WHEAT RESPONSE TO WATER AND NITROGEN LEVELS

by

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SUMMARY

Super X and Mexicali wheat cultivars were grown using sprinkler irrigation on Superstition sand near Yuma. The water applied ranged from 12.1 to 29.0 inches and the nitrogen levels varied from 62 to 309 pounds per acre. Yield response was mainly a function of the amount of water applied. Maximum yields of 3¼ and 3½ tons per acre were measured for the Super X and Mexicali cultivars, respectively. Percent yellowberry was greatest where high water and low nitrogen was applied. Bushel weight was not greatly affected by either water or nitrogen levels. For yields of 2.5 tons per acre total nitrogen and phosphorus uptake was 200 and 40 pounds per acre, respectively. More studies will be conducted so that maximum yields can be obtained with minimum water and nitrogen applications. Colorado River water which averages 1000 ppm total soluble salts was used for irrigation.

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INTRODUCTION

Traditionally, the main crop on the Yuma Mesa has been citrus, and the method of irrigation has been flood. The amount of water applied per acre has been in excess of 10 feet per year because of the high infiltration rates and low water holding capacity of these sandy soils. Recently many of the citrus groves have been taken out of production because of difficulties with trees on Rough Lemon rootstock and the overall poor economic return of citrus. In most cases, alfalfa has been planted in groves that have been removed, but it requires about 12 feet of water per year with flood irrigation. Some growers have grown wheat; however, it normally requires 5 to 8 feet of water and 300 pounds of nitrogen to produce a 2.5 ton/acre yield. If other crops are to be grown on the Yuma Mesa, a more efficient irrigation system that will not waste water and fertilizer is needed. One such method is sprinkler irrigation.

Sprinkler irrigation has been used in many parts of the United States and even on the Yuma Mesa for many years. Some of the disadvantages of having to move the older sprinkler irrigation systems by hand have been overcome by the modern self-moving lateral and center pivot sprinkler systems.

New developments in self-moving sprinkler irrigation systems utilizing low pressure sprinkler, spray, or drop hose techniques show possibilities for saving energy, improving efficiency of water and fertilizer use, and using more saline water to irrigate crops that are salt sensitive. These new techniques in sprinkler irrigation have enlarged the possible combinations of soil, water and crops. This experiment was designed to evaluate water and nitrogen conservation using sprinkler irrigation on various agronomic and horticultural crops grown on the sandy soils of the Yuma Mesa.

The experiment is located on the University of Arizona Yuma Mesa Experiment Station. The farm land was developed when the Yuma Mesa Division, Mesa Unit, was initiated. The experimental field used in this study has been in limited research and was in alfalfa two years prior to initiating this project. The soil is a Superstition sand series. The infiltration rate of the soil is quite high, approaching 3 inches per hour, and the water holding capacity is low, less than one inch per foot.

PROCEDURE

The sprinkler irrigation system is a self-moving lateral system. The pumping plant straddles a concrete ditch to obtain a continuous supply of water. The versatility of the system makes it especially suitable for an irrigation and nitrogen management research study. Maximum speed of the system is 7 feet per minute and it can be operated at any speed between 5% and 100% of this maximum speed. This allows a range of water application of 0.2 inches to 3 inches of water. The sprinkler system can operate forward or reverse, with or without water.

A central composite rotatable statistical design with 2 variables, water and nitrogen, is used in this experiment. The water levels vary from 50% to 150% water applied (W.A.) and the nitrogen levels vary for 33% to 167% nitrogen (N) per acre. This statistical design can determine the crop response function (yield) for the two variables, water and nitrogen. Figure 1 shows a typical production function of 2 variables, water and nitrogen. As noted in this figure, the center point (100% W.A. and 100% N) is replicated 5 times.

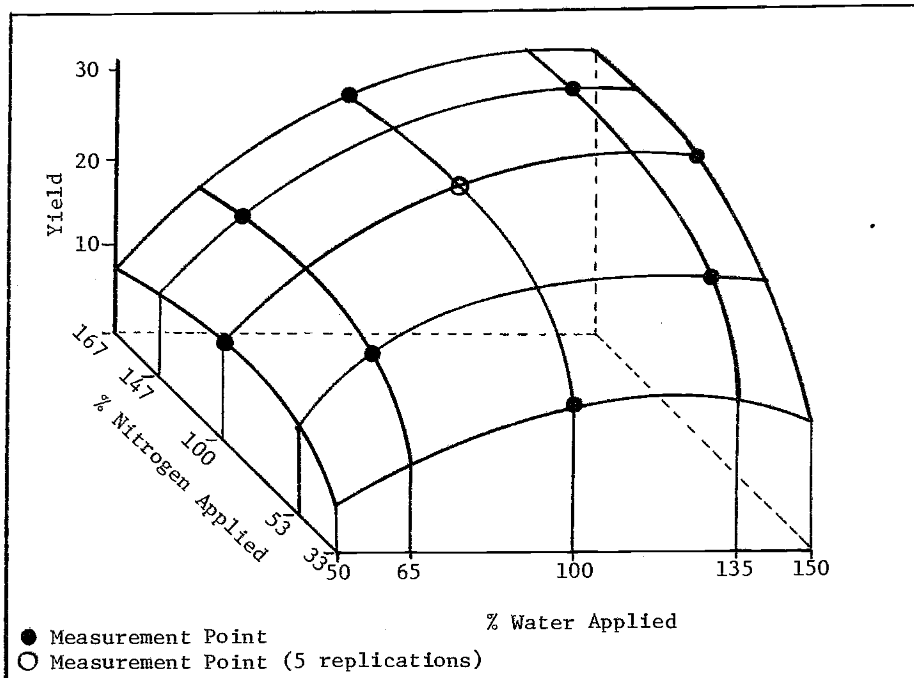

FIGURE 1. Production Function of 2 Variables Water and Nitrogen

The water and nitrogen rates specified in this design are:

TREATMENT	% W.A.	% N
1	50	100
2	65	53
3	65	147
4	100	33
5	100	100
6	100	100
7	100	100
8	100	100
9	100	100
10	100	167
11	135	53
12	135	147
13	150	100

Water applied in this experiment is defined as not only the unit or amount of water used on a given area for transpiration, the building of plant tissues, and evaporation from adjacent soils, but also that amount of water necessary to keep the total soluble salts in the soil at a desirable level and maintain an adequate yield.

A total of nine different levels of water and nitrogen combinations are defined by this statistical design with the center treatment replicated 5 times. This gives a total of 13 areas where different levels of water and nitrogen are applied. Each of these 13 water and nitrogen plots are 40 feet in length. The 13 plots were randomized down the crop row.

The sprinkler irrigation system was modified so that 3 separate spray lines are attached to the sprinkler system. One line is used to irrigate Replication 1 and the second line is used to irrigate Replication 2. The spray lines are designed to give each area its correct amount of water and nitrogen.

A third spray line was added which has a uniform water application the full row length. The different amounts of water applied is accomplished by using nozzles of different orifice size. Thus, the nozzles used in the 150% W.A. plots apply 3 times the amount of water as the nozzles used in the 50% W.A. plots. The amount of water applied during each irrigation is determined by measuring the time required to travel a selected distance. The different nitrogen application rates are accomplished by using different size orifices in each plot to meter the nitrogen into the irrigation water. Water samples are collected each week when the nitrogen is injected to verify that the correct rate of nitrogen is being applied. The amount of nitrogen applied per application varies from 10 to 60 pounds per acre by changing the machine travel speed from 100 to 15%. High nitrogen applications result in high water applications since both are controlled by the machine travel speed. The nitrogen fertilizer applied in the irrigation water raises the total soluble salts about 100 ppm.

Two cultivars of wheat were planted on December 16, 1980 at a rate of 110 pounds per acre and irrigated with the uniform spray bar to accomplish uniform germination and initial plant growth. The two cultivars of wheat were Super X, a hard red wheat, and Mexicali, a durum wheat. Both cultivars were planted in the same fields and both received the same irrigation, nitrogen, and cultural management. One month later, January 16, 1981, the variable spray bars were used to irrigate wheat until maturity. During the germination stage, 3.6 inches of water was applied. At the time of converting to the variable spray bars, nitrogen applications of 20 pounds per acre were applied each week until March 11. During germination and until February only two irrigations per week were applied. Three irrigations per week were applied from February until maturity because of increased water demand and low water holding capacity of the soil. The last irrigation was applied on April 28. The amount of water applied to the 100% treatment was 20.5 inches including the germination water. The amount of nitrogen applied to the 100% treatment was 187 pounds of nitrogen per acre. Both cultivars were harvested on May 5, 1981.

RESULTS

Results are shown in Table 1 for both wheat cultivars. The values shown are an average of both replications. Plant height increased with increased amounts of water and nitrogen. This also increased

TABLE 1. Summary of Wheat Results

Mexicali Cultivar

	inches water*	pounds nitrogen	plant height inches	percent lodging	yield tons/acre	percent protein	percent hard vitreous	bushel weight pounds
1	12.1	187	31.5a**	0a	1.7a	14.5 cd	98 b	60.3a
2	14.6	99	33.5ab	0a	2.0ab	12.0a	98 b	62.8a
3	14.6	275	33.0a	0a	1.5a	16.2 de	100 b	58.5a
4	20.5	62	36.5 bc	10a	2.5 bc	10.8a	86 b	61.3a
5	20.5	187	37.6 cd	30a	2.5 bc	14.1 bc	94 b	59.3a
6	20.5	309	36.8 bc	30a	2.4 bc	18.8 f	96 b	60.0a
7	26.4	99	36.0 bc	0a	2.9 cd	11.1a	31a	61.3a
8	26.4	275	37.8 d	50a	3.1 d	18.2 ef	80 b	62.0a
9	29.0	187	38.0 d	10a	3.5 d	12.5ab	45a	61.5a

Super X Cultivar

	inches water*	pounds nitrogen	plant height inches	percent lodging	yield tons/acre	percent protein	percent hard vitreous	bushel weight pounds
1	12.1	187	30.5a	10ab	1.6a	15.1 bc	98 b	58.0a
2	14.6	99	31.5a	0a	1.8a	11.1a	99 bc	60.3a
3	14.6	275	30.0a	0a	1.5a	16.2 cd	100 c	58.0a
4	20.5	62	37.3 b	10ab	2.6 c	11.1a	98 b	59.0a
5	20.5	187	35.7 b	30ab	2.2 b	13.9 b	99 bc	58.3a
6	20.5	309	35.5 b	50ab	1.8a	19.1 e	100 c	58.8a
7	26.4	99	35.5 b	10ab	3.0 cd	10.5a	86a	63.3 b
8	26.4	275	38.5 b	80 b	2.6 c	17.7 de	98 b	59.8a
9	29.0	187	38.5 b	40ab	3.2 d	14.5 bc	85a	59.0a

*Includes 3.6 inches germination water.
**Means followed by the same letter are not significantly different at the 5% level.

the tendency for plant lodging. The highest percent of plant lodging was measured in Treatment 8 for both wheat varieties.

The measured wheat yields in tons/acre are shown for each cultivar in Table 1. The data collected from each cultivar were fitted by regression to a quadratic equation. This quadratic equation is used to predict the yield for all levels of water and nitrogen applied in this study. The yield contours in tons per acre are shown in Figure 2 for the Mexicali cultivar. The equation used to predict these values is:

$$YIELD = 2.508 + 0.631W - 0.039N + 0.006W^2 - 0.069N^2 + 0.151WN$$

R = 0.856** LOFF = 1.308ns F = 10.96** STD. ERROR = 0.348 tons/acre

** = 99% confidence interval LOFF = lack of fit F ns = no significance

Where: W = water level
N = nitrogen level

As noted in Figure 2, the yield was mainly affected by the amount of water applied. The more water that

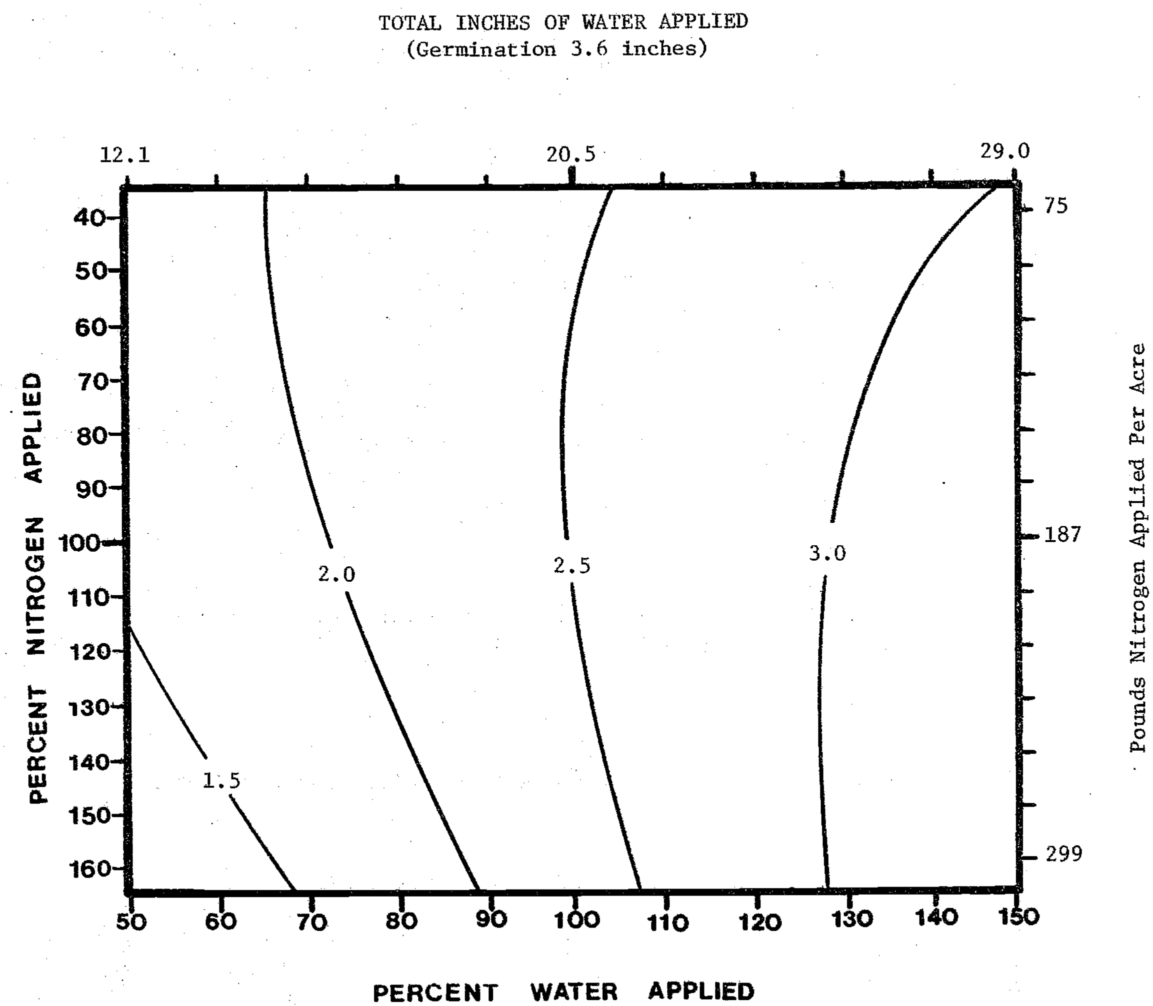

FIGURE 2. Yield Contours of Mexicali Wheat in tons/acre, Spring 1981.

was applied the greater the yield. Maximum yield was not obtained with the scheduling and levels of water and nitrogen used. If maximum yield is to be obtained, more water will need to be applied and nitrogen will probably need to be applied more frequently than once a week. It appears that the nitrogen was leached when high levels of water were applied. Similar results were obtained from Super X.

The percent protein of the wheat was calculated by multiplying the total percent nitrogen by 5.7. The total percent nitrogen was determined by the Kjeldahl method. The average value of percent protein for each cultivar is shown in Table 1. The percent protein is mainly a function of the amount of nitrogen applied. The percent protein increased with greater amounts of nitrogen applied regardless of the amount of water applied. At the higher levels of N applied, there probably is a substantial amount of inorganic N in the grain that has not been incorporated into protein. This would account for some of the very high "protein" values obtained.

The percent hard vitreous Mexicali seed was below the acceptable level of 75% when high water and medium to low nitrogen levels were applied (see Table 1 for Treatments 7 and 9). Values of 31% and 45% were measured for Treatments 7 and 9, respectively. This same trend is also observed in the Super X cultivar where Treatments 7 and 9 were approximately 10% less than the other treatments. However, all treatments for the Super X cultivar were above the 85% level. These data agree with previously reported data that percent yellowberry increases with lower levels of nitrogen and high levels of water. The bushel weights for each cultivar and treatment are shown in Table 1. Statistical analyses of these data indicated little or no differences due to water or nitrogen treatments.

The nitrate levels from Super X wheat stems in ppm are shown in Table 2 for each treatment and several sampling dates. Values of less than 2000 ppm for each treatment are considered to be deficient.

TABLE 2. Nitrate Levels from Wheat Super X Stems in ppm

Treatment	Inches Water	Pounds Nitrogen	Days from Planting (December 16, 1980) 41	57	69	84	97
1	12.1	187	7400 ef*	4000 bcd	500a	100a	0a**
2	14.6	99	5400 c	2700abc	600a	300a	0a
3	14.6	275	6900 e	5400 cd	4000 b	3400 b	1500 b
4	20.5	62	4600 b	800a	300a	0a	0a
5	20.5	187	6300 d	4800 cd	2200a	1400a	430a
6	20.5	309	7600 f	5900 d	5800 b	4400 b	1900 b
7	26.4	99	3400a	1400ab	900a	500a	0a
8	26.4	275	5500 c	2300abc	780a	450a	250a
9	29.0	187	4100 b	2400abc	750a	380a	0a

*Means followed by the same letter are not significantly different at the 5% level.
**Values underlined are considered deficient when less than 2000.

All but 2 treatments were nitrogen deficient 69 days after planting. If maximum yield is to be obtained, nitrate levels in the stems need to be above 2000 ppm when higher levels of water are applied. This may require applying nitrogen during each irrigation rather than once a week.

Total nitrogen and phosphorus uptake in pounds per acre are shown in Figure 3 for Treatment 5 where the yield was about 2.5 tons per acre. Total nitrogen uptake was about 200 pounds per acre and phosphorus uptake was 40 pounds per acre. If greater yields are to be obtained by applying more water, nitrogen uptake will probably increase.

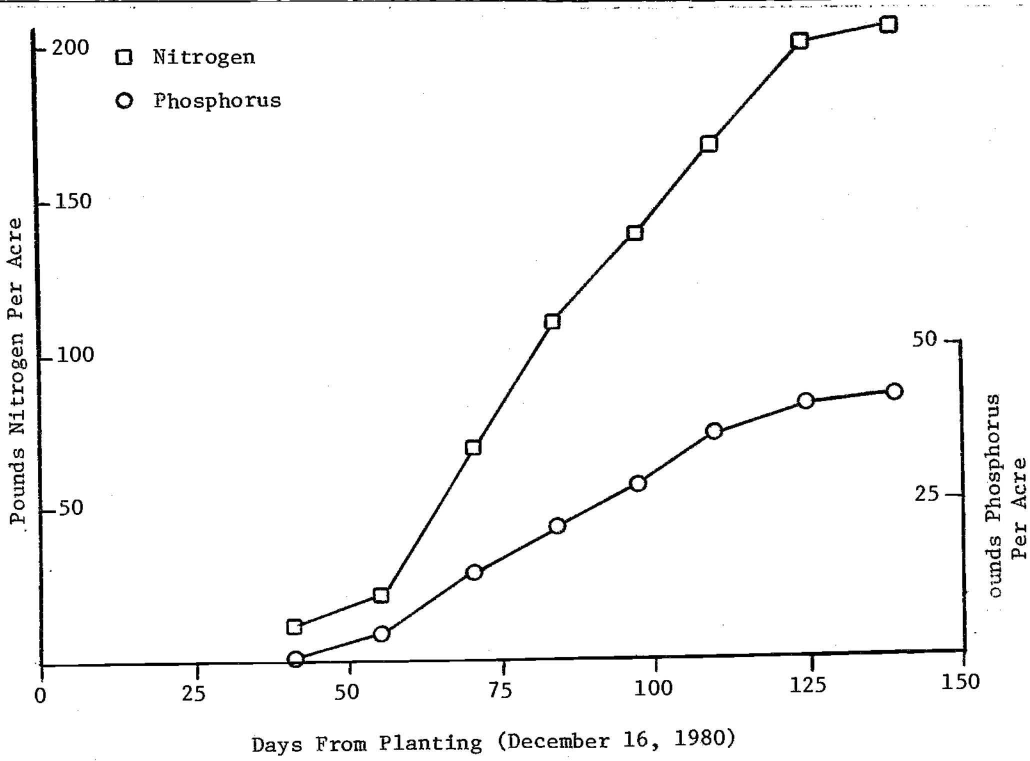

FIGURE 3. Total Nitrogen and Phosphorus Uptake of Super X in the 100% W.A. and 100% N Treatments