	.144	.540	.392	.635
Heads per Sample	.263	.403*	.356	.604
Field Weight	.472	-.267*	.205	.074*
Head Wgt. (in bags)	.203	-.429*	-.001*	-.017*
Head Wgt. (at thresh)	.478	-.220*	-.014*	.264*
Seed Wgt./Head (B, C-2)	.801	.682	.672	.640
C-2 Seed Wgt./Head	.561	-.321*	.436	.468
Head Wgt. Loss	.215	.672	-.039*	.414
Threshing Fraction	.477	-.401*	.378	-.082*
Seed Wgt. Loss	-.088*	.000*	.246	.095*
Dry Matter Fraction	.422	.463	.361	.405
Lab. Percent Moisture	.114*	.181*	.257	-.047*
Seeds per Head	.621	-.540	.431	.398
Wgt. per Seed	.077*	.273*	.309	.251
Avg. Head Diam. (B)	.196	-.243*	.148*	.111*
Avg. Head Diam. (C-2)	.543	-.397*	.250	.632
Days: Clip to Harvest	-.176	-.405*	-.115*	-.548

* not significant at $\alpha = .20$

1/ Samples by Size Category:

<2900	87	79
>2900	10	17
Total	97	96

2/ Using C-2 weights only, ignores field weight

Table IV-7: Correlations with Net Minus Farmer Yield
By Year and Size 1/

Variable	<2900	>2900	<2900	>2900
Farmer Reported Yield	-.127*	-.367*	-.050*	.077*
Net Yield	.925	.897	.858	.990
C-2 Gross Yield 2/	.502	-.191*	.502	.761
C-2 Net Yield 2/	.545	-.305*	.612	.789
Harvest Loss	-.257	.879	-.255	-.618
Heads per Acre	.037*	.518	.322	.707
Heads per Sample	.231	.361*	.293	.713
Field Weight	.387	-.361	.134*	-.008*
Head Wgt. (in bags)	.143	-.482	-.090*	-.080*
Head Wgt. (at thresh)	.401	-.286*	-.067*	.185*
Seed Wgt/Head (B, C-2)	.702	.633	.588	.621
C-2 Seed Wgt./Head	.477	-.353*	.261	.418
Head Wgt. Loss	.228	.733	.042*	.410
Threshing Fraction	.453	-.324*	.280	-.013*
Seed Wgt. Loss	-.143*	.000*	.066*	.135*
Dry Matter Fraction	.408	.561	.289	.468
Lab. Percent Moisture	.056*	.007*	.244	.013*
Seeds per Head	.594	-.597	.275	.427
Wgt. per Seed	-.025*	.322*	.120*	.181*
Avg. Head Diam, (B)	.101*	-.363*	.059*	.031*
Avg. Head Diam. (C-2)	.455	-.449	.130*	.625
Days: Clip to Harvest	.003*	-.453	.037*	-.637

* not significant at $\alpha = .20$

1/ Samples by Size Category:

< 2900	87	79
> 2900	10	17
Total	97	96

2/ Using C-2 weights only, ignores field weight

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