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Introduction

With increased livestock feeding activity in southeastern Idaho and increased availability of corn hybrids adapted to silage production in the area, interest in the culture of corn has increased. Because little information was available on the influence of irrigation practices on yield and quality of corn grown for silage, a study was initiated at Aberdeen, Idaho, in 1957, to determine the effect of irrigation frequency and soil-moisture levels on corn yield and quality. The interactions of soil-moisture levels and relative fertility were also considered. This study was conducted from 1957 to 1960, and the results are herein reported.

Climatic and Soil Conditions

The Aberdeen area has cool, dry summers with a large proportion of sunny days and a low annual precipitation. The 50-year-average-annual precipitation is 8.5 inches. The average annual precipitation during the term of this experiment was approximately 6.5 inches. Monthly precipitation is about evenly distributed throughout the calendar year with the most precipitation normally occurring in May and the least in July. Table 1 gives the mean temperature and precipitation with departures from normal for the years of study.

The trials were located on the Aberdeen Branch Experiment Station on adjacent fields. The soil was classified as Declo loam, which in the trial area was approximately 15 feet deep overlaying basalt rock. The surface 12 to 14 inches of Declo loam is a medium-brown to light-brown mellow, friable, and calcareous loam. It is underlain to a depth of 40 inches by a lime layer. Declo loam has a high waterstorage capacity and is fairly well drained. The fertility of Declo loam may be ranked just below the highly fertile

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Table 1 — Mean monthly summer temperature and departure from normal at Aberdeen, Idaho

	May		June		July		August	
	Mean	Departure	Mean	Departure	Mean	Departure	Mean	Departure
1957								
Temperature (°F)	54.5	+.7	61.9	0	68.8	—.8	67.8	+.4
Precipitation (in.)	2.64	+1.59	.38	—.42	.07	—.37	.12	—.35
1958								
Temperature (°F)	60.6	+6.8	63.5	+1.6	66.5	—3.1	68.0	+.6
Precipitation (in.)	.33	—.72	.84	+.08	.36	—.08	.04	—.43
1959								
Temperature (°F)	49.8	—4.0	64.8	+2.9	67.0	—2.6	56.2	—11.2
Precipitation (in.)	1.07	+.02	.29	—.51	—	—.44	.28	—.19
1960								
Temperature (°F)	51.5	—2.3	63.7	+1.8	71.8	+2.2	64.5	2.9
Precipitation (in.)	.21	—.84	.26	—.54	.31	—.13	.77	+.30
48 year average								
Temperature (°F)	53.8		61.9		69.6		67.4	
Precipitation (in.)	1.05		.80		.44		.47	

Table 2 — Irrigation and consumptive use data for Idahybrid 216 corn grown under 3 soil moisture levels at Aberdeen, Idaho in 1957 and 1958.

Soil Moisture Level	Number of Irrigations[1]	Irrigation Interval (days)[2]	Consumption Use (inches)	
			Average daily[3]	Total Seasonal
High	12	5.8	0.22	14.62
Medium	6	11.7	0.16	11.53
Low	3	20.0	0.21	11.98

[1] Irrigation before planting not included.
[2] Average between successive irrigations at peak consumptive use.
[3] Average at peak consumptive use.

Portneuf series. The topography of the field was fairly uniform with a 0.5 percent slope in the direction of irrigation. Surface drainage was good and the field well adapted for an irrigation experiment.

Procedure

Culture Practices and Harvest

The field on which the experiment was to be conducted was irrigated several days before planting to assure a uniform soil moisture level for all plots. The soilbed was prepared and Idahybrid 216 field corn was planted in 36-inch rows as recommended by Owens (4). Planting dates for the 4 years ranged from May 16 to May 20 with May 19 the average planting date. A planting rate of 23,250 plants per acre was used. The field was cultivated only when necessary for weed control. After the initial cultivation, surface contour ditches were made to each replication. Each plot, therefore, received water independently of the other plots.

In 1957 and 1958 3 irrigation treatments were arranged in 6 replications. The plots were 120 feet long and 48 feet wide including buffer rows. The field was planted with a standard 2-row planter and a 20-foot section of the plot row was harvested for yield. Four buffer rows separated the harvested rows. In 1959 and 1960, 4 irrigation treatments were similarly arranged in 5 replications.

The harvest dates for the 4 years occurred between September 6 and September 16 with September 9 the average date. The individual plot rows were harvested by hand with stalks and ears weighed separately to obtain total silage yield. The stalks and the ears of three plants were chopped, bagged in mesh bags, and dried to a constant weight in a forage dryer to ascertain the dry-matter content. Ears from 3 plants were observed for maturity and the following numerical index applied:

0.0 — blister
1.0 — milk
2.0 — soft dough
3.0 — hard dough
4.0 — early dent
5.0 — dent

Irrigation and Fertilizer Treatments

In 1957 and 1958 3 irrigation treatments were maintained by applying water at 3 frequencies based on the amount of moisture in the soil at the time of application. The plots were irrigated when the available soil moisture in the root zone had been 35 percent depleted, 50 percent depleted, and 70 percent depleted. These treatments were described as a high soil-moisture level, medium soil-moisture level, and low soil-moisture level. After each irrigation, the soil-moisture level was at field capacity regardless of the irrigation treatment. Furrows were made between all corn rows and water was applied to every furrow.

Each irrigation plot was split into 12 fertilizer plots in 1957 and 1958. The fertilizer treatments consisted of 3 rates of nitrogen -O, 60, and 120 pounds nitrogen per acre; 2 rates of phosphate -0 and 20 pounds P_2O_5 per acre; and 2 rates of potassium -0 and 40 pounds K_2O per acre. The fertilizer treatments were applied in in all possible combinations with each other. Fertilizer application was made with a plot bander which applied the material 6 inches to each side and 2 inches below the seed. All plots were banded within a few days after planting.

The growing seasons were divided in 1959 and 1960 into two periods. The first, or early period, was from planting to the tassel stage and the second, or late period, was from tassel to plant maturity. Two soil moisture levels, wet and dry, were maintained on the plots over the early period of the growing season. At tasseling time the plots were split and similarly two soil moisture levels were maintained over the second period of the growing season. The irrigation frequencies of the two soil-moisture treatments were arranged to apply irrigation water when the available soil moisture in the root zone was 35 percent depleted in the west plots and 60 percent depleted in the dry plots. The 2 soil moisture treatments over the 2 periods of the growing season resulted in 4 irrigation plots as follows:

Treatment No.	Early Period	Late Period
1	wet	wet
2	wet	dry
3	dry	wet
4	dry	dry

Fertilizer treatments in 1959 and 1960 consisted of 3 rates of nitrogen -0, 60, and 120 pounds nitrogen per care, and 2 rates of phosphate -0 and 80 pounds P_2O_5 per acre. The fertilizer treatments were applied in all possible combinations with each other making six fertilizer plots. The fertilizer was applied in the same manner as in 1957 and 1958.

Soil-Moisture and Consumptive Use

Soil Moisture samples were taken with a soil auger at planting time, before irrigation, 24 hours after irrigation, and at harvest time to determine soil-moisture and consumptive use under each irrigation treatment. Samples were also taken periodically between irrigations to determine when the available soil moisture in the root zone had been depleted to the point requiring irrigation. Samples were taken from all plots in each treatment. Approximately the same location was used for each sampling period. At each location, samples were taken from the 0-12-inch depth and 12-24-inch depth. The water content of the samples was determined gravimetrically.

The soil moisture percentage by weight was multiplied by the volume weight of the soil to convert to percentage moisture by volume. The amount of water consumptively used from the area of the root zone sampled was the difference in volumes of water in the samples between irrigations. The actual consumptive use measured between irrigation was extrapolated to include the consumptive use during the irrigation process.

Water in the soil that can be considered available for plant use exists between certain limits. These are field capacity and wilting point. Moisture in excess of field capacity is soon drained away by gravity, and that below the wilting point is held too tightly by the soil particles to be available for plant use. Field capacity and witing point are influenced by soil texture, soil structure, salt content, root distribution, and weather conditions.

Accurate determination of filed capacity is difficult. For this study, field capacity was defined as the amount of moisture remaining in the soil following an irrigation and a free drainage period of 24 hours (2). The average field capacity of the soil was found to be 22.5 percent water by weight. The wilting point was defined as the amount of moisture remaining in the soil when permanent plant wilting occurred. This limit was found to be 7.5 percent water by weight.

Leaf-Firing and Silking Date

Leaf firing is a condition of the corn plant in which leaves discolor prematurely. This condition is generally caused by a plant nutrient deficiency. Deficiencies of different nutrients cause the leaves to discolor in a different manner. For example, a phosphate deficiency will turn the outside edges of the green leaf purple while nitrogen deficiency causes a leaf to turn yellow, first in the center and then the entire leaf. Firing of the basal leaves in corn is common in many locations throughout southern Idaho. This condition may affect only a relatively few leaves at the base of the plant or it may extend more than half the distance up the stalk.

To each plot of the experiment, a leaf-firing index number was assigned, based on a direct count, from the first node upward, of fired or partially fired leaves. The leaf-firing index reading was made in 1957.

The silking date of corn is an early indication of its relative maturity. An early silking plant will generally develop more mature ears by harvest time. To determine when individual plots had silked, the half-silking method was used. In this method the plot was considered to have silked when 50 percent of the plants in the plot had developed silks. The silking date was determined for all 4 years of the project

Table 3 — Irrigation and consumption use data for Idahybrid 216 field corn grown under 2 soil moisture levels over 2 periods of the growing season at Aberdeen, Idaho in 1959 and 1960.

Soil Moisture Level				
First Period	Second Period	Number of Irrigations[1]	Consumption Use (inches)	
			Average daily[2]	Total Seasonal
High	High	10.0	0.25	16.69
High	Low	6.0	0.24	13.38
Low	High	6.5	0.25	13.87
Low	Low	2.5	0.16	10.47

[1] Irrigation before planting not included.
[2] Average at peak consumptive use.

Experimental Results

Soil Moisture and Consumptive Use

Data obtained from the oven-dried soil samples were used to determine irrigation frequency and seasonal consumptive use for the irrigation treatments.

The total seasonal consumptive use and the average daily consumptive use data during the peak use period are shown in tables 2 and 3. Figure 1 shows the rate of accumulative consumptive use for high soil-moisture-level and low soil-moisture-level treatments. The difference in consumptive use under different irrigation treatments could be attributed to surface evaporation between irrigation (3). Each irrigation produced a wet soil surface, giving a high evaporation opportunity. Therefore the number of irrigations had an effect on consumptive use. Over the 4-year period the high moisture-level plots were irrigated an average of 11 times and the low moisture-level plots an average of 3 times. In the high moisture treatments, the plants used consumptively an average of 1.3 inches of water between irrigations. In the low moisture treatments the amount of water used between irrigations was 3.0 inches.

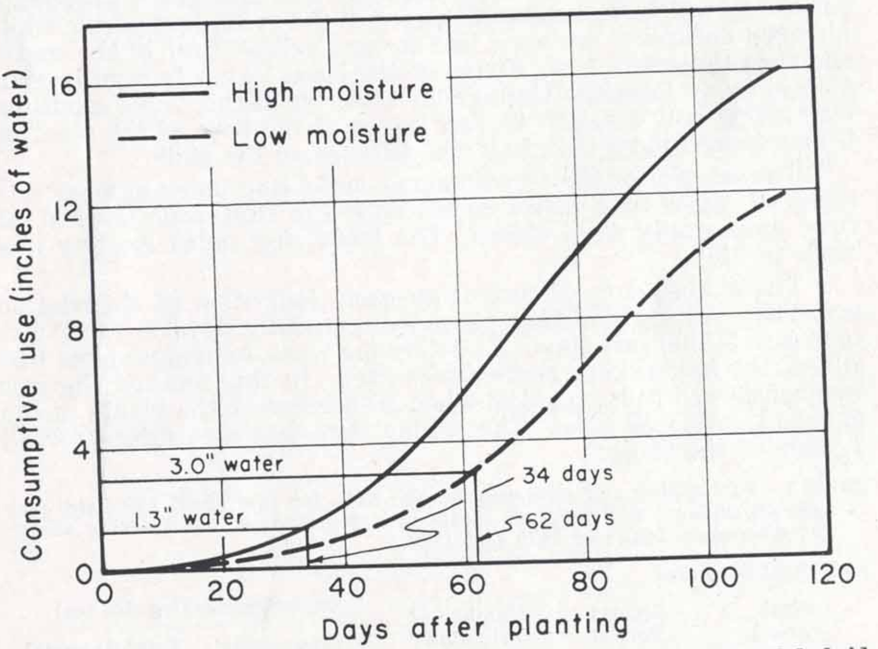

Figure 1 — Seasonal accumulative consumptive use of water by Idahybrid 216 corn grown under high and low soil moisture levels at Aberdeen, Idaho.

With this information and the curves from figure 1, the irrigation interval for all periods of the growing season can be predicted with reasonable accuracy. Assuming that the total available soil moisture in the root zone was equivalent to 4.5 inches of water and irrigation according to the low soil moisture treatment was desirable, and allowable 3.0 inches (67 percent of the total available moisture) would be consumptively used between irrigations. The curve for the low-moisture treatment (figure 1) indicates that 3.0 inches of water would be sufficient for approximately the first 62 days of the growing season. At the end of this period the soil should be irrigated until 3.0 inches of water has been replaced. This amount of water will now last only 17 days. If the grower decided to irrigate according to the high soil-moisture treatment, 1.3 inches (30 percent of the total available moisture) would be consumptively used between irrigations. This amount of water would be sufficient for the first 34 days of the growing season at which time it would have to be replaced. After 34 days of the growing season had elapsed, 1.3 inches of water would last only 10 days and would have to be replaced again. The irrigation interval decreases until it reaches a minimum value at approximtely 80 days after planting.

The minimum irrigation interval will occur at the point of maximum daily consumptive use. This point is reached in the hottest part of the growing season when the plants are developing most rapidly. Figure 1 indicates that the maximum daily consumptive use by corn grown under the high soil-moisture treatment was 0.24 inches per day and that grown under the low soil-moisture treatment was 0.22 inches per day. During this period of peak use, the irrigation interval would be 14 days for the low soil-moisture treatment and 5 days for the high soil-moisture treatment. The period of maximum consumptive use extended from approximately 65 to 90 days after planting. The irrigation interval became slightly longer as the end of the growing season approached.

Silage, Yield, and Moisture

Total yield and silage moisture content of corn grown under three irrigation treatments in 1957-58 is presented in table 4. During these 2 years the application of nitrogen fertilizer resulted in increased yield regardless of the irrigation treatment. The addition of 120 pounds nitrogen per acre over 60 pounds per acre was not justified except with the medium-moisture treatment. None of the three irrigation treatments materially altered the total yield when all application rates of nitrogen were considered.

Silage moisture was affected by irrigation treatments but was not materially altered by the application of nitrogen. If 70 percent of the available soil moisture was used, the silage moisture content was reduced. A greater silage moisture content resulted when only 35 percent of the available moisture in the soil was depleted.

The corn crop reacted to phosphate applications in 1960. The yield resulting when no phosphate was applied was 21.49 tons per acre. With 80 pounds per acre applied the yield was 22.29 tons per acre. This is a small increase but is significant at the 5 percent level.

No observed response resulted from the addition of potassium fertilizer.

Table 4 — Total silage yield and silage moisture as affected by soil moisture levels and nitrogen fertilizer in 1957-58.

Nitrogen	Soil Moisture Level				Soil Moisture Level			
	High	Medium	Low	Average	High	Medium	Low	Average
	Silage yield (Tons/A)				Silage moisture content (percent)			
0 lbs/A	19.25ab[1]	19.85bc	18.86a	19.33f	75.4	74.5	73.0	74.3
60 lbs/A	22.14e	21.02d	20.48cd	21.21g	75.2	74.5	72.8	74.2
120 lbs/A	22.97e	22.80e	20.92d	22.23h	75.3	73.7	72.3	73.8
Average	21.45	21.22	20.10		75.3k	74.2j	72.7i	

[1] Values followed by different letters are significantly different at the 5 percent level and those followed by the same letter are not significantly different on the basis of Duncan's Multiple Range Test (1).

Table 5 — Total silage yield and silage moisture as affected by 2 soil moisture levels the first half and 2 soil moisture levels the second half of the growing seasons of 1959-60.

Soil moisture level from tassel to maturity	Soil moisture level from planting to tassel					
	High	Low	Average	High	Low	Average
	Silage yield (Tons/A)			Silage moisture content (per.)		
High	21.40	23.10	22.25	77.3	77.9	77.6j
Low	21.00	21.80	21.40	76.7	76.4	76.6i
Average	21.20a[1]	22.45b		77.0	77.1	

[1] Values followed by different letters are significantly different at the 5 percent level and those followed by the same letter are not significantly different on the basis of Duncan's Multiple Range Test (1).

In addition to nitrogen's effect on total yield in 1957-58, nitrogen also affected yield in 1960 when the preceding crop was alfalfa with the third cutting plowed down. Zero, 60, and 120 pounds of nitrogen per acre resulted in 21.01, 21.59, and 23.07 tons of silage per acre respectively. The silage yield from a 120-pound rate of nitrogen was significantly greater than that of the 0 and 60 pound rate.

Corn-silage yield and moisture content of corn grown under 2 soil-moisture levels from planting to tassel and 2 soil moisture levels from tassel to maturity are presented in table 5. When 60 percent of the available soil moisture was used between irrigations during the first period of the growing season, an increase in total yield occurred. This indicates that the corn plant can easily be over-irrigated during the first part of the growing season. The frequent applications of water during this period possibly decreased yield because soil temperature was decreased and soil air content reduced. There was no significant difference in total silage yield due to high and low soil moisture level treatments from tassel to maturity.

A higher silage-moisture content resulted when the available soil-moisture level from tassel to maturity was 35 percent depleted. The soil-moisture level in the root zone from planting to tassel did not affect the silage moisture at harvest time.

Leaf Firing

Leaf firing index readings were made August 19, 1957, at which time the corn plant had tasseled and silked and any nitrogen deficiency was clearly apparent. The effect of 3 soil moisture levels, 3 nitrogen treatments, and 3 phosphate treatments on leaf firing is shown in table 6. When 70 per cent of the available soil moisture was depleted between irrigations, leaf firing was considerably reduced. This could be attributed to more nitrogen remaining in the root zone because of less leaching when the irrigation

Table 6 — Leaf firing index[1] as affected by soil moisture levels, nitrogen and phosphate levels in 1957.

Soil Moisture Level		
High	Medium	Low
17.8b[2]	20.3b	12.5a

Nitrogen		
0 lbs/A	60 lbs/A	120 lbs/A
28.3f	15.6e	6.8d

Phosphate	
O lbs/A	10 lbs/A
17.9j	15.9i

[1] Leaf firing index described in Procedure; the larger the index number the greater the extent of leaf firing.
[2] Values followed by different letters are significantly different at the 5 percent level and those followed by the same letter are not significantly different on the basis of Duncan's Multiple Range Test (1).

interval was long enough to attain the low soil moisture level treatment.

The availability of nitrogen to the plant probably affects leaf firing more than any other single cause. Significantly less leaf firing appeared when 60 pounds of nitrogen per acre were applied than when no nitrogen was applied. The 120-pounds-of-nitrogen per-acre rate also reduced leaf firing below that of the 60 pound rate. To a small degree, the application of 80 pounds of phosphate per acre reduced leaf firing.

Silking Date

Idahybrid 216 field corn grown in Aberdeen developed silks on half the stalks 84, 74, 81, and 76 days after planting for the years 1957 through 1961 respectively. The seasonal variation of the silking date was quite large. The soil-moisture level effect on silking date was quite small with the high soil-moisture level delaying silking date approximately 1 day over an average of 4 years. The effect of any fertiizer treatments on silking date was not significant.

Ear Maturity

Ear Maturity index readings taken in 1957-58 resulted in the index number of 3.16, 3.32, and 3.45 for the high, medium, and low soil-moisture treatments respectively. The index number of 3.16 for the high soil-moisture treatment was significantly lower than the index numbers for the medium and low moisture treatments and the high soil-moisture treatment resulted in fewer mature ears. The results of maturity readings taken in 1959 and 1960 show that soil-moisture level from planting to tassel does not affect ear maturity. The high soil-moisture-level treatment from tassel to harvest resulted in a maturity index of 3.38; the low soil-moisture treatment gave an index number of 3.55. The low moisture treatment resulted in ears significantly more mature than those produced by the high soil-moisture treatment.

Table 7 — Ear weight to total yield ratio as affected by nitrogen fertilizer in 1957-58.

	Nitrogen			
Year	0 lbs/A	60 lbs/A	120 lbs/A	Average
1957	0.325a[1]	0.361b	0.379c	0.355f
1958	0.371c	0.375c	0.369c	0.372e
Average	0.348i	0.368j	0.372j	

[1] Values followed by different letters are significantly different at the 5 percent level and those followed by the same letter are not significantly different on the basis of Duncan's Multiple Range Test (1).

Ear Weight to Total Yield Ratio

The ear-weight to total-yield ratio indicates the quality of silage that will result from a corn crop. Table 7 presents the ear-weight to total-yield ratio as affected by the application of 0, 60, and 120 pounds of nitrogen per acre in 1957 and 1958. In 1957 the application of 60 and 120 pounds of nitrogen per acre increased the ratio respectively. In 1958 the application of nitrogen did not significantly effect the ear-weight to total-yield ratio.

In 1959 and 1960 the soil-moisture level in the root zone during the first part of the growing season was found to affect the ear-weight to total-yield as shown in table 8.

When the moisture was 35 percent depleted during this period, the ear-weight to total-yield ratio was 0.367 percent. This was significantly less than the ratio of 0.398 resulting when the soil moisture was 60 percent depleted. Withholding nitrogen during these 2 years also resulted in a lower ear-weight to total-yield ratio.

Table 8 — Ear weight to total yield ration as affected by soil moisture in the first part of the growing season and nitrogen fertilizer in 1959-60

Soil Moisture Level	Nitrogen 0 lbs/A	60 lbs/A	120 lbs/A	Average
High	0.364	0.369	0.369	0.367e
Low	0.384	0.403	0.407	0.398f
Average	0.374a[1]	0.386b	0.388b	

[1] Values followed by different letters are significantly different at the 5 percent level and those followed by the same letter are not significantly different on the basis of Duncan's Multiple Range Test (1).

Summary

A project was initiated in 1957 and conducted for 4 years to test the effect of soil moisture level and fertility on the yield, moisture content, and quality of corn silage. For the first 2 years of the project, 3 soil moisture levels were maintained by varying the irrigation frequency. Twelve fertilizer treatments were used — combinations of 3 rates of nitrogen, 2 rates of phosphate, and 2 rates of potash. After 2 complete years, different irrigation treatments were selected to maintain a high and low soil-moisture level from the time the crop was planted until tasseling occurred and a high low soil-moisture level from tasselling to harvest. The number of fertilizer treatments was reduced at this time to 6-3 rates of nitrogen and 2 rates of phospate.

The soil-moisture level maintained in the root zone throughout the entire growing season did not materially affect the total yield of corn although the high soil-moisture treatments resulted in a higher silage-moisture content. Results showed that a low soil-moisture level early in the growing season resulted in a greater yield of silage. The number of desirable characteristics such as high ear-weight to total-yield ratio, early silking rate, and mature ears was increased by maintaining a relatively low soil moisture level in the eary part of the growing season.

The results of the project on corn irrigation and fertilization can be summarized as follows:

(1) Consumptive use was increased as the soil-moisture level was increased. This was due to the increased opportunity for surface evaporation from the soil kept moist by frequent irrigation. The increase in consumptive use of the moist soil was more noticeable in the first half of the growing season.

(2) Maximum total yield was obtained from plants grown under a low soil moisture level from planting until tassels appeared — moisture varying from 100 percent to 40 percent field capacity.

(3) Plants grown under low soil-moisture level the second half of the season produced as much silage as those grown under the high moisture levels.

(4) The application of nitrogen increased yield most significantly when applied to the high soil-moisture level plots.

(5) Silage moisture was increased as soil moisture was increased, especially in the last half of the growing season.

(6) Nitrogen deficiency caused a great increase in leaf firing. Leaf firing occurred in cases where nitrogen was not applied to the plots or where the amount of available nitrogen was reduced by the application of excess irrigation water.

(7) Ear-weight to total-yield ratio was increased as the soil-moisture level was decreased in the early part of the growing season.

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Recommendations

1. Plant field corn in a moist, well-prepared seedbed so evaporation will not be excessive early in the growing season.
2. Nitrogen fertilization requirements will vary slightly with location. Generally, 80 pounds of available nitrogen will suffice for yields normally expected in southeastern Idaho.
3. Apply phosphate according to soil test. Response to phosphate will probably be limited to soils tested under the medium range.
4. Apply potash according to soil test. There are probably few areas in the Snake River Valley and adjacent valleys in which any response to potash fertilization will be observed in corn.
5. Irrigate after planting when about 60 percent of the available soil moisture in the root zone is used.
6. Excessive irrigation early in the season will decrease silage yields. Use at least 60 percent of the available soil moisture between irrigations until the corn has tasseled. After tasseling, irrigations can be more frequent.
7. Do not irrigate according to the number of days from the previous irrigation or a fixed date on the calendar. Your soil may has a different water holding capacity than the soil on which this experiment was conducted and, therefore, require a different number of irrigations. Irrigate according to the soil and plant needs.
8. Field corn uses water until it is dead from frost, maturity, or harvest. Do not allow the soil-moisture level to approach the wilting point at any time.