BAILEY, WILLIAM RUSSULL, JR.

EVALUATION OF ONION (ALLIUM CEPA L.) YIELD USING RESPONSE SURFACE DESIGN, GROWN UNDER MULTIPLE CONTROLLED CULTURAL FACTORS

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EVALUATION OF ONION (*ALLIUM CEPA* L.) YIELD USING RESPONSE SURFACE DESIGN, GROWN UNDER MULTIPLE CONTROLLED CULTURAL FACTORS

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William R. Bailey, Jr.

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STATEMENT BY AUTHOR

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SIGNED: William R. Bailey Jr.

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Paul M. Bessey
PAUL M. BESSEY
Associate Professor of
Plant Sciences

Dec. 7, 1984
Date

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ABSTRACT

The effects of water frequency, spacing, fertilizer, pesticide, herbicide, and harvest date on the response of onion (*Allium cepa* L.) cultivar 'Granex 429' in the 1983-84 season under field conditions at the University of Arizona Experiment Station at Tucson.

Water levels showed quadratic effects at intervals ranging from 2 to 12 days on total yield. Large-bulb yield showed a positive linear response.

Spacing showed linear effects on yield at spacings ranging from 0.5 to 4.5 inches. Total yield was negatively and large-bulb yield was positively correlated.

Fertilizer showed positive linear response on total yield and large-bulb yield. Levels ranged from 0 to 594 lb N/A.

Harvest date showed positive linear response on total and large-bulb yield with dates ranging from May 27 to June 16.

Pesticide and herbicide were insignificant at any level.

The design used in the experiment was response surface.

CHAPTER 1

INTRODUCTION

The common onion (Allium cepa L.) has been in cultivation for more than 5,000 years. Its origin is thought to be in Iran and western Pakistan and the mountainous region to the north. The onion is used by most people on a daily basis, although not usually in large quantities. The onion is consumed for a wide range of uses, from fresh on a hamburger to onion powder for seasoning, and more recently, the use of the onion to make fried onion rings. No other vegetable has such a wide variety of usages.

For the farmer, the main concern is to grow the best quality crop in the largest possible quantity or yield, and get that crop onto the market as soon as possible while prices are high before the market is flooded. To accomplish this, the grower must have a very good understanding of his particular crop. With this knowledge, the grower can manipulate his particular situation and produce the crop that he desires and have it harvested at the time he estimates to be best for him and his crop.

Under present cultural practices, a yield of 310 hundred-pound sacks per acre is considered average according to Knott's handbook. If we look at the factors which we consider to most affect the yield of the onion, and look at several factors at the same time, we can find the optimum level for each factor and therefore optimize the yield by studying the interactions.

The purpose of this study is to increase the yield of bulbing onions in a field situation by looking at several cultural factors or practices and how they interact with each other to produce a certain yield. The cultural factors which were considered to most affect yield were water, nitrogen rate, plant spacing, herbicide effect on onion seed, pesticide on thrips and the harvest date. These were looked at on onion yield of cultivar 'Granex 429' under the conditions of the Southwest, particularly Arizona.

Response surface design was used to evaluate the effects of these factors and their interactions since it gives the most information and insight with the fewest number of plots. This design can only be used to the fullest extent if the factors looked at simultaneously are shown to be maximized within the confines of the study.

CHAPTER 2

REVIEW OF LITERATURE

Water Effect on Yield

The effect of water at differing levels has been of interest longer than any other factor influencing crop yield. Since it now appears that water will become increasingly valuable in the future, water will continue to be of major importance. The use of water to its full potential without wasting significant amounts is the direction that water-use problems must take.

Mortenson and Hawthorn (1933) reported the effect of different irrigation levels on the yield of onions. They used a range of from 6 to 16 irrigations over the season to grow a crop. They reported that the yield of marketable onions and also of U.S. No. 1 onions decreased at a steady rate as the number of irrigations increased.

Irrigation was being looked at for use in midwest areas such as Iowa by Erwin and Haber (1934). They used the onion cultivars 'Riverside Sweet Spanish' and 'Southport Yellow Globe.' The irrigated plots received 8.2 acre inches average over the plots receiving only native rainfall. 'Southport Yellow Globe' showed a 69.6 percent increase in yield over check, and 'Riverside Sweet Spanish' showed an 89.1 percent yield increase over the control.

Curry (1937) did work with different levels of irrigation on onions at the New Mexico Agricultural Experiment Station. He used the 'Early Grano' cultivar and was interested in the effects of the irrigation on the production of U.S. No. 1 bulbs. Curry reported that the highest yields of this grade came in those plots receiving the heaviest irrigation.

Hawthorn (1938) tended to agree with Curry that the best yields could be obtained with more frequent irrigations. He studied irrigation effects in Texas on the 'Yellow Bermuda' bulbing onion. Hawthorn went further in his conclusions that the irrigations which would produce higher yields would be light-frequent rather than heavy-frequent irrigations.

MacGillivray and Doneen (1942) note that the water requirements of a crop and its ability to overcome over- or under-watering will depend on soil type, evaporation rate, temperature, type of crop, and amount of native rainfall. They concluded that a crop like onions could be grown satisfactorily in eastern states with one acre inch of water while the west and southwest may require several acre inches at each irrigation.

Doneen and MacGillivray (1946) did further studies with onions and other commercial truck crops at the California

Agricultural Experiment Station. The study was done with the onion cultivar 'Australian Brown.' They used a dry treatment and three irrigation level treatments and found that the dry treatment produced 49.4 percent of U.S. No. 1 bulbs compared to 90 percent for all three irrigation treatments. It was reported that onion quality was not affected.

MacGillivray (1950) again looked at onion yield as affected by irrigation, this time using six varieties including 'Early Grano,' 'Stockton Yellow Globe,' 'Southport White Globe,' 'Australian Brown,' 'Sweet Spanish' and 'California Early Red.' Dry, medium and wet irrigations were 0, 6.6 and 11.2 inches of water, respectively. All irrigations were significantly higher than the zero treatment, but medium and wet were not different statistically in 'Early Grano' and 'Australian Brown.' U.S. No. 1 onions were significantly higher in the high irrigation as compared to either medium or zero levels. As a result of insufficient moisture, bulbs matured earlier. The response to higher irrigations was explained by the shallow root system of the crop.

Using two hybrid varieties, 'Asgrow Y-41' and 'Y-42,' Drinkwater and Janes (1955) used four irrigation levels to study their effect on yield. The four irrigations used were: no irrigation, heavy and infrequent (1.0 inch every 10 to 12 consecutive rainless days), light and frequent (0.25 inches every 4 to 5 consecutive rainless days), and heavy and frequent (0.5 inches every 4 to 5 consecutive rainless days). Non-irrigated matured first followed by heavy and infrequent, light and frequent, and last to mature was heavy and frequent. Heavy and frequent gave higher yields of U.S. No. 1 bulbs than any other treatment.

Jones and Johnson (1958) used a series of soil moistures to find the optimum level for onion and potato yield. For the onion plots, the irrigation of every 4.3 days on the average gave the higher yields as compared to the 9.8-day interval of irrigation.

Bradley (1960) studied the effects of the irrigation on onions, potatoes, and snap beans. The soil moisture was held at 50 percent available soil moisture and downward. There was a direct relationship shown between available soil moisture at the time of irrigation and the yield of onions. This increase in yield at higher moisture levels was due to increased bulb size, not population.

Others have done work with moisture stress at different times. Ponce, DeLis, Cavagnaro, and Tizio (1967) worked with onions in this way using early, continual light stress, or late stress. In their work, they found that drought treatment at the beginning of bulb formation, or late stress, induced a significant 30 percent reduction in yield over that of the maximum yield.

El-Tabbakh, Behairy and Behairy (1981), using the onion cultivar 'Behairy,' studied onion yields as related to irrigation intervals of 2, 3, 4 or 5 weeks over a 12-week period. Intervals of three weeks gave higher yields than either 2, 4 or 5 weeks. The 2-week and 5-week intervals were reported to dwarf the plants and reduce the dry matter.

Bucks, Erie, French, Nakayama, and Pew (1982), using subsurface trickle irrigation, studied the response of onions to different irrigation levels in the Phoenix area. They concluded that the onion would respond most favorably under a daily irrigation level. Highest yields were obtained at water application rates equal to or slightly higher than the seasonal evapotranspiration values determined with furrow irrigation methods.

Herbicide Effect on Yield

The effect of pre-emergence herbicide on seed of the crop already planted has been covered quite thoroughly in the literature. Since the seed coats of crop plants are similar to those of weeds to be treated, the effect of herbicides on crop seeds, through leaching of the chemical spray, can be damaging to the crop as well as to the undesirable plants.

Ogle first noted in 1954 that there was an interaction between herbicidal movement and soil type. Application of the same herbicide at the same concentration will have dramatically different effects on a sandy soil versus a clay soil.

The herbicide in a sandy soil is easily leached due to less adsorption to sand particles than clay particles and can easily reach the zone of the onion or other crop seed in the row.

Also in 1954, Guzman and Wolf did work on 'Texas Early Grano' onions and pre-emergence herbicide treatments including 2,4-D, NIX, diesel, stoddard solvent, CIPC, and oktone. All the herbicide treated plots were significantly different from the hand-weeded check. The check gave 521 lb/plot as compared to 395 for CIPC, 401 for 2,4-D, 386 for NIX, 392 for diesel, 321 for stoddard solvent, and 376 lb/plot for oktone.

Guzman and Wolf did work in 1955 on pre-emergence herbicides on 'Granex,' 'Texas Early Grano,' and 'Early Grano.' CIPC was applied at 12, 16, and 20 lb/A. There were differences in the stand of onions at 28 days and an effect on growth of up to three months after treatment, but no significant difference in total yield at the end of the experiment.

Wolf and Guzman again studied the three varieties of onions by CIPC pre-emergence in 1955. This time the CIPC treated plots produced higher yields than the hand-weeded check. This study was on a muck soil which adsorbs herbicides much better than arid soils as was earlier noted.

Dallyn, Sawyer, and Hallburton (1955) and Lachman, Michelson and Allen (1958) both reported extensive damage to the onion crop due to the addition of a pre-emergence application of CIPC. These studies showed that the soil type and the amount of water available for leaching can make the difference between damage to the crop and good efficient weed control.

EPTC (Ethyl N, N-di-n-propylthiolcarbamate), a pre-emergence herbicide used on oat crops, was shown to cause injury to oats in a study reported by Ashton and Sheets (1959). They showed that the amount of herbicide needed to cause 50 percent loss of fresh weight differed depending on the soil type. The amount which caused injury was less with a sandy soil and increased through sandy clay loam, clay loam, silty clay and clay. The soil particles of the latter could more easily adsorb the herbicide and make the ppm necessary for injury to be increased.

Frank and Waywell (1970) studied the effect of pre-emergence herbicide on a tomato crop. The research involved the use of diphenamid and pebulate as herbicides. Pebulate at any level caused injury to top weight in tomatoes compared to control and for any treatment level over 4 lb/A for diphenamid. The weight of roots of tomato plant was significantly altered with the use of diphenamid or pebulate at rates above 4 lb/A in 120 gallons of water.

The use of CIPC (Isopropyl N [3-Chlorophenyl] Carbamate) as a pre-emergent herbicide was further studied by Hiller and Weigle (1970). The onion types were 'Iowa Yellow

Globe,' 'Brigham Yellow Globe,' 'Crookham,' 'Yellow Sweet Spanish,' 'Peckham,' 'Downing Yellow Globe,' and 'Trapp.' CIPC significantly reduced yield in 'Yellow Sweet Spanish,' 'Peckham,' 'Downing Yellow Globe,' 'Trapp' and 'Iowa Yellow Globe.' The other two varieties were not significantly affected by CIPC. Even some inbreds of the same variety reacted differently to CIPC applied pre-emergence.

Talbert and Kennedy (1973) reported a series of experiments of herbicides in vegetable crops. In okra, the use of trifluralin gave superior weed control, but the okra crop was damaged giving a yield reduction of 22 percent compared to a less effective yet safer herbicide, diphenamid. Spinach and snap beans showed damage to crop yield as compared to hand-weeded check. Hercules 22234 used on spinach did not show any difference in yield even compared to the weedy check. With snap beans, this was true for many of the herbicides evaluated, including oryzalin, fluorodifen and chloramben.

The effect of acifluorfen used pre-emergence on peas, snap beans and lima beans was evaluated by Teasdale and Frank (1983). Acifluorfen tended to reduce snap bean and lima bean fresh weight significantly at all rates applied over control. Both stand and vigor were reduced. The shoot cracked the soil surface but died before completing emergence, probably due to acifluorfen becoming phytotoxic in the light. Total yield was reduced at the 4.5 kg/ha level.

Griffin, Jung, and Hartwig (1984) studied the effect of pre-emergence herbicide on yield of Brassica species, turnip and rape. Metolachlor, acetamidel, pendimethalin, and nitrofen were used in the study. Pendimethalin at 2.2 kg/ha was phytotoxic to both turnips and rape reducing yield 67 and 17 percent respectively compared to untreated. Pendimethalin and nitrofen together caused a decrease in yield, 3590 kg for control versus 1180 kg for combination for turnips. This combination also reduced yield of rape 3790 for combination versus 4540 kg for control.

Fertilizer Effect on Yield

One of the early studies on the fertilization of onions with nitrogen was done by Killen (1900). The two plots were unmanured versus a complete fertilizer containing 4 percent N, 8 percent phosphoric acid, and 10 percent actual potash at a rate of 1,000 lb/A. The yield for fertilized plots was 353 bushels against 105 bushels for the unfertilized.

Kunkel (1947) used treatments of nitrogen fertilizer with half from ammonium sulfate and half from nitrate of urea. The levels were 0, 40, 80, and 40 + 20 lb N/A sidedress later. The only significant difference at the 5 percent level of probability was between 80 and 0 and between 40 + 20 and 0 lb N/A fertilizer. At the 1 percent level the 80 lb N/A was the only level significantly different from the 0 application.

Using 'Granex,' 'Texas Early Grano' and 'L303' cultivars, Paterson, Blackhorst and Siddiqui (1960) studied the effect of nitrogen fertilizer on yield. Their levels were 0, 50, and 100 lb/A of nitrogen from ammonium nitrate. All three showed a highly significant increase in yield from 0 to 50 lb/A of nitrogen but a decrease when going from 50 to 100 lb/A of nitrogen.

Quedding, Rodigo and Lazo (1963) used several different fertilizers on onions to evaluate yield. Their levels were 750, 1000, and 1250 kg/ha. The differences among the three were insignificant relating to yield. It was stated in their conclusions that this was due to excessive fertilizer at all three rates.

Laso, Queddend and Caliwag (1969), using ammonium sulfate as the fertilizer, applied three levels of nitrogen, including 50, 100, and 150 kg/ha. The yields were 16.86, 21.64, and 20.67 tonnes/ha, respectively. The 100 kg/ha yield was significantly higher than either of the others at the 5 percent level.

The fresh weight of bulbs, plant height, diameter of bulbs and total yield were studied as affected by nitrogen fertilizer by Pande (1969). Four levels of nitrogen were used including 0, 56, 112, and 168 kg/ha of nitrogen. Increasing levels of nitrogen continued to increase the yield of onions up to and including 168 kg/ha. The best economic yield of the four levels was 112 kg/ha.

Singh and Singh (1969) used a three-level experiment with nitrogen to assess its effect on onion yield, using 84, 168 and 252 kg/ha. Their results showed no significant difference among any of the three levels; and in fact, the 84 kg/ha of nitrogen was the highest-yielding treatment.

Lazic (1971) studied onion yield as affected by nitrogen over a three-year period. The rates were 50, 70, and 100 kg/ha of nitrogen. The best yields were obtained with 70 kg/ha giving 102.7 g/bulb average.

Pande and Mundra (1971) studied the response of the bulbing onion to varying levels of N, P, and K. They were interested in the fertilizer effects on several different plant characteristics, such as plant height, number of leaves, length of bulbs, diameter of bulbs, fresh and dry weight of top growth, and yield of bulbs per hectare. Application of nitrogen over control increased all of these characteristics significantly.

The influence of nitrogen fertilizer on onion yield was also studied by Randhawa and Daljitsingh (1974) using 0, 75, and 150 kg/ha of nitrogen. The 150 kg/ha nitrogen application produced the highest yield of the three treatments, significant over only the 0 treatment. The 150 and 75 kg/ha were not significantly different.

Hassan and Ayoub (1978) evaluated the 'Nasi' cultivar bulbing onion in relation to nitrogen effect on yield. The rates were 0, 90, and 180 kg/ha nitrogen. The 90 kg/ha gave a yield of 20.4 kg/ha of onion yield, while the higher nitrogen level of 180 kg/ha gave only 19.6 kg/ha onion yield. Both were higher than the 0 treatment level.

Villagran and Escaff (1983) studied the effects of spacing and nitrogen fertilizer on onion yield of the 'Valencia' cultivar. They looked at five levels of nitrogen to include 0, 30, 60, 90, and 120 kg/ha. Market yields increased linearly with increasing nitrogen application. There was said to be no interaction of the fertilizer on spacing of the onions.

Patil, Mahorkar, and Patil (1983) also studied the effect of nitrogen on the yield of bulbing onions. They looked at three levels of nitrogen application including 0, 75, 150 kg/ha. As with Villagran and Escaff, the yields simply increased linearly with increasing nitrogen application.

Pesticide Effect on Yield

The onion thrips (*Thrips tabaci* Lindeman) has been reported in the literature since the very early 1900's. With today's insecticides, the onion thrips have become somewhat less of a problem; and in some researchers views, the thrips pose no threat to onion production at all.

It has been shown that the first two nymphal stages feed in the protected chit of the plant. The last two nymphal stages are passed in the soil at the base of the plant. After developing to the adult stage, the thrips will feed over the entire plant. The males are scarce and wingless in the thrips population. The adult females are winged, very active, and produce large numbers of offspring. The eggs are laid in the tissue of the onion plant near the bases of the leaves. (Jacks, Harrison, and Dawe, 1954).

Early entomologists discovered the workings of the thrips and how they reduce yields and their relationship to non-setting of fruit. The mouth parts are described as being used almost entirely for sucking or intermediately between sucking and chewing (Borden, 1915). They begin feeding by forward and backward movement of the head; and by this rasping movement, they puncture epidermal cells of the plant. They feed on the plant juices in this area and then move on up and down the onion leaf blade, leaving dead areas with a silvery glow behind.

In 1929, Boune found that the control of thrips on onions was more thorough when a spray was used rather than a dust as had been used earlier. The dust could not get to the axils of the inner leaves or "chits" where the largest percentage of thrips were inhabiting. Since 80 to 90 percent of the population could be found here, it was desirable to have a liquid which could more effectively reach the area than a dust. Due to the waxy surface of onion leaves, the chemical should have good adhesive and spreading qualities.

Studies at Cornell University in 1944, by Ewart et al, reported the use of tartar emetic as an insecticide to control the population of thrips in onions. Thrips per plant were 15.1, 9.1, 10.0 and 51.5 (check). Although these were significant, the bu/A yields of 493, 489, 515, and 535, respectively, were not significantly different. In the summary, Ewart stated that insect populations were so low that reductions in the already low numbers resulted in little or no correlation with yield. He concludes that levels do not reach damage proportions in certain years due to natural factors, and those levels do not warrant the cost of labor and material to be applied. The suggestion was made that it is economically sound in years of high infestations or with high-value crops or ones used for seed production.

Chapman et al, in 1945, studied the control of thrips using DDT. The insecticide was used as a 5-10 percent dust and the numbers of thrips were controlled. No yield data was shown due to the onions being pulled early to take advantage of a favorable market.

Douglass and Shirk, in 1949, stated that thrips are the major limiting factor in onion production in Idaho. The reductions in thrips population and number of surviving thrips were not closely correleted with yield response, although check yields were 179 hundred-lb bags/A versus DDT + nicotine sulfate giving 256 hundred-lb bags/A. They concluded that it was not clear as to whether or not plant growth was affected by treatment of chemicals alone.

A study using chlordane, DDT, toxaphene, parathion and others was carried out by Willcox and Howland, 1950, in the Coachella Valley, California. Adults were controlled significantly from 2.1 for chlordane to 5.2 for the check. The yields on the other hand showed no significant difference, with the least number of adults giving 414 fifty-lb sacks/A and the check giving 355 fifty-lb sacks/A.

Richardson used a variety of insecticides to control thrips in Texas in 1953. The chemicals ranged from DDT to malathion. Malathion reduced thrips by the greatest amount, 84 percent. This study showed that a reduction in thrips did increase yield, from 409.2 hundred-lb sacks/A with insecticide to 362.5 without. Although, the number of thrips did not always correlate across with a proportional yield, 29 thrips/plant gave 409.2 hundred-lb sacks/A, 44.1 gave 389.2 sacks, and 69.2 gave 404.0 hundred-lb sacks/A.

The following year, similar studies were conducted; and of the phosphate insecticides, malathion was again the most effective over such sprays as parathion, methyl parathion, and metacide to name some. This time, although reductions in thrips numbers were highly significant, there was no mention of yield difference or significance. Data showed LSD values for comparing check and other treatments, such as heptachor, were not statistically different.

Shirck and Douglass reported in 1956 the use of DDT, toxaphene, parathion and chlordane and their effect on 'Yellow Sweet Spanish' and 'Yellow Globe' onions. The '48-'49 experiment showed no significance in relation to yield, but the '49-'50 experiment did show significance of the thrips control to onion yield.

In 1961, Harding reported a highly significant difference in the number of thrips per plant using malathion at 7- 14- 21-day intervals. This gave thrips counts of 98, 176 and 223 respectively with 429 for the untreated check. The yield was not significantly correlated giving 30,129 lb/A; 31,363 lb/A; 30,274 lb/A; and 32,307 lb/A for untreated.

Getzin reported, in 1973, that several researchers had noted that onion thrips do not reduce yield unless the insect population is severe. L. E. Sandvol, from the University of Idaho, conducted studies on onion thrips and their relationship to onion yield and concluded that thrips will not affect yield levels unless severe infestations develop at an early point in the growth of the plants.

Plant Spacing Effect on Yield

Plant spacing of onions has been under consideration for its effect on yield since the 1800's. The effects of competition between crop plants at different distances is of major importance to the study of cultural practices and methods on yield.

One of the earliest notations in the literature of the effect of plant spacing was by Sharpe (1898). He advised that the plant should be spaced in rows at about 3 1/2 to 4 inches. He found that closer plants matured faster and developed seed stalks quicker than plants spaced farther apart.

Janes (1929) studied dry bulb onions and used spacings of 3, 4, 6, 8, and 12 inches apart on 18-inch beds. Average weight per bulb increased from 0.395 for the 3-inch spacing up to 0.780 pounds per bulb for the 12-inch spacing. The yield in pounds per acre decreased from the 3-inch to the 12-inch spacing. Yield was 45,612 lb/A for 3 inches and down to only 21,796 lb/A for 12-inch spacing. He also noted that the farther spaced, the longer the delay in maturity.

Swynnerton (1949) found that the spacing of 4.5 inches gave the highest yields compared to wider spacings. This was conducted in the east African area.

Bleasdale (1966) concluded that the yield of direct seeded onions increased as row spacing decreased or plant density increased. A 12-inch row spacing gave 30 percent higher yield than 18-inch rows. It was concluded that optimum density for yield proved to produce too small an onion for normal market purposes, although they could be pickled. He states that it is best to grow onions at densities below optimum yield.

In Tasmania, as elsewhere, the requirement for onions is mainly that of 5 cm in diameter or greater. This was researched by Frappell (1973). Maximum production of this range occurred at 70 plants/m^2, but this represented only 80 percent of potential yield. At 90 percent of total yield, there was a 156 plant/m^2 population required. This only gave somewhat less than half of the bulbs in the desired range. It was concluded that there must be an acceptance in yield reduction to increase the number of 5 cm, or larger, bulbs produced.

Eunus, Kamal, and Shahiduzzaman (1974) used spacings of 5, 10, 15, and 20 cm on 20 cm rows center to center. The 5 cm spacing gave the highest yield of onions over all other spacings. The 10 cm spacing was observed to be the best overall, giving good yields and bulbs with fewer defects. The 5 cm spacing produced small bulbs and poor shapes due to crowding.

Randhawa and Daljitsingh (1974) varied the intra-row spacing while keeping the inter-row spacing at 15 cm. The spacings were 10, 15, and 20 cm. The maximum yield was found to be at the 15 x 10 cm spacing. The difference was only significant over the 20 cm spacing, not the 15 cm spacing.

The effect of closer spacing on increased yield was further shown by Saeed and Ahmad Gill (1977). Inter-row spacings were 9, 12, and 15 inches and intra-row spacings were 3, 4 1/2, and 6 inches. The highest yield came from a 9 x 3 plot of 31.83 lb/plot as compared to the lowest of 16.45 lb/plot for 15 x 6-inch spacing. Average bulb size was highest for 15 x 6 and lowest for 9 x 3-inch spacing, giving 5.98 cm and 3.73 cm average, respectively.

Hassan (1978) studied spacing of onions using three inter-row spacings and three intra-row spacings of 50, 60, and 70 cm and 5, 10, and 15 cm, respectively. Inter-row spacing had no effect on yield but the intra-row spacing was significant. The 5-cm spacing gave 20.31 tonnes/ha followed by 19.71 and 17.52 tonnes/ha for 10- and 15-cm spacings. Hassan also reported that the close spacing produced onions with an average bulb weight of only 116 g.

Brewster and Salter (1980) reported that yield increased with plant density up to 129 plants/m^2. This was obtained using a distance of 30 cm between beds. They concluded that a plant density of 88/m^2 would produce the largest number of ware bulbs, or bulbs greater than 4.5 cm in diameter. It was concluded that the production of ware bulbs could be increased 20 percent by adopting a new inter-row spacing of 11.4 cm.

Hartridge-eshand Bennett (1980) also used the plants/m^2 to optimize yield instead of concentrating only on the intra-row spacing. Ratios were used of inter-row space in relation to intra-row space to give a rectangle at farther spacing and a square arrangement at closer spacing. A ratio of 7 gave 22 percent lower yield than a ratio of 1.8. They suggest that the grower can control the size or grade by adjusting both density and ratio.

Sabota and Downes (1981) studied the effect of spacing on the yield of cultivar 'White Grano.' Two spacings of 7.62 and 10.16 cm were used with two rows on 102 cm beds. They reported the two spacings did not affect yield significantly. This is not surprising since they did not really study enough of a range.

Squella, Prado, Novoa, and Garrido (1983) researched the effect of plant spacing on onion yield of cultivar 'Valencia.' They found that the highest yield was with a density of 220,000 plants/ha or higher, giving 60,000 kg/ha. There was no mention of bulb size at this density.

Maeso and Villamil (1983) reported that there was an increase in the percentage of bulbs 5 to 7.5 cm in diameter at a spacing of 6 to 8 cm. This gave bulbs weighing 150-200 g.

The plants were spaced inter-row on 40 cm beds center to center.

Harvest Date Effect on Yield

Harvest date is important and can be very critical. For some, it comes at a time of peak quality within a very short span of days. For other growers, the harvest date is decided upon through knowledge of the market on a daily basis. An onion crop setting in the field an extra week or two, using all existing moisture and nutrients without further application, can increase yield without significantly increasing cost of production.

Romanowski (1962) studied the effect of time of harvest on yield of onions, scale retention, storage loss and firmness. He reported that delaying harvest from 80-90 percent die-down, until only two or three leaves remained green significantly increased the yield of onions, 15-20 percent.

Kepka, Sypien, and Smolinska-stepien (1972) carried out similar studies on the effect of harvest date on yield. They reported comparable results from the delay of harvest. Delaying harvest from 25 percent top-down to 100 percent top-down and desiccated resulted in a 30-40 percent yield increase. The delaying in harvest also resulted in a decrease in storability of the onion bulbs. The most economic yield for the study were reported to be at the 30-50 percent top-down stage.

Others such as Park, Choi, Kim and Kim (1975) found similar results as had been previously reported. They broke harvest down into early, usual, and late harvest. As before, they reported that the early harvest markedly reduced yield, but that the storage quality was much improved over either the usual or late harvests.

Cheyney and Paulson (1975) were the first to make up an indices to predict when to harvest optimally by the temperature maximums and minimums over a several week period. They reported a close correlation between average maximum temperatures two and four weeks before May 6 and the date of first harvest.

The effect of harvest date on yield, keeping ability and skin quality was further studied by Rickard and Wickens (1977). They looked at harvest dates beginning in early August and continuing in two-week intervals until early October. They concluded that calendar date was a better indicator of bulb size than foliar-fallover. Skin quality was high in early August, but the yields were too low. Early September gave near maximum yields without loss of skin quality. Late September and after gave highest yields but was too high in number of onions lost from skin splitting.

Steen (1977) researched the effects of five different harvest dates on yield and keeping quality of onions. He reported that a delay of from 10 percent top-down to 100 percent top-down increased the yield 4 percent. Delayed harvest decreased the number of small bulbs (<4 cm) steadily. The three earliest dates were best for keeping quality because of less splitting and sprouting.

K"Kam"Kova (1977) harvested onions in mid-July, late-July, and mid-August and evaluated yield. His reported results were that the yield of early harvested onions was not significantly less than the later harvest dates. The early harvest was concluded to be the most labor productive of the three harvests.

Nassar and Waly (1978) used similar methods to evaluate the yield of onions affected by date of harvest. There were three harvests: 1. tops green and upright (late March), 2. tops green but bent (early April), and 3. tops dried and bent (late April). The reported yield of exportable bulbs was increased with bulb maturity.

O'Conner (1979) found that the three harvest dates of June 28, July 7, and July 20 did significantly affect yield of bulb onions of a Japanese cultivar. The yields indeed did increase from early to late, giving 41.5 tonnes/ha for June 28, 47.0 tonnes/ha for July 7, and 51.0 tonnes/ha for July 10. Again the main cause of loss of later harvested onions was due to skin splitting. The quality was greatest at June 28 and decreased thereafter.

The yield and quality of onions harvested at different dates was again studied by Mustafa and Chzhao (1983). Bulbs were harvested on August 10, 16, 21, and 28 and on September 2 and 15. The increase was linear with respect to delay in the date of harvest and yield. Yet the bulbs harvested on August 21 and 28 had the highest quality and stored longer.

Response Surface Methodology

Response surface methodology has been around since the very early 1950's and was developed by Box and Wilson (1951). Response surface decreases the number of plots for any set of experimental variables and makes the analysis of interactions and quadratic responses much simpler, especially with the use of computers.

The experimenter decides which factors should be varied, in what way they should be varied, and by how much factors should be varied. Box (1954) noted that the final success of the experiment depends on the skill of the experimenter. He states that no amount of artistry in design can make up for omission of the most important factor. Box notes that use of steepest ascent in a series of experiments should be used until no further increase or a near stationary region is reached. At this point, a second order equation can be fit using a response surface design to optimize the dependent variable.

Hader, Harwood, Mason, and Moore (1957) also found the response surface to be much easier to use than a factorial or even a fractional factorial design. They concluded this to be so when experimental variables exceed two. They stated that a second degree polynomial approximation was satisfactory for practical purposes.

Robinson and Nielson (1960) found that the rates for variables should be selected from previous experience with the soils or soil type to be used. They noted that the composite design has no advantage over the factorial design at the three factor level or lower. In fact, it only becomes useful when the number of factors exceeds five.

Miller and Ashton (1960) used the response surface design to analyze the influence of nitrogen and phosphorus on oats. The two noted that the design permitted effective depiction of the relationships among the factors considered with a marked reduction in the number of experimental units related to a complete factorial.

Hermanson (1965) experimented with maximizing potato yield and analyzed the results using response surface. He felt that the use of RSM in applied science was limited due to the fact that the major factors which influence yield in his case were not appropriately included in the function. He concluded that this design left major unexplained experimental error due to lack of resources or ability to control dominant factors.

Mead and Pike (1975) reviewed the use of response surface methodology from a biological viewpoint. They note that the response surface should be used much later in experimentation to answer specific questions or refining points of maximum rather than using it as a first step in experimentation. They concluded that the first experiments are usually too tentative and preliminary for refined response surface.

The use of RSM has been further studied by Myers (1971), Box, Hunter and Hunter (1978) and by Montgomery (1976). The major advantages of the use of this design, in their view, is that the experimental problem is cast in readily understood geometric terms. Another major reason for its acceptance is that it is applicable for any number of independent variables. They suggest that graphical summaries and contour plots are the most effective, easily digested and most quickly understood for most people rather than lengthy and confusing mathematical equations, which are sometimes not even fully understood by the experimenter.

As stated by Henika (1982) the RSM cuts costs, measures effects objectively, and most importantly that a computer calculates the Taylor second-order equations defining the relationship between the variable and the response, such as yield, including any interactions that might be present.

CHAPTER 3

MATERIALS AND METHODS

Onion (<u>Allium</u> <u>cepa</u> L.) cultivars 'Granex 429,' 'Ring-Gold,' 'White Sweet Spanish' and a dehydrator variety were selected for this experiment. The number of varieties was found to be too many for the bed width so the 'Granex 429' and 'Ring-Gold' were selected as the two to use for this study. The seed for the 'Granex 429' variety was obtained from the Asgrow Seed Company in Phoenix, Arizona. The 'Ring-Gold' was not delivered so an older batch of seed was used, which proved to be a mistake. The seed was less potent so it was planted at a higher rate. This still didn't prove to be enough, and the resulting stand was very poor. So, the 'Granex 429' was the only variety from which numbers could be taken.

Experimental Design

The design in this experiment was central composite-rotatable response surface with each of the 53 plots randomly assigned across the field, but only one time. With more space the treatments could have been repeated; but since the field was all that was available, it was only done once. This design evaluated the response of six different cultural practices or factors, each at five different levels, interacting with the others and looking at the effect this had on yield of the onion cultivar 'Granex 429.' The optimum values are set at what is currently thought to be the most successful levels for each factor in an Arizona environment. The extremes are set so that the plant will hopefully show some noticeable difference from the normal onion plant. The other two levels are set using the formula for the response surface design at the 6-factor level. All the levels and each of the rates for each factor are shown in Table 1.

Cultural Practices

Water Treatment

The irrigation was a drip system using Chapin drip hose, with holes every 8 inches. The lines were 30 feet long and fed off one of the five header lines, connected with 3/4-inch tubing. The onions were watered overall until a good stand was present across the field, and until the meters for the lines could be obtained. The water treatment was implemented on February 1 and carried through the last harvest on June 16. At first the optimum water was set at 7 days since this had proven optimum prior to starting the treatment for water. The optimum had to be moved up when temperatures increased in early May. Therefore, the interval was changed to 3 days for optimum on May 10. The rate was 25 gallons per line per treatment or irrigation. Any future irrigation treatments should alter water levels and keep the intervals

Table 1. Levels and rates for factors used on 'Granex 429' and 'Ring-Gold' onion varieties.

Coded Levels	Water (Days between)	Fertilizer (lbs/A N)	Plant Spacing (Inches)	Herbicide (lbs/A)	Pesticide (ml/gal.)	Harvest Date (Mo./Day)
+2.378	12 (5)	584.0	4.50	20.0	30.0	June 16
+1	9 (4)	414.8	3.25	14.2	21.4	June 10
0	7 (3)	292.0	2.50	10.0	15.0	June 6
-1	5 (2)	169.2	1.75	5.8	8.6	June 2
-2.378	2 (1)	0.0	0.50	0.0	0.0	May 27

the same to allow for ease in adjustment due to climate. The drip line was 6-mil size, with the inner hose pressure 6 PSI and the spacing between outlets was 8 inches. The amount of water output was 0.77 GPM per 100 feet of drip line.

Fertilizer Treatment

The fertilizer included only nitrogen since the field had, had heavy phosphorus fertilization in the previous experiment. The fertilizer which was chosen was Ammonium Sulfate (21-0-0), from the Arizona Agro-chemical Company, Phoenix, Arizona. This was chosen since the onions can use the sulfur to some extent and it was readily available. It would have been more precise to put the fertilizer in through the drip tapes; but since they were all on different water levels than fertilizer, the fertilizer had to be hand applied. It was sprinkled down each row, by hand, between the two onion varieties. At first the fertilizer levels were set using Knott's handbook for levels of nitrogen needed, which was optimum at 146 pounds N/acre. Since the way in which the fertilizer was applied was thought to be less efficient than either drip application or even a furrow system, the amounts were doubled and the optimum set at 292 pounds/acre. After each application, the onions were watered overall to allow for the lower water treatments to have their fertilizer available at the same time as higher treatments. Applications were on February 14, March 14, April 14, and May 14.

Plant Spacing Treatment

The onions were spaced after the planting, which proved to be a major job in thinning. In future work, I would suggest that spacing be dealt with at the time of planting. The optimum distance for spacing seemed to be quite vague in most sources which were covered. It seemed to be 2 to 3 inches, so 2.5 inches was chosen as the optimum. The plants were spaced with a ruler to the correct spacing. All rows had gaps in some spots which had to be transplanted into at the time of spacing. This was done across the field where needed. The spacing was begun on March 1, and I started with the widest spacing since the closer ones wouldn't be affected as much by a delay.

By hand, each row took 1 to 2 hours to space which is why any future work with plant intra-row spacing should be done at the time of planting.

Herbicide Treatment

The herbicide treatment was going to be used to see if the herbicide had any effect on the onion seed as far as its yield due to possible poisoning of energy-related systems. The herbicide selected was Dacthal-75. It was chosen as the herbicide because there are not many other pre-emergent herbicides listed or available for onions. The optimum level was taken from the instructions on the label. This was set at 10 pound/acre. It was applied on the field with a 5-gallon sprayer at 40 psi. Numbers were also taken on the weeds to see if the different concentrations would affect weed numbers. Weed counts were not different across the field since nearly all were of the mustard family and Dacthal does not control this weed family.

Pesticide Treatment

The major insect pest of the onion is the thrips insect. This very minute insect is thought to decrease yield through damage of the photosynthetic area of the leaves of the onion. It was included to see if its control would affect the yield of the onions. Thrips were first noticed in the field on February 18 and treatments begun thereafter. Malathion was chosen as the pesticide to use. It was applied at an optimum of 15 mil/gallon and this, as were the other levels, was applied to 100 square feet of row. This was the level listed on the label for thrips control. Since the malathion does not last long on the plant, the treatment was repeated every two weeks until the last row was harvested on June 16.

Another pest, the cutworm, was found in the field and became a problem since they would cut the plants off at ground level and leave them lying in the row. The onion field was treated overall with a pellet bait containing carbaryl. The compound was Sevin-5% and it was applied at a rate of 40 pounds/acre. They were Wilbur-Ellis Sevin-5% pellets from Glendale, Arizona.

Harvest Date Treatment

The usual onion harvest dates in Arizona are in June. The optimum date of June 6 was set as the onions began maturing. As the tops began to fall, it was estimated when the 50 percent level would be reached and all other dates were then set. The first one foot was cut off each row and 15 feet were harvested out of the 30-foot row. This was due to the fact that several buildings had shaded a portion of the field; and, therefore, it had to be cut off all across the treatments. The onions were harvested in the morning of each date, graded, and weighed fresh. They were then cured for 5 days and the tops and roots cut off and then re-weighed for the final cure weight.

Data Collection

The main data collection was that of yield of the onion 'Granex 429.' This was a cure weight taken 5 days after harvest. Fresh weight with whole plants were taken at harvest with roots, bulb and leaves included.

Dry weight of leaves were also taken. Leaves were selected from 20 plants per plot of the third tallest leaf of 1- to 2-inch bulbs.

Plant height was measured across the plots to see how treatment affected this characteristic. The plant height was measured mainly to relate it to yield of that particular plot or treatment.

CHAPTER 4

RESULTS AND DISCUSSION

The results are reported in this section by way of yields of onions per acre, their correlations with factors which were injected into the experiment, significance levels for the factors used to a minimum acceptance of 5 percent, graphs of predicted and actual responses of significant factors, and the combination within the experiment of the factors which produced the optimal yield. The responses looked at were cure weight yields of all sizes together, large size alone, and medium size alone. A list of treatments is given in Appendix 1 along with total and large-bulb yield responses.

The discussion involves the relating of the analysis of results to the factors used within the range covered. The significant factors are discussed at length and the non-significant factors are also discussed but mainly to note what reasons were behind their insignificant effect. Conclusions are drawn from the results, again, to the extent that the experimental range entails and not outside the area covered. Conclusions and any recommendations to growers are a compilation of what can be drawn from present research plus any important related data obtained in literary review. ANOVA results and variables in the equation, for stepwise regression, are given in Tables 2 and 3 respectively.

Response surface design was brought into this experiment to see if it could be of use in agricultural experimentation as it has been used in chemical and engineering research to optimize processes of multiple factor influence. In the past, the effectiveness of the use of RSM in applied sciences such as agriculture has been of limited success. One main reason is that the adjustments made at the end of each season of experimentation, to try and reach the optimal point either potentially or economically, would come after one crop season. The next season's results, coming another year in the future and so on, would slow the final optimization. In a chemical and/or engineering system, the experiments can be repeated many times in one year. Also the factors which are used in a chemical or engineering situation can be easily and very precisely controlled, whereas the agricultural factors in a changing environment can and are going to affect the precision of the results of experimentation.

The use of RSM is a last step or refinement step in what should be a stepwise steepest ascent type of experimentation. With fractional factorial design, the number of treatments would be 81 versus 53 for RSM at the six-factor level. This type of design would have progressively climbed

Table 2. ANOVA for the stepwise regression of total bulb yield.

ANALYSIS OF VARIANCE				
	Sum of Squares	DF	Mean Square	F Ratio
Regression	3.5296 + 09*	9	3.9218 + 08	15.11
Residual	1.1163 + 09	43	2.5960 + 07	

*Denotes power.

Table 3. Variables in equation for stepwise regression of total yield.*

Variable	Coefficient	Standard Error of Coefficient	Standard Regression Coefficient	F to Remove
Water	-5778.96	805.61	-.536	51.46
Fertilizer	2248.99	769.22	.219	8.55
Space	-3949.71	749.43	-.394	24.94
Harvest Date	3814.37	763.79	.373	27.78
Herbicide	70.22	773.96	.007	.01
Pesticide	1006.20	777.12	.097	1.68
Water x Water	-2847.79	877.41	-.243	10.53
Space x Space	1375.58	529.54	.194	6.75
Water x Space	-1633.51	900.70	-.136	3.29

*y-intercept 53,828.46.

the mountain until all six began to drop and the RSM design could have been used to find optimal points, and shown graphically the response chosen. Choosing ranges that proved in the past to be adequate, when we do not have data on the other factors that were a part of the range chosen, can lead to results in an RSM study which will not be what was expected. In the future, the use of RSM should indeed be based on previous background work with the same factors to be used on the same soils and with previous knowledge of stepwise steepest ascent experimentation.

A major strength of the RSM design is that it reduces experimental plots which can significantly reduce the amount of funding a researcher has to acquire before he can proceed with his project. The analysis of an RSM experiment which has worked for all factors can indeed produce insight into interactions and optimizing which do not always come with other designs. The trick is to know where and when to use this type of design and not to abuse or exploit the design in a situation where a factorial or fractional factorial design would cover the range more clearly and more easily.

Factor Effects on Total Yield

Water Effect on Total Yield

The water level, as might be expected, was one of the top factors in the significant effect it had on yield. Taken alone, or in linear terms, the water proved to be highly significant at greater than the one percent level. The lowest level of water, which came at a 12-day interval, had drastic effects on the yield of total cure weight onion poundages including all onion grades. This level of irrigation produced a yield of only 38,042 lb or 380 hundred-lb bags per acre. Of all the treatments in the experiment, the low water level gave the smallest yield of any of the 53 treatments covered in this design.

The actual gallonages applied for the different water treatment levels ranged from only 384,006 gallons per acre for the 12-day interval to 2,071,423 gallons per acre for the 2-day interval treatment. The acre inches applied range from 14.1 for the 12-day interval to 76.3 for the 2-day interval. The optimum water level for the onions in this experiment appeared to be at the 7- or 5-day intervals at a rate of between 35.4 and 51.5 acre inches respectively. The consumptive use of bulb onions as measured from November to May in Mesa, Arizona, is 29.3 acre inches. The 35.4 acre inches at the 7-day interval is very close to the consumptive use of onions in Arizona.

The results of this experiment were similar to that of El-Tabbakh, Behairy and Behairy (1981) in which it was the intermediary levels of irrigation that produced the higher yields as opposed to either excess moisture or excess drought.

It was the 5- to 7-day irrigation which produced the best yields with the center point check type treatments producing a mean of 53,595 lbs per acre or 536 hundred-lb bags per acre. This mean was from a replicate of nine different treatments. The other extreme of irrigating the onions on a 2-day schedule and then later on a daily schedule, as the temperature rose, produced a declining yield as well and produced 49,368 lb per acre or 494 hundred-lb bags per acre.

For the reason that these yields at the extremes were in fact dropping off relative to the optimum value, it was especially valid to have the quadratic values fit to this factor. Although it is true it was significant in the linear form, the fitting of the quadratic response was significant at the one percent level showing that the line for water's effect on yield was very close to intermediary between linear and quadratic.

Since the extremes in these instances are not replicated, the response line to the factors imposed can be somewhat suspect. For this reason, there is only so much that can be said about the results. It is true that it appears that there is in a declining slope on either side of the optimum, and in fact the low water level response was well below the range of yields for the optimum irrigation. The irrigation in the extreme other direction, or excess water levels, also gave a decreasing effect, but it must be mentioned that the value does fall within the range of the optimum water levels. Since there is no replication of this value, it could well be the lower response to such a treatment and any other normal response to the same treatment may be higher as in the water response graph shown in Figure 1. If this were to be true , the result would be that the response for yield as affected by irrigation levels could be only a linear response within the range observed in this experiment.

The water levels were in fact the most highly correlated with yield in respect to the total yield of harvested onions. The way in which this experiment could have been furthered or have been more precise is to have replicated the extreme points to ensure that the values obtained were the most accurate possible. The design is such that these extremes do not supposedly need to be repeated because the response is expected to be maximum, or nearly maximum, at the optimum factor level.

At the very low water level, we can be quite sure that the response is an accurate expectation of such a low irrigation level. As was reported in the literature review, the onions did mature much earlier than any other treatment and the average bulb size produced was the lowest by far over any other treatment.

The onion response to the over-watering treatment, or every other day irrigation, as has been stated is less clear

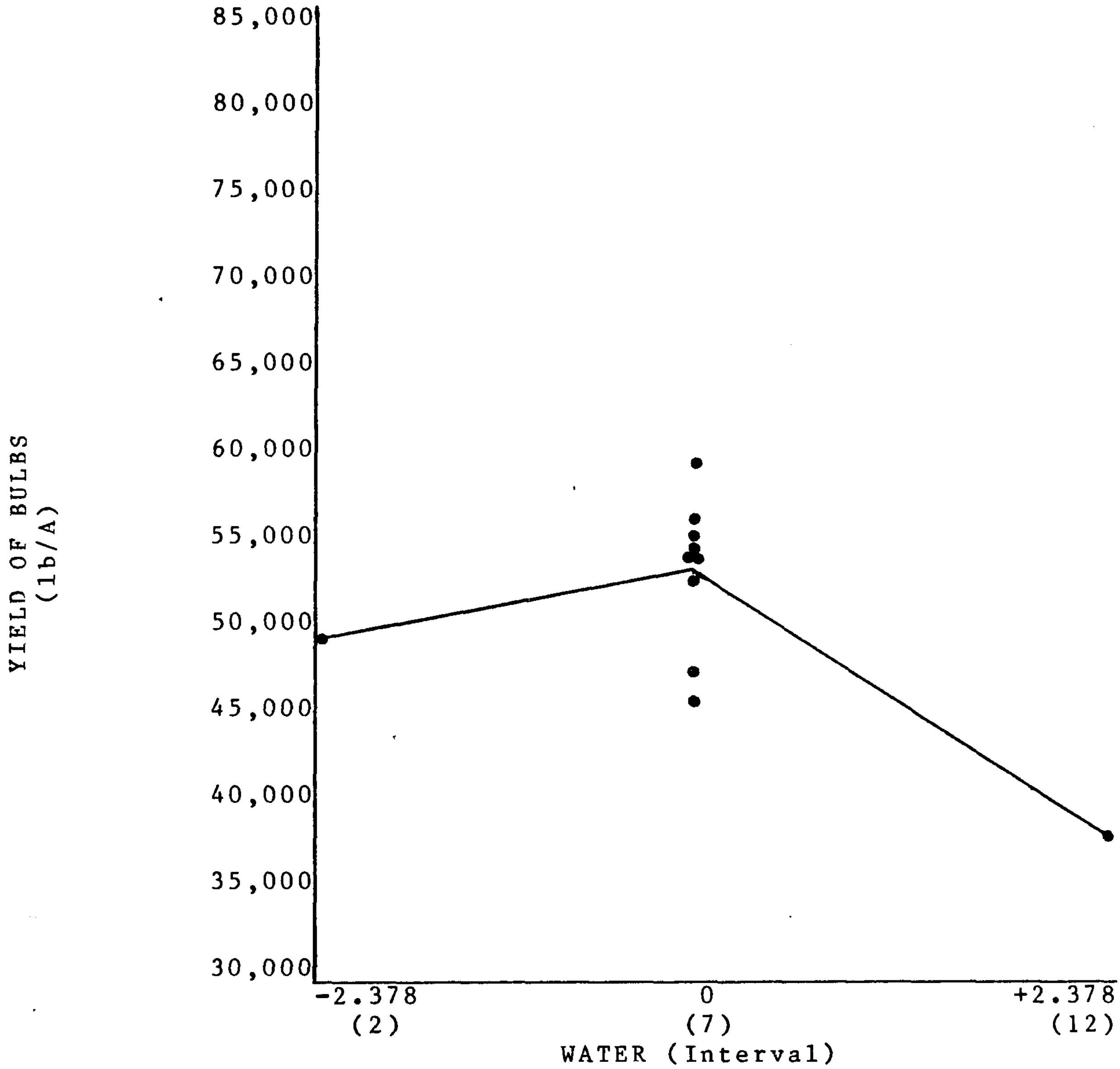

Figure 1. Response of yield at differing water intervals.

as to how the water level affects the onion yield. This is the question if we accept that the response is indeed quadratic. The excess irrigation could in fact be simply water logging the soil to the extent that the roots cannot get their necessary oxygen to continue optimum growth. This effect was not mentioned in any of the literature which reported middle levels to be optimum for their onion bulb yield. Also the response may be due to less availability around the root area of fertilizer applied. Since the fertilizer could have moved outward and downward quicker than the roots could make optimum use of the fertilizer applied, this may have changed the actual nitrogen available as opposed to that of the optimum water level treatments which received identical fertilizer application.

The conclusion that the oxygen is in fact the limiting factor in the over-watering treatment is probably the most accurate theory to follow. Dr. O'Keefe, at the University of Nebraska, has used an oxygen trickle type irrigation and has shown an increase in yield. For this reason, I would suggest the lack of oxygen availability to be the reason for yield reduction at the high irrigation level.

Spacing Effect on Total Yield

The spacing of the onions was shown to be highly significant in its effect on yield. The spacing was the one other factor which had a quadratic response, as did the water factor. The problem with this is that it did not reach a high at the centers then drop off as might be expected. What it did was increase in an exponential way on the closer spacing side of the optimum onion spacings as shown in Figure 2.

The range of spacings was from 0.5 inches at the closest to 4.5 inches for the farthest spacing. The spacing of 2.5 inches, which was the optimum level set for the bulb onions, gave a range of 46,174 pounds per acre or 462 hundred-lb bags to 59,822 pounds per acre or 598 hundred-lb bags. There were nine of these center points measured with optimum levels for each of the six factors.

The far extreme of 4.5 inches gave an onion yield of 45,012 pounds per acre or 450 hundred-lb bags. The other extreme in the direction of closer spacings of 0.5 inches gave the highest yields of any other single treatment row out of the 53 treatment rows at a rate of 83,635 pounds per acre or 836 hundred-lb bags.

It has been reported several times in the literature that the closer the plant spacing, the higher will be the total onion yield. The only thing is that the higher the plant density, past a certain point, or the closer the spacing of the onion plants, the smaller the bulbs are at maturity. The number of marketable bulbs per acre is increasingly decreased as the spacing falls below a critical point.

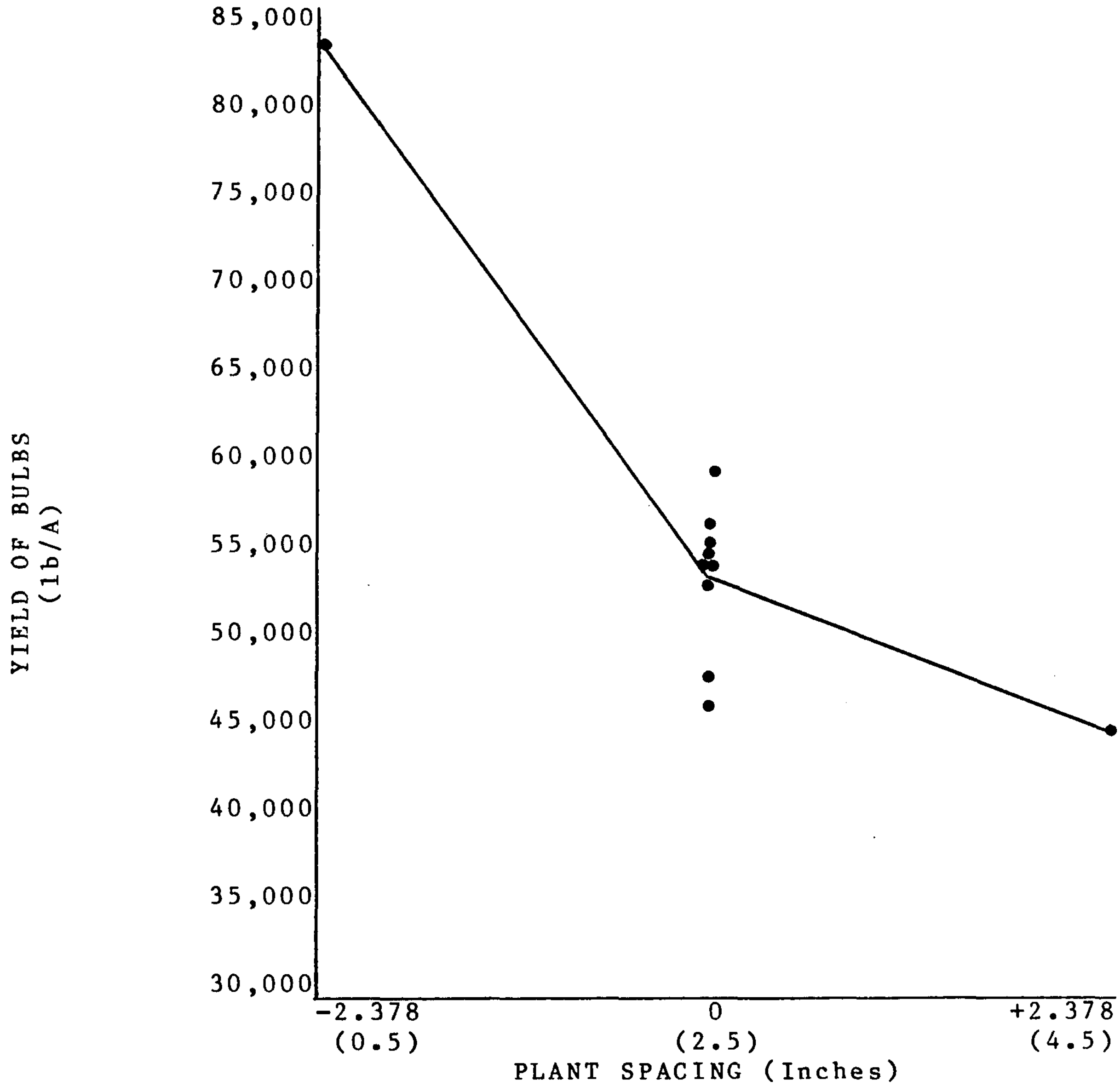

Figure 2. Response of yield at differing plant spacings.

The number of large (>3 in.) and medium bulbs (2-3 in.) was affected rather drastically as the spacing moved from the 0.5-inch spacing up through the 4.5-inch spacing. The percentage of large bulbs indeed increased through the widest spacing, but the yield per acre had begun to drop at this point. This widest spacing produced bulbs in the large and medium size range, and did not produce any bulbs in the small size of 1 to 2 inches. Since it had begun to lose yield, the spacing must be considered to be too wide for the 'Granex' bulbing onion at 4.5 inches.

The best treatment, out of the 53 in the experiment, for the production of large-size bulbs was treatment number 43. It produced a yield of 65,630 lb/A or 656 hundred-lb bags of large bulbs. The spacing in this treatment was at the +1.0 above optimum. This came at a distance of 3.25 inches between bulbs. The best treatment for the production of both large- and medium-size bulbs also came with the 3.25-inch spacing and also was treatment 43. With both large and medium included, the yield was 71,826 lb/A or 718 hundred-lb bags. For the yield of most marketable bulbs, the bulbs should indeed be spaced at a distance of 3.25 inches.

The grower of an onion crop can easily manipulate the end-product by the use of different spacings. If he contracts for pickling the onions, he can use much closer spacing and not worry about size. If his particular market uses a regular bulb onion, but of moderate size, he could go with a 2.5-inch spacing. If the market sells more of a larger onion, then the grower would be better off with the 3.25-inch spacing of the onion plants.

As was reported in the literature, the close spacing can and usually does lead to an early maturity of the onion plant. This close spacing also may lead to bolting of the crop and thus make it unmarketable. The closer spaced crop may be better off if held up in planting a bit, to decrease the chance of bolting of the onion plant.

The closer spacing of onions leads to the crowding of the plants; and this in turn leads to the squeezing and denting of bulbs in the spacings up to and including, in some treatments, the 2.5-inch spacing. The degree of misshapen bulbs was increased drastically as the distance between plants decreased. Some bulbs, being weaker, would be crushed between others which would take up the room that would have been used by the squeezed-off plant had it been able to keep up in growth with the others.

The far space was reported in the literature to produce bulbs which did not store for nearly as long as did those bulbs of a closer spacing. This was reported to be due to the fact that the bulbs at increasingly further spacings had increasingly more split and cracked bulbs. This was reported to increase the entry of pathogens and general breakdown by the environment. In the wider spacings of this experiment, it was indeed found that the bulbs did tend to split and crack more than the closer spaced bulbs. As has been reported, there was an increase in defects due to splitting open linearly as you go from 0.5 inches to 4.5 inches of distance between the onion bulbs. Some of the wider treatments showed a trend toward 50 percent and more of the bulbs showing splitting and cracking. The bulbs of such treatments with spacings of 3.25 inches or greater can and should be harvested earlier to prevent such losses in storage or of saleable bulbs. The best treatment combinations of 3.25 spacing and above predicted optimum water levels could have been harvested in the latter part of April to early May when the average size was already exceeding 3 inches.

The yields of onions in the future, on a per acre basis, can be drastically increased simply by closer inter-row spacings. More of a square ratio of an arrangement, rather than rectangular, can produce significantly higher yields than what is now being produced with furrow irrigation. This experiment was conducted using drip irrigation, with rows 18 inches center to center. This can be trimmed to possibly 10 inches or less, at near a 2:1, and significantly increase onion yield, not on a per bulb basis, but certainly on a per acre basis.

The interaction of water and spacing was the only interaction out of fifteen possible which was significant. This interaction was significant at the 5 percent level of probability when run through simple regression. When the stepwise regression is employed, and the factors are taken one at a time and put into the model, the significance rises to the one percent level.

The water and spacing both had negative effects on yield at the +2.378 end of the range. When the interaction was measured at this combination of wide spacing and wide interval between irrigation, the effect on yield was increasingly negative. In other words, as the bulbs were spaced farther apart, the water factor was more important and the wide interval between watering had more of an effect on yield reduction than at a closer spacing. This is due to the fact that the closer-spaced bulbs can make more efficient use of what little water was supplied at the far extreme of a 12-day interval.

This means that a closer-spaced crop, which can better utilize the same amount of water as a farther spaced crop, can be grown with less water before affecting yield significantly. This is another consideration in the spacing of an onion crop, especially with the water problems seen here in Arizona. Drip lines could be made to fit optimum onion spacings so that the water could be applied directly at each bulb. This could allow for spacing at the distances desired.

Harvest Date Effect on Total Yield

The effect of differing harvest dates had a highly significant effect, at greater than the one percent level of probability. The effect was that the longer the delay in harvesting, the higher was the yield. This was a positive linear response to delaying harvest as shown in Figure 3.

Most time-of-harvest studies do not find a significant reduction in the yield of bulbs over time, if allowed to run through a normal crop season. A reduction in onion weights would only be seen when the onions were left in the field for an unreasonable amount of time after tops were down and dry. At this time, it would be possible to begin seeing a loss in weights or total yield due to a dessication of the onion bulbs remaining in the field. In the warmer climates, this could be a significant loss prior to storage if steps were not taken to remove the onions from the field after this critical point. For this study, the final harvest, which came on June 16, still had a portion of the crop showing green leaves. This would allow the onions to continue adding more weight until final leaf dry down was reached.

The experiment which was conducted predicted the time of 50 percent top down, which is used in the harvesting of onions as an optimum, at the time that the onions began to

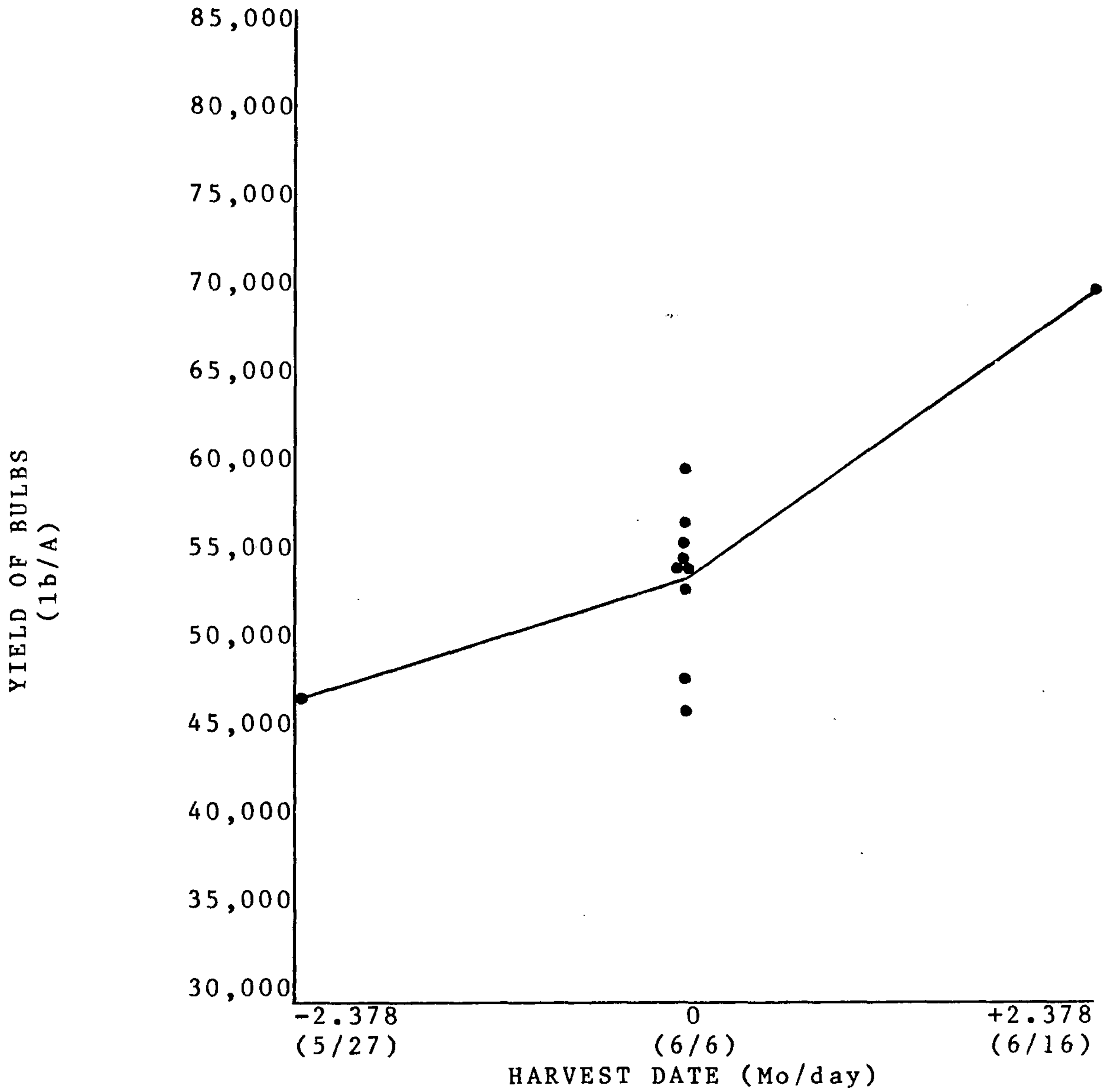

Figure 3. Response of yield at differing harvest dates.

fall in the latter part of May. That is one reason that the harvesting of the onions did not show any reduction or even any slowing in addition of poundages to the crop yield. This is why the quadratic effect which was being looked for did not arise. The significance of the quadratic response was so low because it could not accept the fitting of such a line to the numbers provided by the results of the experiment.

The early harvest (-2.378) came on May 27, 1984. At the extremes of harvest date, as with the other factors, there is only one measurement. This can cause some concern, as was mentioned, but it is felt that this response is quite accurate due to the nature of the factor. This extreme treatment date yielded 46,754 lb/A or 468 hundred-lb bags. There was only one measurement within the checks which was lower than this at 46,174 lb/A or 462 hundred-lb bags. The nine optimum harvest-date treatments, which came on June 6, 1984, produced an average of 53,595 lb/A or 536 hundred-lb bags.

The late harvest (+2.378) was on June 16, 1984. It also was not replicated since it was an extreme. This harvest date showed a rise in onion bulb poundages on a per acre basis. The treatment produced a yield of 70,277 lb/A or 703 hundred-lb bags.

The major concern with the delay in harvest is that the post-harvest storage may be affected. Nearly all of the researchers who looked at harvest date mentioned that the longer the delay in harvest, the more defects and losses in storage. This occurred even if the yield had not yet begun to plateau or drop off. The longer the onion plants are left in the field, the larger they will grow. This growth, after about 3.5 to 4 inches begins to cause splitting of the outer scales. This cracking or splitting causes an increase in the loss of water from the bulb and an increase in susceptibility to post-harvest diseases. This is what causes the greatest loss in storage of this grade of onion. If the grower is considering holding onions or even if the onions are to be sold immediately to a favorable market, he will have to consider the losses in saleable onions when growing them to an excess size.

The harvest date had no interaction with any other factor. This was on a total yield basis. When the U.S. No. 1 large bulbs were considered by themselves and mediums by themselves, there were also no interactions. So harvest date yields were unaffected by different water, spacing or fertilizer levels. Since pesticide and herbicide were not significant on total yield, they of course did not interact.

The grower will have to make the decision as to when the onion crop should be harvested and this will mainly be a function of his own circumstances. If the price is considerably high for the size of onion on the average within the field, the grower may decide to pull his crop early in the season to take advantage of the price.

Fertilizer Effect on Total Yield

The nitrogen fertilizer (ammonium sulfate) had a significant effect on yield of the onions at the 5 percent level of probability. This was a linear effect so that as the level of fertilizer was increased, the yield of the 'Granex' onion increased. The quadratic formula could not be fit to the model with any significance since the response of the yield was a positive linear one which increased through the range of the experiment as shown in Figure 4.

The fertilizer was applied over the top by broadcast method. With the drip line it could have been applied very efficiently but with the experiment having different water levels from fertilizer levels, the lines were not attached so that the fertilizer could not be applied through the drip lines. These levels started out at 146 lb N/A for optimum but were increased later to account for the fact that the fertilizer was being applied in a less than efficient method.

The +2.378 fertilizer treatment, or the positive extreme for nitrogen, was 584 lb N/A. This level of fertilizer gave a yield of 53,434 lb/A or 534 hundred-lb sacks per acre. This extreme, as well as all others, had all other factors held at predicted optimum levels. This yield fell within the range of the nine optimum treatment yields, which gave 53,595

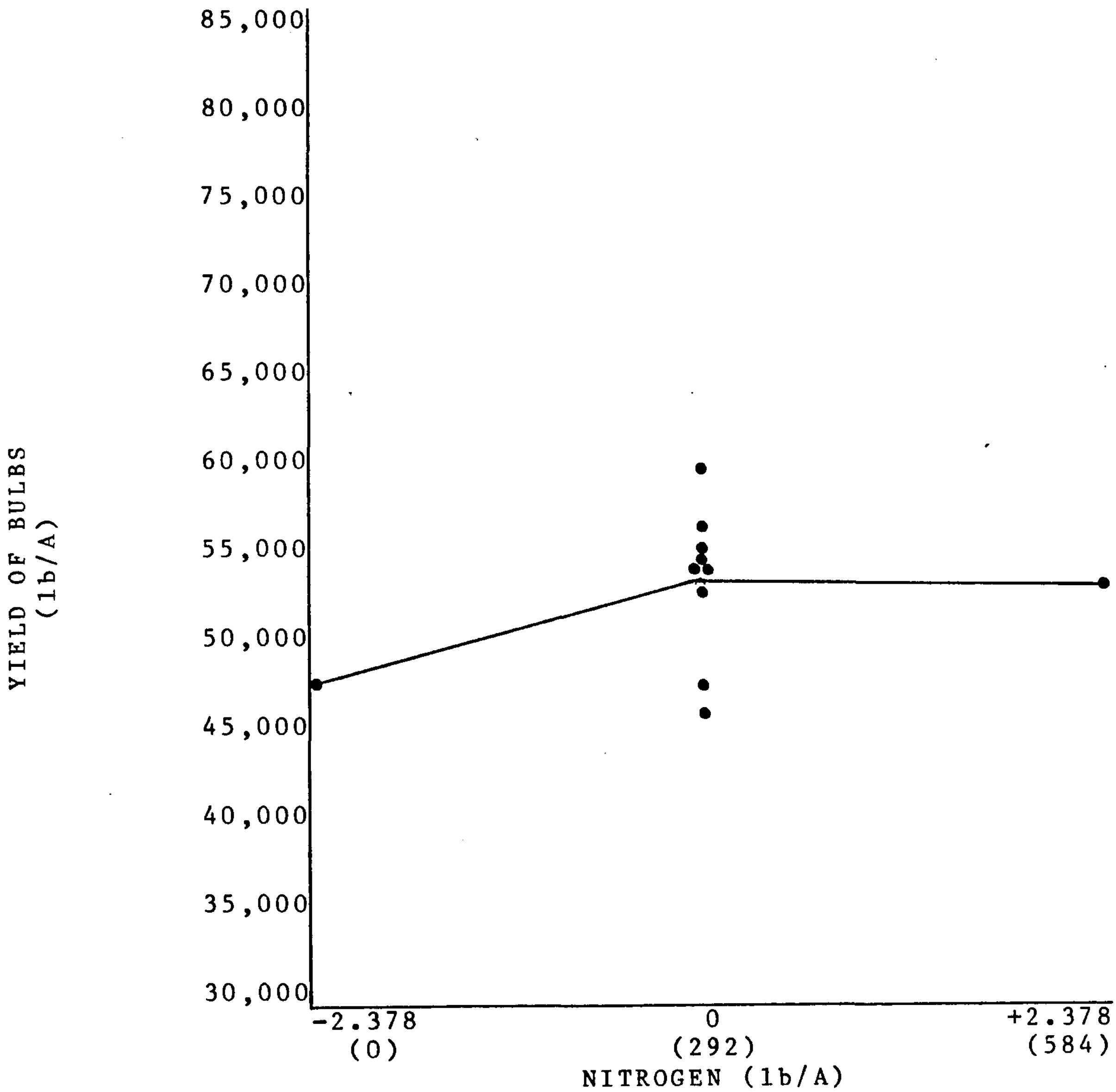

Figure 4. Response of yield at differing nitrogen levels.

lb/A or 536 hundred-lb sacks per acre. Even so, the model used predicted a positive linear response of yield to increasing nitrogen levels.

The -2.378 level of nitrogen fertilizer was the opposite extreme or the negative extreme of optimum fertilizer level. This level of nitrogen was set at zero lb N/A. This treatment produced a response in yield of 47,916 lb/A or 480 hundred-lb sacks per acre. This, as with the other extreme, fell within the range of the check treatments. Unlike the positive treatment, this treatment produced a yield very close to the lower limits of the check plots.

The response of yield to the differing levels of nitrogen can best be described as increasing up to the maximum and then probably beginning to level off. This assumption is based on the fact that the +2.378 treatment produced a yield of slightly lower amounts than the checks. So in all probability the fertilizer level at the +2.378 level should be approaching a maximum.

The fertilizer, as with the harvest date factor, did not show any significant interactions with any of the other five cultural factors. This lack of interaction was on a total yield basis. The fertilizer factor showed interaction with spacing and harvest date if looked at only on a large bulb basis. In the total yield analysis, the fertilizer was only a function of its own levels.

Future experimentation with these factors should include a slight adjustment of nitrogen levels to the positive side of what has been observed in this experiment. As was mentioned, the fertilizer treatment appears to be very near maximum, and so little if any increase in levels is required. The way that nitrogen was added could be changed to increase efficiency and thus allow for the same levels to be used in the next step of experimentation.

The best treatments produced right at 700 hundred-lb sacks per acre of bulbs, which were 80 percent plus over the size of 3 inches. These two treatments both were ones which had a +1 nitrogen fertilizer level. This came out to be an application of 414.8 lb N/A split into four applications. This as well as the +2.378 treatment shows that further nitrogen levels probably will not produce higher yields in the same or similar environment.

Pesticide Effect on Total Yield

This factor was not significant in the response on yield. It was neither significant in the linear respect nor in the quadratic fit of the model. As has been mentioned in the literature, thrips (<u>Thrips</u> <u>tabaci</u> L.) effect on yield is dependent on the population of the onion thrips across the field. The population of thrips, if not extensive at the early part of the season, will not significantly affect the yield of onion bulbs. This is true even if the small numbers can be significantly changed by malathion.

Herbicide Effect on Total Yield

The herbicide was the least significant of any factor or any interaction covered in the treatments of this experimental design. The herbicide was not significantly affecting the yield of onion bulbs either linearly or quadratically. The dacthal which was used pre-emergence did not apparently leach through to the onion seed or seedling root zone in any amount significant enough to affect the growth of the onion, the yield of the onions or the germination of the onion seeds. The dacthal is so tightly held to the soil colloid surface that it is not easily leached especially under a low-moisture system. The fact that drip irrigation puts on lower amounts of water and the amount of rainfall was extremely minimal could be two reasons why the dacthal did not have any significant effect on yield of the 'Granex' onions. The other problem with this herbicide is that it does not control the mustards in onions, which can be a major problem in onion production.

Highest-Yielding Treatments for Total Yield

There were three treatments out of the 53 which produced yields 20,000 lb/A over that of the average check plot. One was the +2.378 level for harvest date. This treatment was one in which the other five factors were held at optimum levels, and the harvest date was pushed to the far positive extreme. This treatment produced a response in yield of 701 hundred-lb sacks per acre.

The other two treatments which produced very high yields came from two of the treatments included in the design to account for interactions. These were rows 42 and 43. They both contained the +1 factor level for each of the four significant factors which are: water, spacing, fertilizer, and harvest date. Since the factors were not maximized, except for water, there is only so much that can be said about the best treatment for onion production. As the factors are adjusted and the experiment run again, the combination of the factor levels which will produce maximum bulb production could and probably will change from what is seen now. These two treatments both produced over 80 percent bulbs over 3 inches and also zero percent bulbs in the small size range of less than 2 inches.

It should be mentioned again that an average yield in the U.S. is 310 hundred-lb sacks per acre for bulb onions, and a good yield is considered to be 400 hundred-lb sacks per acre. Even the average check yields were above the projected "good" yield.

The three treatments which produced the 700+ hundred-lb sacks per acre were more than twice an average yield and nearly twice a good yield. These are high yields, but the fact is that the onions of 'Ring-gold' cultivar, which were on one side of the drip line row, were not counted in this yield due to a population too low to be spaced correctly in the experiment. Still, these onions would have produced another 20,000 lb/A yield even with their small numbers. If the crop had come up to a good stand, the yield would have been nearly doubled. Of course, a solid row of onions on both sides of the row would have competed somewhat to keep the onions from doubling yields per treatment row. Even with conservative estimates, the yields for the best treatments would have been well over 100,000 lb/A or 1,000 hundred-lb sacks per acre. A movement towards closer inter-row spacings could be made easily without competition between rows. This would increase yields even more on a per acre basis on the order of 1,500 hundred-lb sacks per acre. These closer spacings would increase efficient use of water, fertilizer, and compete more readily with weeds to reduce control costs.

Economics of Yield

The economics of yield could be a separate thesis in itself. The effects of different levels of each factor would have to be considered. The combinations of each treatment would have to be calculated.

Treatments may produce the higher yields but perhaps they are not economically superior to a treatment producing less yield but at a much reduced cost of production. This is where the response surface would have come into use if the system had been optimized.

For the experiment, the rows 42 and 43 would have been ready for harvest at such an early date that they would have produced the most economical crop. These two treatments could have been harvested by the latter part of April to early May and would have easily been in the medium size to large for some of the onions. This was the time when the prices were high and the market had not yet been flooded. By the time the plots were ready for harvest beginning on May 27 and continuing through June 16, the price was so low that many growers could not even afford to harvest the onions; and, therefore, many were plowed under.

Factor Effects on Large-Bulb Yield

The large size bulbs were singled out to see if the model fit it better, as were the medium size bulbs. It was thought that if the small plants were excluded that any error due to transplanting could be minimized and this might make the model fit more accurately. The stepwise regression procedure allows for the addition of one variable at a time to see what effect each has on the model fit and the variation for which each accounts. The results of the ANOVA for the stepwise regression of large-bulb yield are given in Table 4. The variables in the equation are listed in Table 5.

Table 4. ANOVA for the stepwise regression of large-bulb yield.

ANALYSIS OF VARIANCE				
	Sum of Squares	DF	Mean Square	F Ratio
Regression	6.9991 + 09*	13	5.3839 + 08	22.36
Residual	9.3895 + 08	39	2.4076 + 07	

*Denotes power.

Table 5. Variables in equation for stepwise regression of large-bulb yield.*

Variable	Coefficient	Standard Error of Coefficient	Standard Regression Coefficient	F to Remove
Water	-7081.72	775.82	-.503	83.32
Fertilizer	2726.91	740.77	.203	13.55
Space	7771.70	721.88	.593	115.91
Harvest Date	4118.25	735.72	.308	31.33
Herbicide	707.85	745.34	.052	0.90
Pesticide	615.14	748.38	.045	0.68
Water x Space	-2558.15	867.39	-.162	8.70
Water x Date	-2027.75	867.39	-.129	5.47
Fert. x Space**	2439.18	867.30	-.155	7.91
Fert. x Date	1950.74	867.31	.124	5.06
Space x Date	1979.35	867.39	.126	5.21

*y-intercept 25,044.48.
**Fertilizer x Space.

Water Effect on Large-Bulb Yield

The water in this analysis did not come out to have a quadratic fit as did the total yield. The response of water on large-bulb yield was a positive linear one. This is shown in Figure 5.

The excess water produced a yield of 28,266 lb/A or 283 hundred-lb sacks. The minimal water level or 12-day interval produced a yield of only 10,648 lb/A or 106 hundred-lb sacks per acre of large bulbs.

The nine check treatments produced an average of 26,781 lb/A or 268 hundred-lb sacks. The low water level fell well outside the range of checks by more than 10,000 lb/A. The high water level did fall inside the range of the checks but was 2,000 lb/A above the average. It may suggest a tapering off of the response of yield at this water level; but with only one treatment row at this level of water, there is only so much that can be said from the data.

Water in the large bulb analysis was a function of spacing and harvest date. Water interacted with spacing to have less of an effect at closer spacing than at a wider spacing. Water also interacted with harvest date. The interaction was such that as harvest date increased, the effect of water levels was more significant. In other words, low water levels had more of a negative effect on yield at the later harvest date than at the early date.

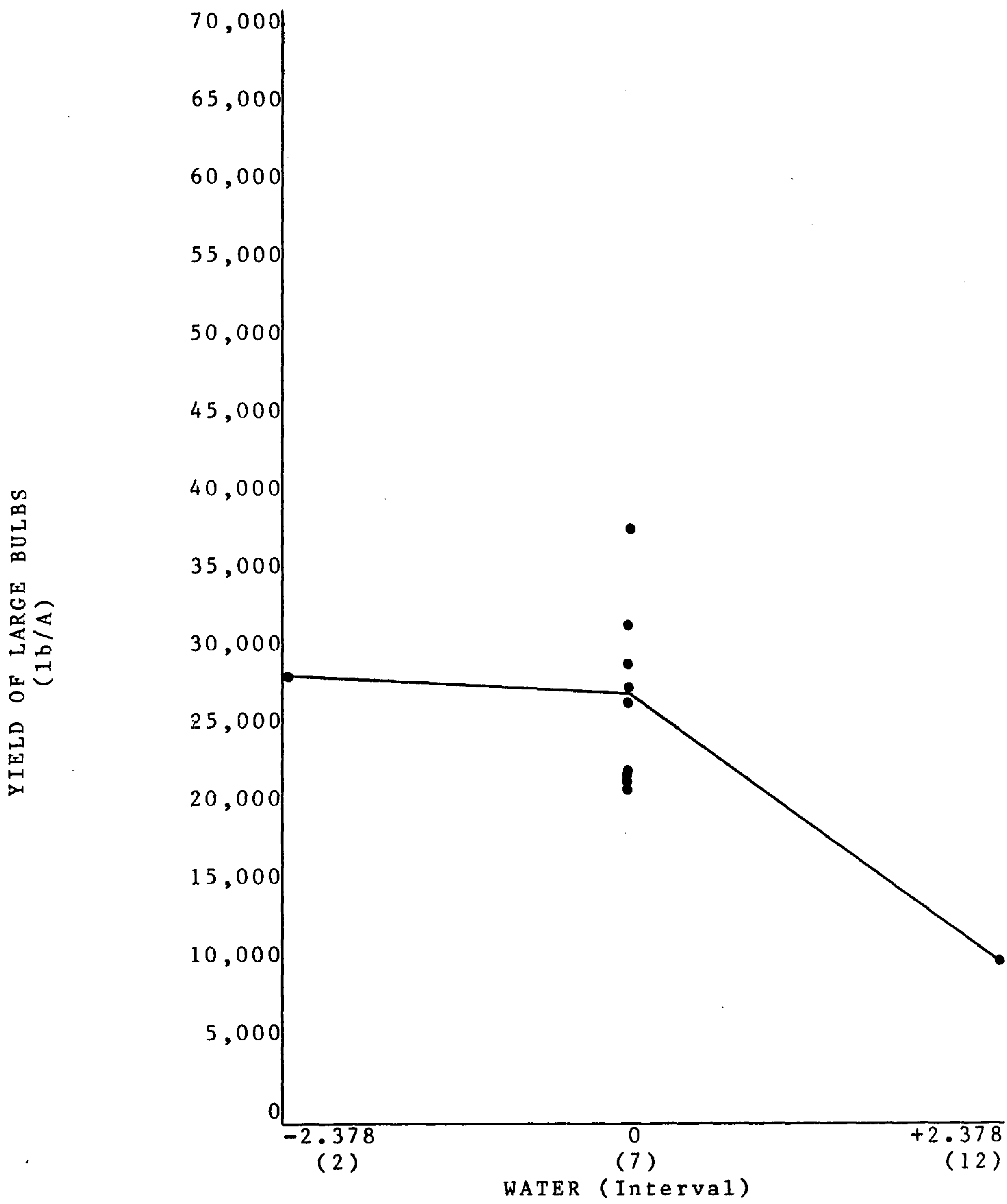

Figure 5. The effect of water interval on large-bulb yield.

Spacing Effect on Large-Bulb Yield

The spacing in this particular analysis was not quadratic in response of yield. The response of large-bulb yield to spacing was a positive linear one. This is shown in Figure 6.

The far spacing of 4.5 inches produced a yield of 42,398 lb/A or 424 hundred-lb sacks per acre. The closest spacing of 0.5 inches produced no yield at all of the large size bulb.

Both of these extremes fell well outside the range of the checks. These values make spacing the most significant of all factors in the large bulb analysis.

The spacing in this analysis was a function of water, date and fertilizer. The interactions were all significant at the 5 percent level or higher.

The water-space interaction has already been discussed previously. Spacing had more of a positive effect on yield of large bulb onions as the fertilizer level increased. The interaction made the spacing effect more significant on yield response. The space-harvest date interaction was also a positive one. The spacing of the onion plants was also more significant as the date of harvest was delayed. As the season progresses, the spacing of the onions becomes more important since the crowding becomes increasingly severe as the plants grow. These interactions were not seen in the total yield.

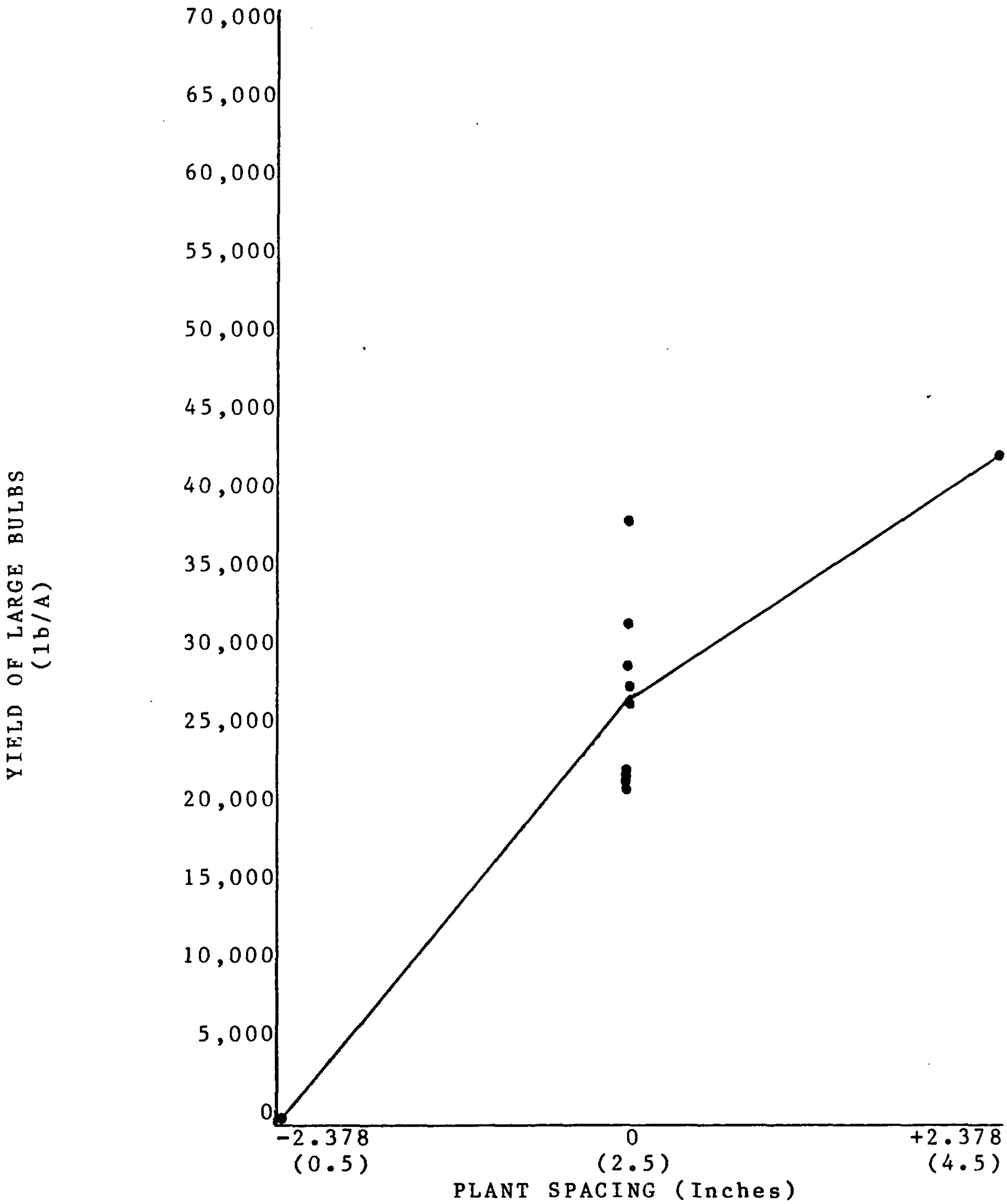

Figure 6. The effect of plant spacing on large-bulb yield.

Fertilizer Effect on Large-Bulb Yield

The fertilizer had a positive linear effect on yield. This is shown in Figure 7.

The high fertilizer level produced a yield of 29,234 lb/A or 292 hundred-lb sacks. This fell within the range of the checks, but within the upper one-third. The low fertilizer level produced a yield of 15,101 lb/A or 151 hundred-lb sacks. This was well outside the range of the checks.

The fertilizer was a function of plant spacing and harvest date. The fertilizer-spacing interaction was already discussed previously, but the relationship was such that fertilizer became more significant at wider spacings. The fertilizer also interacted with harvest date. The interaction was such that the fertilizers positive effect was increased as the harvest date was delayed.

Harvest Date Effect on Large-Bulb Yield

The harvest date had a positive linear effect on the response of large bulb yield. This was similar to the total yield analysis. Figure 8 shows the response of yield at the +2.378, 0, and -2.378 harvest dates.

The latest harvest date produced a yield of 44,722 lb/A or 447 hundred-lb sacks. This was well outside the range of the check plots. The early date gave a yield of 26,340 lb/A or 263 hundred-lb sacks. This would fall very close, within a few hundred pounds, to the average of the check

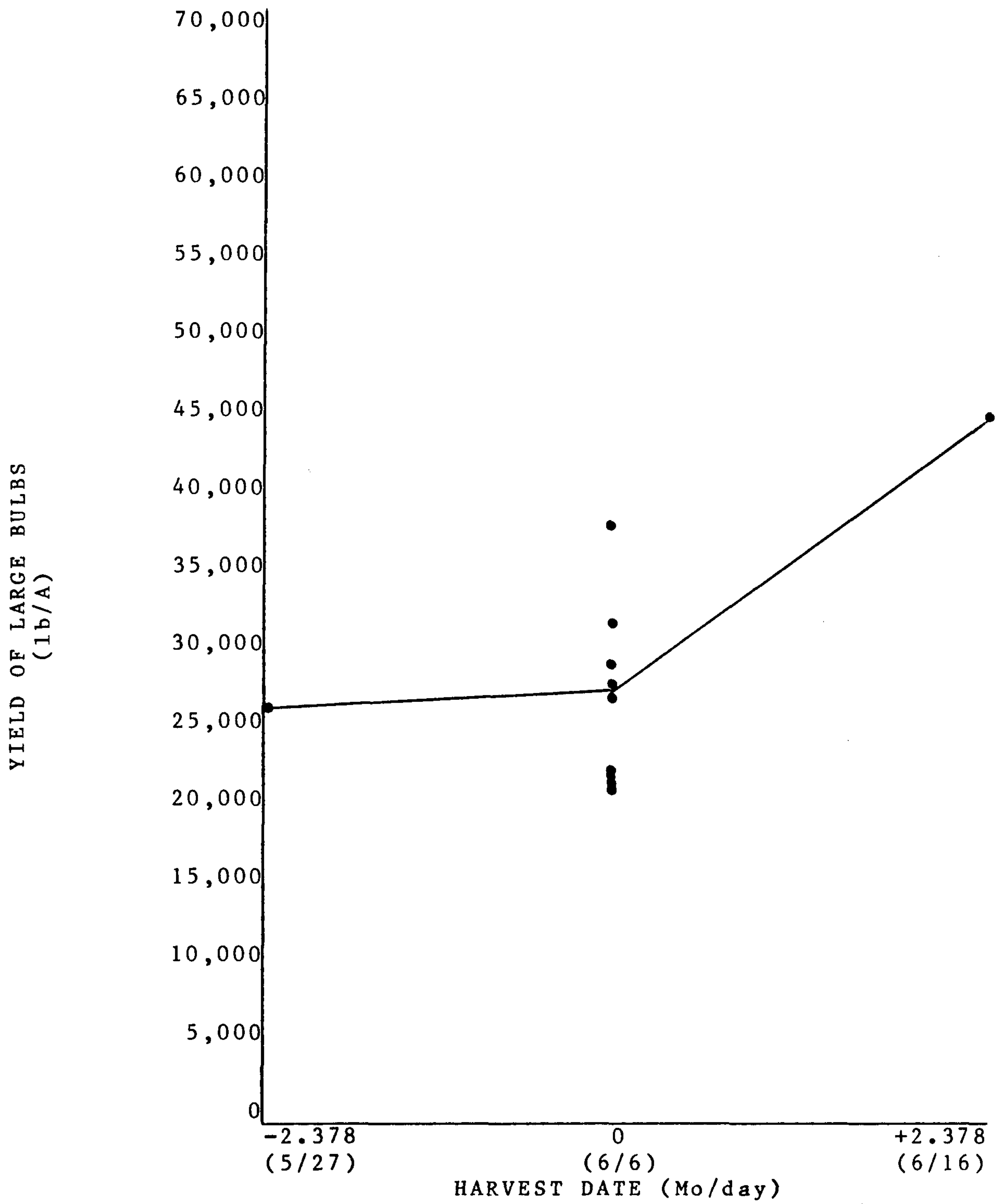

Figure 7. The effect of harvest date on large-bulb yield.

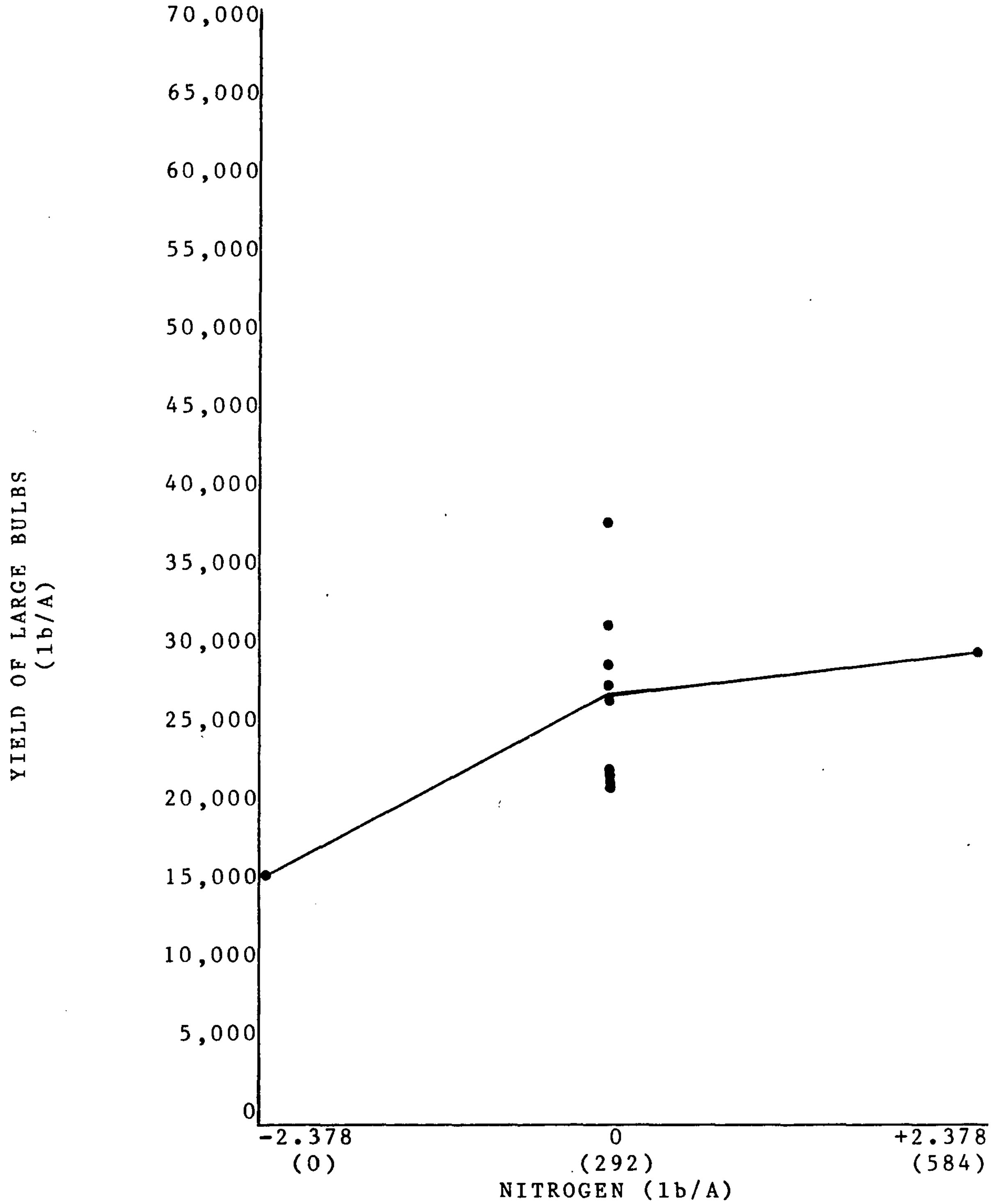

Figure 8. The effect of nitrogen fertilizer on large-bulb yield.

plots. The model still predicts a highly significant effect of harvest date.

The harvest date was a function of the spacing, fertilizer and water level. All these interactions have been discussed previously in this section.

Pesticide Effect on Large-Bulb Yield

Again the pesticide was not significant on the response of large bulb yield as was also true for total yield. The reason was low thrips populations at early onion growth stages.

Herbicide Effect on Large-Bulb Yield

This was also not significant even with the small and medium bulbs excluded. As was mentioned, lack of rain and the use of drip irrigation probably were the two main reasons for seeing no significant response of yield to differing dacthal herbicide levels.

Factor Effects on Medium-Bulb Yield

This analysis gave no useful or significant data on factors covered in the experiment.

Factor Effects on Leaf Dry Weight and Plant Height

Neither leaf dry weight nor plant height were significant in analysis of total, large, or medium bulb yield.

SUMMARY

This experiment tried to see if the present cultural practices in growing bulb onions were in the range which would produce the maximum onion yield for Arizona farmers. The fact is that for most of the six factors, the optimum values have not yet been reached.

Water was one in which an optimum level was reached and further application began to decrease yield on a total yield basis. Since this is the major factor in all agricultural crop response research, it would be the one factor in which a favorable response would be most desired. In relation to large bulb yield, there was less of a quadratic response. In fact, the response was quite linear in favor of increased water application for increased yield of large bulbs. Interactions of water and spacing were seen with total yield and water with spacing and date in large bulb yield.

Spacing gave a negatively linear response on yield when taken on a total yield basis. This was deceiving since most of the bulbs in the close spacing were unsaleable due to small size. The analysis of large bulbs only produced a linear response also, but this time it was a positive one. The farther the spacing, the higher the yield, with the 0.5-inch spacing giving a zero yield of large bulbs. Spacing interacted with water, fertilizer and harvest date, and its re-sponse was a function of all of them.

Fertilizer gave a positive linear response to the yield of total onions. This was a very gradual slope and appeared to possibly peak at the highest level. The analy-sis of large bulbs only produced a similar response on yield. Fertilizer was a function of and interacted with plant spacing and harvest date.

Harvest date had a positive linear effect on total onion yield. The latest harvest added 20,000 lb/A over the checks within a 10-day interval. The harvest date was also positive and linear with respect to the large bulb yield alone. Harvest date was a function of spacing, fertilizer and water level.

Neither the pesticide (malathion) nor the herbicide (dacthal) were significant in relating to response of yield. This was true in both the total yield and the large bulb yield.

The response surface design did in fact reduce the number of experimental plots for the field. This could be important for someone with limited space or funds to cover the project. Response surface could be a valuable tool in agri-culture if proper stepwise steepest ascent experiments precede it. Without prior knowledge of how the factors interact in a given environment, the design can be less efficient than a factorial or even a fractional factorial design. With the proper background, this design could be of benefit in the optimizing of cultural practices in the search for maximum yields at minimal cost to the grower.

APPENDIX 1

TREATMENTS AND YIELDS OF TOTAL AND LARGE BULBS

ROW	TMT	TOT.Y	L.BULB	WATER	HERB	FERT	PEST	SPACE	DATE
1	1	59822	28846	-1	-1	-1	-1	-1	-1
2	41	83635	00000	0	0	0	0	-2.38	0
3	3	52272	24006	-1	+1	-1	-1	-1	+1
4	28	38333	20715	+1	+1	-1	+1	+1	-1
5	33	49368	28266	-2.378	0	0	0	0	0
6	51	56628	28846	0	0	0	0	0	0
7	47	46174	22458	0	0	0	0	0	0
8	39	50239	27878	0	0	0	-2.378	0	0
9	9	65050	27298	-1	-1	-1	+1	-1	+1
10	17	55466	43947	-1	-1	-1	-1	+1	+1
11	6	49368	13939	+1	-1	+1	-1	-1	-1
12	13	50239	13165	-1	-1	+1	+1	-1	-1
13	49	55176	31750	0	0	0	0	0	0
14	19	44431	28266	-1	+1	-1	-1	+1	-1
15	2	47045	12584	+1	-1	-1	-1	-1	+1
16	14	49078	13358	+1	-1	+1	+1	-1	+1
17	50	53143	21877	0	0	0	0	0	0
18	34	38042	10648	+2.378	0	0	0	0	0
19	52	47916	22845	0	0	0	0	0	0
20	36	52562	20715	0	+2.378	0	0	0	0
21	45	54305	26523	0	0	0	0	0	0
22	10	44141	12584	+1	-1	-1	+1	-1	-1
23	21	55176	41237	-1	-1	+1	-1	+1	-1
24	22	47916	29814	+1	-1	+1	-1	+1	+1
25	15	68244	38333	-1	+1	+1	+1	-1	+1

APPENDIX 1 (cont.)

ROW	TMT	TOT.Y	L.BULB	WATER	HERB	FERT	PEST	SPACE	DATE
26	40	57790	35622	0	0	0	+2.378	0	0
27	25	49368	37365	-1	-1	-1	+1	+1	-1
28	27	59532	48787	-1	+1	-1	+1	+1	+1
29	32	51691	39688	+1	+1	+1	+1	+1	+1
30	8	53724	19941	+1	+1	+1	-1	-1	+1
31	35	59822	29040	0	-2.378	0	0	0	0
32	43	46754	26330	0	0	0	0	0	-2.38
33	31	56047	45302	-1	+1	+1	+1	+1	-1
34	53	59822	37558	0	0	0	0	0	0
35	7	59532	24587	-1	+1	+1	-1	-1	-1
36	30	38623	20909	+1	-1	+1	+1	+1	-1
37	24	38333	26330	+1	+1	+1	-1	+1	-1
38	46	54305	27104	0	0	0	0	0	0
39	18	36300	29909	+1	-1	-1	-1	+1	-1
40	26	39494	21490	+1	-1	-1	+1	+1	+1
41	5	62726	31170	-1	-1	+1	-1	-1	+1
42	23	69406	62726	-1	+1	+1	-1	+1	+1
43	29	71729	65630	-1	-1	+1	+1	+1	+1
44	11	56918	22845	-1	+1	-1	+1	-1	-1
45	12	53724	20102	+1	+1	-1	+1	-1	+1
46	20	40075	28459	+1	+1	-1	-1	+1	+1
47	38	53434	29234	0	0	+2.378	0	0	0
48	42	45012	42398	0	0	0	0	+2.378	0
49	37	47916	15101	0	0	-2.378	0	0	0
50	16	52272	16069	+1	+1	+1	+1	-1	-1
51	48	54886	22070	0	0	0	0	0	0
52	4	47335	18586	+1	+1	-1	-1	-1	-1
53	44	70277	44722	0	0	0	0	0	+2.38

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