Bulletins

South Dakota State University Agricultural Experiment Station

2-1-1964

Crop Production Practices for Irrigated Land in the James Basin and Angostura Areas

L. O. Fine

N. A. Dimick

R. E. Campbell

H. M. Vance

Recommended Citation

Fine, L. O.; Dimick, N. A.; Campbell, R. E.; and Vance, H. M., "Crop Production Practices for Irrigated Land in the James Basin and Angostura Areas" (1964). *Bulletins.* Paper 517.
http://openprairie.sdstate.edu/agexperimentsta_bulletins/517

Bulletin 517
February 1964

CROP PRODUCTION PRACTICES FOR IRRIGATED LAND

❖ James Basin
❖ Angostura

AGRONOMY DEPARTMENT
AGRICULTURAL EXPERIMENT STATION
SOUTH DAKOTA STATE COLLEGE, BROOKINGS

CONTENTS

CROP PRODUCTION PRACTICES FOR IRRIGATED LAND

in the James Basin and Angostura Areas [1]

L. O. FINE, N. A. DIMICK, R. E. CAMPBELL and H. M. VANCE[2]

This bulletin presents agronomic irrigation information obtained since 1954. Most of the work reported herein was conducted at the Irrigation Development Farm near Redfield, but results from other irrigated research locations in South Dakota are included.

Water management research, which concerned the consumptive use of water by plants, moisture extraction from the soil profile, field irrigation efficiences, and sprinkler irrigation, was conducted in the period, 1948-1953. The results of this work prior to 1954 were reported in South Dakota Agricultural Experiment Station Circulars 104 and 107.

COMPARISON OF DRYLAND AND IRRIGATED CROP YIELDS

A study of the effects of irrigation, fertilizer, and crop rotations on the performance of corn, wheat, and alfalfa was begun in 1949 as an 8-year experiment. Two basic rotations were set up to incorporate these variables into one experiment. One system was a simple corn-wheat cropping pattern. The other rotation was corn-wheat-alfalfa-alfalfa. Both rotations were established on irrigated and nonirrigated land with two replications.

Six basic fertilizer treatments

---

[1] Contribution from South Dakota State Agricultural Experiment Station and the Soil and Water Conservation Research Division, Agricultural Research Service, USDA. Grateful acknowledgement is herewith expressed to Walter E. Zich, former graduate research assistant, for assistance in the field phases of the research conducted at the Angostura Irrigation Project.

[2] Professor and Head, Department of Agronomy, South Dakota State College; Agricultural Engineer, USDA, Newell, S. D.; Research Soil Scientist, USDA, Huntley, Mont. (formerly at Brookings, S. D.); and Soil Scientist, Soil Conservation Service, USDA, (formerly with Agricultural Research Service, Brookings, S. D.), respectively.

were established within each cropping block of the system. These treatments included nitrogen, phosphorus, and potassium in various combinations. Nitrogen rates of 0 and 30 pounds per acre were used on nonirrigated plots and 0 and 60 pounds per acre on irrigated plots as a control and estimated optimum fertility rate, respectively, for corn and wheat production. Manure was also used as a nitrogen source in combination with phosphorus.

Most of the results are concerned with the effect of nitrogen fertilizer since it was found to be the most common limiting nutrient. There was seldom any response to phosphorus and never any to potassium.

Table 1. Effects of Irrigation and Fertilizer on Crop Yields, Redfield, S. D., 1949-1955 Averages

	4-Year Corn-Wheat-Alfalfa-Alfalfa Rotation				
	Corn		Wheat		
	No Fert.	Fert.*	No Fert.	Fert.	Alfalfa
	Bushels per Acre				T/A
Irrigated	92	97	28	37	5.31
Non-irrigated	32	35	23	27	2.47
Increase from irrigation	60	62	5	10	2.84
	2-Year Corn-Wheat Rotation				
Irrigated	78	95	24	35	
Non-irrigated	42	50	16	25	
Increase from irrigation	36	45	8	10	

*Fertilizer used: 30 lbs. nitrogen per acre per year on dryland; 60 lbs. on irrigated land.

Average yields obtained during the 7 years (1949-1955) of corn, wheat, and alfalfa are reported in table 1. Corn following alfalfa in the nonirrigated rotations was practically a failure in the very dry years 1952 and 1955. Data from these two years were included in the average. Yields from 1956 were lost due to hail.

Fertility Effects—Legume Rotation

The full effect of 2 years of alfalfa was not evident in the rotation until the crop year 1951. After this time, corn responded very little to additional nitrogen over and above that supplied by alfalfa.

Average irrigated corn yields over the 7-year period in the legume rotation were 92 bushels per acre without fertilizer and 97 bushels per acre with fertilizer. Somewhat the same response occurred with this rotation under nonirrigated conditions. Corn yields on dryland were 32 and 35 bushels per acre, respectively, with 0 and 30 pounds of nitrogen per acre.

Wheat showed a marked response to nitrogen throughout the period of measurement in the corn-wheat-alfalfa-alfalfa rotation. The nonirrigated wheat yield increase was 4 bushels per acre and the irrigated wheat yield was 9 bushels per acre.

Irrigation Effects—Legume Rotation

Yield increases from irrigation were much greater, percentagewise, for corn than for wheat. Corn yields were approximately three times as high, with or without fertilizer, under irrigated conditions as under nonirrigated conditions. Irrigated wheat yields were only about 22% greater than nonirrigated wheat yields when no fertilizer was applied.

When fertilizer was applied, irrigation resulted in average yield increases of 10 bushels per acre, or 37%. Thus, the effect of irrigation water on increasing wheat yields was about twice as great when fertilizer was used as when fertilizer was not used, even in this rotation which included alfalfa on the land half the time. The alfalfa yields were 2.47 tons per acre under nonirrigated conditions and 5.31 tons per acre under irrigated conditions for a yield increase ofover 100% as an average for the 7 years.

The remarkable response of corn to irrigation is a result of two factors—the exhaustion of subsoil moisture by alfalfa preceding corn and the full season growth period of corn in a semiarid climate with low late-season precipitation. These are well-recognized hazards of nonirrigated agriculture in this area.

Fertility and Irrigation Effects—Nonlegume Rotation

In the 2-year corn-wheat cropping system, nonirrigated corn yields averaged 42 bushels without fertilizer and 50 bushels per acre with fertilizer. In the same cropping system, the irrigated corn yields were 78 bushels per acre without fertilizer and 95 with fertilizer, approximately a 90% increase. There was a much greater advantage for the use of fertilizer under both irrigated and nonirrigated conditions in this rotation than in the 4-year legume rotation.

Nonirrigated wheat yields averaged 9 bushels per acre higher with nitrogen fertilizer than without. Under irrigated conditions yields averaged 11 bushels per acre higher as a result of nitrogen fertilizer. Nitrogen fertilizer had a slightly greater effect than irrigation in raising yields in these experiments.

In evaluating the effects of fertilizer applications in this cropping system, the most profitable use of fertilizer found for dryland farming was on wheat, where 30 pounds of nitrogen produced an average yield increase of 9 bushels per acre. The same application resulted in an average increased corn yield of 8 bushels per acre over the same period. Under irrigated conditions, the most profitable use of nitrogen appeared to be for corn production. The rate of nitrogen application was 60 pounds per acre for both wheat and corn under irrigation; the average yield increase for corn was 17 bushels per acre and for wheat, 11 bushels per acre. The relative profitability of the two choices would depend on the relative price of corn and wheat.

Fertilizing Irrigated Rotations

In 1953 an irrigated experiment was initiated to compare a rotation in which alfalfa was on the land 40% of the time to one in which no alfalfa was grown. This experiment was designed to study the performance of corn, barley, and alfalfa in these two cropping systems and to study methods of fertilizing these two irrigated rotations.

For the legume 5-year rotation, alfalfa followed barley and was left on the land for 2 years. Corn followed alfalfa for 2 years and was used as the primary crop to measure the effect of alfalfa on productivity. In the nonlegume 3-year rotation, barley was followed by 2 years of corn. Ten different fertility treatments were superimposed on each of the crop blocks. These treatments involved the application of several rates of nitrogen and the application of phosphorus at various levels and times in the cropping sequences.

Effect of these rotations on soil nitrogen and soil organic matter levels will be reported in another publication.

The effect of various selected fertility treatments on the yield of first-year corn following alfalfa in the legume rotation is presented in table 2. Fertilizers used were nitrogen and phosphorus, alone and in combination, at various levels. Potassium was not used. Practically no response to phosphorus alone occurred, but when nitrogen and phosphorus were combined in an 80-22-0[3] combination, an additional response occurred above that to nitrogen alone. The yields for 80 pounds of nitrogen alone and in combination with 22 pounds of phosphorus were 98 and 102 bushels of corn, respectively, over the period from 1953 through 1958. The additional yield of 4 bushels of corn alone would be questionable justification for the use of phosphate. However, increased phosphate content of alfalfa hay produced in this rotation would have to be considered as a partial justification for the use of phosphate if the nonfertilized hay is below 0.23% phosphorus.

Table 2. Response of First-Year Corn Grain Yield to Fertilizer in a Rotation of Barley-Alfalfa-Alfalfa-Corn-Corn, Redfield, S. D., 1953-1958

	Fertilizer Treatment					
Applications lbs. per acre*	0-0	80-0	0-22	40-22	80-22	120-22
1953-1958 Av. yield, bu.†	86.6	97.8	86.2	93.2	102.1	101.2

*First number designates pounds of nitrogen; second, pounds of phosphorus.

†The year of 1956 is omitted because of complete hail loss.

Table 3 presents the response of corn following barley to fertilizer in a rotation of barley-corn-corn. The yields for unfertilized corn were approximately 56 bushels per acre in this rotation, as compared to 86 bushels without fertilizer in the legume rotation. A yield increase of 30 bushels of corn per acre thus may be attributed to the use of alfalfa by comparing these two rotations. The yields of corn in this rotation after applying approximately 40 pounds of nitrogen were quite similar to those in the alfalfa rotation with no fertilizer applied, but ap-

---

[3] In number combinations designating fertilizer applications, the first indicates pounds of nitrogen, the second, pounds of phosphorus, and the third, pounds of potassium applied per acre. To convert phosphorus to P_2O_5 equivalent, multiply by 2.29. To convert potassium to K_2O, multiply by 1.2.

Table 3. Response of First Year Corn Grain Yield to Fertilizer in a Rotation of Barley-Corn-Corn, Redfield, S. D., 1953-1958

	Fertilizer Treatment					
Applications, lbs. per acre*	0-0	80-0	0-22	40-22	80-22	120-22
1953-1958 Av. yield, bu.†	55.9	101.3	58.3	89.5	104.7	98.9

*First number designates pounds of nitrogen; second, pounds of phosphorus.

†The year of 1956 is omitted because of complete hail loss.

proximately 80 pounds of nitrogen per acre appeared to be necessary in this nonlegume rotation in order to reach a yield of around 100 bushels of corn per acre.

Table 4 presents the response of barley to fertilizer in both irrigated rotations. The yield of barley in the unfertilized legume rotation was approximately 11.5 bushels per acre greater than in the unfertilized nonlegume rotation. However, the application of 40 pounds of nitrogen per acre in the nonlegume rotation brought the yield of barley to about the same level as the application of 40 pounds of nitrogen per acre in the legume rotation. This crop responded slightly to phosphate, especially in the legume rotation. Phosphate alone gave about a 3-bushel yield increase, whereas phosphate with 40 pounds of nitrogen gave about a 4-bushel increase.

Table 4. Response of Barley Grain Yield to Fertilizer in Two Irrigated Rotations, Redfield, S. D., 1953-1958*

	Fertilizer Treatment				
Applications, lbs. per acre	0-0	40-0	0-22	40-22	60-22
Yield in legume rotation bu/A	35.7	47.5	38.1	51.7	48.7
Yield, nonlegume rotation bu/A	24.1	46.1	26.4	49.6	48.5
Difference due to legumes bu/A	11.6	1.4	11.7	2.1	.2

*The data for 1956 are omitted because of a complete hail loss.

MISCELLANEOUS CROP AND SOIL MANAGEMENT EXPERIMENTS

Row crops such as corn, sorghum, sugar beets, potatoes, soybeans, and perhaps dry beans have a much greater potential response to irrigation than the small grains, under the climatic conditions of South Dakota. The yield potential of grasses and legumes for forage and seed production is also high. Numerous intensive experiments have been conducted throughout the state on the water, crop, and soil management practices for optimum production of some of these crops.

Corn

Experiments were conducted in 1955 at the Redfield Development Farm, on the Angostura Irrigation Project, and in Yankton County on private farms to study aspects of corn production such as plant population, choice of hybrids, irrigation regimes, and fertilizer practices. Responses of hybrid corn to irrigation regimes and fertilizer treatments on the Angostura project are given in table 5. Five different schedules of irrigation were involved in the experiment, but only

Table 5. Effect of Irrigation Management on Fertilizer Response of Corn on Three Soils at Angostura Project, S. D., 1955.

Fertilizer Treatment		Farland Sandy Loam		Gap Silt Loam		Orman Clay	
N	P	M_2*	M_5†	M_2	M_5	M_2	M_5
Lbs./A.		Bu. /A.	Bu. /A.	Bu. /A.	Bu. /A.	Bu. /A.	Bu. /A.
0	35	71.7	54.3	42.9	42.7	49.6	61.1
60	35	77.0	95.3	58.6	63.2	71.1	83.4
120	35	49.1	97.8	73.5	82.5	67.2	86.8
240	35	69.4	106.4	60.4	75.2	61.7	62.3
120	0	81.6	96.9	48.1	85.3	70.9	93.8
120	35+manure @ 25 T/A	70.9	108.8	59.2	78.8	70.6	93.4
Average		**70.0**	**93.3**	**57.1**	**71.3**	**65.2**	**80.1**

*Irrigated when available soil moisture in the upper 4 feet of the soil profile dropped to 50-60%, except during tasseling and silking, when it was irrigated only after severe wilting occurred.

†Irrigated when available soil moisture in the upper 4 feet of the soil profile dropped to 50-60%.

two are reported here. All six fertility treatments used are reported.

The corn yields reported in table 5 show that poor response to fertilizer occurred when the irrigation of the crop was neglected during the critical tassel to silking stage. In this experiment, the first moisture treatment allowed the soil to approach the wilting point in the 4-foot root zone during this tassel-silk stage. In the second moisture treatment, irrigation water was added when the moisture content of the root zone approached the midpoint between field capacity and the wilting point. At either phosphorus fertility level with adequate nitrogen under the latter moisture treatment, satisfactory corn yields were obtained. However, with the poor irrigation treatment, the maximum yield obtained was only 81.6 bushels per acre.

The data in table 6 were obtained from plots in an irrigated field on the Angostura project in 1956. All farm operations were performed by the farm operator, including preparing seedbed, planting corn and cultivating. He attempted to follow, as nearly as possible, recommended irrigation management practices.

Soil tests taken before applying fertilizer indicated that nitrogen was the only nutrient needed for high corn production. The additional yield of 22 bushels of corn from plots receiving 80 pounds of nitrogen (over the nonfertilized area) was economically feasible. Figuring nitrogen at 14 cents per pound and corn at $1 per bushel, this would return nearly two to one on the investment in the first 80 pounds of nitrogen. The next increment of 40 pounds, which increased yield another 7 bushels, also returned more than the cost. Subsequent experiments in the eastern part of the state have also indicated

Table 6. Effect of Fertilizer on Irrigated Corn Production, Angostura Project, 1956

Fertilizer, Lbs. N/A.	Yield, Bu./A.*
0	65.8
80-PD	89.0
120-PD	96.0
40-PD, 40 SD†	90.1
60-PD, 60 SD	92.1

*Yield was determined on actual corn picked by tractor picker and calculated to 15.5% moisture No. 2 corn.

†PD=fertilizer plowed down; SD=fertilizer side-dressed July 13.

side-dressing to be an efficient method of nitrogen application when adequate water is used afterwards to move the nitrogen into the active root zone.

Results obtained in the 1956 Yankton County experiment were similar to those in the 1955 Angostura experiments (table 7). The maximum corn yield with the best fertility practice was 94 bushels per acre when soil moisture was allowed to become limiting during the tassel-silk browning stage of growth. However, under conditions of adequate irrigation, a maximum corn yield of 137 bushels per acre was obtained with the same fertility treatment.

In this experiment, the application of phosphorus without nitrogen gave a poorer yield than no fertilizer, and the yield depression caused by phosphorus alone was much greater where poor irrigation management was practiced than where there was good irrigation. The higher yield received under better irrigation management probably occurred because the opportunities for release of soil nitrogen were better than when the soil was allowed to become quite dry during part of the growing season.

Table 7. Effect of Fertilizer and Irrigation Treatment on Yield of Corn, Yankton County, 1956

Fertilizer* N†	P	Irrigation Treatment Inadequate Irrig.	Adequate Irrig.
		Bu./A.	Bu./A.
0	0	81.2	88.0
0	26	43.6	72.2
40	26	72.8	126.8
80	26	89.5	119.3
120	26	94.0	137.2
120	0	66.9	120.8
Average		**74.7**	**107.2**

*Fertilizer applied broadcast and disced in after plowing.

†N applied in form of ammonium nitrate, phosphorus as treble superphosphate.

Seasonal distribution of nitrogen needs. Because of the major importance of nitrogen fertilization in the growth of the corn crop, further experiments were conducted to study the distribution of nitrogen needs during the growing season. In 1955, corn plants were sampled at four dates on three different soils with the same fertilizer treatment from the research plots in the Angostura irrigation project. The soils were Farland sandy loam, Gap silt loam, and Orman clay. Dates of sampling of the corn plants were: before tassel (July 12), tassel (July 22), milk (August 1), and mature (October 1). Each time the complete corn plants were harvested at ground level and analyzed for their nitrogen content.

Sample values were converted to total nitrogen content for an acre basis, and the percentage of the final nitrogen content in the crop at harvest found to be present at each of the four dates was calculated. This was also done for an experiment on Beotia silt loam at the Redfield Irrigation Farm in 1956. On this soil, unfertilized corn plants were compared with corn plants which were well fertilized. The percentages of the total nitrogen in the corn crop at harvest that were

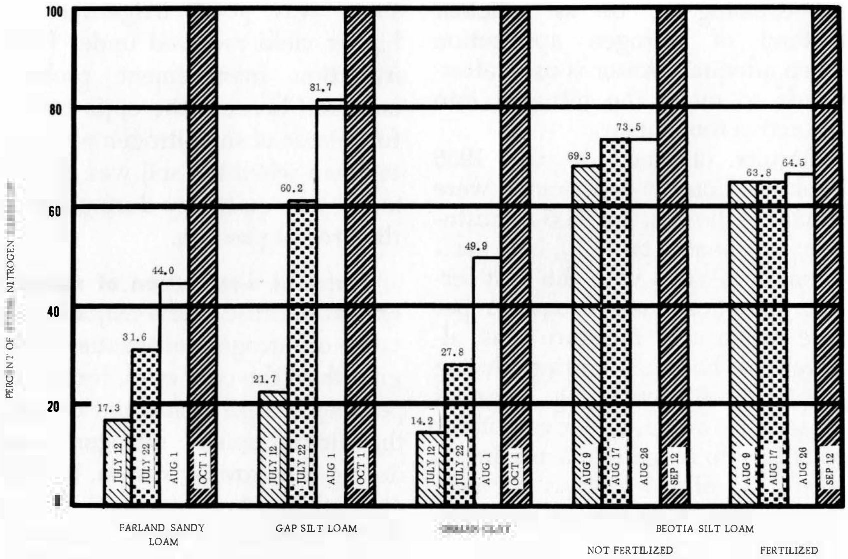

Figure 1. Percentages of total nitrogen uptake at harvest absorbed by corn at various times during growing season on four soil types.

found on the four dates of sampling are plotted in figure 1.

Although the total uptake of nitrogen varied widely among soils under nonfertilized and fertilized conditions, the time distribution of the nitrogen uptake by corn was quite similar under these five conditions of measurement except the second and third samplings on Gap silt loam. The dates of sampling at Redfield did not coincide with those at the Angostura irrigation project. At Redfield, corn was sampled on August 9, August 17, August 26, and September 12.

Figure 1 indicates that by August 1, the percentages of the final total nitrogen uptake accomplished were 44, 81, and 49 on the Farland, Gap, and Orman soils, respectively. Thus, approximately half the nitrogen was yet to be absorbed by corn in August and September on the Farland sandy loam and the Orman clay, but only one-fifth remained to be absorbed on the Gap silt loam. The reason for this marked difference between soils is not yet clear.

Results on the Farland sandy loam and the Orman clay were much the same as those on the Beotia silt loam at Redfield. By the time of the first date of sampling on the Beotia silt loam (August 9), 69% of the total nitrogen assimilated at the end of the season had been taken up on unfertilized land and 64% on fertilized land. The total amount of nitrogen absorbed on the fertilized land was about 50% greater than that on unfertilized land at the end of the growing season. It should be noted that a considerable portion of the total nitrogen was taken up in the last few weeks of the growing season. This is an important factor in getting complete filling of the ear and in obtaining high protein corn.

Experiments involving hybrids of various maturities in combination with several stand densities, fertilizer practices, methods of planting, or combinations of several of these variables, have been conducted in Yankton, Brookings, and Spink Counties for several years.

Differences among hybrids have been noted with respect to response to increasing plant populations. All hybrids tend to reduce ear size as plant density is increased, but the full-season hybrids, in general, tend to maintain ear size a little better than short-season hybrids. Raising the plant population from 16,000 to 19,000 plants per acre increased yields by 10 or more bushels per acre, whereas the next 3,000 increase in plant population raised the yield only about half as much, or 5 bushels per acre (100 to 105 bushels) with fertility and water management the same in all cases.

Years of observation and experiments with irrigation indicate that (1) a plant population of 18,000 to 20,000 stalks per acre generally provides near maximum or maximum yields under these climatic conditions; (2) hybrids that mature 4 or 5 days later than those used on dryland can usually be used with the same probability of mature corn; (3) adequate soil moisture supply is essential in the period from tasseling to silk-browning; (4) nitrogen uptake continues until denting or later and the supply must be adequate at all times; (5) alfalfa in the rotation increases available nitrogen by about 60 pounds of nitrogen per acre for 2 years of corn production; (6) in nonlegume rotations, nitrogen additions of from 80 to 100 pounds per acre per year are necessary for near maximum yields.

Grass Seed and Hay Production

Experiments under irrigation have been conducted over the past 8 years with various tame and native grasses to test the performance of these grasses in seed production under various conditions of management. In most experiments a combination of several row spacings, usually 9, 18, and 36 inches apart, and fertilizer applications were superimposed to measure the effect of fertility and row spacing with cultivation.

Table 8 indicates the seed yields of four tame grasses (smooth brome, crested wheat, intermediate wheat, and tall wheatgrass) and two native

Table 8. Influence of Row Spacing and Cultivation on Grass Seed Yields, Redfield, S. D.

Row Spacing*	Smooth Brome†	Crested Wheatgrass†	Intermediate Wheatgrass†	Tall Wheatgrass†	Slender Wheatgrass‡	Western Wheatgrass‡
In.			Lbs./A.			
9	302	519	321	257	180	172
18	362	488	294	266	286	231
36	237	317	201	190	231	170

*The 18- and 36-inch rows were cultivated.

†Yields for first year after planting in 1954.

‡Average of first and second years' production. Planted 1957.

grasses (slender wheat and western wheat) when planted in 9-, 18-, and 36-inch rows. The tame grasses were planted in 1954. Yields of the four grasses reported in this table are for the first year after planting. The yields of slender wheatgrass and western wheatgrass, planted in 1957, are averages for the first and second years' production (1958 and 1959).

Performances of bromegrass, crested wheatgrass, intermediate wheatgrass, and tall wheatgrass were nearly as satisfactory in 9-inch rows as in 18- and 36-inch rows. This has been true for the first year after planting with nearly all grasses. In the second and third year after planting, the nitrogen deficiency became more and more acute, and the seed yields dropped rapidly with 9-inch or solid planting of grasses unless nitrogen fertilizer was added. However, at 18-inch and 36-inch row spacings, satisfactory seed yields were maintained without the use of nitrogen fertilizer by cultivating between the rows two or three times during the growing season.

When 9-inch row spacing or solid planting is used, the application of nitrogen fertilizer at the rate of 40 to 60 pounds per acre per year is necessary to maintain seed yields at satisfactory levels. The yields of slender wheatgrass and western wheatgrass seed shown in table 8 were quite satisfactory with 18-inch row spacing and cultivation. However, neither 9-inch spacing nor 36-inch spacing produced the seed yields that the 18-inch rows did.

Additional grasses, including Russian wildrye, little bluestem, big bluestem, tall oatgrass, green needlegrass, and switchgrass have been incorporated in recent experiments. Satisfactory stands of these grasses have been difficult to obtain. Also profitable seed yields are more difficult to obtain than with the wheatgrasses and brome.

To illustrate the effect of nitrogen applications on grass seed yields, some of the results on bromegrass, tall wheatgrass, and crested wheatgrass for the third year of production are shown in table 9.

Factors other than soil nitrogen supply are also important in grass seed production. Seed yield occasionally decreased when more than 80 pounds of nitrogen per acre were

Table 9. Seed Yields of Three Grasses Grown at Three Row Spacings and Three Levels of Applied Nitrogen. Yields Are Averages of 4 Replications in Pounds of Clean Seed Per Acre. Redfield, S. D., 1957

	Bromegrass			Tall Wheatgrass			Crested Wheatgrass		
Nitrogen	9" Rows	18" Rows	36" Rows	9" Rows	18" Rows	36" Rows	9" Rows	18" Rows	36" Rows
					Lbs./Acre				
0	41	98	178	252	362	508	105	251	398
80	121	259	194	370	493	576	489	659	480
160	78	253	276	371	526	492	454	610	445

applied. This was usually the result of extreme lodging following a heavy rain and incomplete seed development because of high humidity or dew remaining on the grass for long periods in the forenoons. However, severe lodging was experienced only with bromegrass and tall wheatgrass. Crested wheatgrass, as well as intermediate wheatgrass, remained upright even with 160 pounds of nitrogen.

Data from these experiments show that the application of 80 pounds of nitrogen per acre is approximately the optimum rate for seed production on Beotia silt loam or similar soils. The hay which can be cut after seed harvest with all these grasses retains a high crude protein content and should be utilized. Furthermore, an irrigation after the harvest of the seed crop and the first hay crop usually results in a very appreciable and rapid regrowth so that a second crop of hay can be cut in the late summer.

Table 10. Crude Protein Produced in Variously Fertilized Grass Hays. Values Are Pounds of Crude Protein Per Acre in Two Hay Cuttings, Huron, S. D., 1952*

Grass	No Nitrogen	40 Lbs. Nitrogen/A	80 Lbs. Nitrogen/A	160 Lbs. Nitrogen/A
	Lbs./Acre			
Alta Fescue	145	297	514	818
Crested wheat	189	292	362	694
Intermediate wheat	217	383	473	815
Brome	166	303	525	960
Red Fescue	113	290	464	881
Russian wildrye	148	369	661	872
Average	**163**	**322**	**500**	**840**

*Alfalfa-brome combination produced 1465 pounds crude protein per acre under similar conditions.

Value of nitrogen in increasing protein production by tame grasses used for hay is shown in table 10. All grasses were grown in solid stands.

The percentage recovery of fertilizer nitrogen applied, in terms of increased yield and increased protein content, was almost as high at the 160-pound level as at the 40-pound level with most grasses. Crude protein values as high as 18.4% were observed. The exact value this nitrogen recovered and calculated as crude protein after laboratory analysis would have in a feeding program has not been fully established. All of the crude protein represented is probably not in the form of essential or usable amino acids or protein, but ruminant animals on high-energy rations use most of this crude protein.

Production of crude protein as measured by the same laboratory procedures indicated that the alfalfa-brome combination can exceed fertilized stands of grasses alone even when 160 pounds of nitrogen per acre are applied to the pure grass stand. The alfalfa-brome production, 1,465 pounds of crude protein per acre, was contained in a hay yield of approximately 4 tons per acre, having a protein content of 18.5%. The hay yields of pure grass stands from which comparative data were calculated ranged from approximately 1,110 pounds of hay where no nitrogen was applied to approximately 7,000 pounds of hay per acre when 160 pounds of nitrogen was applied. Not all grasses yielded 3½ tons of hay per acre, but brome, intermediate wheat, crested wheat, and Russian wildrye have very high productive capacity when adequately fertilized.

Soybeans

Soybean production under irrigation has been investigated in experiments at the Redfield Development Farm and on private farmland in Yankton County. The major question investigated was the effect on yields of various row spacings and plant spacings. Some work has also been done on performance of adapted varieties in the areas studied, and the effect on variety performance of row spacing and irrigation practice. Generally, when adapted varieties are used, yields are much less affected by changing variety than by changing row spacing or irrigation practice.

Table 11 illustrates the effect observed on the yields of soybeans in a row spacing and water management experiment at the Redfield Development Farm. The three varieties used differed slightly in performance; however, variety differences were far outweighed by the effects of changing the row spacing from 36 inches to 18 inches.

Table 11. Effect of Irrigation Management and Row Spacing on Soybean Yields, Redfield, S. D., 1953

	No Irrigation	Adequate Irrig. Until 3 Weeks After 1st Bloom	Adequate Irrig. Until Maturity	Average
		Bu./Acre		
18″ rows	33.2	35.1	36.6	35.0
36″ rows	27.0	28.4	29.8	28.4
Average	**30.1**	**31.8**	**33.2**	

Whether the beans were grown without irrigation or irrigated at an optimum moisture level, a yield increase of 6 to 7 bushels was obtained with the 18-inch rows. A 3-bushel yield advantage was obtained in this particular experiment for the best irrigation treatment as compared with no irrigation at all, at any given row spacing. The yield advantage for irrigation would likely be much greater than this during dry seasons. A yield increase of 3 bushels for irrigation over a 30-bushel dryland yield represents only a 10% increase, and soybeans would doubtfully be a profitable crop to irrigate under these conditions.

Another experiment with soybeans was conducted in Yankton County in 1956 where row spacing was not a variable, but moisture levels and fertility were. In this experiment the nonirrigated plots averaged 21.6 bushels per acre. The best irrigation treatment averaged 30.5 pounds per acre. In this instance, when 40-inch rows were used, the yield increase for irrigation was approximately 41%.

Only limited work has been done on the effect of fertilizer applications on soybean yields. In general, phosphorus alone has not shown any yield response. Nitrogen alone has shown only a slight yield response, and nitrogen and phosphorus in combination had no further effect. Present evidence indicates that if the crop preceding soybeans is well fertilized or yields satisfactorily, no advantage will result from adding fertilizer for the soybean crop. However, soybeans should always be inoculated before planting to insure nitrogen fixation from atmospheric sources and to provide the soybean plant with adequate nitrogen supply.

Potatoes

The potato offers a good potential for a high return per acre if adequate crop care and proper soil and irrigation management are practiced.

An experiment was conducted in 1953 (table 12) with five varieties of potatoes adapted to the northern James River Basin. These varieties ranged in yield from 171 to 217 bushels per acre with irrigation but no fertilization. When a high fertility program was used, involving in this case 180 pounds of nitrogen per acre and 22 pounds of phosphorus, the yields of the five varieties ranged from 311 to 472 bushels of No. 1 potatoes per acre. The potato plant has a somewhat limited root system and consequently requires a high level of available soil nutrients and moisture all through the major part of the growing season. Care should be taken to insure that neither of these factors becomes critical in the growth stage from blossom to approximately 4 weeks thereafter, and water must be adequate at all times.

Insect damage should be kept to a minimum in potato production. Leaf hoppers often carry leaf blight diseases which can defoliate the crop in a very short time. If this occurs while tubers are de-

Table 12. Yields of Potatoes As Affected by Fertilizer Applications*
Redfield, S. D., 1953

Fertilizer, Lb./A. N	P	LaSoda	Kennebec	Bliss Triumph	Red Pontiac	Early Ohio	Avg. All Varieties
				Bu./Acre			
0	0	217	209	172	172	171	188
120	0	386	399	324	302	274	337
0	22	228	239	209	185	159	204
60	22	314	288	336	298	225	292
120	22	417	394	340	333	251	347
180	22	468	472	311	359	329	388

*Data are in bushels of No. 1 potatoes per acre, averages of 3 replications.

veloping, near failure often results. In cool seasons, potatoes can yield 500 to 550 bushels per acre, if the most productive varieties and an adequate fertility and irrigation program are used. However, as an average, one could expect 350 to 400 bushels per acre with most varieties that are presently used.

Dry Beans

Edible Great Northern dry beans have also received attention in experimental work. An experiment at Angostura in 1956 combined five water management practices and seven fertility levels in all possible combinations. The yield results from three of the water management practices and their corresponding fertility treatments are reported in table 13.

No effect of fertilizer on bean yields was evident other than that early ripening with the 17-pound rate of phosphorus caused harvesting loss. However, water management had a marked effect on the yield.

The change in foliage color was used as an irrigation guide for this bean experiment. Results showed that beans should be irrigated at the first sign of a darkening of the foliage. On this particular soil (a sandy loam) this occurred approximately every 10 to 12 days. Observations on plant development indicated that adequate moisture is especially important in the stages of flowering and pod filling. The soil moisture reservoir should not drop below about 50% of the capacity to hold available water in the root zone.

Conclusions and Recommendations

Crop yields in a dryland-irrigated rotation comparison were measured on Beotia and Harmony soil at the Redfield Irrigation Development Farm. Two years of alfalfa in a 4-year rotation supplied adequate nitrogen for 1 year of subsequent irrigated corn yield. Commerical fertilizer can be utilized, however, to gain similar yields from irrigated corn without a preceding crop of alfalfa.

Alfalfa hay yields of 5 tons per

Table 13. Effect of Irrigation and Fertilizer Management on the Production of Field Beans, Angostura Project, 1956

Irrigation Management*	Fertilizer Treatment						
	0-0-0	40-0-0	100-0-0	0-40-0	40-18-0	100-39-0	40-18-40
	Pounds Per Acre						
M-1	1658	1752	1522	1447	1542	1650	1552
M-3	1906	1538	2031	1648	1832	1712	1605
M-5	1190	1135	1035	903	1017	1138	1188

*M-1 plots received 5 irrigations; available moisture was kept above 50%.

M-3 plots received 4 irrigations; not irrigated at time of first irrigation of other plots (July 10).

M-5 plots received 4 irrigations, were not irrigated at time of third irrigation of other plots (Aug. 1).

acre can be expected with good management under irrigation. This is about double dryland production in the Northern James River Basin.

Considered as independent factors in these studies, fertilizer contributed more to wheat yields than did irrigation.

One year of alfalfa contributed about as much fertility toward irrigated corn yields as 40 pounds of commercial nitrogen. This resulted in an increased yield of 30 bushels per acre.

Nearly all corn varieties adapted for dryland do well under irrigation, but a hybrid 4 to 6 days later than that normally used for dryland should be used.

Fertilizer is essential for high corn production in most of South Dakota. Nitrogen is the major deficient nutrient.

For profitable irrigated corn production, good water management is vital. The crop should not suffer from drought between the tasseling and denting stage, and particularly in the tassel to silk browning stage.

A large portion of the total nitrogen is taken up by the corn plant during the last 4 weeks of its growth. This appears to be a very critical nutritional period for high corn yields.

Successful grass seed production requires proper attention to fertility and irrigation. Too much nitrogen will cause severe lodging, poor pollination, and consequent poor seed yields. Cultivation of grass for seed production is practical and beneficial. A row spacing of 18 inches is well adapted for grass seed production.

The forage remaining after the seed has been removed is of high quality and can be utilized for hay or grass silage. Fertilizer contributes remarkably to a high protein content of this forage.

Row spacings of soybeans of 18 to 22 inches with plants 2 to 3 inches apart and inoculation of seed are neccessary for highest yields. Irrigation increases yields to some extent in most years, but during years of normal rainfall in eastern South Dakota, it is not economically profitable unless narrow row spacings are used. Soybeans have not shown much response to fertilizer.

Potato yields under irrigation can triple those on dryland. The limited root system of the potato crop requires that an adequate supply of soil nutrients and water be available during the entire season. Frequent, light irrigation applications appear to be most beneficial.

Dry bean production under irrigation can be profitable in the southwestern portion of the state. Successful bean production is dependent upon good management practices. Small, frequent applications of water are necessary for high yields. The change in color of the foliage is a fair irrigation guide; however, care should be taken during the critical stage of blossoming and pod filling to make sure the crop does not suffer from drought.

The place of alfalfa-grass mixtures in the cropping system depends upon (1) livestock enterprises of the farm and (2) the need of grass-legume plantings in the rotation to maintain satisfactory soil structure.

If livestock enterprises can utilize hay to the point that alfalfa-grass mixtures in the rotation can furnish the major share of the nitrogen needed by other crops in the rotation, this is the most economical way to supply nitrogen. However, some commerical nitrogen must be used in all cropping systems tried thus far to maintain maximum production.

Grass-legume mixtures rather than straight legume hay must be used to maintain soil structure, good tilth, water infiltration and storage capacity, and aeration. Alfalfa alone has not benefited soil structure in experiments conducted thus far.