ALFALFA IRRIGATION MANAGEMENT

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Yield Versus Applied Water

Yield depends on the evapotranspiration of the crop. Evapotranspiration is the amount of water both transpired through the plant leaves and evaporated from the soil. The higher the evapotranspiration, the higher the yield until maximum evapotranspiration is reached. Maximum evapotranspiration depends on climatic conditions (solar radiation, wind, humidity, and temperature) and on the amount of soil moisture. If the soil moisture is limited because of inadequate irrigations, evapotranspiration, and thus crop yield, will be reduced.

Evapotranspiration is small during the winter months, but increases during the summer months. Figure 1 shows evapotranspiration ranging from about 0.10 inch per day during March, but increasing to about 0.25 inch per day during July in the San Joaquin Valley.

Because the soil moisture level depends on irrigation in California, yield is also related to the amount of irrigation water applied to a crop. The more water applied, the higher the yield until maximum yield is reached. If the applied water is less than that needed for maximum yield, deficit irrigation occurs. Yield and profits may be reduced. Applied water in excess of that needed for maximum yield will be wasted, thus reducing profits.

Figure 2 shows yield-applied water relationships for alfalfa for three areas in California. For each area, yield increases with applied water. Maximum yield in the Fall River Valley occurs at about 30 inches, whereas, maximum yield in the Barstow area is at about 80-90 inches. Maximum yield in Tulare County of the San Joaquin Valley requires about 50 inches.

Differences in these areas reflect different climatic conditions. A shorter growing season exists in the Fall River Valley than in the Barstow area. However, regardless of the climatic conditions, inadequate irrigations will suppress yield, and decrease profits. Irrigations should be managed to provide maximum profits.

When Should I Irrigate and How Much Should I Apply?

The first key to good irrigation water management is to answer, "When should I irrigate?". and, "How much should I apply?". This involves using irrigation scheduling to estimate the soil moisture depletion after an irrigation. Proper irrigation scheduling depends on the evapotranspiration rate of the crop, the available soil moisture, the allowable depletion, the stage of growth of crop, and the root depth. Evapotranspiration rates depend on the time of year, geographic location, and stage of growth. Available soil moisture depends on soil texture and depth of soil profile. Allowable depletion depends on the percent of the available soil moisture that can be used without suppressing crop yield, normally about 50 percent for alfalfa. Root depths depend on the stage of growth and any impedance to root development in the soil profile.

The maximum days between irrigations depends of the allowable soil moisture depletion. An estimate of the days between irrigations can be obtained from Tables 1, 2, and 3. These tables are irrigation scheduling guides for the Sacramento, San Joaquin, and coastal valleys. They provide an estimate of the days between irrigations for different soil types and for different times of the year. The soil moisture depletion, or the amount to be applied, can be estimated by multiplying the days between irrigations times the evapotranspiration rate. For example, in the Sacramento Valley, July irrigations in a sandy loam soil should be about every 12 days for a 4-foot root depth. The soil moisture depletion is about 12 days time 0.25 inches per day, or 3 inches. If the actual irrigation schedule differs greatly from this estimate, reasons for differences should be investigated.

As a check, other methods are available to help estimate days between irrigations. These methods include:

CIMIS evapotranspiration estimates - estimates crop evapotranspiration from climatic data; available from the State Department of Water Resources,

2. Tensiometers - measures the soil water pressure which can be related to the soil moisture level,

3. Gypsum blocks - measures the soil water pressure which can be related to the soil moisture level,

4. Neutron probe -measures the soil moisture; not recommended for most growers,

5. Soil "feel" method - estimates the soil moisture from feel of soil and soil appearance.

<u>When Should I Start Irrigating?</u>

When should the first seasonal irrigation start? This irrigation should occur when 50 percent of the available soil moisture has been depleted. This requires monitoring soil moisture levels. The easiest way is to install a tensiometer at about one-quarter to one-third of the root depth. The first irrigation should occur when tensiometer readings approach 70 to 80 centibars. Soil moisture can also be easily monitored using the soil "feel" method.

<u>Irrigating with Limited Water Supplies</u>

Limited water supplies may require an irrigation cutoff date before the end of the growing season, potentially reducing crop yield. However, several studies throughout California and Nevada have shown that higher yields per cutting occur early in the growing season compared to later, as shown in Table 4. Thus, although an early cutoff date can reduce yields, its effect may be relatively small if the early cuttings are irrigated adequately.

Table 5 shows an effect of cutoff date on yield for a site in the San Joaquin Valley. Yields declined for the early cutoff dates, however, the tons per acre per inch of water was higher for the cutback strategies compared to the normal two irrigations per cutting.

Table 4. Yield per cutting, Tulare County (Source: Frate, Carol. 1988. Alfalfa irrigation - alternative for a dry year.)

Cutting	Yield (tons per acre)
1	2.07
2	2.14
3	1.54
4	1.38
5	1.11

Table 5. Effect of irrigation cutoff on yield and applied water (Source: Frate, Carol. 1988. Alfalfa irrigation - alternative for a dry year.)

Treatment	Yield (tons/acre)	Applied Water (inches)	Water Use Efficiency
3 irrigations per cutting	8.9	52	0.17
2 irrigations per cutting	9.1	41	0.22
1 irrigation per cutting	8.0	30	0.27
2 irrigations per cutting; no irrigations in July-Aug;irrigation in Sept.	6.6	26	
2 irrigations per cutting; July cutoff	5.7	19	

Note: Water use efficiency is the yield divided by the applied water. Units are tons per acre per inch of water.

Based on these results in Tables 4 and 5, the following is recommended for irrigation with limited water supplies:

1. Irrigate between every cuttings if the water supply is sufficient to do so. However, adequately irrigate the earlier cuttings. Any cutbacks in the number of irrigations per cutting should occur starting with the last cutting, then the next-to-last cutting, and soforth.

2. If the water supply is insufficient to apply at least one irrigation per cutting, irrigations should be eliminated starting with the last cutting, then the next-to-last cutting, and soforth.

Effect of Delay of Irrigation After Cutting

Delaying an irrigation after cutting can substantially reduce the yields of subsequent cuttings. While some delay may be needed because of plant damage from wheel traffic, irrigation should start as soon as possible after cutting. Table 6 shows that a delay of several days can greatly reduce the yield, the result of excessive soil moisture depletion.

Table 6. Yield versus delay of irrigation. (Source: H. J. Finkel. 1983. Irrigation of alfalfa. In: Handbook of Irrigation Technology, Volume II. CRC Press.)

Days between cutting and irrigation	Yield (%)
1	100
2	89
3	86
4	86
6	70

Root Development Versus Delaying Irrigations

A practice used by some is to delay irrigations to force roots deeper into the soil profile. The reasoning behind this practice is that the deeper root depth will increase the available soil moisture.

Little evidence exists to justify this practice. Studies have shown that delaying irrigations has little effect on root distributions with depth. These studies indicate that at least 80 percent of the roots are within the top three feet of the soil profile. These are the roots that provide most of the water to the plant.

While delaying irrigations has little effect on root development, it can have a substantial effect on yield. If the delay results in excessive soil moisture depletions, yield can be reduced.

How Much Water Am I Applying?

Applying irrigation water efficiently requires knowing how much to apply, i.e. the soil moisture depletion, and how much is being applied during the irrigation. Irrigation scheduling answers the first. The second depends on the irrigation system.

Sprinkler Irrigation

Sprinkler irrigation is the easiest irrigation method to manage efficiently. The following procedure can be used to manage a sprinkler system for alfalfa irrigation:

1. Estimate the gross depth of water to be applied. The gross depth is the soil moisture depletion divided by the irrigation system uniformity (about 75% for a properly designed and maintained

wheel-line system).

Gross Depth = Soil Moisture Depletion/Uniformity

Example. Calculate the gross depth to be applied for a soil moisture depletion = 3 inches and a uniformity = 75%.

Gross depth = 3 inches/0.75 = 4 inches

2. Estimate the sprinkler application rate. Data needed are the flowrate of a single sprinkler head and sprinkler spacings. The sprinkler flowrate can be determined by dividing the irrigation system flowrate by the number of sprinkler heads, or by inserting a hose over a sprinkler nozzle and measuring the time to fill a 5 gallon bucket.

The following equation is used to calculate the application rate.

$$I = (96.3 \times q)/(Sl \times Sm)$$

where I = application rate (inches per hour),

q = sprinkler flowrate (gallons per minute),

Sl = spacing along lateral (feet),

Sm = spacing along mainline (feet).

Example. Calculate the application rate for a flowrate of 6 gallons per minute, a lateral spacing of 40 feet, and a mainline spacing of 60 feet.

$$I = (96.3 \times 6)/(40 \times 60) = 0.24 \text{ inches per hour.}$$

3. Calculate the depth of water applied by multiplying the application rate times the hours per irrigation set, or

Depth applied = I x hours per set.

Example. Calculate the depth applied for the above application rate and a 12-hour set time.

Depth applied = 0.24 x 12 hours = 2.9 inches.

Compare the depth applied with the gross depth to be applied. If they are about the same, then the irrigation efficiency is high. If the depth applied greatly exceeds the gross depth, overirrigation is occurring. If the depth applied is much less than the gross depth, deficit irrigation is occurring.

Border Irrigation

Border irrigation is the most difficult irrigation method to manage efficiently. These irrigation systems are capable of high irrigation efficiencies. However, their performance depends on complex interactions between soil infiltration rate, border flow rate, field length, slope, and surface roughness.

Most of these properties are very difficult to measure with any degree of reliability. Thus, border system management is somewhat of a trial-and-error approach.

A rough estimate of the evenness or the uniformity of the infiltrated water along the border length is to measure the time water is ponded at the upper and lower ends. If these times are about the same, then more or less the same amount of water infiltrated along the border length. If the ponded time is much larger at the upper end than at the lower, then the border flowrate should be increased to get the water to the end of the border faster.

The depth of water infiltrated into the soil at any location along the border length depends on the ponding time at that location and the soil infiltration rate. However, the soil infiltration rate is generally unknown, preventing an reasonable estimate of the infiltrated amount.

An alternative to estimating the depth of infiltrated water is to place tensiometers or gypsum blocks at several depths below the ground surface, and then read these instruments during and just after the irrigation. The maximum depth at which a response in the instrument reading occurs is the depth of wetting. Another approach is to periodically push a steel probe into the soil during the irrigation. The depth of penetration of the probe is the depth of wetting.

Summary

Maximum-profit irrigation requires knowing when to irrigate, how much to apply, and how much is being applied. Answering these concerns can result in more of the irrigation water being used by the crop, thus increasing profits.

Practices to be encouraged are:

1. Prevent soil moistures depletions from exceed 50% of the available soil moisture,

2. Schedule irrigations using the previously-mentioned methods,

3. Know the application rate of your sprinkler system,

4. Monitor water infiltration in border systems,

5. Start the first irrigation when about 50% of the available soil moisture has been used.

6. Do not delay irrigations to "promote" root development,

7. Irrigate as soon as possible after a cutting.

Table 1

Irrigation Scheduling Table - Days Between Irrigations
Alfalfa
Sacramento Valley

Root Depth (feet)	Jan	Feb	Mar	Apr	May	Ju	Jul	Aug	Sep	Oct	Nov	Dec
ET Rate (inches per day)												
	-	-	0.10	0.14	0.19	0.24	0.25	0.22	0.17	0.11	-	-
Coarse Sand (0.5 inch per foot)												
3	-	-	8	5	4	3	3	3	4	7	-	-
4	-	-	10	7	5	4	4	5	6	9	-	-
5	-	-	13	9	7	5	5	6	7	11	-	-
6	-	-	15	11	8	6	6	7	9	14	-	-
Fine sand, loamy sand (1.0 inch per foot)												
3	-	-	15	11	8	6	6	7	9	14	-	-
4	-	-	20	14	10	8	8	9	12	18	-	-
5	-	-	25	18	13	10	10	11	15	23	-	-
6	-	-	30	21	16	13	12	14	18	27	-	-
Sandy loam (1.5 inch per foot)												
3	-	-	22	16	12	9	9	10	13	20	-	-
4	-	-	30	21	16	12	12	14	18	27	-	-
5	-	-	-	27	20	16	15	17	22	-	-	-
6	-	-	-	-	24	19	18	20	26	-	-	-
Fine sandy loam, loam, silt loam (2.0 inches per foot)												
3	-	-	30	21	16	12	12	14	18	27	-	-
4	-	-	-	29	21	17	16	18	23	-	-	-
5	-	-	-	-	26	21	20	23	29	-	-	-
6	-	-	-	-	32	25	24	27	-	-	-	-
Clay loam, silty clay (2.2 inches per foot)												
3	-	-	33	24	17	13	13	15	19	30	-	-
4	-	-	-	31	23	18	18	20	26	-	-	-
5	-	-	-	-	29	23	22	25	32	-	-	-
6	-	-	-	-	-	28	26	30	-	-	-	-
Clay (2.3 inches per foot)												
3	-	-	-	25	18	14	14	16	20	[illegible]	-	-
4	-	-	-	33	24	19	18	21	27	-	-	-
5	-	-	-	-	30	24	23	26	-	-	-	-
6	-	-	-	-	-	29	28	[illegible]	-	-	-	-

NOTES:

1. The above values are based on irrigations occurring when 50% of the available soil moisture has been used. The available soil moisture is in the parenthesis for each soil texture.
2. For the months where no values are listed, irrigation scheduling should be based on soil moisture monitoring or on evapotranspiration estimates.
3. For the early part of the year, soil moisture monitoring should be used to determine the first irrigation. The values in this table then can be used to determine the times of subsequent irrigations. The easiest method to monitor soil moisture is to install a tensiometer at a depth of about one-quarter to one-third of the root depth and then irrigate when the tensiometer reading approaches 70 to 80 centibars.

Table 2

Irrigation Scheduling Table – Days Between Irrigations
Alfalfa
San Joaquin Valley

Root Depth (feet)	Jan	Feb	Mar	Apr	May	Ju	Jul	Aug	Sep	Oct	Nov	Dec
ET Rate (inches per day)	-	-	0.10	0.16	0.21	0.25	0.25	0.21	0.16	0.10	-	-
Coarse Sand (0.5 inch per foot)												
3	-	-	8	5	4	3	3	4	5	8	-	-
4	-	-	10	6	5	4	4	5	6	10	-	-
5	-	-	13	8	6	5	5	6	8	13	-	-
6	-	-	15	9	7	6	6	7	9	15	-	-
Fine sand, loamy sand (1.0 inch per foot)												
3	-	-	15	9	7			7	9	15	-	-
4	-	-	20	12	10	8	8	10	12	20	-	-
5	-	-	25	16	12	10	10	12	16	29	-	-
6	-	-	30	19	14	12	12	14	19	30	-	-
Sandy loam (1.5 inch per foot)												
3	-	-	22	14	11	9	9	11	14	22	-	-
4	-	-	30	19	14	12	12	14	19	30	-	-
5	-	-	-	23	18	19	15	18	23	-	-	-
6	-	-	-	28	21	18	18	21	28	-	-	-
Fine sandy loam, loam, silt loam (2.0 inches per foot)												
3	-	-	30	19	14	12	12	14	19	30	-	-
4	-	-	-	25	19	16	16	19	25	-	-	-
5	-	-	-	31	24	20	20	24	31	-	-	-
6	-	-	-	-	29	24	24	29	29	-	-	-
Clay loam, silty clay (2.2 inches per foot)												
3	-	-	33	21	16	13	13	16	21	33	-	-
4	-	-	-	27	21	18	18	21	27		-	-
5	-	-	-	-	26	22	22	26	-		-	-
6	-	-	-	-	31	26	26	31	-		-	-
Clay (2.3 inches per foot)												
3	-	-	-	21	16	14	14	16	21	-	-	-
4	-	-	-	28	21	18	18	21	28	-	-	-
5	-	-	-	-	26	23	23	26	-	-	-	-
6	-	-	-	-	[illegible]	28	28	31	-	-	-	-

NOTES:

1. The above values are based on irrigations occurring when 50% of the available soil moisture has been used. The available soil moisture is in the parenthesis for each soil texture.
2. For the months where no values are listed, irrigation scheduling should be based on soil moisture monitoring or on evapotranspiration estimates.
3. For the early part of the year, soil moisture monitoring should be used to determine the first irrigation. The values in this table then can be used to determine the times of subsequent irrigations. The easiest method to monitor soil moisture is to install a tensiometer at a depth of about one–quarter to one–third of the root depth and then irrigate when the tensiometer reading approaches 70 to 80 centibars.

Table 3

Irrigation Scheduling Table – Days Between Irrigations
Alfalfa
Central Coastal Valleys

Root Depth (feet)	Jan	Feb	Mar	Apr	May	Ju	Jul	Aug	Sep	Oct	Nov	Dec
ET Rate (inches per day)												
	-	-	0.11	0.15	0.18	0.21	0.22	0.19	0.16	0.12	-	-
Coarse Sand (0.5 inch per foot)												
3	-	-	7	5	4	3	3	4	5	6	-	-
4	-	-	9	7	6	5	5	5	6	8	-	-
5	-	-	11	8	7	6	6	7	8	10	-	-
6	-	-	14	10	8	7	7	8	9	12	-	-
Fine sand, loamy sand (1.0 inch per foot)												
3	-	-	14	10	8	7	7	8	9	12	-	-
4	-	-	18	13	11	10	9	10	13	17	-	-
5	-	-	23	17	14	12	11	13	16	21	-	-
6	-	-	27	20	17	14	14	16	19	25	-	-
Sandy loam (1.5 inch per foot)												
3	-	-	20	15	12	11	10	12	14	19	-	-
4	-	-	27	20	17	14	14	16	19	25	-	-
5	-	-	-	25	21	18	17	20	23	30	-	-
6	-	-	-	30	25	21	20	24	28	-	-	-
Fine sandy loam, loam, silt loam (2.0 inches per foot)												
3	-	-	27	20	17	14	14	16	19	25	-	-
4	-	-	-	27	22	19	18	21	25	-	-	-
5	-	-	-	-	28	24	23	26	30	-	-	-
6	-	-	-	-	30	28	27	31	-	-	-	-
Clay loam, silty clay (2.2 inches per foot)												
3	-	-	30	22	18	16	15	17	21	27	-	-
4	-	-	-	29	24	21	20	23	28	-	-	-
5	-	-	-	-	30	26	25	29	-	-	-	-
6	-	-	-	-	-	31	30	-	-	-	-	-
Clay (2.3 inches per foot)												
3	-	-	30	23	19	16	16	18	22	29	-	-
4	-	-	-	30	26	22	21	24	29	-	-	-
5	-	-	-	-	30	27	26	30	-	-	-	-
6	-	-	-	-	-	30	31	-	-	-	-	-

NOTES:

1. The above values are based on irrigations occurring when 50% of the available soil moisture has been used. The available soil moisture is in the parenthesis for each soil texture.
2. For the months where no values are listed, irrigation scheduling should be based on soil moisture monitoring or on evapotranspiration estimates.
3. For the early part of the year, soil moisture monitoring should be used to determine the first irrigation. The values in this table then can be used to determine the times of subsequent irrigations. The easiest method to monitor soil moisture is to install a tensiometer at a depth of about one–quarter to one–third of the root depth and then irrigate when the tensiometer reading approaches 70 to 80 centibars.

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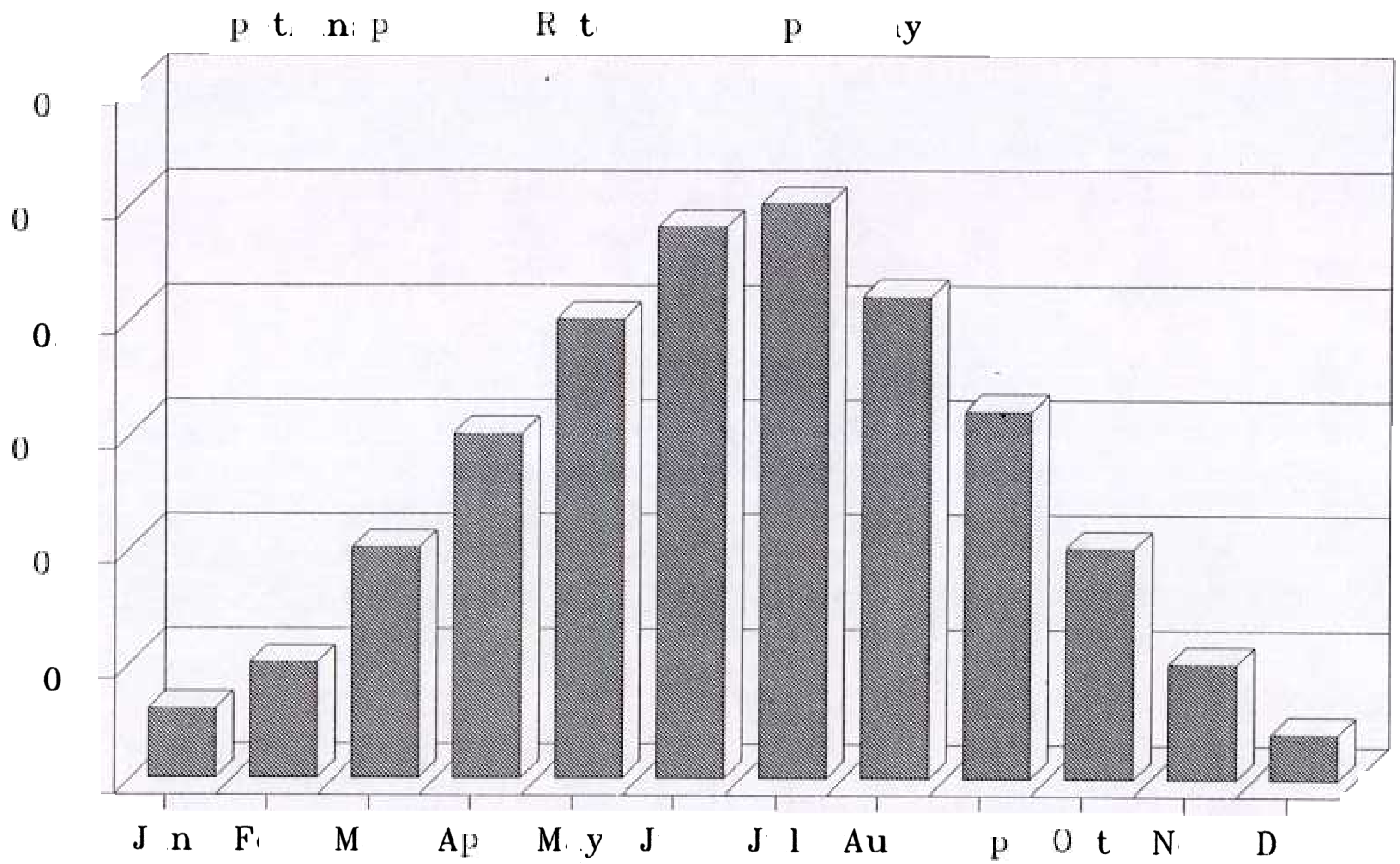

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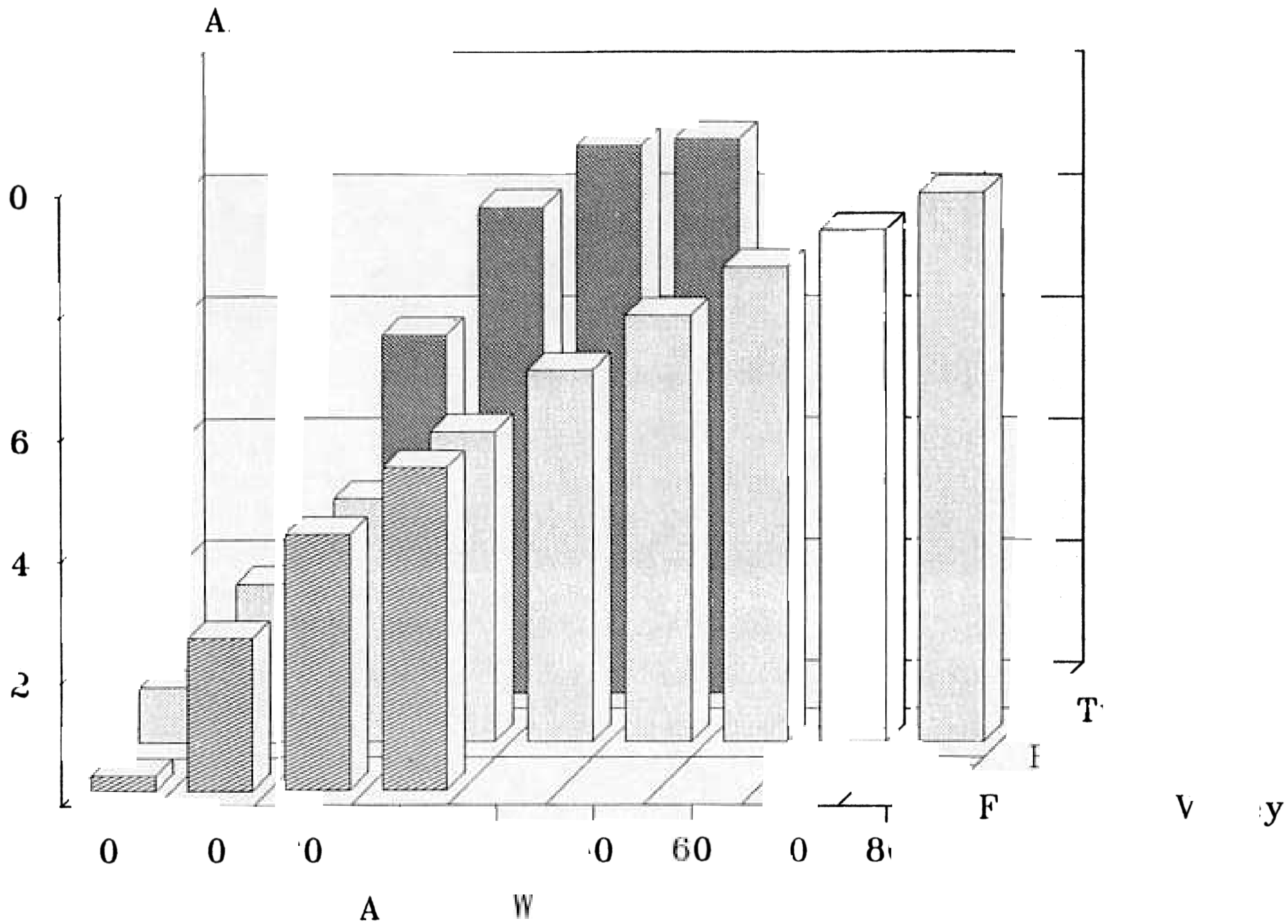

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