Sequential changes in some characteristics of two-row barley (Hordeum distichon L., VAR. Betzes) induced by differential irrigation and fertility regimes
by David John Vaughan Redgrave

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Crop and Soil Science
Montana State University
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Abstract:
Two-row malting barley (Hordeum distichon L., VAR. Betzes) was grown under irrigation and N-P fertilization in southwestern Montana. The experiment was conducted to elucidate changes in the harvest grain which had been observed in previous experiments conducted in the same area. Irrigation application was keyed to the plant growth stage. Plant samples were collected periodically from the boot stage through harvest. A moisture stress caused changes in the gross plant weight, grain weight and grain protein percentage. The magnitude and direction of these changes was modified both by the fertility level under which the plant was growing and the growth stage of the plant when the stress was applied. The effects of a moisture stress during a given growth stage may not become evident until a later stage. Subsequent application of water did not provide a recovery from the deleterious effects of a prior moisture stress.

For the production of malting quality barley, it is essential that soil moisture supply be adequate during the tillering, boot and milk stages. A yield increase and protein decrease was noted when samples taken at the hard dough stage were compared to harvest samples. The magnitude of these changes needs further study and clarification.

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ABSTRACT

Two-row malting barley (Hordeum distichon L., VAR. Betzes) was grown under irrigation and N-P fertilization in southwestern Montana. The experiment was conducted to elucidate changes in the harvest grain which had been observed in previous experiments conducted in the same area. Irrigation application was keyed to the plant growth stage. Plant samples were collected periodically from the boot stage through harvest. A moisture stress caused changes in the gross plant weight, grain weight and grain protein percentage. The magnitude and direction of these changes was modified both by the fertility level under which the plant was growing and the growth stage of the plant when the stress was applied. The effects of a moisture stress during a given growth stage may not become evident until a later stage. Subsequent application of water did not provide a recovery from the deleterious effects of a prior moisture stress.

For the production of malting quality barley, it is essential that soil moisture supply be adequate during the tillering, boot and milk stages. A yield increase and protein decrease was noted when samples taken at the hard dough stage were compared to harvest samples. The magnitude of these changes needs further study and clarification.

INTRODUCTION

In 1965, field experiments were initiated in southwestern Montana, which were concerned with the nitrogen and phosphorus fertilization rates and irrigation regimes which would be necessary to produce high-quality, two-row malting barley. In 1966, three locations were used. These locations were near the towns of Manhattan, Dillon and Twin Bridges. The irrigation regimes were concerned with the timing of application of water based on the growth stage of the plant. These stages were the tillering, boot, milk and dough stages of development as defined by Feekes (14) and illustrated by Large (24) (Table II). During the 1966 season, plant samples were taken at the Manhattan and Dillon locations in an attempt to follow the changes that took place in the plant during the latter stages of development and how these changes were influenced by the fertility status and the soil moisture regime under which the plant was growing. Samples were taken by harvesting the entire plant at ground level for 3 feet in a row. Ten heads were selected from this sample; and the stems, leaves and heads were separated and frozen in the field using dry ice in order to stop metabolism as quickly as possible. These samples were then transported back to the laboratory and oven dried in a forced air oven at 65° C. The samples were analyzed for nitrogen and 1000-kernel weight was determined on the grain. On the basis of the information gained from that sampling, it appears that protein percentage of the kernels changes during the latter stages of growth and development. However, the changes that were noted in the protein percentage of the grain may be primarily a function of the amount of carbohydrates that were translocated into the kernel. This was

indicated by the changes in 1000-kernel weight and the changes in the protein percentage. If 1000-kernel weight decreased, the protein percentage increased. As 1000-kernel weight increased with time, protein percentage tended to decrease. The present experiment was conducted in 1968 at Dillon, Montana, to further investigate these changes. Irrigation treatments were the same as those used previously. In addition to nitrogen treatment rates, various phosphorus rates were included. Plant sampling began at the boot stage and was accomplished by harvesting one meter of a row and subsequently separating the heads from the plants. The first set of samples was taken during the early boot stage before heads had emerged. The later samples all had heads. After the sample was taken, soil samples were taken from the area from which the plants had been removed. These soil samples will be analyzed for available phosphorus and nitrogen to determine the uptake and movement patterns of these materials under various irrigation treatments. In previous studies, it has been shown that the protein content and the yield of the grain are influenced by the nitrogen fertility under which the plant was growing as well as the irrigation regime. Thus, this thesis is concerned with the changes in the plant weight and the weight and protein content of the grain from boot stage to maturity and how these changes are influenced and modified by the nitrogen and phosphorus fertilizer application rate and the irrigation regime under which the plants were grown.

REVIEW OF LITERATURE

Many experiments have been conducted to investigate the relationships between plant growth and soil moisture supply. Kramer (23) has summed up the general results.

"In spite of an enormous amount of research on soil-plant-water relationships during the past half century, we are not yet certain what constitutes an adequate supply of water for the good growth of plants. Many of the results from research on the relationships between plant growth, crop yields and soil moisture have been inconclusive or even contradictory. This probably is because attention has been centered on one part of the soil-plant system. Too much emphasis has been placed on soil-water stress and too little on plant-water stress and on the reasons why water stress reduced plant growth."

One of the reasons for the disparity between the results is that many of these investigations have been conducted in such a way that irrigation timing was keyed to a given level of soil moisture. When the supply had been depleted to a predetermined level, additional water was applied. This approach ignores the fact that plants show a differential reaction to moisture stress depending upon the growth stage of the plant (31,32,36,37). Experimental results will then not be consistent unless the soil moisture depletion pattern and the plant development pattern were similar.

Combining the results of experiments with various small grain crops, a pattern emerged which leads to certain relationships.

The three major stages during the growth of a plant are tillering, head formation or flowering and grain filling (37). A moisture stress during

tillering decreases the final yield due to the lower number of tillers produced (12). The lower vigor of the plants after an early moisture stress may be related to the decrease in P uptake which is limited under conditions of low soil moisture (13). N absorption is less affected by soil moisture content than is P (13). The subsequent growth and development of the plant is adversely affected by this lack of P during the early stages and increasing P supply or soil moisture at a later stage does not provide for complete recovery (5,6).

A limiting supply of soil moisture during the boot and flowering stages results in an increase in the protein percentage of the grain (38, 39). The critical nature of a moisture stress during the flowering period has been shown on corn (20,36,44), barley (31,3238) and grain sorghum (13). Some investigators have suggested that if a limited amount of water is available, such as with a supplemental irrigation system, then the most advantageous time for the application of this water is at the boot stage (18,27).

With barley, a moisture stress during the filling of the grain produces an increase in the protein percentage, a decrease in the yield and a decrease in the percentage plump kernels 1/ (10,34,37,38). It has been thought that yield and protein percentage for a given variety were related. But the concept that protein percentage changes are related to the dilution effect of carbohydrate accumulation has been questioned (32,38,40).

1/ Percent plump is defined as those kernels remaining above a sieve with openings 6/64 inch wide (1,24).

The application of N and P also affects the quantity of barley produced, the protein percentage, and the plumpness (26,32,37,42,43,45). Increasing the application rate of N and P increased the changes in the grain up to a point.

Usually, the effects of the N and P application are modified by the irrigation or soil moisture stress regime under which the plants were grown (19,32,37,38,41).

Under some conditions the effect of N application will mask the effects of the irrigation regime. At other times, the irrigation regime becomes the dominant factor (19,32).

Most of the foregoing results were observed by changing the N and P fertility status of the soil and modifying the soil moisture regime under which the plant was grown. The changes that were then observed in the harvested grain were attributed to the effects of the moisture stresses which were imposed at various growth stages.

Important as these results are, in many cases it is not known when the observed changes actually occurred. It has been assumed that the moisture stress during a certain growth stage affected its changes during that period, but this assumption may not be valid.

The need for a dynamic approach to irrigation research was well put by Harlan (16). "The factors affected by irrigation are so numerous and so involved that the final statement of yield per acre does not afford much basis for interpretation." He explains this feeling by adding, "The period during which the quantity of water or the application of water

affects the size of the kernel is worth determining. Knowledge of the period during which the application of water affects the growth or maturation of the plant affords a basis for the better understanding of irrigation."

The general growth pattern of barley is an increase in the weight of the plants until two to three weeks before harvest after which the weight declines (7,17). Moisture stress affects the development of the plant by decreasing the rate of dry matter production and altering the translocation pattern of carbohydrates into the developing grain. The effect of moisture stress during grain development is a decrease in the rate of grain weight accumulation up until the hard dough stage, after which the pattern changes (7,11). Some reports indicate that a decrease in grain weight occurs between the hard dough stage and harvest (11,22), and an increase or no change during this period has also been reported (21,29).

The changes in the protein percentage of the grain during the latter stages of growth are also variable with increases (16), no change (11), and decreases (22) being reported.

Some of the variability in the reported protein changes may be due to the difference in protein content between the main and secondary growths. In wheat it has been shown that the protein content of the main crop grain can be lower than that of the secondary, and this effect seems to be modified by the moisture status during ripening (30).

Of the recent reports, the most comprehensive is the one by Krall (22) who reports that for barley the general pattern is for the yield to

decline from hard dough to harvest and the protein percentage to increase during the same period. The magnitude of these changes was influenced by the variety of barley grown and was further modified both by the differences in environment during the ripening stages and by whether the crop was grown under dryland conditions or irrigation.

The reasons for the research on moisture stress effects and irrigation regime as they influence plant growth have been well stated by Richards and Wadleigh (35), "A knowledge of the relation of crop response to the soil-moisture status is a primary consideration in establishing the most economical over-all management plan."

This research project was initiated with the hope of adding to this knowledge.

MATERIALS AND METHODS

Location

The field plots were located in southwestern Montana approximately 5 miles north of Dillon. The experimental area is on the southern part of the Bureau of Reclamation's East Bench Project of the Beaverhead River. The area was adjacent to and above the main canal of the project at approximately $45^{o}15'N$ and $112^{o}33'W$ with an elevation of 5200 feet and a uniform slope to the north of less than 1 percent.

Soil

The soil, Avalanche silt loam, is classified as a Borrolic Calciothid. A profile description of this series is given in Table XIX.

During the initial site inspection, three areas were sampled at depths of 0-6 inches, 0 to 1 foot and then at 1-foot intervals down to 6 feet. The analysis data for these samples are given in Table XVIII.

Plot Layout and Design

The experimental design was a split plot with the irrigation plots as the main treatment and the fertilizer treatments placed on the subplots.

Replications were oriented in the N-S direction. The irrigation strips were oriented in the E-W direction and randomized within each replication. The fertilizer strips were randomized separately within each irrigation strip. Each irrigation strip was 85 x 25 feet (25.9 x 7.6m) and subdivided into 12 fertilizer strips which were 25 feet (7.6m) long and 7 feet wide (2.1m).

Statistical Analysis

The statistical analysis was done according to the computational formulas given by Cochran and Cox (8). The analysis of variance provides two error terms designated E_a and E_b. Error A was used to calculate F ratios for the A level treatment, irrigation treatments in this design; and error B was used for the F ratio of the fertilizer rates and the interaction effects. All calculations were performed using a Sigma 7 Computor.

Fertilizer Rates and Materials

Fertilizer was hand applied to each plot and then lightly disced from the south. This provided approximately a six centimeter incorporation. Ammonium nitrate (33.5-0-0), concentrated superphosphate (0-45-0) and muriate of potash (0-0-60) materials were used. Fertilizer rates were calculated in pounds per acre to provide compatability with previous experiments related to this study.

Nitrogen rates were 0, 50, 100, 150 and 200 lbs/A of N; Phosphorus rates were 0, 40 and 80 lbs/A of P; Potassium rates were 0 and 40 lbs/A of K. Table I gives the rates of N, P and K for each fertilizer treatment.

Irrigation Treatments

Irrigation water was applied at four times during the growing season. The application was timed by the growth stage of the plants. The stages were A, tillering; B, boot; C, milk; and D, dough. These stages have been designated by Feekes (14) as A, stage 3; B, stage 10.1; C, stage 10.5.4; and D, stage 11.3 and have been illustrated by Large (24). The irrigation treatments are outlined in Table II.

Table I. Fertilizer Application Rates.

Treatment	Rate in Pounds/Acre 1/		
	N	P	K
1	0 (0) 2/	0 (0)	0 (0)
2	0 (0)	0 (0)	40 (45)
3	0 (0)	40 (45)	40 (45)
4	0 (0)	80 (90)	40 (45)
5	50 (56)	40 (45)	40 (45)
6	100 (112)	0 (0)	40 (45)
7	100 (112)	40 (45)	40 (45)
8	100 (112)	80 (90)	40 (45)
9	150 (168)	40 (45)	40 (45)
10	200 (224)	0 (0)	40 (45)
11	200 (224)	40 (45)	40 (45)
12	200 (224)	80 (90)	40 (45)

1/ N-(NH_4NO_3 33.5-0-0); P-($Ca(H_2PO_4)_2$ 0-45-0); K-(KCl 0-0-60).

2/ Kg/ha.

Table II. Plant stages used to time application of irrigation water.

Irrigation	Plant Growth Stage	Feekes Scale a/
A	Tillering	3.0
B	Boot, awns just protruding	10.0-10.1
C	Milk--Soft Dough	10.5.2-10.5.4
D	Hard Dough b/	11.2-11.3

a/ As illustrated by Large (24).

b/ 11.3 kernel is hard and difficult to divide by thumbnail.

The irrigation treatments consisted of omitting one of the irrigation stages. Thus including the treatment receiving all of the irrigations, five irrigation treatments were used.

A sprinkler irrigation system was used to apply the water with four sprinklers in an irrigation strip. These sprinklers were connected to a 3-inch diameter main line and were run until 3 inches of water had been applied to the irrigation strip. The amount of water applied was measured by placing two or three small cans in each irrigation strip. The date of each irrigation is given in Table III.

Seeding

The area was seeded June 14, 1968, with certified betzes barley (Hordeum distichon L. (3)) at a rate of 100 pounds per acre using a seven-row (one-foot spacing) press wheel seeder. Seeding was done in a N-S direction. About a week after seeding, heavy rain partially filled in each row furrow so that when the plants began to emerge, some of them were buried quite deeply--as much as 2 to 2 1/2 inches. When the plants began to emerge, this meant that the first leaf, rather than the coleoptile, was attempting to emerge through the soil cover. This was one of the factors resulting in a low stand density on row 5 and a spotty stand on some of the other rows. The plants did not emerge well, and many did not emerge at all.

Periodic Plant Samples

Each fertilizer strip consisted of seven rows running for 25 feet

Table III. Dates of Irrigation.

Date	Irrigation	Plant Stage
July 15	A	Tillering
August 6 and 7	B	Boot
September 9	C	Milk
October 5	D	Hard Dough

(7.6m) in the N-S direction. The rows were numbered from the west side of the plot. After the A stage (tillering) irrigation, a stand survey was made to determine how the plot would be divided for periodic sampling and harvest. At this time, row 5 had a very low stand density. Row 5 was completely removed in all plots, and row 6 was used for periodic sampling. The periodic samples consisted of 1 meter of row with approximately 10 to 15 centimers between successive samples. A 5-meter row sample was taken from row 4 to provide a harvest sample which would be compatable with the periodic samples of row 6. Rows 1 and 4 became the borders for rows 2 and 3 which were used for harvest samples and neutron access tubes. The plants were partially air dried in the field and subsequently oven dried in a forced air oven at 60°C. After oven drying, the grain-bearing heads were hand separated. The stems and leaves were ground in a Wiley mill in preparation for chemical analysis. The heads were weighed, counted and threshed; and the grain weighed. The grain was also ground in a Wiley mill.

Periodic Soil Samples

After the plants were removed, a soil sample was taken from the sampling area. Two samples were taken at the 0-6 inch depth and combined; other samples were taken from the 0-1 foot, 1-2 foot and 2-3 foot depths. All of the samples were taken with a King tube. The samples were placed on a 9-inch paper plate in the plot until air dry, were then bagged and subsequently oven dried in a forced air oven at 65°C.

After drying, the samples were sieved through a number 10 sieve (0.078 inch openings).

Nitrogen Analysis

Nitrogen (NH_3) was determined using the Kjeldahl procedure with the boric acid modification as outlined in the American Association of Cereal Chemists method 46-12 (2). Methyl Red and Bromocresol Green indicator was used and the received solution back titrated using a sodium acid sulphate ($NaHSO_4 \cdot H_2O$) solution as suggested by Reeder and Patton (33). The normality of the acid was adjusted so that a 0.4 gram sample of grain or plant material required 10-25 ml. of solution for back titration. This solution was 0.1142 normal. The entire procedure was calibrated by using samples of ammonium oxalate. Grain protein percentage was calculated by multiplying percent N by 6.25 (1,2).

1000-Kernel Weight

A 15-gram subsample of the grain was used to measure kernel weight. The number of kernels in the subsample was determined with an electronic seed counter. If the grain sample was less than 15 grams, then the entire sample was used. The number of seeds in a 15-gram sample varied from 500 to 800. It was not possible to do a sieve analysis on the grain due to the small sample size.

Neutron Readings

Aluminum neutron access tubes were installed in replications 3 and 4 on selected treatments. These tubes were installed between rows 2 and 3 in an area which was judged to have a good stand. Soil samples were taken for moisture content determination at the same time as the installation of

the neutron tubes and subsequently air dried in a forced air oven at 110°C. Readings that were taken with a Nuclear Chicago Neutron Meter were used in conjunction with these moisture samples to provide a calibration curve.

Precipitation Data

Precipitation was recorded at the Dillon Airport. The weather station at this airport is part of the Environmental Science Services Network. The station is located approximately 1.5 miles north of the experimental area. The data is given in Table XX.

RESULTS AND DISCUSSION

The size of the error terms in the analysis of variance indicated a large amount of variability between and within replications. This variation was probably caused by the nonuniform stand and was aggravated by the small sample size of one meter of row. The results of the statistical analysis for the various factors measured is given in Table XVII. A perusal of the treatment means will show that differences between treatments exist and are significant at .10 as shown by the LSD values. These differences are sometimes not reflected in a significant F value for the treatment effect. This discussion will present the major trends shown in the data. If a change was consistent between treatment and times of sampling, then this effect was considered as real without resorting to rigid statistical proof of this reality.

Total Plant Weight

The total dry weight of the plants from a meter of row showed the most rapid increase between the tillering and boot stages. The weight continued to increase until the hard dough stage, and then showed a decrease at harvest. The magnitude of these changes was influenced by the irrigation regime. Figure 1 shows the weight of plants as a function of time for the complete irrigation treatment (ABCD). The total weight increased rapidly between the boot and milk stages. The rate of dry matter accumulation slowed down between the milk and hard dough stages and then showed a decrease until harvest time. Subtracting the weight of grain from the total weight showed a similar increase between the boot and milk stages; but then between the milk and hard dough stages, the rate of accumulation

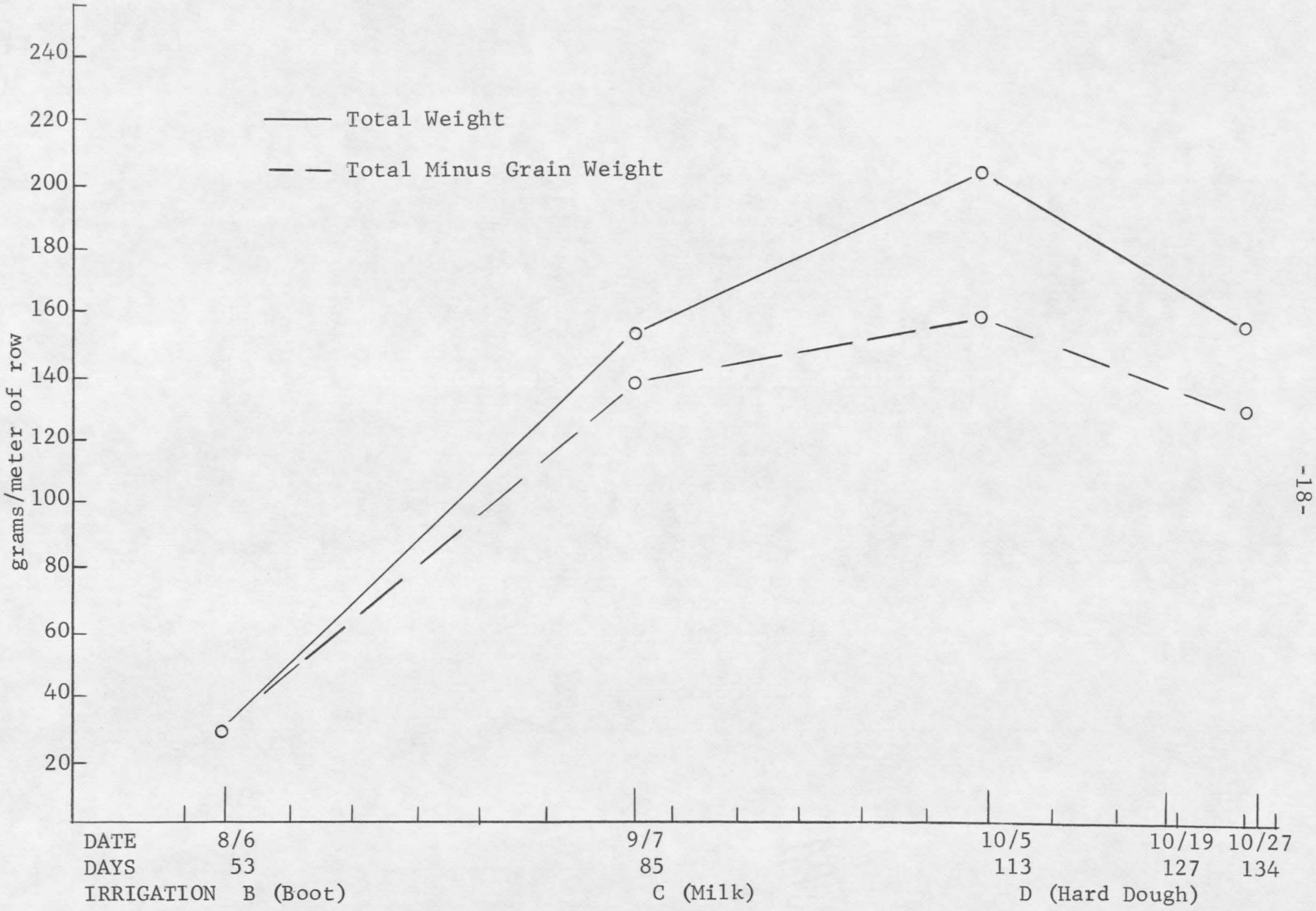


Figure 1. Dry weight of plants. Means for irrigation treatment 1 (ABCD).

of vegetative material decreased markedly. In fact, it became almost negligible. The same pattern is shown with the -A irrigation regime, as given in Figure 2. The rate of vegetative material increase was lower between the boot and milk stages when the A irrigation was omitted, was approximately the same between milk and hard dough stages, and then showed a decline to harvest similar to the complete regime. The weight of vegetative material for the -A irrigation regime was lower throughout the season then the complete, and yet the rate of change was very similar. This seems to indicate that the major effect of omitting the A irrigation was to reduce plant growth during the early stages. This decrease was evident through harvest time, even though the -A irrigation treatment subsequently received the B, C and D irrigations. Application of water at the later stages of growth did not overcome the adverse effects of water stress during the tillering stage.

The effectsof omitting the B irrigation, compared with the complete irrigation treatment, are shown in Figure 3. Omitting this irrigation caused the rate of dry matter accumulation to be markedly less between the milk and hard dough stages in comparison with the complete irrigation treatment. As would be expected, the rate of dry matter accumulation between the boot and milk stages was less when water was omitted at the boot stage. This effect also carried over when water was applied at the later stages. Even the application of water at the milk stage did not cause an increase in the weight of the plants.

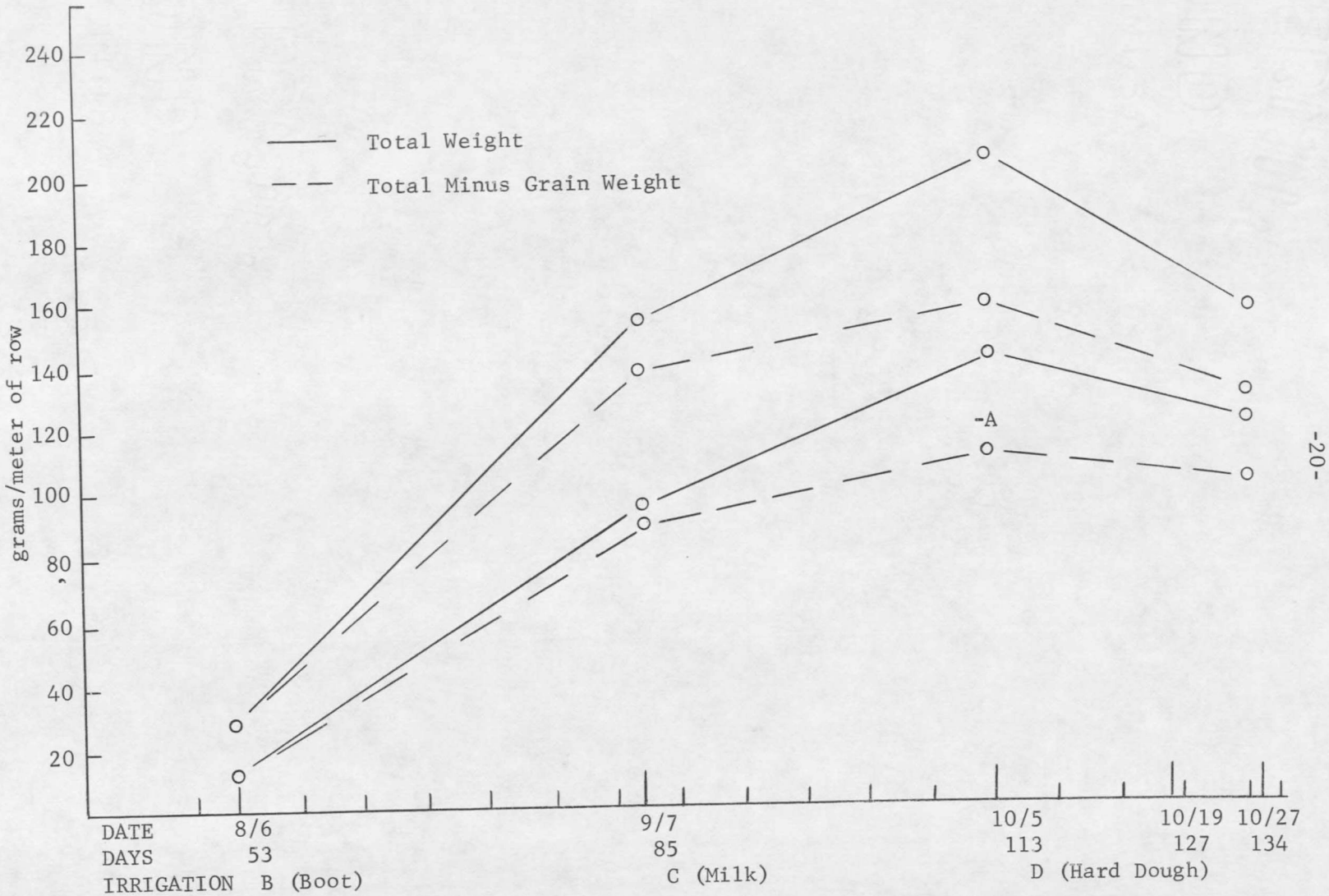


Figure 2. Dry weight of plants. Means for irrigation treatments 1-(ABCD) and 2-(-BCD).

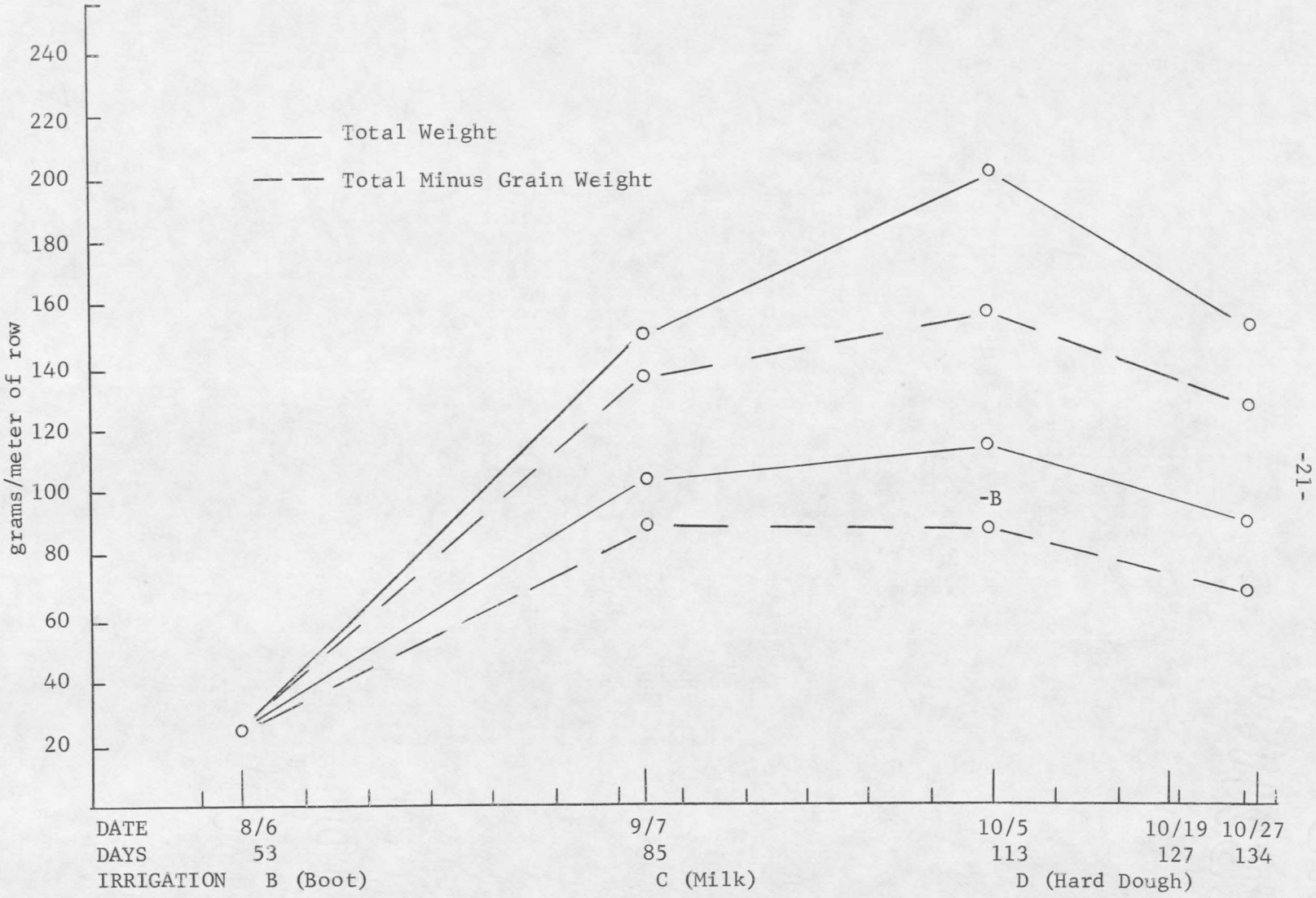


Figure 3. Dry weight of plants. Means for irrigation treatments 1-(ABCD) and 3-(A-CD).

Omitting the application of the C irrigation, shown in Figure 4, also resulted in no increase in dry matter between the milk and hard dough stages. There was a marked decrease in the vegetative part of the plant between the milk and hard dough stages when the C irrigation was omitted. This decrease was probably associated with the increase in the weight of the grain during this period. There was no increase in total dry matter; and yet translocation to the grain continued, but at a slower rate than under the complete irrigation regime. This will be shown in another graph which is concerned with grain weight changes. The loss in weight from the hard dough stage until harvest was greater when the D irrigation was omitted than when this irrigation was applied as in the complete irrigation regime. These effects are shown in Figure 5. In addition to the total plant weight decrease, the vegetative weight also decreased in approximately the same order of magnitude.

Summary of Plant Weight Changes

One of the primary reasons for this study was to evaluate the effects of omitting one of the four stages of irrigation as compared to the application of all four irrigations. Figure 6 shows the weight of plants at each stage as a percentage of the complete irrigation. With the -A treatment, the total plant weighed approximately 55% of the complete irrigation treatment at the boot stage. Application of the B, C and D irrigations to this -A treatment allowed it to increase the total plant weight in relation to the complete; but still at final harvest, it was only about 76% of the complete treatment. Omission of the boot stage irrigation resulted

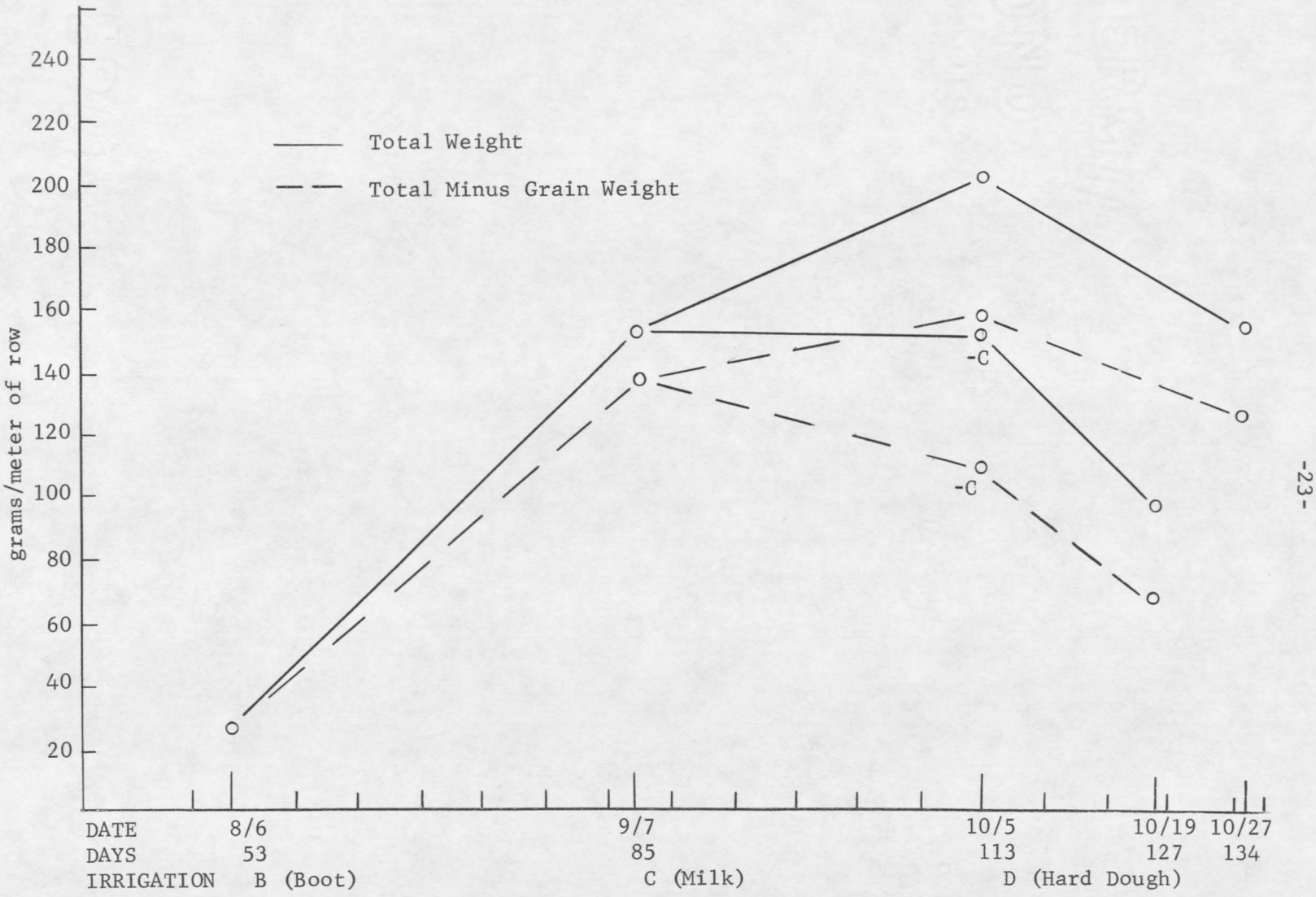


Figure 4. Dry weight of plants. Means for irrigation treatments 1-(ABCD) and 4-(AB-D).

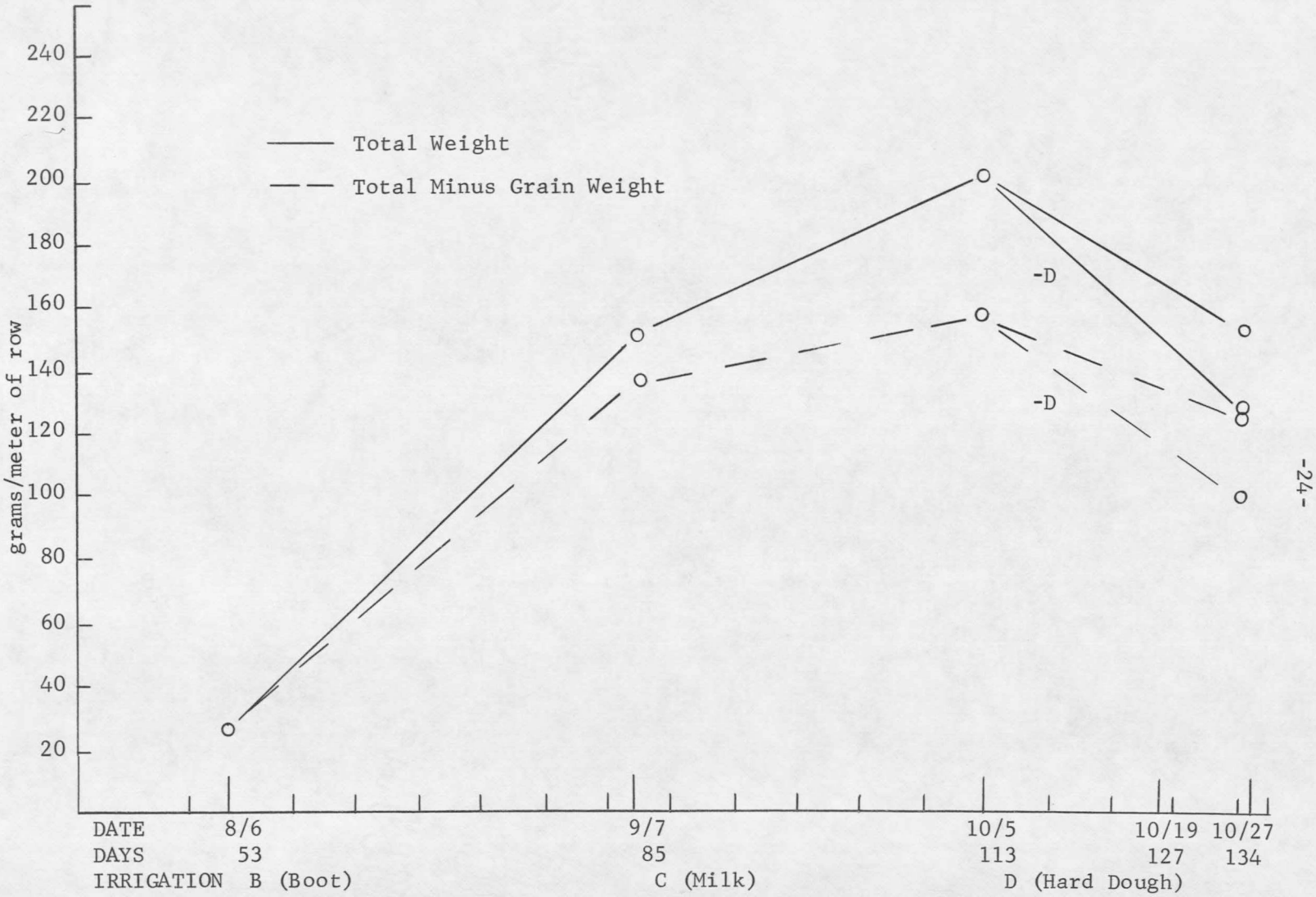


Figure 5. Dry weight of plants. Means for irrigation treatments 1-(ABCD) and 5-(ABC-).

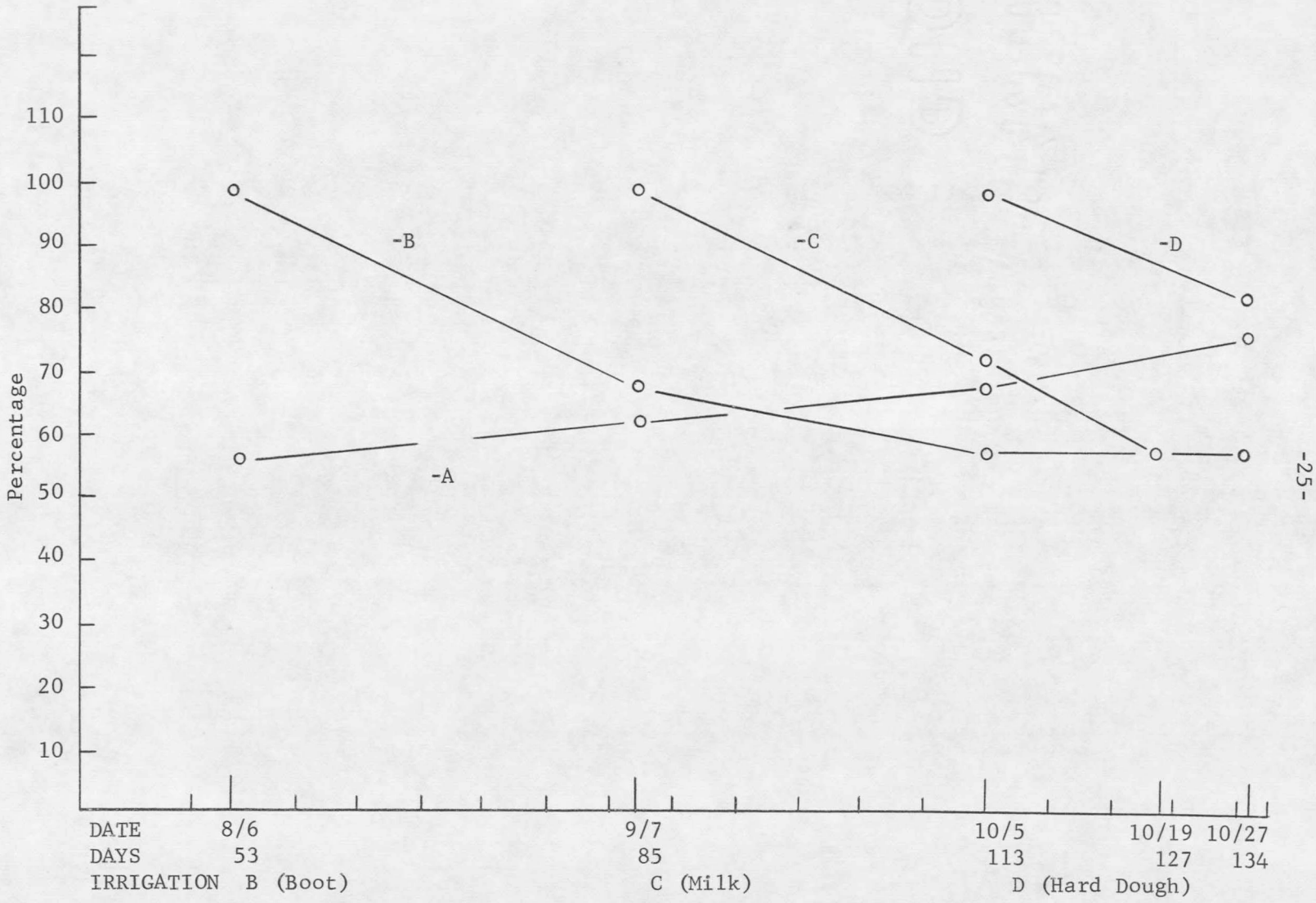


Figure 6. Dry weight of plants. Means for irrigations as percentage of irrigation treatment 1-(ABCD).

in a rapid decline to approximately 70% of the complete treatment at the milk stage. Application of water at the C and D irrigation stages did not provide a recovery from the effects of the B irrigation; and at harvest, the total plant weight of the -B treatment was approximately 60% of the complete treatment.

Similar effects are noted with the -C and -D irrigation regimes. Omitting the C irrigation caused a rapid decrease in the plant weight in relation to the complete irrigation regime. Subsequent irrigation at the hard dough stage with the -C treatment did not show a recovery from the effects of a moisture stress at the milk stage. At harvest, the -C treatment was approximately 60% of the complete treatment, and the -D treatment was 80% of the complete.

With the complete irrigation, increasing N rates from 0 to 200 lbs/A increased the weight of the plants. At the hard dough stage, this increase, shown in Figure 7, can be seen to be an effect of prolonging the vegetative growth period past the milk stage as shown in Figure 8. The effects of changing phosphorus rate from 0 to 80 lbs/A are shown in Figure 9. The addition of 80 lbs/A of P resulted in the plant weight increasing after the milk stage. This was similar to the changes when N application rate was increased.

The omission of irrigation B showed the greatest affect on the weight of the plants, in relation to the complete irrigation regime. Figure 10 shows the affect on the plant of varying N rate with the -B irrigation treatment. Under this irrigation regime, the affect of 200 lbs/A of

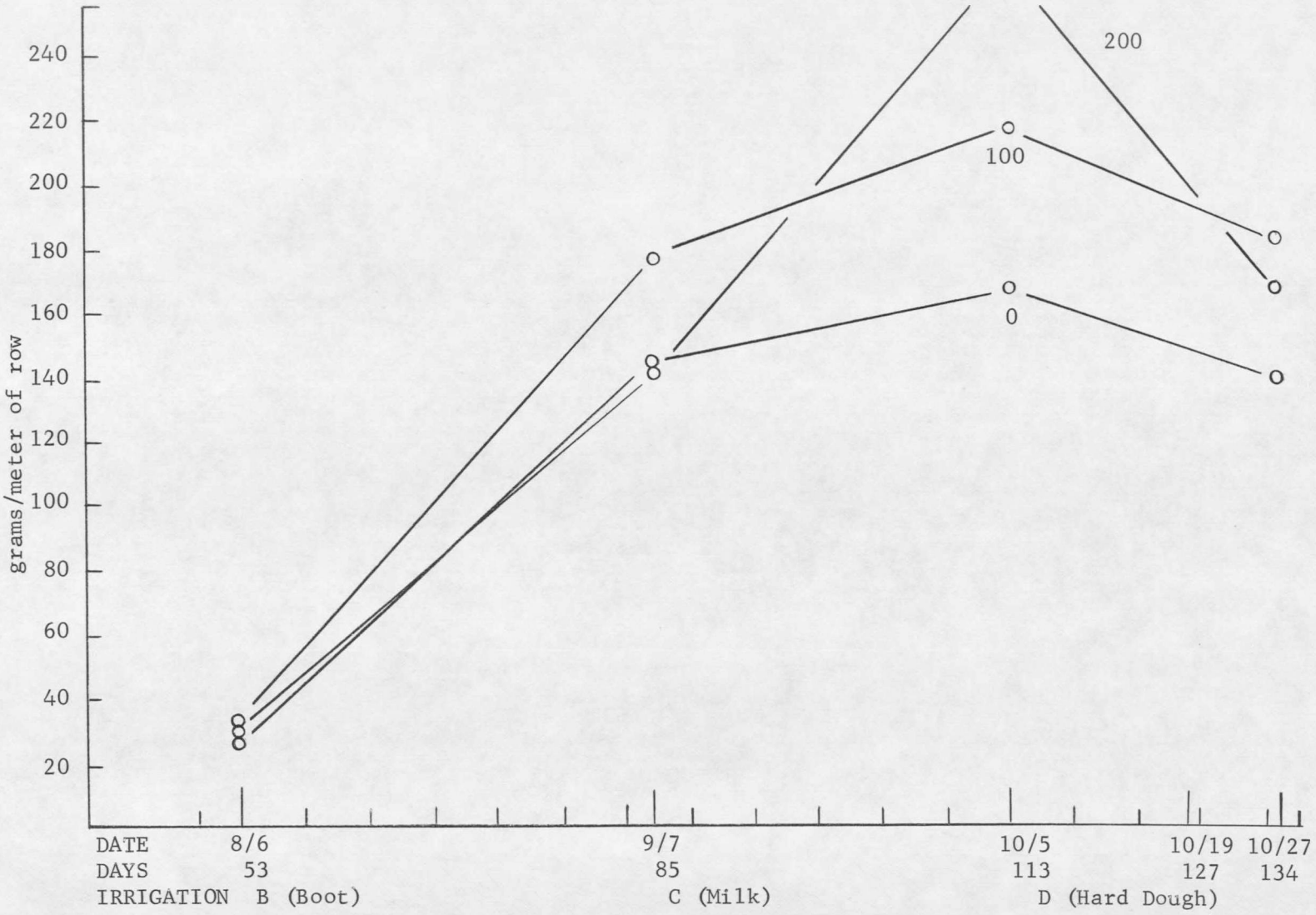


Figure 7. Dry weight of plants. Means of the 0, 100, and 200 lbs/A N rates of irrigation treatment 1-(ABCD).

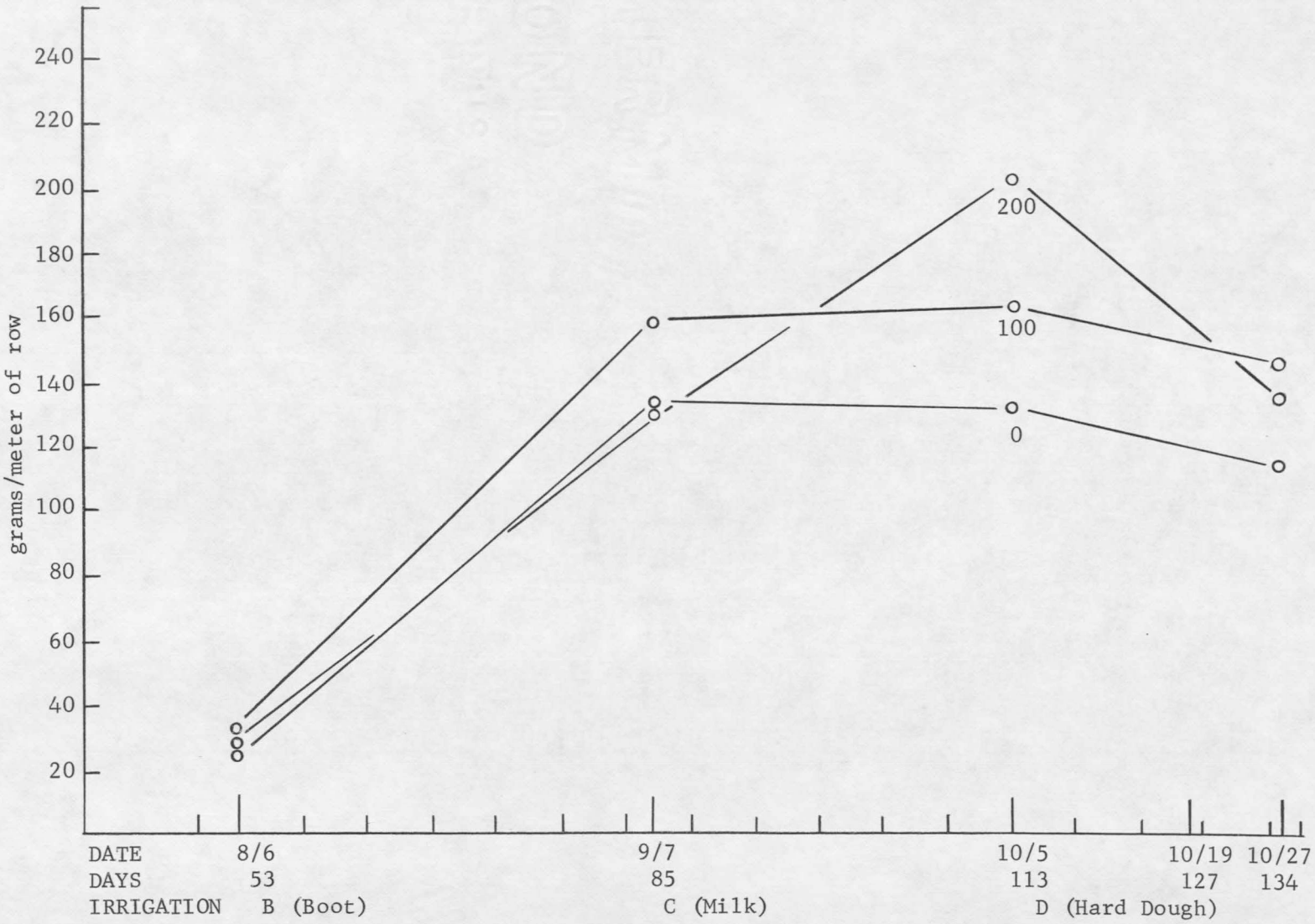


Figure 8. Dry weight of plants minus weight of grain. Means of the 0, 100, and 200 lbs/A N rates of irrigation treatment 1-(ABCD).

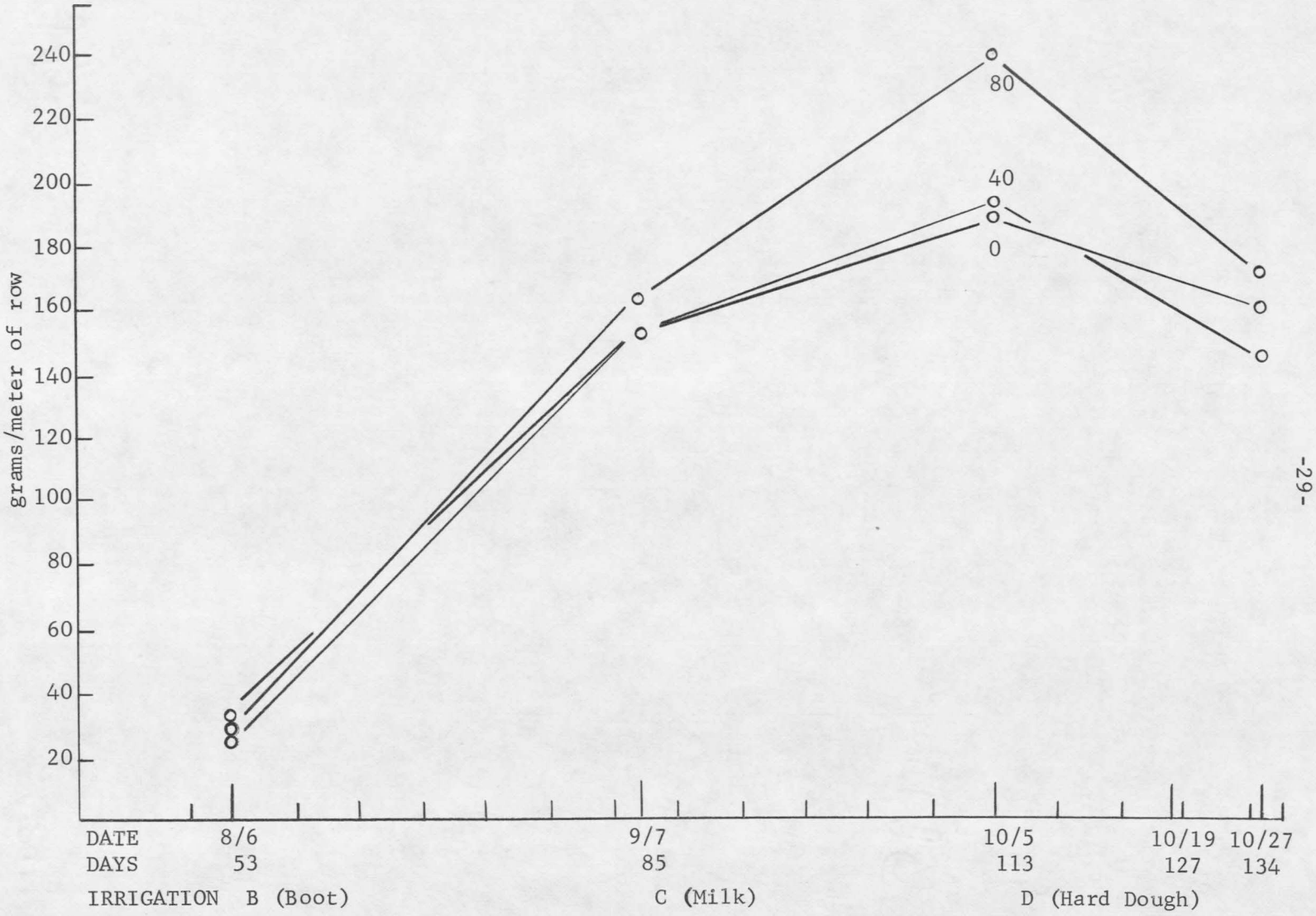


Figure 9. Dry weight of plants. Means of the 0, 40, and 80 lbs/A P rates of irrigation treatment 1-(ABCD).

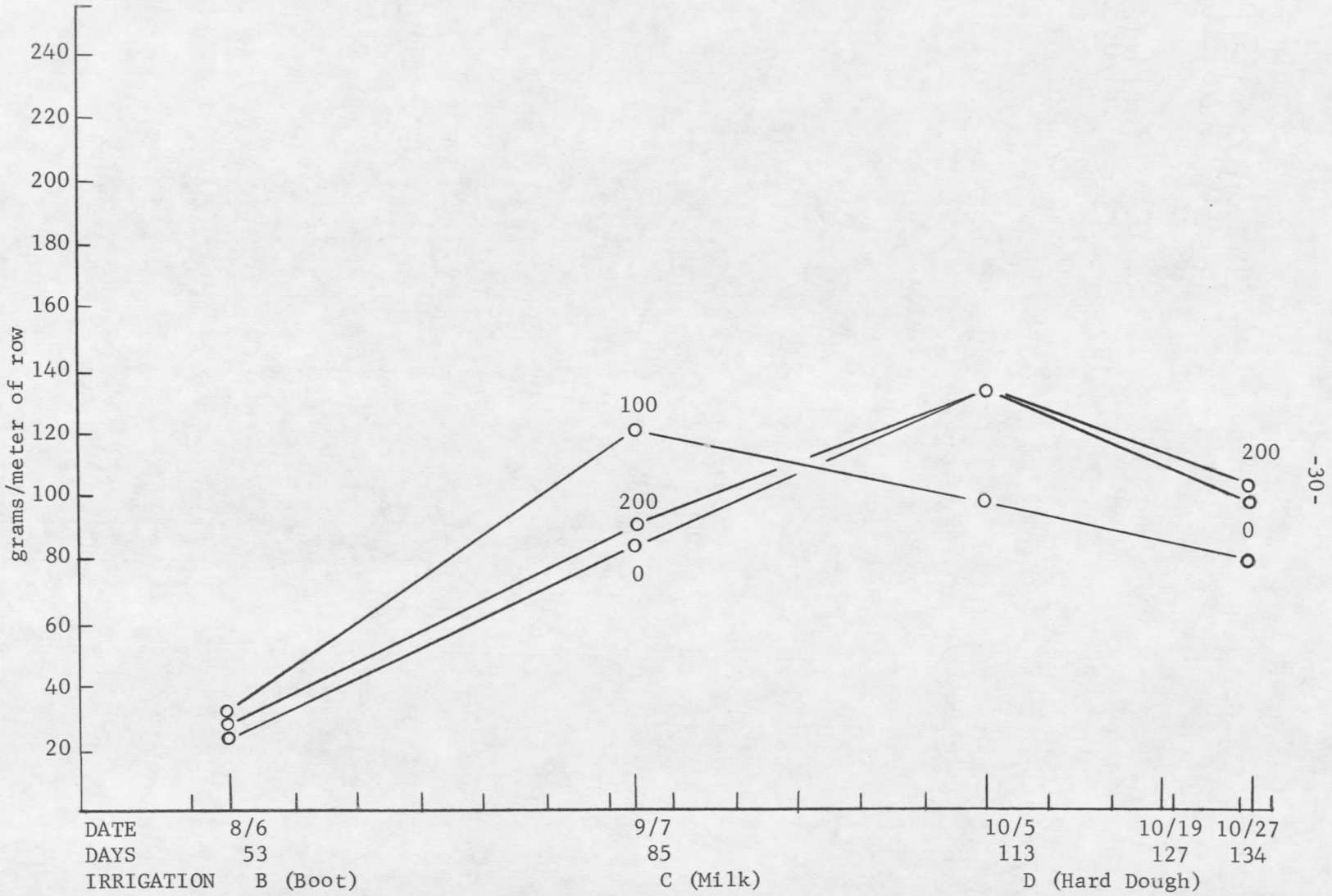


Figure 10. Dry weight of plants. Means of the 0, 100, and 200 lbs/A rates of irrigation treatment 3-(A-CD).

applied N increasing the vegetative growth period was overshadowed by the depression of the growth rate caused by the omission of the boot stage irrigation. Figure 11 shows the weight of the plants under the -B irrigation regime when P application rate was varied from 0 to 80 lbs/A. As with the applied nitrogen, the changes in the growth pattern due to P application was masked by the lack of water at the boot stage.

Grain Weight

At the first sampling date, none of the irrigation or fertilizer treatments had any emerged heads. This sampling was during the boot stage and just the awns had emerged from the sheath.

The weight of the grain as it changed throughout the season under the complete irrigation regime is shown in Figure 12. The grain weight increased from the boot stage to the milk stage, but the most rapid increase in grain weight occurred between the milk and the hard dough stages. From hard dough to harvest, a decrease in grain weight was noted. This decrease will be discussed in a later section.

When the A irrigation was omitted, the rate of grain formation between the boot and milk stages was less than when this irrigation was applied. Figure 13 compares the complete irrigation treatment with the -A treatment in relation to the changes that occurred in the grain weight. The -A irrigation treatment also showed a decrease in grain weight between the hard dough and harvest.

When the B irrigation was omitted, the rate of grain formation between the tillering and milk stages was the same as with the complete

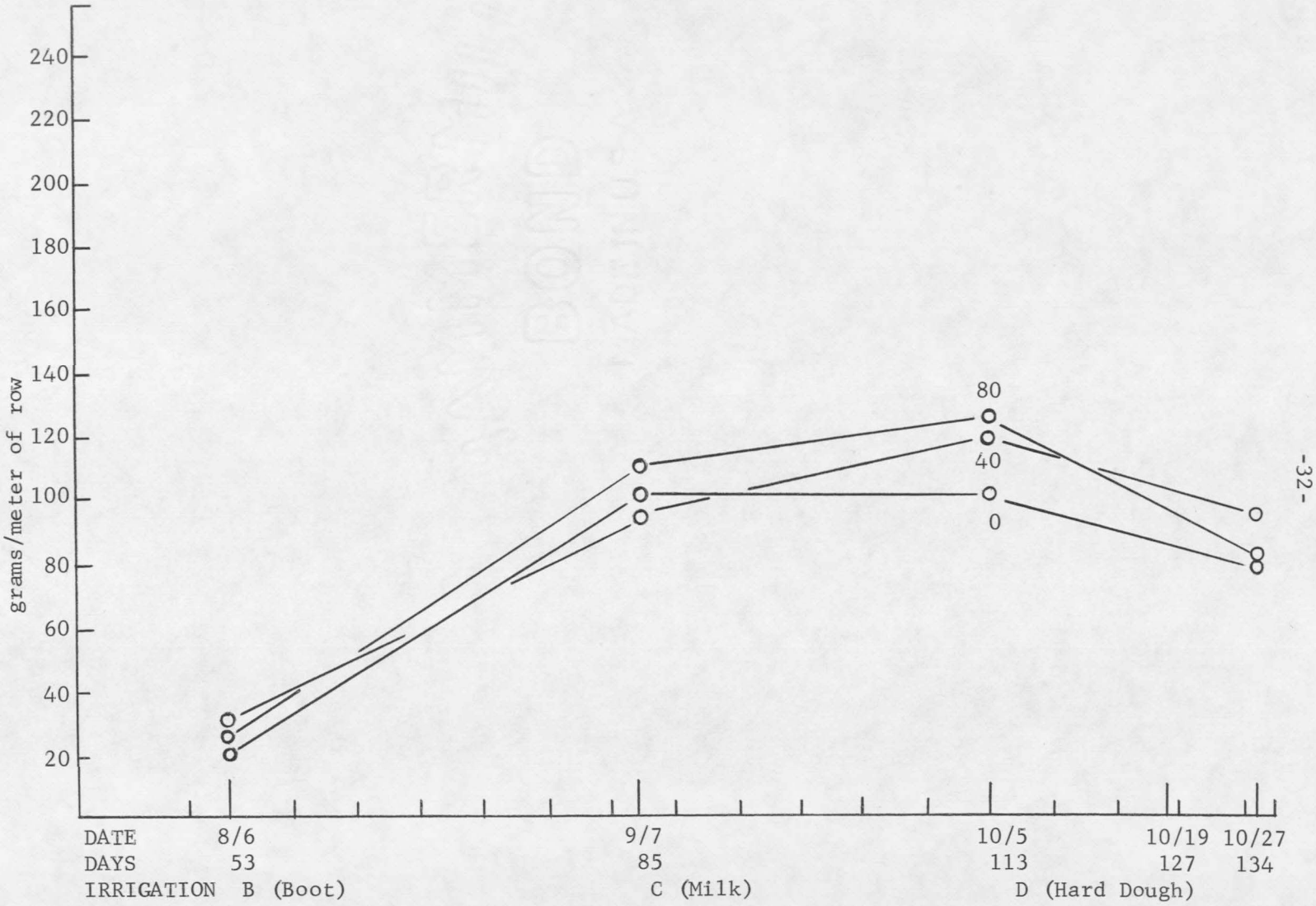


Figure 11. Dry weight of plants. Means of the 0, 40, and 80 lbs/A P rates of irrigation treatment 3-(A-CD).

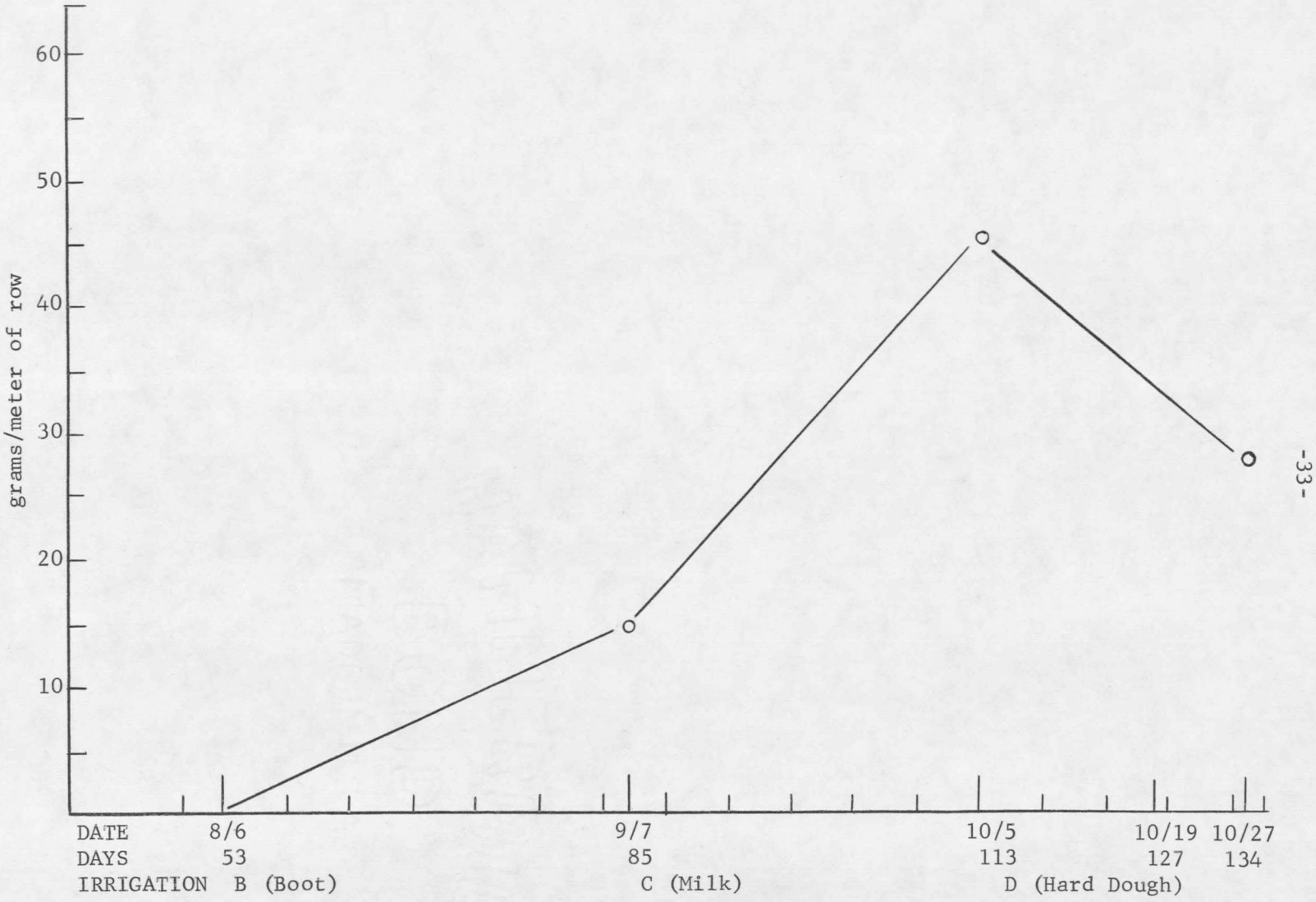


Figure 12. Dry weight of grain. Means for irrigation treatment 1-(ABCD).

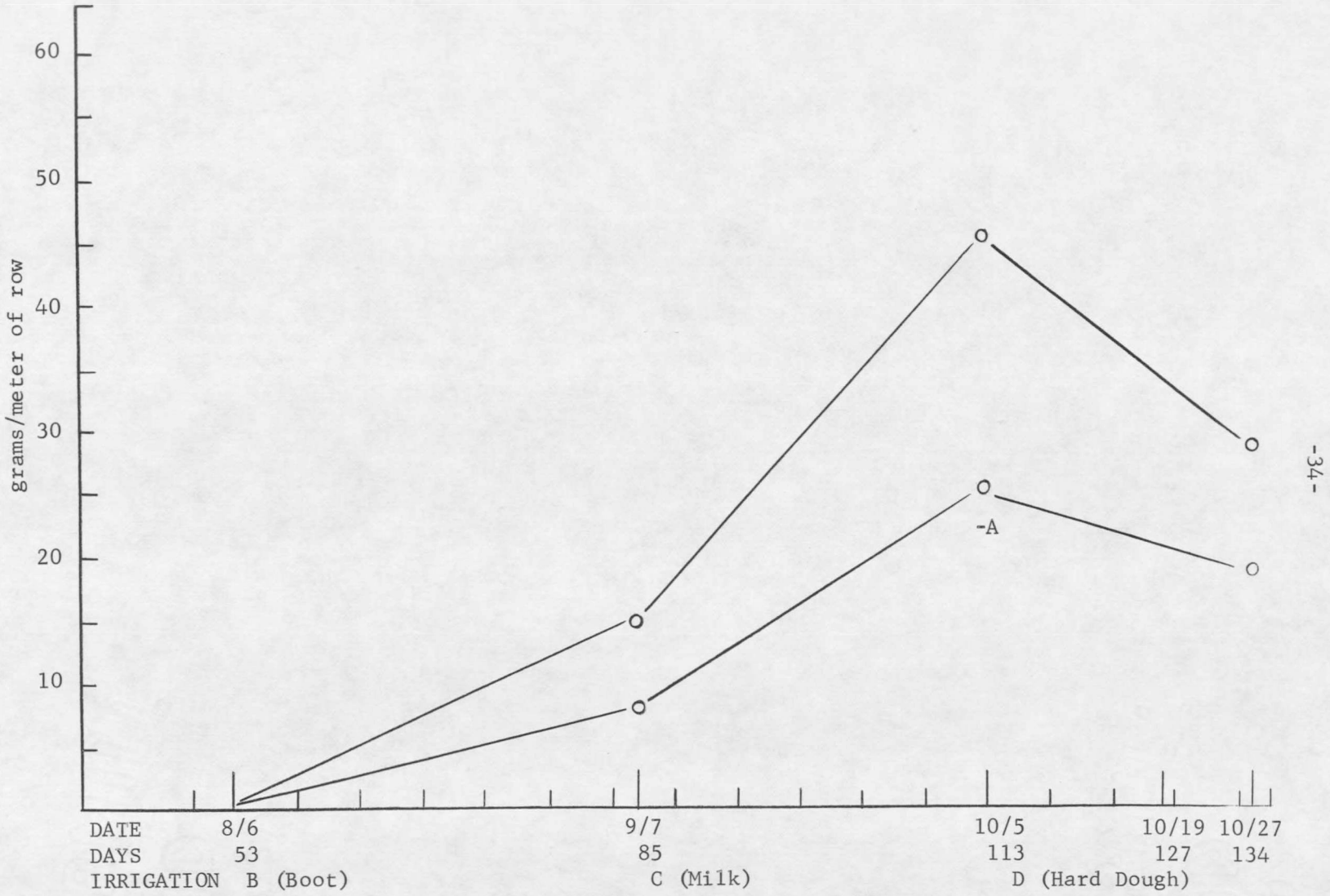


Figure 13. Dry weight of grain. Means for irrigation treatments 1-(ABCD) and 2-(-BCD).

irrigation regine, Figure 14. After the C irrigation was applied, however, the complete irrigation regime showed an increase in the rate of grain formation; but the -B irrigation treatment, even though it subsequently received water at the milk stage, did not show this increase in grain formation rate. The -B irrigation treatment also showed a decrease in grain weight between the hard dough stage and harvest.

In a previous experiment, conducted during the 1966 season, omission of the B irrigation resulted in a lack of yield response when the N application rate was increased from 0 up to 200 lbs/A (32). This affect on yield, of omitting the boot stage irrigation, seems to be related to the pattern of head development.

The number of grain-bearing heads at each stage of development for the complete and -B irrigation treatments are presented in Figure 15. The formation rate of grain-bearing heads between the tillering and milk stages was similar whether water was applied or withheld at the tillering stage. When water was then applied at the milk stage, the complete irrigation treatment showed an increase in the number of grain-bearing heads; but the number of grain-bearing heads did not increase as rapidly under the -B irrigation regime. With a constant 40 lbs/A P rate, when the N rate was increased from 50 to 100 lbs/A with the -B treatment, grain formation rate seems to have ceased after the milk stage irrigation. This effect was negated to some extent when N rate was increased to 150 lbs/A as shown in Figure 16.

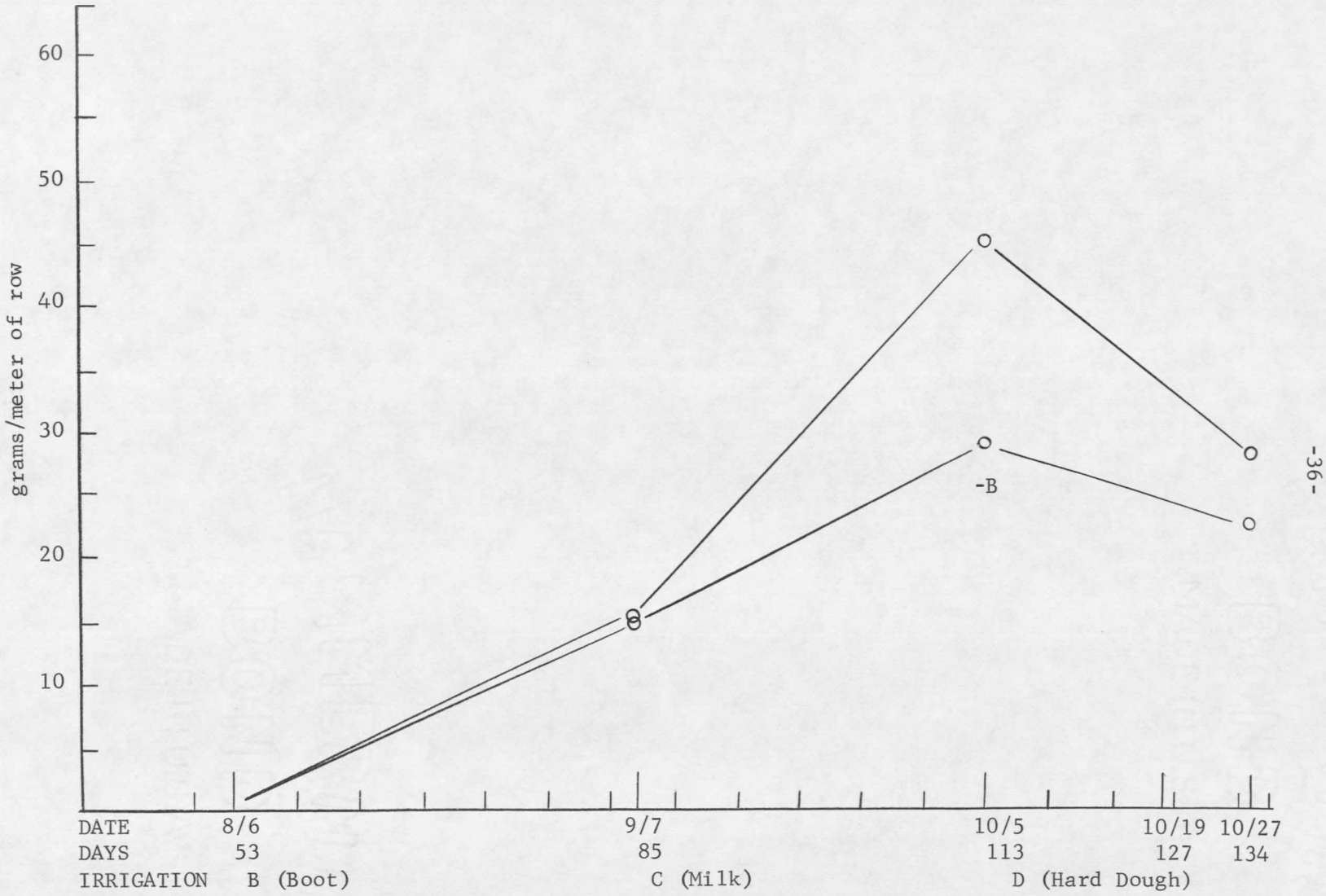


Figure 14. Dry weight of grain. Means of irrigation treatments 1-(ABCD) and 3-(A-CD).

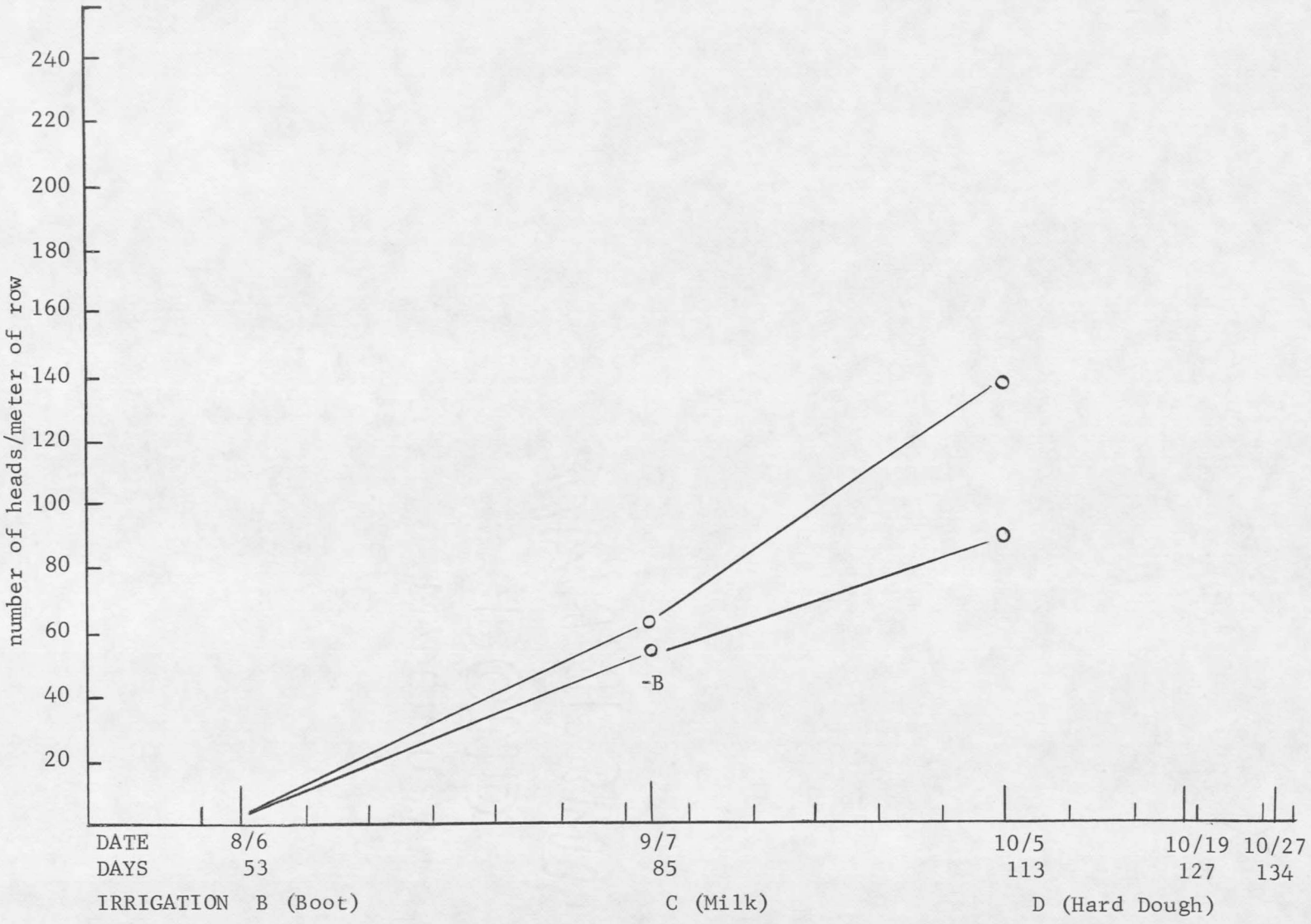


Figure 15. Number of grain-bearing heads per meter of row. Means of irrigation treatments 1-(ABCD) and 3-(A-CD).

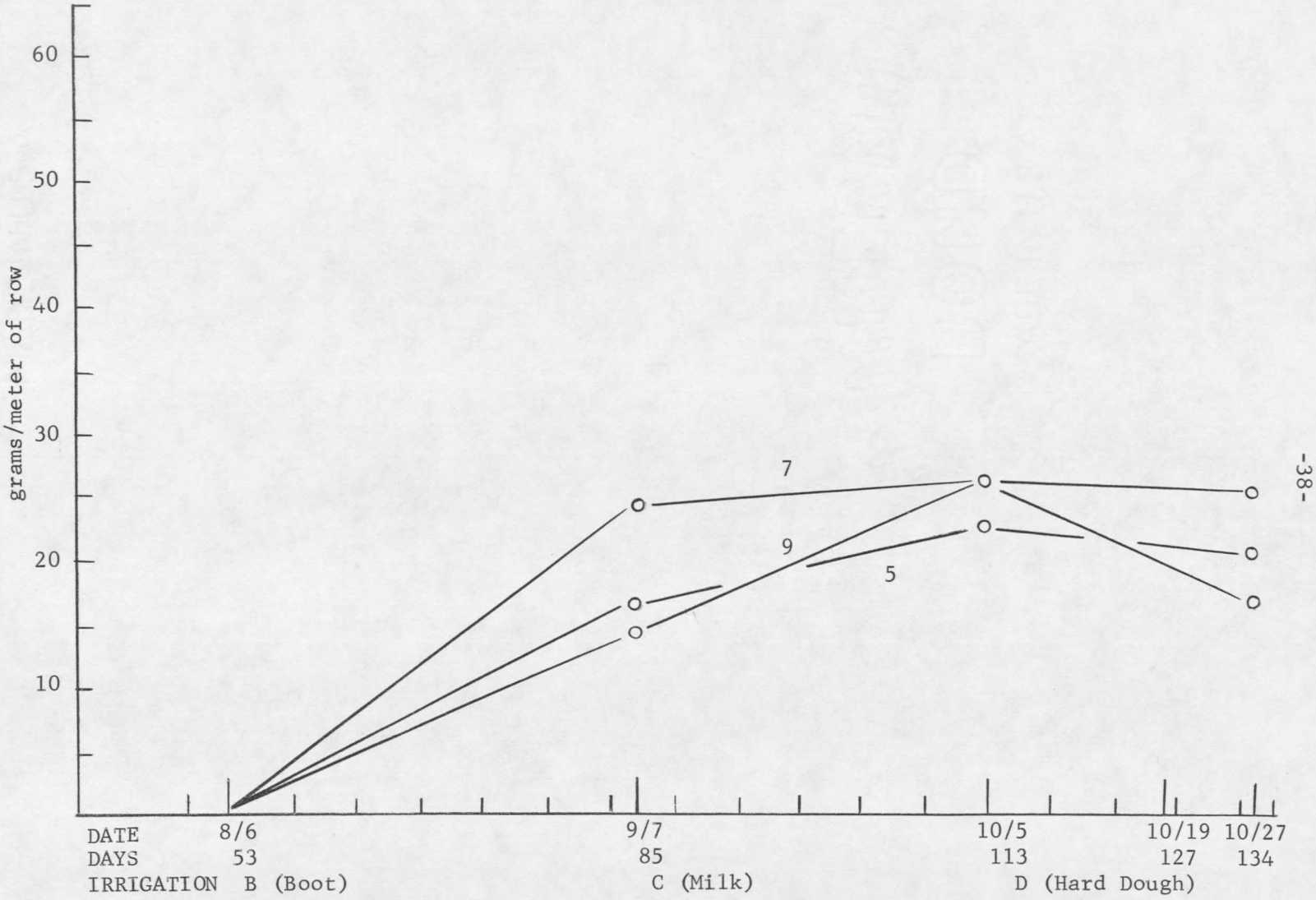


Figure 16. Dry weight of grain. Replication means of fertilizer treatments 5-(50-40-40), 7-(100-40-40), and 9-(150-40-40) of irrigation treatment 3-(A-CD).

The number of grain-bearing heads for the -B treatment which were formed after the C irrigation is also low. This is shown in Figure 17. What seems to have occurred is that when the B stage irrigation was omitted, grain formation between the boot and milk stages proceeded at a normal rate; but then after the milk stage, no more heads or grain were formed. This effect is partially negated by increasing N rate to 200 lbs/A. With this N rate, the number of heads had increased to 128 at the hard dough stage, Table XVI.

With a constant rate of 100 lbs/A of N, the zero P rate showed no increase in grain between the milk stage and harvest. Increasing P to 40 pounds increased the amount of grain formed by the milk stage but again no grain was formed past this time as shown in Figure 18.

This lack of grain formation was not caused by a decrease in the carbohydrate translocation, but was related to the amount of heads that were formed. The number of grain-bearing heads for the -B irrigation treatment when P was varied from 0 to 80 lbs/A at a constant N rate of 100 lbs/A is shown in Figure 19. With 0 and 40 pounds of P, the number of grain-bearing heads was constant between the milk and hard dough stages; however, with 80 pounds of P, some increase in the number of grain-bearing heads was noted during this period. The ability of applied P to lessen the adverse effect of the -B irrigation on the number of heads was the same with the zero N rate. The number of heads increased from 95 to 105 at the hard dough stage when the P rate was varied from 0 to 80 lbs/A. With the 200 lbs/A N rate, the effect of the N rate on negating the adverse effect

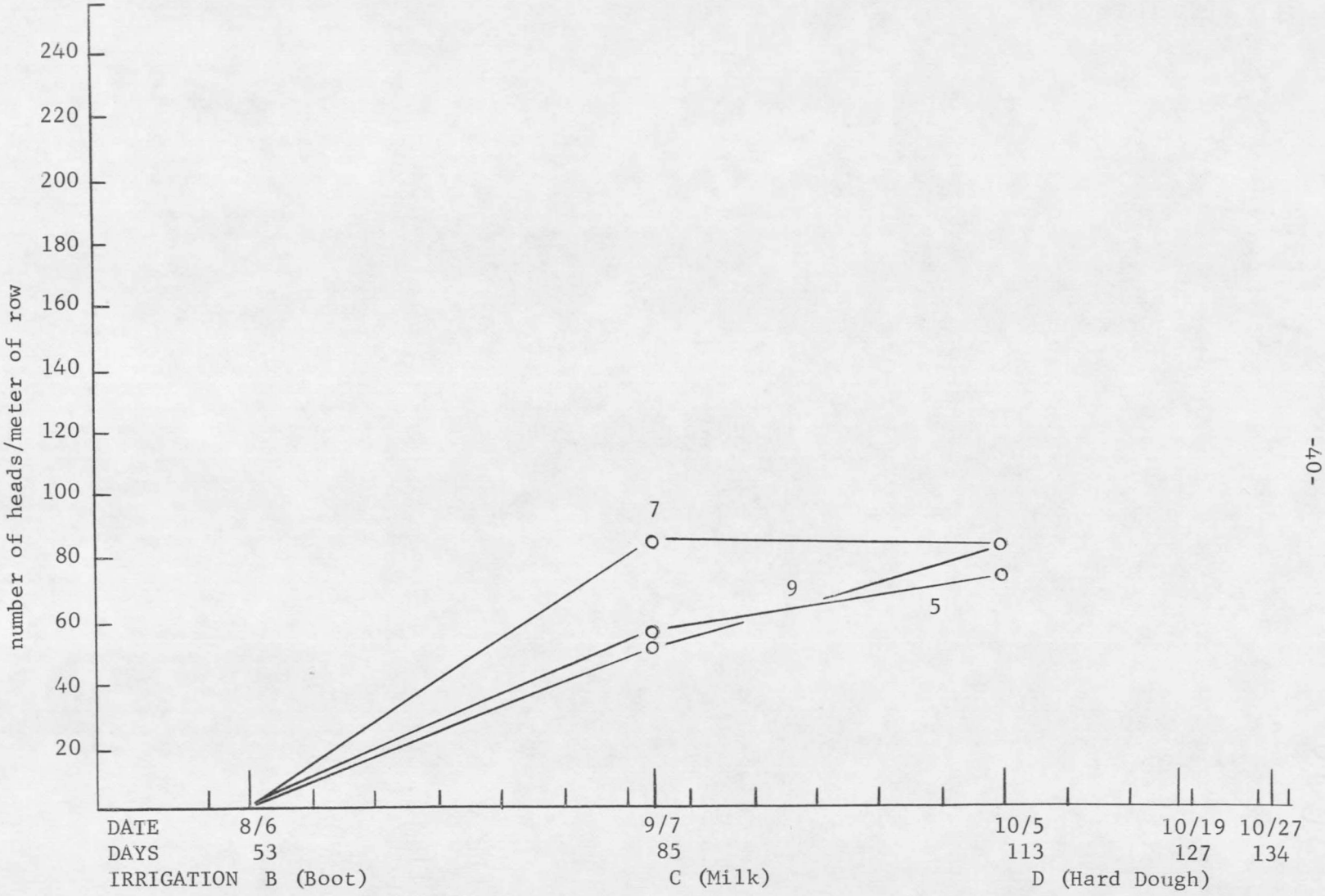


Figure 17. Number of grain-bearing heads per meter of row. Replication means of fertilizer treatments 5-(50-40-40), 7-(100-40-40), and 9-(150-40-40) of irrigation treatment 3-(A-CD).

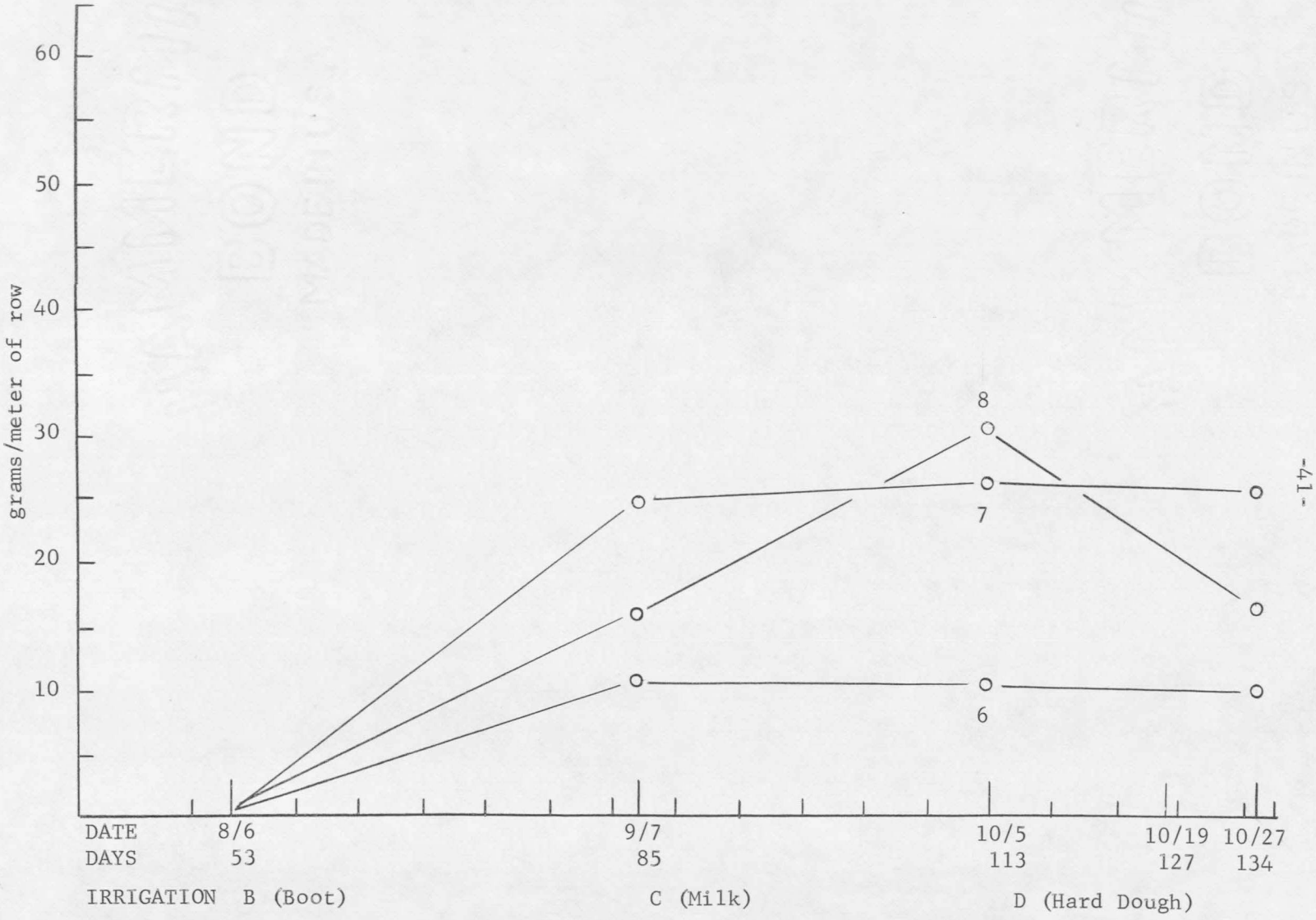


Figure 18. Dry weight of grain. Replication means of fertilizer treatments 6-(100-0-40), 7-(100-40-40), and 8-(100-80-40) of irrigation treatment 3-(A-CD).

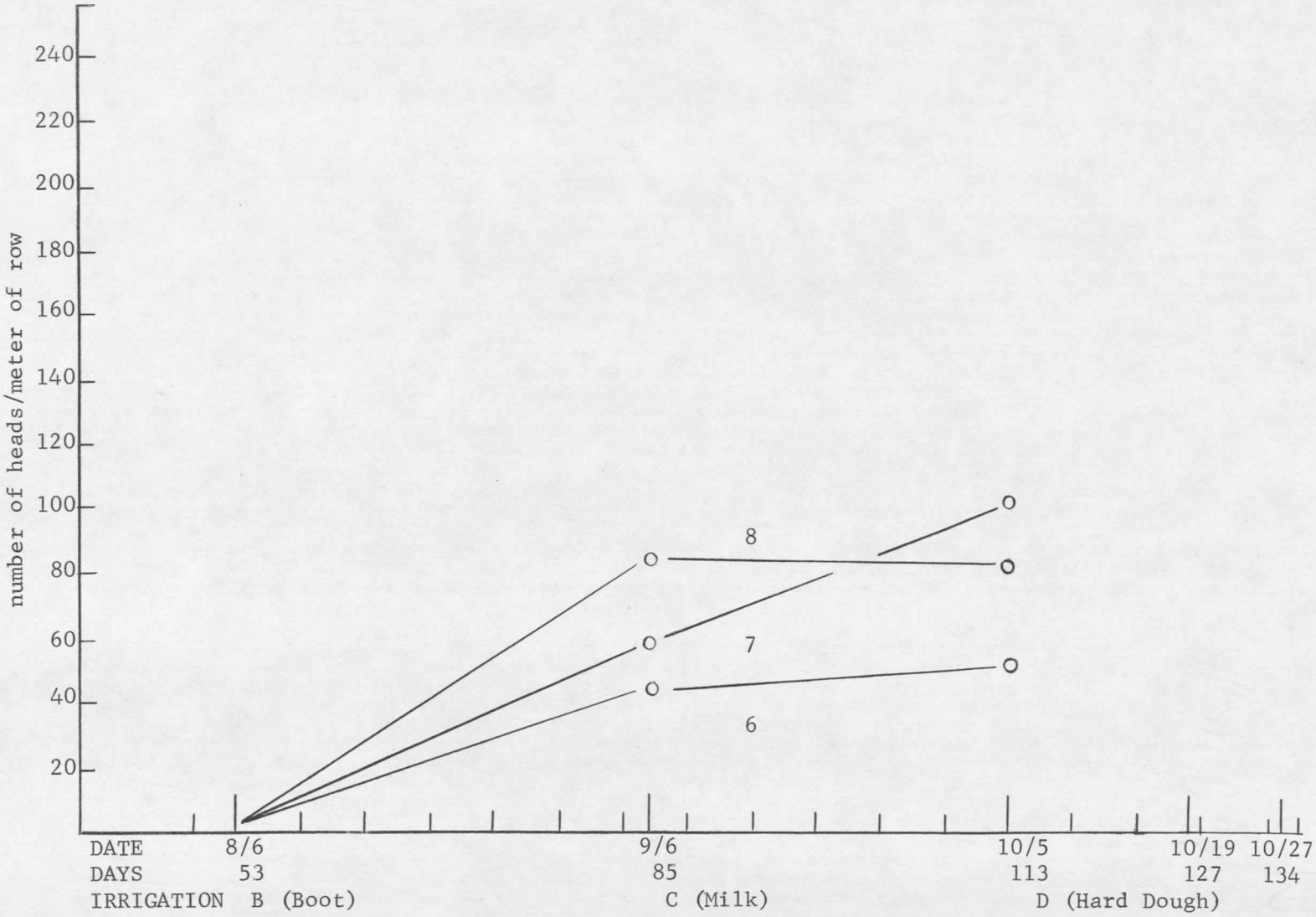


Figure 19. Number of grain-bearing heads per meter of row. Replication means of fertilizer treatments 6-(100-0-40), 7-(100-40-40), and 8-(100-80-40) of irrigation treatment 3-(A-CD).

of -B irrigation overshadowed the effect of increasing the P rate, Table XVI.

This effect of omitting the B irrigation on yield response to applied N seems to be caused by the lack of continual formation of heads after the boot stage. The full effect was not expressed until the milk stage, however. What probably occurred was that when the B irrigation was omitted, grain formation proceeded at the same rate as when this irrigation was applied; but the later tillering of the plants was inhibited. When water was applied at the milk stage, the complete irrigation treatment had developing tillers which could then continue to produce grain-bearing heads.

The -B treatment, on the other hand, had already filled the grain in all the heads that had been formed; even though water was then applied at the milk stage, no more heads were available to be filled. This affect could also be caused by the lack of water at the boot stage interferring with the fertilization or pollination of the plants. Those heads which had already been fertilized would form normally even though moisture was limiting; however, when water was then applied at the milk stage, the heads that normally would have filled after this period were sterile and did not produce grain.

With the -C irrigation treatment, the rate of grain formation immediately after the milk stage irrigation was less than the rate of grain formation when this irrigation was applied. These effects are shown in Figure 20.

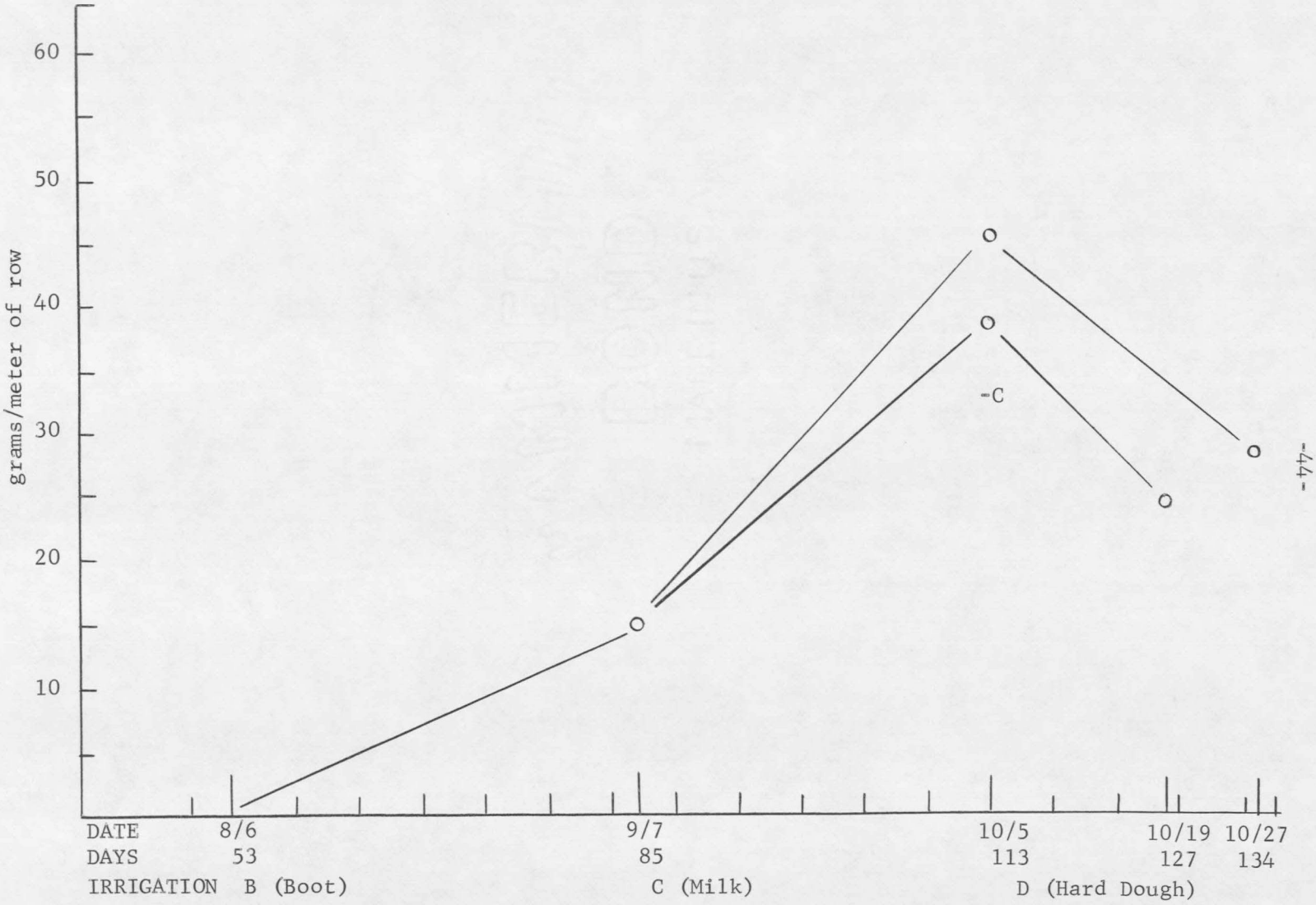


Figure 20. Dry weight of grain. Means of irrigation treatments 1-(ABCD) and 4-(AB-D).

As with the -B irrigation treatment, this lack of grain formation when the C irrigation was omitted also seems to be related to the number of grain-bearing heads formed. At the milk stage, both the -C and the complete irrigation treatment had 62 heads per meter of row. At the hard dough stage, the number of heads per meter of row with the complete irrigation regime had increased to 140. The number of heads for the -C treatment had only increased to 100--Table XVI, irrigation treatment means. The number of heads at the hard dough stage for the -C treatment was approximately 70% of the number formed with the complete irrigation treatment. At this time, the amount of grain for the -C treatment was approximately 80% of that for the complete treatment.

Omitting the D irrigation did not result in much difference in the amount of grain at harvest when compared to the complete irrigation treatment as shown in Figure 21.

Summary of Grain Weight Changes

Figure 22 shows the weight of grain for each irrigation treatment as a percentage of the complete irrigation treatment at each stage of measurement. At the milk stage, the -A treatment (tillering) had only about 50% of the grain weight of the complete treatment even though it had received moisture at the boot stage. Application of water at the milk and hard dough stages allowed the -A treatment to form sufficient grain that at harvest, it yielded approximately 70% of the complete treatment.

Omission of the B irrigation (boot stage) resulted in the amount of grain at the milk stage being the same as that with the complete irrigation

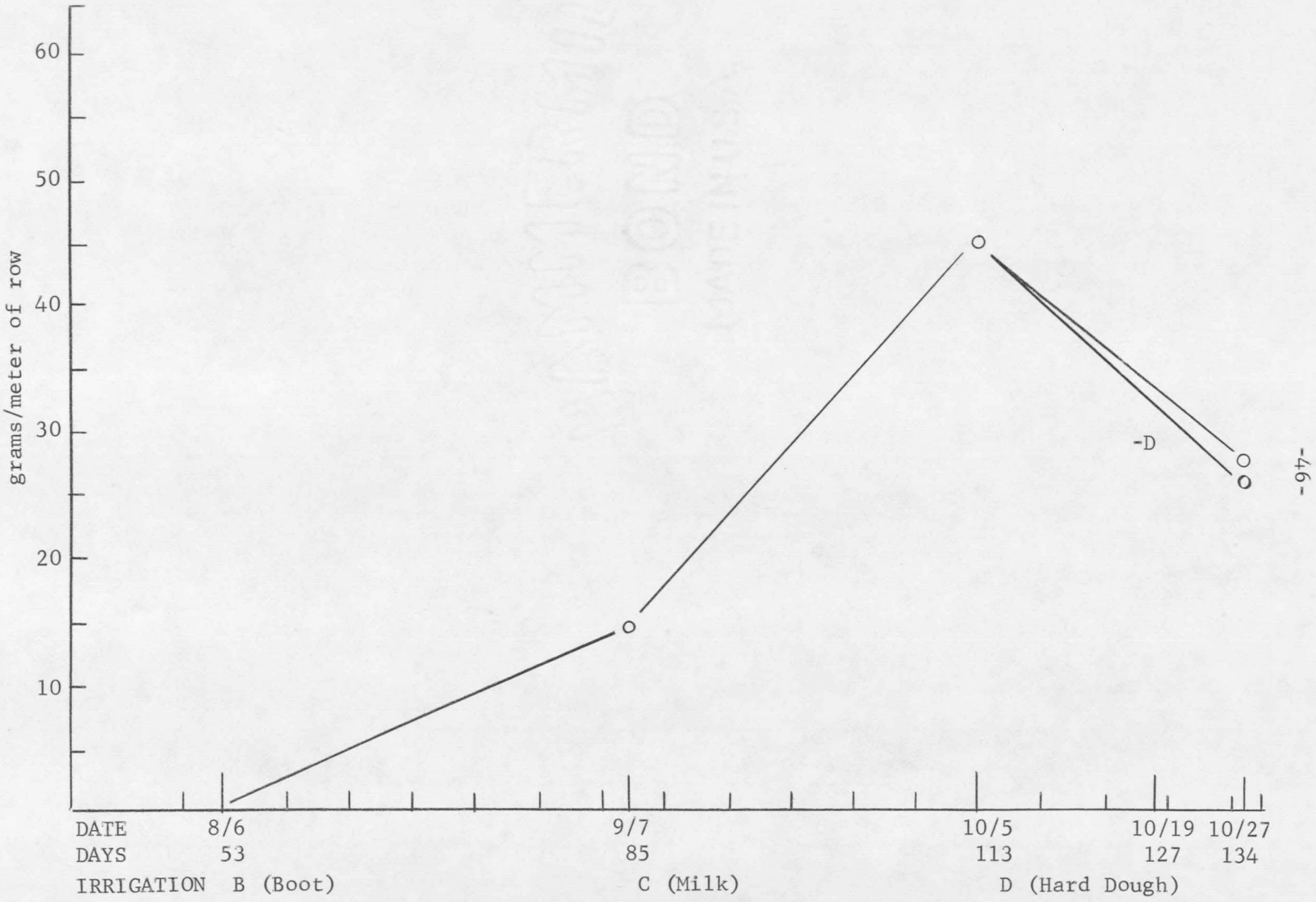


Figure 21. Dry weight of grain. Means of irrigation treatments 1-(ABCD) and 5-(ABC-).

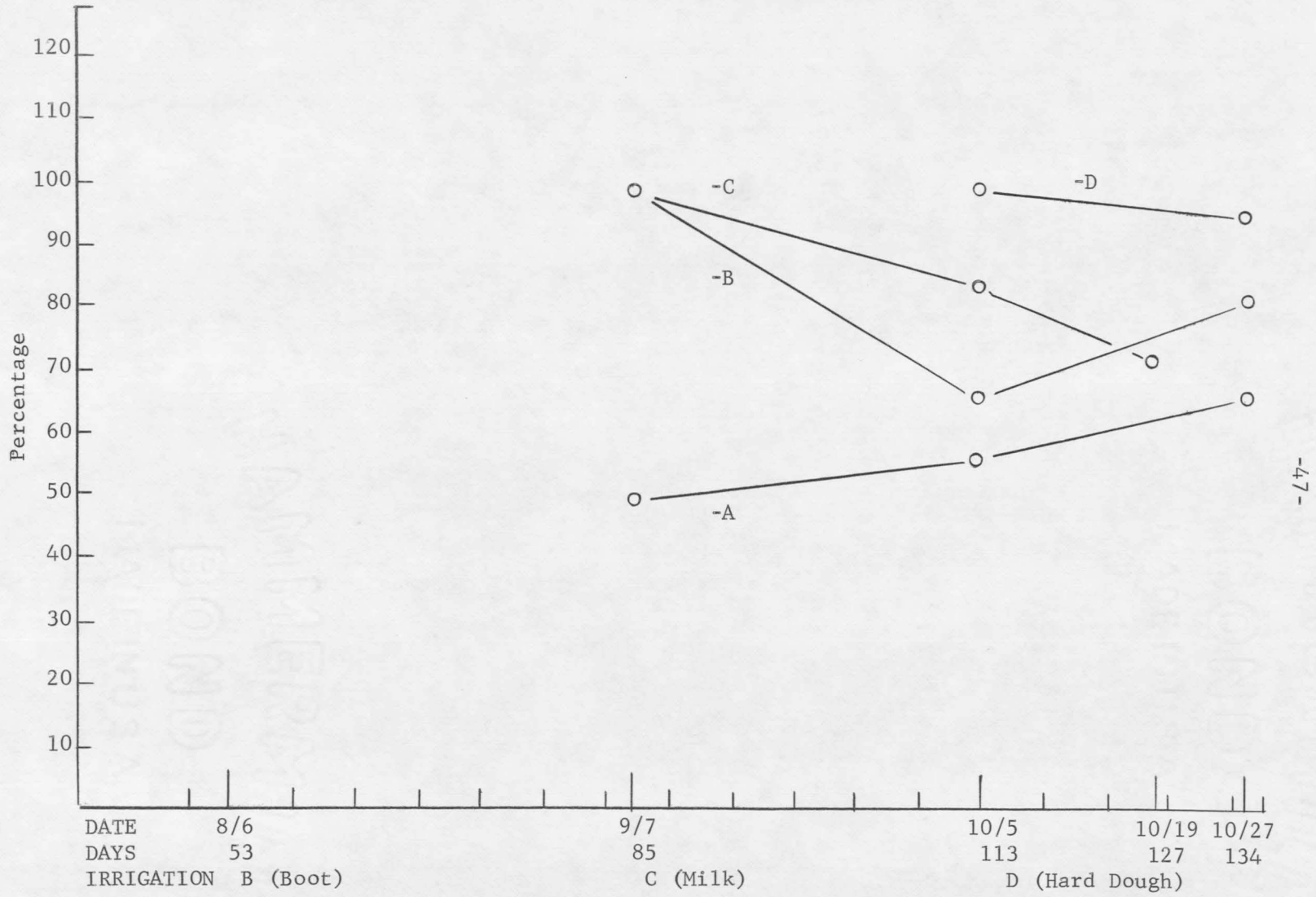


Figure 22. Dry weight of grain. Means of irrigation treatments as percentage of irrigation treatment 1-(ABCD).

treatment; but at the hard dough stage, the -B irrigation treatment had only about 70% of the grain weight of the complete irrigation regime. The application of water at the hard dough stage for the -B treatment allowed the grain yield of this treatment to increase up to about 80% of the complete treatment at harvest. It should be recalled, however, that this treatment was late in forming heads.

Omitting the milk stage irrigation caused a decrease in the amount of grain in comparison with the complete treatment at the hard dough stage. Application of water at the hard dough stage did not seem to alter the adverse effects of omitting the C irrigation on the amount of grain formation by harvest. In fact, this treatment matured a week earlier than any of the other treatments. At harvest the -C irrigation treatment showed only 70% of the grain formed with the complete irrigation treatment.

Omitting the D irrigation showed very little decline in the amount of grain formed in comparison with the complete irrigation regime.

A relationship seems to exist between the weight of grain at the hard dough stage and the subsequent changes that occurred in this weight between the hard dough stage and harvest. When the grain weight per meter was low at the hard dough stage, the weight at harvest was the same or showed a slight decrease. When the weight per meter was high, then a decrease in weight at harvest was noted. The magnitude of the decrease seems to be directly related to how much grain was present at the D stage irrigation--Table XII, treatment means.

Grain Protein Percentage

No grain had been formed by the boot stage, thus grain protein percentage was first measured at the milk stage. Protein was also determined on both the hard dough stage and harvest samples. Under the complete irrigation treatment, the protein percentage decreased between the milk and hard dough stages, and then increased slightly up to harvest. These changes are shown in Figure 23. The initial decrease in grain protein percentage and subsequent increase for this irrigation treatment is inversely related to the grain weight changes which were shown in Figure 12.

The total grams of grain protein per meter of a row for the complete irrigation treatment increased between the milk and hard dough stages as shown in Figure 24. Thus, although the percent grain protein was decreasing at this time, protein may have been accumulating in the grain; and the decrease in percent protein would have been related to the faster rate at which carbohydrate material was being translocated into the grain. It appears that the increase in grain protein percentage between the hard dough stage and harvest was related to the decrease in grain weight. Figure 24 shows that the total grams of grain protein per meter of a row also decreased. Since protein percentage showed a slight increase during this period, this would indicate that the rate of absolute grain protein decrease may have been less than the rate of decrease of carbohydrate material in the grain during this period. The net result was a slight increase in the grain protein percentage.

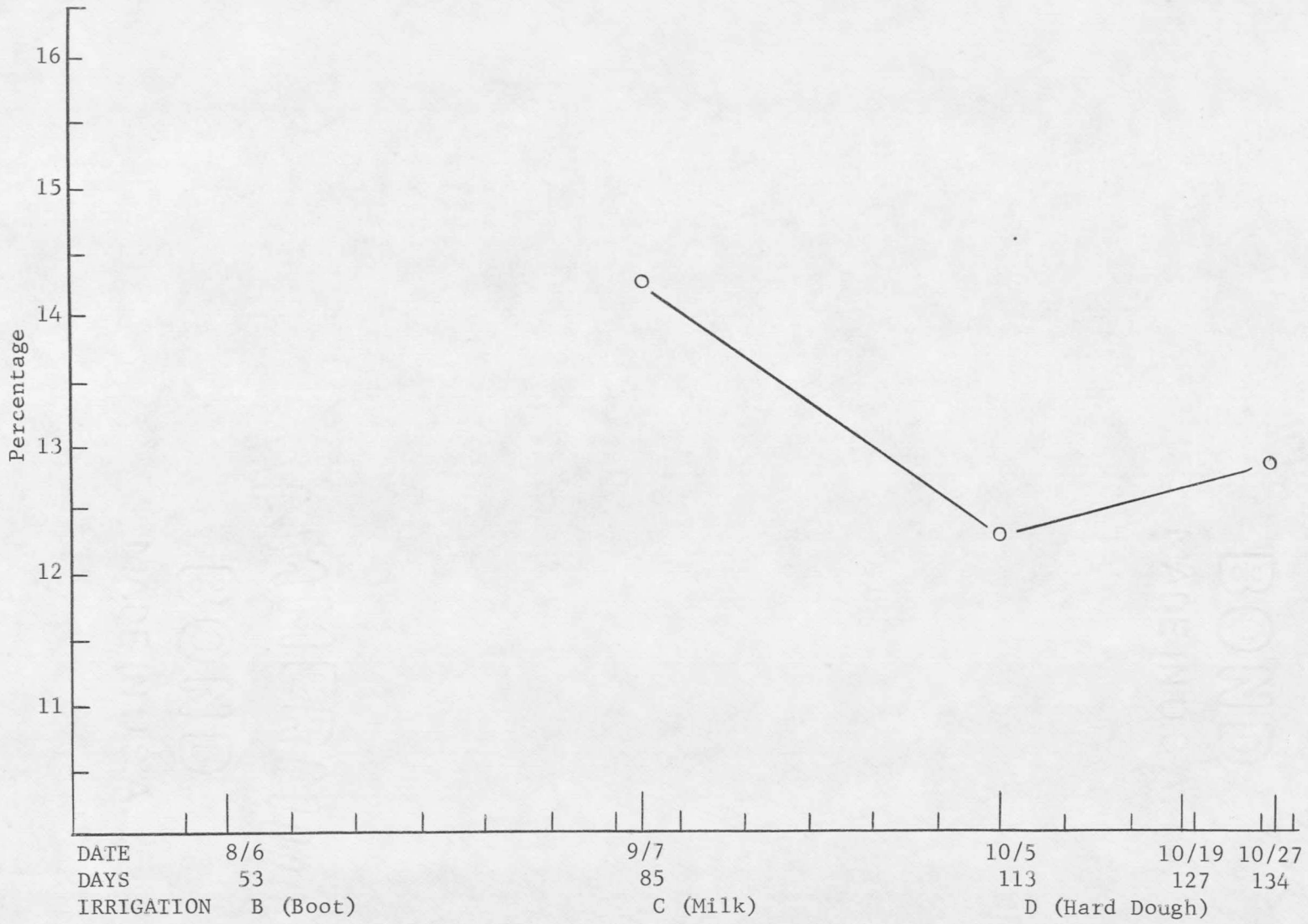


Figure 23. Grain protein percentage. Means of irrigation treatment 1-(ABCD).

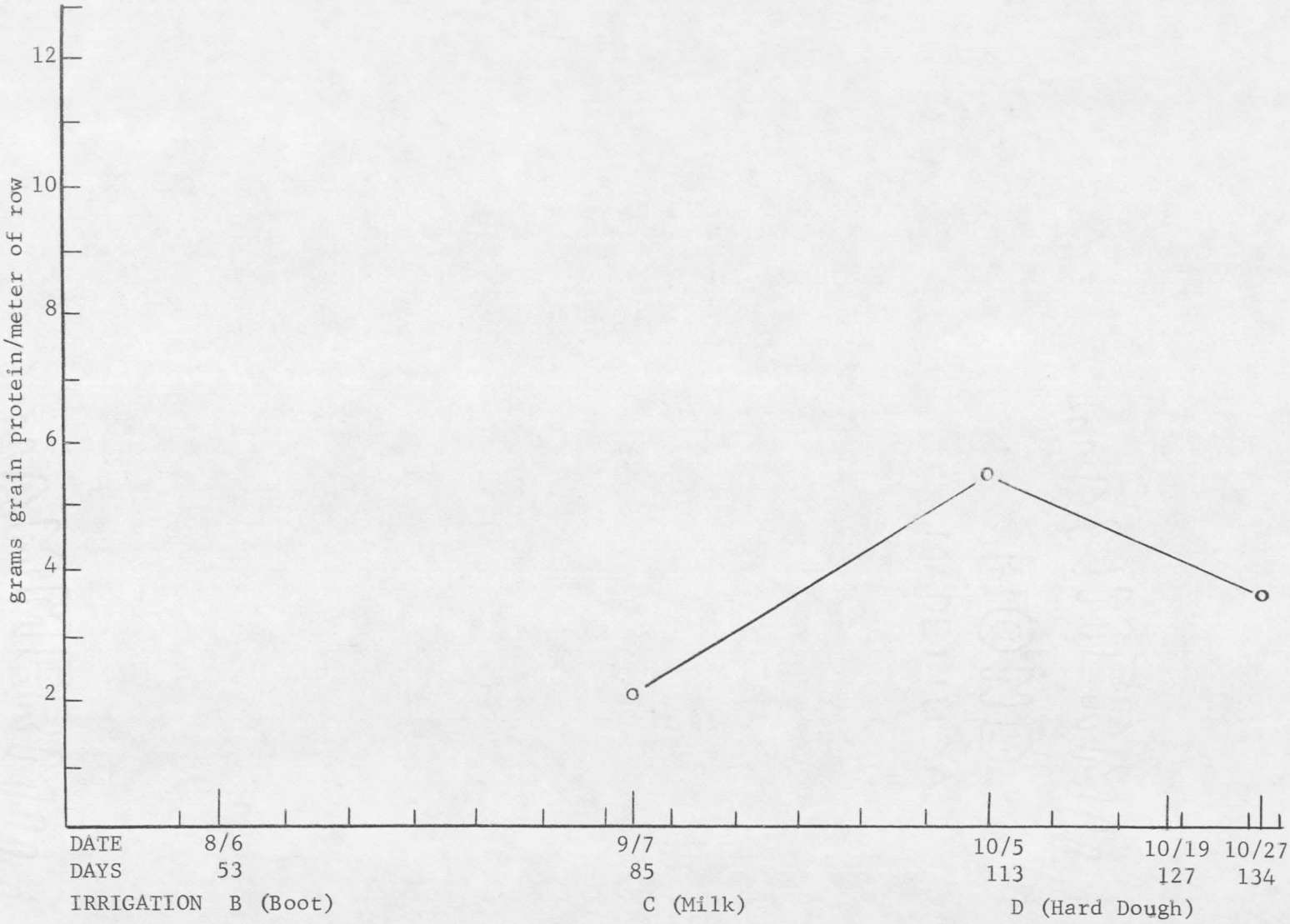


Figure 24. Grams of grain protein per meter of row. Means for irrigation treatment 1-(ABCD).

The question at this point is whether changes in absolute protein content or the changes in the carbohydrate content were responsible for the observed changes in grain protein percentage.

With the complete irrigation treatment, when N rate was increased from 0 to 200 lbs/A, at 40 lbs/A of P, the grain protein percentage was increased. These effects are shown in Figure 25. With 200 lbs/A of N, the grain protein percentage for the complete irrigation regime remained essentially constant from the milk stage until harvest. The total grams of grain protein per meter of row increased to the hard dough stages for this N rate and had decreased at harvest, Figure 26. Since the percentage protein for this fertilizer rate remained the same, it appears that the decrease in grams of grain protein per meter of row was related to the decrease in grain weight. A similar effect was noted with the -B irrigation treatment.

Under the complete irrigation regime, the grain weight and number of grain-bearing heads increased from the boot to the hard dough stage. With normal development, the heads are being continually filled and are in many stages of development on a single plant. Thus with the data gathered during this experiment, it is difficult to determine if the amount of protein in a head is changing with maturity or is constant under the complete irrigation regime.

The -B irrigation regime caused some changes in the developing plant which may help to separate the changes in protein percentage and absolute amount of protein. Under this irrigation regime with 100 pounds of N and

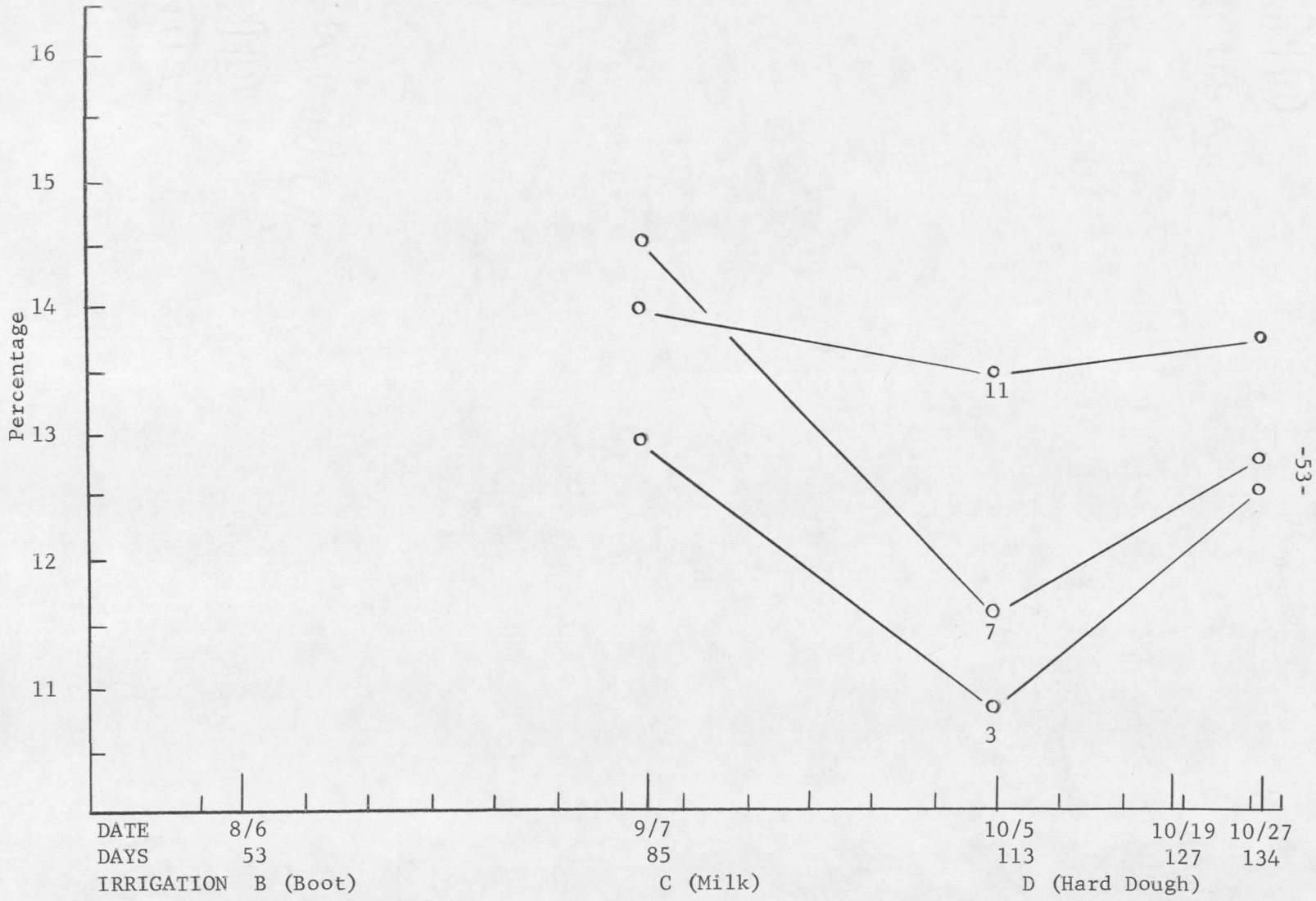


Figure 25. Grain protein percentage. Replication means of fertilizer treatments 3-(0-40-40), 7-(100-40-40), and 11-(200-40-40) of irrigation treatment 1-(ABCD).

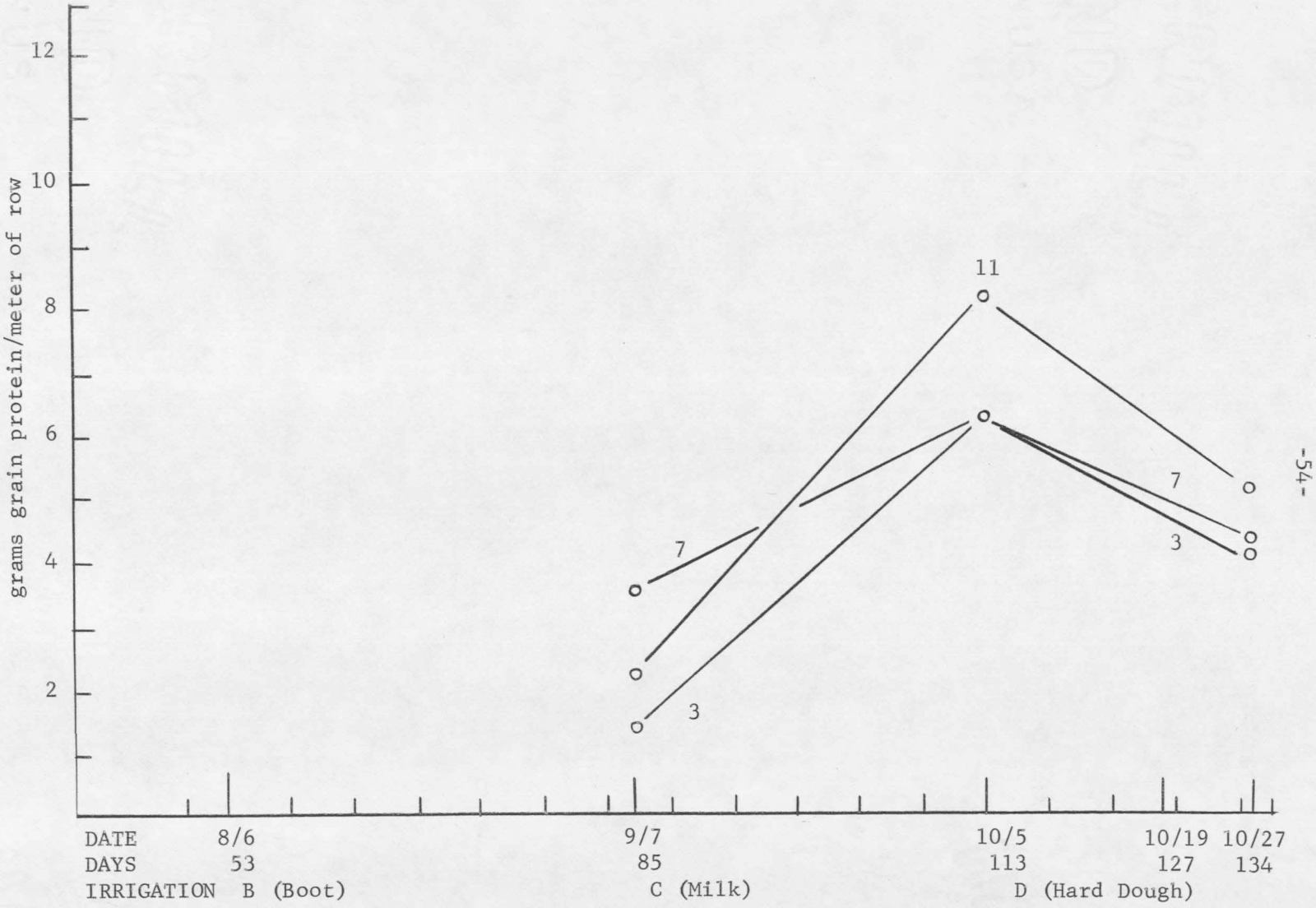


Figure 26. Grams of grain protein per meter of row. Replication means for fertilizer treatments 3-(0-40-40), 7-(100-40-40), and 11-(200-40-40) or irrigation treatment 1-(ABCD).

zero pounds of P, there were no changes in the weight of the grain from the milk stage until harvest, Figure 18. Also, for these treatments, there were no changes in the number of grain-bearing heads from the milk to hard dough stage. The total grams of grain protein in these treatments remained constant from the milk stage until harvest time as shown in Figure 27. This seems to indicate that the protein content, in absolute amount, was determined before the milk stage. This protein was quite possibly laid down in forming grain at, or just after, the flowering stage. Subsequent changes in grain protein percentage were then caused by the amount of carbohydrates translocated into the forming grain. Admittedly, the -B irrigation regime did not show normal development of the grain; but water was applied at the milk and hard dough stages so that if protein normally would be translocated into the grain during the latter stages of growth, this transfer would not have been inhibited by moisture stress.

With the complete irrigation treatment, the addition of 40 lbs/A of P at the 100 lbs/A N rate showed a decrease in grain protein percentage at both the hard dough stage and harvest. Addition of another 40 lbs/A of P did not enhance the effect. This lack of response to 80 lbs/A of P may be due to the high amount of available P present, Table XVIII. The effect of P in decreasing the protein percentage of the grain, Figure 28, is probably related to the increase in the amount of carbohydrate formed and/or translocated into the grain, Table XII. The changes in the grams per meter of row for these treatments are shown in Figure 29. In this case, the addition of P increased the amount of grain protein per meter of row.

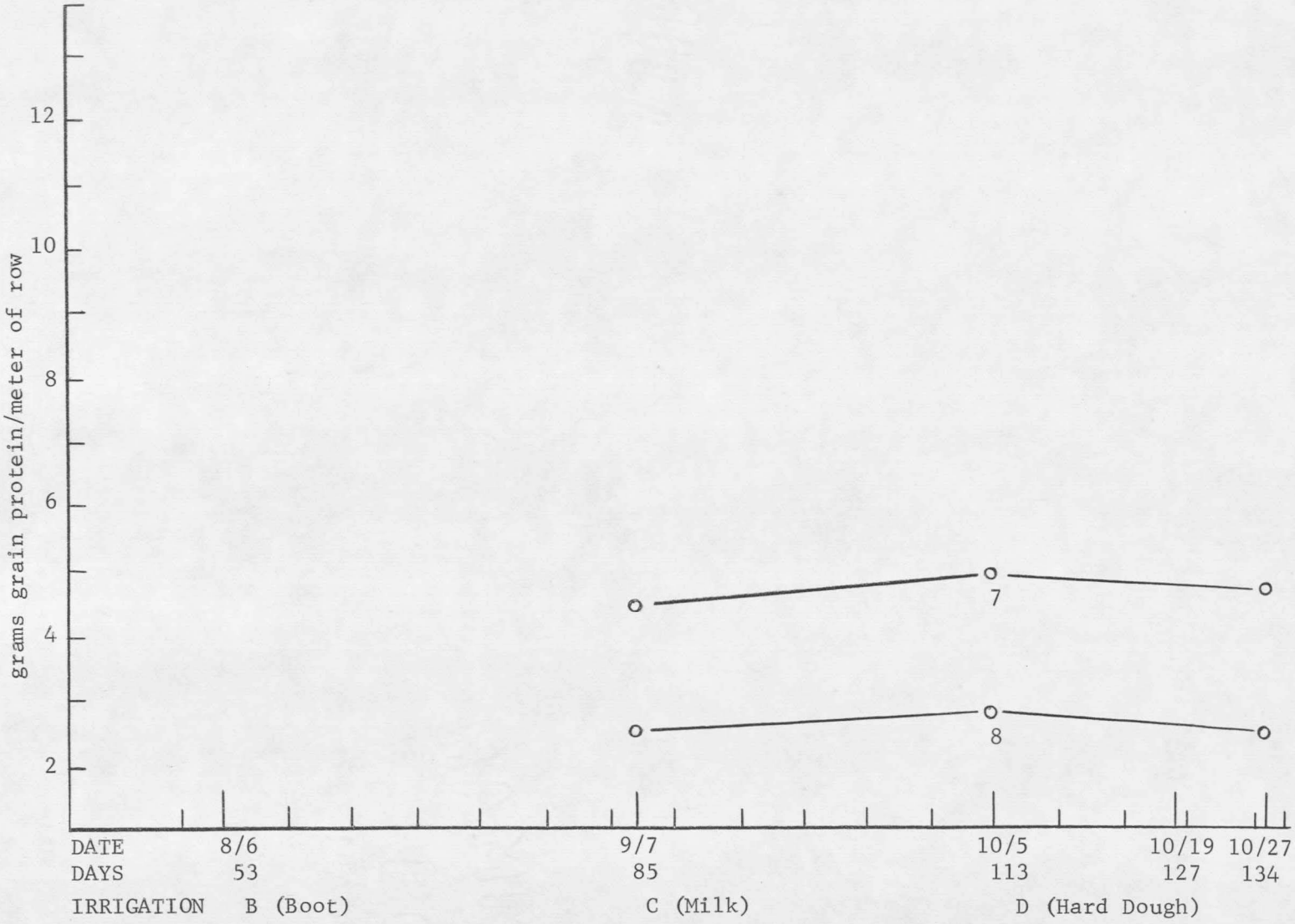


Figure 27. Grams of grain protein per meter of row. Replicationf means of fertilizer treatments 6-(100-0-40) and 7-(100-40-40) of irrigation treatment 3-(A-CD).

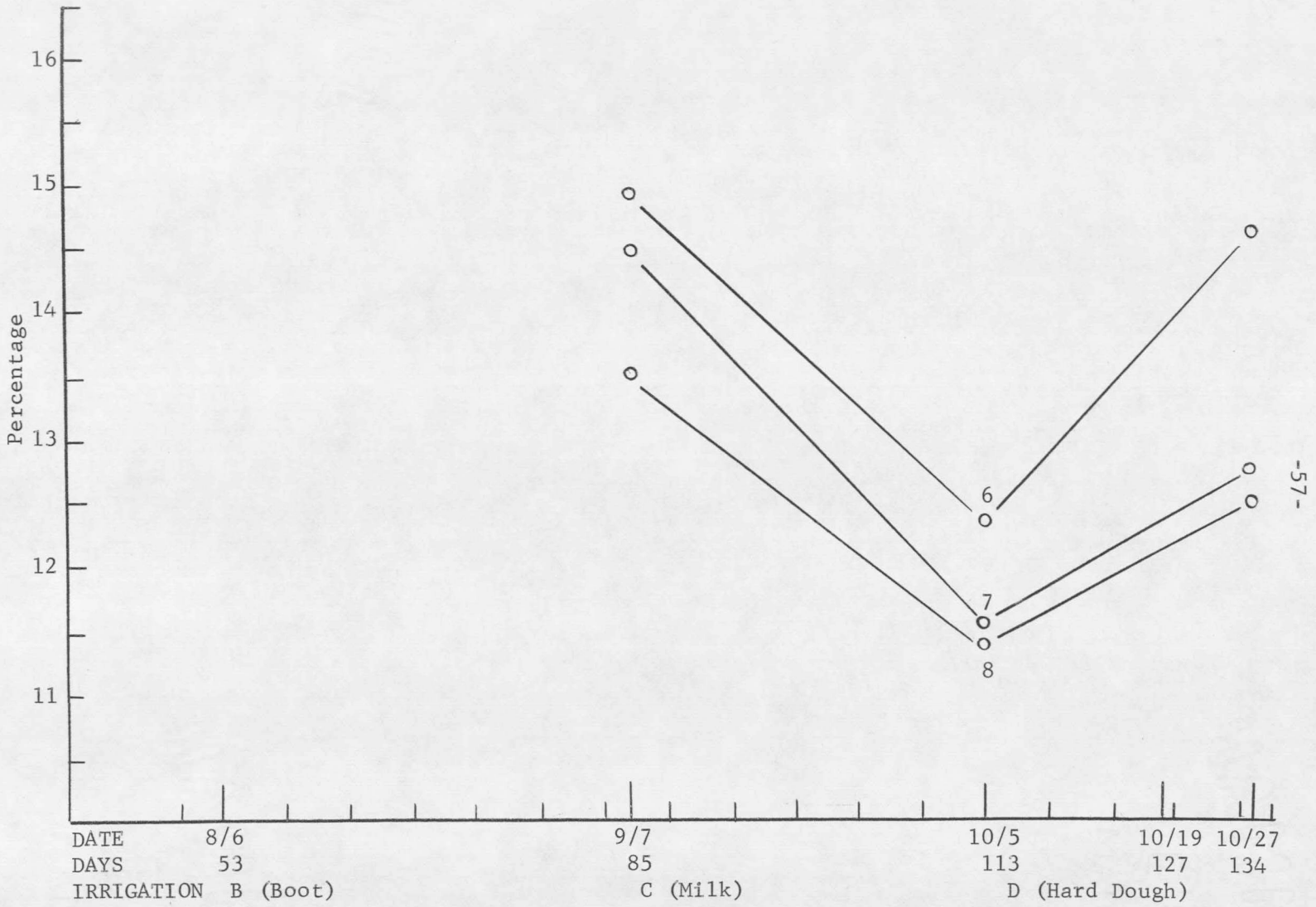


Figure 28. Grain protein percentage. Replication means of fertilizer treatments 6-(100-0-40), 7-(100-40-40), and 8-(100-80-40) of irrigation treatment 1-(ABCD).

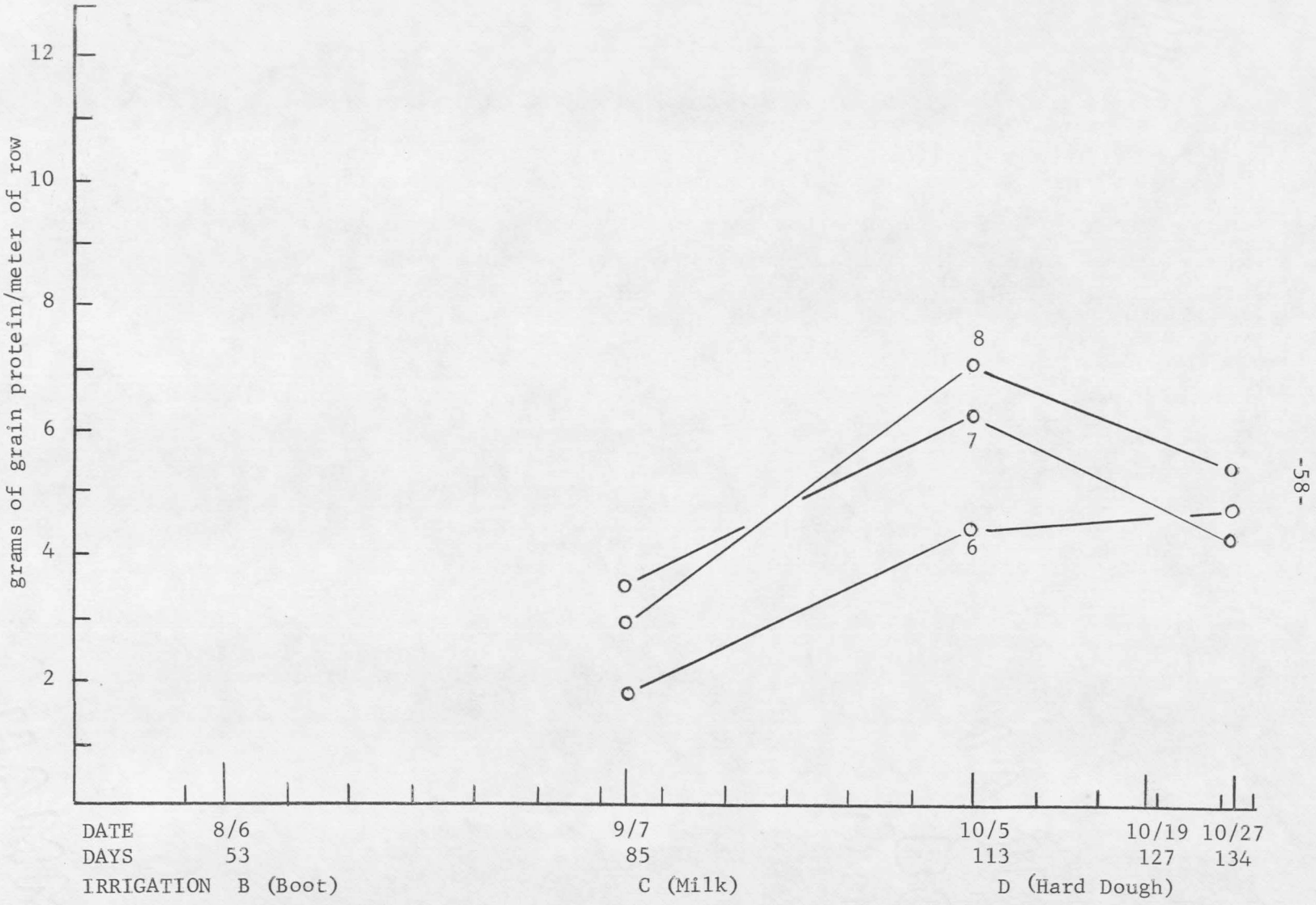


Figure 29. Grams of grain protein per meter of row. Replication means for fertilizer treatments 6-(100-0-40), 7-(100-40-40), and 8-(100-80-40) of irrigation treatment 1-(ABCD).

In addition, these P treatments also increased the grain weight per meter so it is difficult to separate out the effects, Table XII.

The changes in grain percentage when the tillering stage irrigation (-A treatment) had been omitted are shown in Figure 30. The changes are similar to the complete treatment; but the percentage was higher throughout the period, milk stage to harvest. The weight of grain for the -A irrigation treatment was less than the weight of grain for the complete irrigation treatment as shown in Figure 13. Thus, again this could be an effect of the decrease in amount of carbohydrates that are translocated into the grain when the A irrigation was omitted.

The grain protein percentages for the -B and -C irrigation treatments did not show the decline between the milk and hard dough stages that the complete irrigation regime showed, Table XIII.

The changes in grain protein percentage for these treatments are shown in Figure 31. The grain protein percentage for the -D irrigation treatment showed a slight increase over the complete irrigation treatment. This treatment also showed a greater rate of decline in the grain weight when compared with the complete irrigation treatment. This was shown in Figure 21.

Malting Quality Barley

In order to be used for malting, the protein content of barley should be 12.5% of less (28). This is based on a 10% grain moisture content and 12.5% protein at 10% grain moisture is equivalent to 13.90% on a dry weight basis. Figure 31 shows the changes in grain protein percentage for

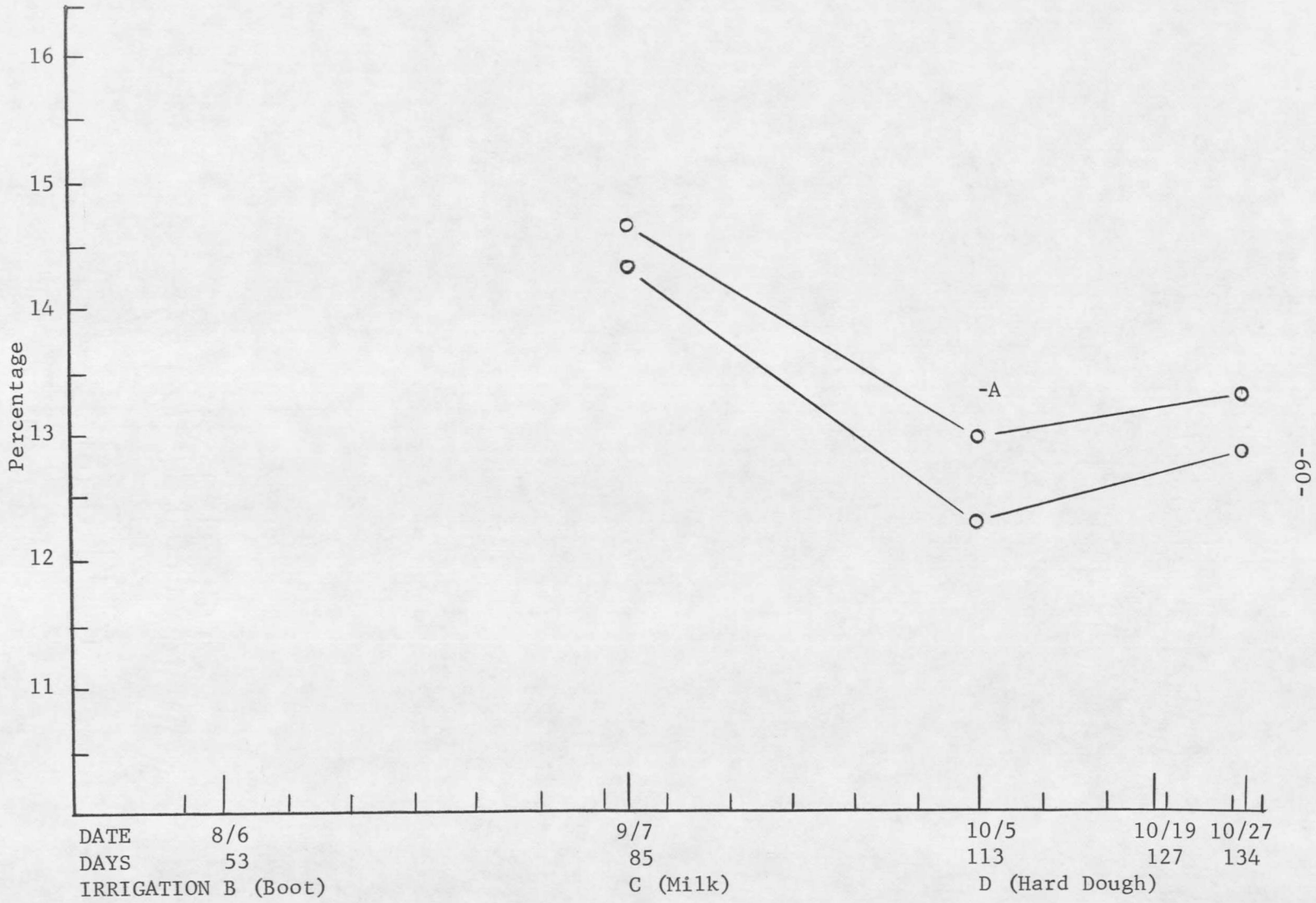


Figure 30. Grain protein percentage. Means of irrigation treatments 1-(ABCD) and 2-(-BCD).

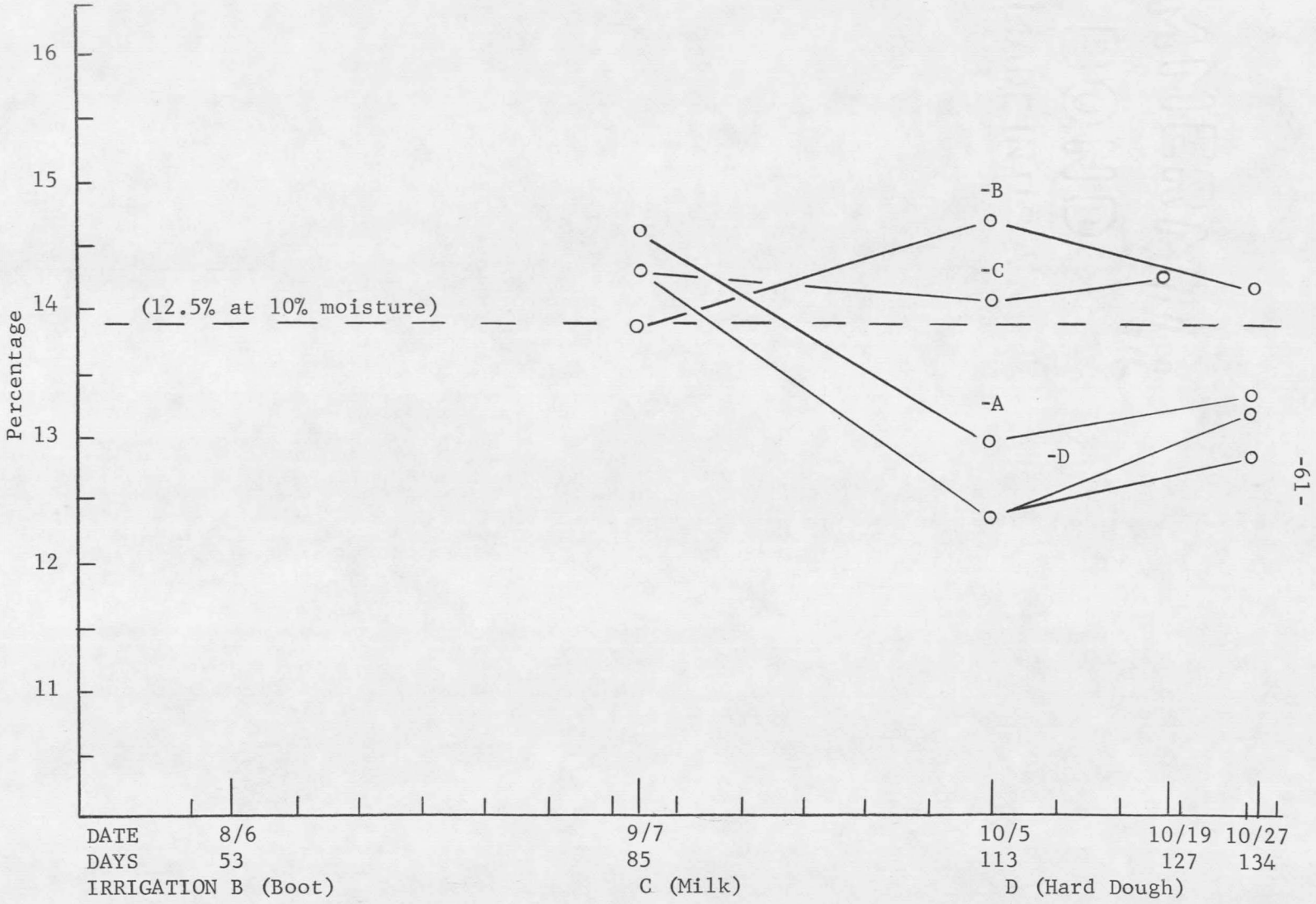


Figure 31. Grain protein percentages. Means of irrigation treatments 1-(ABCD), 2-(-BCD), 3-(A-CD), 4-(AB-D), and 5-(ABC-).

each of the irrigation treatments in relation to the limit of 12.5% protein at 10% grain moisture content.

When the C irrigation was omitted, the protein percentage of the grain stayed essentially constant from the milk stage up to harvest. The slight decrease at the hard dough stage and subsequent recovery were related to the grain weight changes during this period. The greater amount of decrease in the protein percentage shown under the -A and the complete irrigation regime reflects the greater magnitude of the grain weight changes for these two treatments, Figure 13. Likewise, the increase in protein percentage with the -D regime, when compared to the complete treatment, mirrors the grain weight changes of these two treatments, Figure 21.

The -B treatment shows protein percentage changes which are directly opposite to all the other treatments. This seeming disparity can be explained by the fact that the omission of the boot stage irrigation inhibited the formation of new heads but did allow those heads present to fill at a normal rate. When the C irrigation was applied, a limited number of heads began to fill. This caused the -B treatment to be out of phase with the other irrigation treatments as regards the grain development after the milk stage.

With the complete irrigation treatment, protein was below 13.9% at harvest up to 200 lbs/A of N. With the -A treatment, protein exceeded 13.9% at 100 pounds of N. The -B and -C irrigation treatments did not produce barley of less than 13.9% protein at any applied nitrogen rate, Table IX. When the D stage irrigation was omitted, 13.9% or less protein

percentage barley was produced up to 200 pounds of N per acre. These results are consistent with the harvest samples from other experiments in this series (31,32).

In choosing an irrigation regime under which to produce malting quality barley, the -B and -C regimes are excluded from consideration due to the high protein percentage of the grain produced. Omitting the A irrigation does allow the production of low protein barley; however, yields are so severely limited that this regime is also of little value. This leaves the complete irrigation treatment and the -D treatment as possible regimes. Table IV summarized the percentage protein content corrected to 10% moisture for the complete and -D irrigation treatments with various fertilizer rates at both the hard dough and harvest stages. In general, with the complete and the -D irrigation treatments, the protein percentage at the hard dough stage was less than at harvest. Since the price of malting barley increases as the grain protein decreases below 12.5%, it seems it would be advantageous to omit the D irrigation, and, in fact, harvest 2 to 3 weeks before the normal harvest period. In this way, a decrease in protein percentage should result. This change will increase the per unit value of the grain produced.

Table IV. Changes in Grain Protein Percentage Between the Hard Dough Stage and Harvest. Irrigation Treatments 1-(ABCD) and 5-(ABC-).

Fertilizer Rates		Percent Protein 1/			
		Irrigation Treatment			
		1-(ABCD)		5-(ABC-)	
Element	Pounds/Acre	10/5	10/27	10/5	10/27
N 2/	0	9.77	10.74	9.77	12.37
	50	12.61	11.12	12.61	12.24
	100	10.73	12.19	10.73	11.94
	150	12.67	12.42	12.67	11.78
	200	12.14	12.33	12.14	12.24
P 3/	0	11.25	12.01	11.25	11.86
	40	11.58	11.84	11.58	12.54
	80	10.58	11.38	10.58	11.80
N-P-K	0- 0- 0				
	0- 0-40				
	0-40-40	9.82	11.48	9.82	13.89
	0-80-40	9.17	10.38	9.17	11.69
	50-40-40	12.61	11.12	12.61	12.24
	100- 0-40	11.24	13.39	11.24	11.94
	100-40-40	10.55	11.69	10.55	12.19
	100-80-40	10.39	11.50	10.39	11.70
	150-40-40	12.67	12.42	12.67	11.78
	200- 0-40	12.18	12.27	12.18	12.01
	200-40-40	12.28	12.50	12.28	12.63
	200-80-40	11.99	12.21	11.99	12.01
LSD (.10)		1.37		1.37	

1/ Corrected to 10% grain moisture.

2/ N rates of 0, 100 and 200 pounds per acre are the means of the three phosphorous rates.

3/ Means of all N rates within each P rate.

SUMMARY AND CONCLUSIONS

Grain Yield

The yield increase under the -A irrigation regime that was noted in a previous experiment conducted in the same area during 1966 was not found in 1968.

The low yield of the -A irrigation regime in this study is attributed to the growth depression early in the season. Later irrigations could not completely alleviate this initial depression.

The low yield of the -B irrigation regime was caused by the lack of grain-bearing head formation after the milk stage. The rate of grain formation between the boot and milk stages was similar to the complete irrigation treatment; but after the milk stage, grain formation fell off rapidly in comparison with the complete irrigation.

The low yield under the -C irrigation regime is probably related to the lack of grain filling between the milk and the hard dough stages and was further aggravated by the early maturity of the grain.

The yield decline with the -D irrigation, which has been noted previously (32), was thought to be caused by a lack of grain formation during the later stages of growth when soil moisture was limited. Actually the effect seems to be the opposite. The decline in yield with the -D treatment as compared with the complete was actually caused by a greater decrease in grain weight from the hard dough stage to harvest when the D irrigation stage was omitted, than when water was applied at the hard dough stage.

Protein Content

The general observation is that the protein percentage of the grain was high at the milk stage, had decreased by the hard dough stage, and subsequently had increased again by the time the grain was harvested. The protein content of the -B and -C irrigation regimes was too high for malting uses; but the complete irrigation treatment and the -D produced acceptable barley at both the hard dough stage and at harvest, with protein being consistently lower at the hard dough stage, which was 3 weeks prior to harvest time.

The changes in protein percentage of the grain seem to be related to the changes in the carbohydrate content. Under some fertilizer treatments of the -B irrigation regime, no increase in grain weight, number of heads, grain protein percentage and total amount of grain protein was noted from the milk stage to hard dough. The grain weight, grain protein percentage and total protein stayed constant up to harvest. 2/ This indicates that the absolute amount of grain protein is deposited in the kernels at an early stage. The subsequent changes in protein percentage are caused by the dilution effect of the carbohydrates transferred into the developing grain.

Malting Barley Production

The -A irrigation regime produced barley with protein percentage low enough to qualify for malting uses. However, the yield was too low under

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2/ The number of grain-bearing heads was not measured for the harvest samples.

this treatment to consider this regime as a practical production practice. The -B and -C irrigation regimes produced barley with protein percentage too high for malting uses.

The complete and -D irrigation regimes both produced low protein barley. It was noted that the grain yield of these two regimes was higher at the hard dough stage than at maturity. These changes are summarized in Table V and VI.

The magnitude of the yield changes requires qualification. The -D irrigation regime was considered to be the same as the complete regime until after the hard dough stage. Thus, some of the weight changes between hard dough and harvest shown with the -D regime can be attributed to plot variability. The yield changes under the complete irrigation treatment were on samples from a given set of plots at different sampling times. It may be that differential drying of samples and/or shattering contributed to the magnitude of the changes. It is believed, however, that yield does decrease during this period and additional work is being conducted to verify and elucidate the changes noted.

If the grain has reached a sufficient stage of maturity by the hard dough stage to be useful for malting purposes; and if the yield changes noted are real, a yield increase could be realized by omitting the D irrigation and harvesting at the hard dough stage.

Significant yield augmentation has recently been reported by Krall (22) for feed barley. He has shown this effect on six varieties at five

Table V. Changes in Grain Weight Between the Hard Dough Stage and Harvest.

Fertilizer Rates		Grams Grain/Meter of Row			
		Irrigation Treatment			
		1-(ABCD)		5-(ABC-)	
Element	Pounds/Acre	10/5	10/27	10/5	10/27
N 1/	0	35.8	23.4	35.8	20.2
	50	51.5	22.0	51.5	39.7
	100	53.3	37.3	53.3	26.3
	150	26.0	24.0	26.0	34.3
	200	63.8	31.2	63.8	28.9
P 2/	0	41.5	27.4	41.5	21.7
	40	50.9	30.1	50.9	28.9
	80	52.5	29.8	52.5	30.3
N-P-K	0- 0- 0	10.5	14.3	10.5	24.0
	0- 0-40	16.5	18.3	16.5	16.7
	0-40-40	59.5	33.3	59.5	12.7
	0-80-40	31.5	18.7	31.5	31.3
	50-40-40	51.5	22.0	51.5	39.7
	100- 0-40	37.0	34.3	37.0	22.7
	100-40-40	56.5	34.0	56.5	24.0
	100-80-40	66.5	43.7	66.5	32.3
	150-40-40	26.0	24.0	26.0	34.3
	200- 0-40	71.0	29.7	71.0	25.7
	200-40-40	69.0	37.0	61.0	33.7
	200-80-40	59.5	27.0	59.5	27.3
LSD (.10)		13.0		13.0	

1/ N rates of 0, 100 and 200 pounds per acre are the means of the three phosphorous rates.

2/ Means of all N rates within each P rate.

Table VI. Percent Change in Yield at Hard Dough Stages as Compared to Harvest Yield.

Fertilizer Rates		Percent Change Irrigation Treatment	
Element	Pounds/Acre	1-(ABCD)	5-(ABC-)
N	0 1/	52.9	77.2 *
	50	134.1 * 2/	29.8
	100	42.9 *	102.5 *
	150	8.3	-24.3
	200	104.5 *	121.1 *
P	0 3/	51.2 *	91.5 *
	40	69.3 *	76.4 *
	80	76.3 *	73.1 *
N-P-K	0- 0- 0	26.7	56.3 *
	0- 0-40	-10.0	-1.0
	0-40-40	78.5 *	369.6 *
	0-80-40	68.7	0.5
	50-40-40	134.1 *	29.8
	100- 0-40	7.8	63.2 *
	100-40-40	66.2 *	135.4 *
	100-80-40	52.3 *	105.7 *
	150-40-40	8.3	-24.3
	200- 0-40	139.3 *	176.6 *
	200-40-40	64.9 *	81.2 *
	200-80-40	120.4 *	117.7 *

1/ N rates of 0, 100 and 200 pounds per acre are the means of the three phosphorous rates.

2/ Change is significant at .10.

3/ Means of all N rates within each P rate.

locations in Montana under both irrigation and dryland conditions, but not the same magnitude as was noted during this experiment.

APPENDIX

Table VII. Grams of Plant Material Per Meter of Row. Fertilizer Means.

Irrigation	Fertilizer	Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
	N 1/					
A B C D	0	24.50	147.25	170.83		142.22
	100	33.08	179.83	221.00		186.66
	200	29.16	145.48	270.16		170.00
- B C D	0	16.16	85.25	151.50		109.33
	100	14.91	90.66	153.83		127.33
	200	16.33	106.75	131.33		135.33
A - C D	0		186.16	136.83		100.77
	100		121.00	108.00		81.33
	200		92.83	136.16		104.44
A B - D	0			138.83	96.88	
	100			178.50	107.66	
	200			154.66	74.82	
A B C -	0					95.88
	100					126.55
	200					141.22
	P 1/					
A B C D	0	26.16	154.91	129.16		163.22
	40	31.20	155.00	194.00		147.33
	80	29.16	156.50	243.33		174.44
- B C D	0	16.08	88.08	36.33		140.77
	40	15.05	99.05	140.80		116.20
	80	16.75	92.25	158.66		118.88
A - C D	0		103.08	112.33		79.44
	40		97.85	121.00		86.06
	80		111.66	127.16		84.77
A B - D	0		174.99	98.66		
	40		150.20	92.06		
	80		166.66	123.22		
A B C -	0					117.55
	40					140.60
	80					133.60

1/ Pounds per acre.

Table VIII. Grams of Grain Per Meter of Row. Fertilizer Means.

Irrigation	Fertilizer	Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
	N 1/					
A B C D	0		12.00	38.83		23.44
	100		19.58	53.33		37.33
	200		12.41	63.83		31.22
- B C D	0		5.66	26.83		17.44
	100		8.58	23.50		18.88
	200		8.50	24.83		18.77
A - C D	0		17.16	40.50		29.11
	100		17.16	23.22		17.55
	200		10.33	32.83		26.33
A B - D	0			38.00	24.44	
	100			45.66	26.44	
	200			32.33	25.22	
A B C -	0					20.22
	100					26.33
	200					28.89
	P 1/					
A B C D	0		13.25	41.50		27.44
	40		18.60	59.90		30.06
	80		13.41	52.50		29.78
- B C D	0		6.16	21.50		18.77
	40		8.75	27.20		20.13
	80		6.08	30.00		17.33
A - C D	0		10.58	23.33		16.66
	100		16.25	31.90		25.60
	200		17.58	36.83		26.55
A B - D	0			45.83	25.00	
	40			36.90	22.60	
	80			36.83	31.00	
A B C -	0					21.67
	40					28.86
	80					30.33

1/ Pounds per acre.

Table IX. Grain Protein Percentage. Fertilizer Means.

Irrigation	Fertilizer	Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
	N 1/					
A B C D	0		12.97	10.75		11.82
	100		22.50	11.80		13.41
	200		14.55	13.36		13.46
- B C D	0		13.59	12.25		11.96
	100		15.68	13.98		14.03
	200		15.10	11.91		14.06
A - C D	0		13.21	13.97		13.58
	100		14.33	15.49		14.65
	200		13.77	15.12		14.00
A B - D	0			12.28	12.96	
	100			14.71	14.81	
	200			15.27	14.99	
A B C -	0					13.61
	100					13.14
	200					13.47
	P 1/					
A B C D	0		14.03	12.38		13.21
	40		14.49	12.74		13.02
	80		13.97	11.64		12.52
- B C D	0		15.04	10.86		12.99
	40		15.12	14.06		13.60
	80		14.68	13.46		13.60
A - C D	0		14.34	15.22		14.18
	40		13.56	14.78		14.42
	80		14.13	14.51		14.20
A B - D	0			13.67	14.19	
	40			14.46	14.65	
	80			14.45	13.97	
A B C -	0					13.50
	40					13.80
	80					12.98

1/ Pounds per acre.

Table X. Grams of Grain Protein Per Meter of Row. Fertilizer Means.

Irrigation	Fertilizer	Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
	N 1/					
A B C D	0		1.44	3.83		2.69
	100		2.75	6.04		4.95
	200		2.10	5.96		4.30
- B C D	0		0.73	3.28		2.12
	100		1.30	3.27		2.61
	200		1.21	3.55		2.62
A - C D	0		2.20	5.64		3.97
	100		2.39	3.53		2.56
	200		1.56	4.94		3.74
A B - D	0			4.54	3.16	
	100			6.69	3.83	
	200			4.93	3.79	
A B C -	0					2.32
	100					3.45
	200					3.90
	P 1/					
A B C D	0		1.80	5.36		3.67
	40		2.57	6.37		3.99
	80		2.13	6.03		3.76
- B C D	0		0.90	2.80		2.48
	40		1.28	3.85		2.71
	80		0.85	3.96		2.36
A - C D	0		1.41	3.45		2.35
	40		2.29	4.74		3.69
	80		2.43	5.25		3.57
A B - D	0			6.16	3.93	
	40			5.34	3.30	
	80			5.53	4.40	
A B C -	0					2.84
	40					3.97
	80					3.94

1/ Pounds per acre.

Table XI. Plant Weight Per Meter of Row. Treatment Means.

Treatment		Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
Irrigation	1/					
1	A B C D	28.31	154.13	206.63		157.11
2	- B C D	16.00	97.02	142.04		121.72
3	A - C D		106.90	119.96		92.47
4	A B - D			154.75	100.11	
5	A B C -					130.00
LSD (.10)		13.14	6.41	24.88		21.81
Fertilizer	2/ 3/					
1	0- 0- 0	18.00	119.17	133.88	75.00	107.42
2	0- 0-40	18.50	114.00	134.13	105.33	108.67
3	0-40-40	20.00	118.75	152.63	84.33	114.09
4	0-80-40	22.50	116.25	161.74	101.00	113.42
5	50-40-40	25.88	114.00	134.00	77.00	130.66
6	100- 0-40	21.00	116.17	160.50	79.33	129.41
7	100-40-40	27.75	142.92	158.63	107.00	126.25
8	100-80-40	23.25	132.42	176.86	136.67	135.83
9	150-40-40	20.75	113.33	138.40	111.00	124.91
10	200- 0-40	23.88	115.92	166.50	111.33	137.66
11	200-40-40	21.25	97.50	173.73	81.00	132.58
12	200-80-40	23.13	131.74	179.00	132.33	143.00
LSD (.10)		6.77	31.86	27.45		17.04
Irrigation	Fertilizer					
1-(ABCD)	1	17.75	113.25	203.00		132.67
	2	23.00	159.75	107.00		146.00
	3	29.50	155.00	219.00		162.67
	4	21.00	127.00	186.50		118.00
	5	34.75	126.50	165.00		118.33
	6	25.25	153.75	196.50		182.33
	7	36.25	176.25	211.50		155.33
	8	37.75	209.50	255.00		222.33
	9	27.00	155.75	125.50		137.67
	10	30.25	151.25	273.00		161.33
	11	28.50	125.50	249.00		165.67
	12	28.75	160.00	288.50		183.00
LSD (.10)		9.57	37.88	54.89		38.11

Table Continued...

Table XI Continued...

Treatment		Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
Irrigation	Fertilizer					
2-(-BCD)	1	18.25	134.00	115.50		100.67
	2	14.00	61.50	152.50		103.00
	3	10.50	94.25	121.00		114.67
	4	24.00	91.00	181.00		110.33
	5	17.00	95.50	100.50		149.33
	6	16.75	92.25	162.00		156.33
	7	19.25	110.25	150.50		131.00
	8	8.75	69.50	149.00		95.00
	9	14.50	95.75	178.50		94.33
	10	17.50	110.50	94.50		136.00
	11	14.00	99.50	153.50		91.67
	12	17.50	110.25	146.00		151.33
LSD (.10)		9.57	37.88	54.89		38.11
3-(A-CD)	1		110.25	112.00		91.00
	2		120.75	119.50		83.33
	3		107.00	158.50		119.67
	4		130.75	132.50		99.33
	5		84.00	92.00		83.33
	6		102.50	89.50		61.00
	7		142.25	113.50		96.33
	8		118.25	121.00		86.67
	9		88.50	92.50		75.67
	10		86.00	128.00		94.00
	11		67.50	148.50		115.33
	12		125.00	132.00		104.00
LSD (.10)			37.88	54.89		38.11
4-(AB-D)	1			105.00	75.00	
	2			157.50	105.33	
	3			112.00	84.33	
	4			147.00	101.00	
	5			178.50	77.00	
	6			194.00	79.33	
	7			159.00	107.00	
	8			182.50	136.67	
	9			157.50	111.00	
	10			170.50	111.33	
	11			144.00	81.00	
	12			149.50	132.33	
LSD (.10)				54.89	38.11	

(Continued)

Table XI Continued...

Treatment		Sampling Date			Harvest	
		8/6	9/7	10/5	10/19	10/27
Irrigation	Fertilizer					
5-(ABC-)	1					105.33
	2					102.33
	3					59.33
	4					126.00
	5					171.67
	6					118.00
	7					122.33
	8					139.33
	9					192.00
	10					132.33
	11					157.67
	12					133.67
LSD (.10)						38.11

1/ A dash indicates an omitted irrigation.

2/ See Table I for the fertilizer treatments.

3/ Values are in pounds per acre.

Table XII. Grain Weight Per Meter of Row. Treatment Means.

Treatment		Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
Irrigation	1/					
1	A B C D		15.06	45.48		28.03
2	- B C D		7.58	25.67		18.72
3	A - C D		14.94	30.67		23.39
4	A B - D			38.71	25.28	
5	A B C -					27.03
LSD (.10)			6.77	11.07		6.93
Fertilizer	2/ 3/					
1	0- 0- 0		10.58	22.00	22.33	20.00
2	0- 0-40		10.17	31.38	30.33	17.25
3	0-40-40		12.50	35.13	19.33	25.50
4	0-80-40		12.17	39.38	23.67	24.92
5	50-40-40		14.75	34.00	23.67	26.09
6	100- 0-40		11.50	31.63	18.67	22.17
7	100-40-40		20.17	37.13	24.00	27.00
8	100-80-40		13.67	40.63	36,67	25.92
9	150-40-40		13.58	35.25	29.00	24.33
10	200- 0-40		8.33	36.13	26.00	24.00
11	200-40-40		11.67	42.13	17.00	27.92
12	200-80-40		11.25	37.13	32.67	26.42
LSD (.10)			4.35	8.70		5.01
Irrigation	Fertilizer					
1-(ABCD)	1		7.75	10.50		14.33
	2		14.75	16.50		18.33
	3		12.00	59.50		33.33
	4		9.25	31.50		18.67
	5		20.50	51.50		22.00
	6		12.00	37.00		34.33
	7		24.75	56.50		34.00
	8		22.00	66.50		43.67
	9		20.50	26.00		24.00
	10		13.00	71.00		29.67
	11		15.25	61.00		37.00
	12		9.00	59.50		27.00
LSD (.10)			7.53	17.41		11.20

Table Continued...

Table XII Continued...

Treatment		Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
Irrigation	Fertilizer					
2=(-BCD)	1		10.50	17.50		15.67
	2		2.00	25.50		14.67
	3		8.75	13.50		21.33
	4		6.25	41.50		16.33
	5		6.50	20.00		22.00
	6		11.50	27.00		21.33
	7		11.00	20.50		24.33
	8		3.25	23.00		11.00
	9		5.75	45.00		21.67
	10		5.00	12.00		20.33
	11		11.75	37.00		11.33
	12		8.75	25.50		24.67
LSD (.10)			7.53	17.41		11.20
3-(A-CD)	1		13.50	28.00		26.00
	2		13.75	34.50		19.33
	3		16.75	39.00		34.67
	4		21.00	48.00		33.33
	5		17.25	23.50		20.67
	6		11.00	11.50		10.33
	7		24.75	27.00		25.67
	8		15.75	31.50		16.67
	9		14.50	26.50		17.33
	10		7.00	24.00		20.33
	11		8.00	43.50		29.67
	12		16.00	31.00		26.67
LSD (.10)			7.53	17.41		11.20
4-(AB-D)	1			32.00	22.33	
	2			49.00	30.33	
	3			28.50	19.33	
	4			36.50	23.67	
	5			41.00	23.67	
	6			51.00	18.67	
	7			44.50	24.00	
	8			41.50	36.67	
	9			43.50	29.00	
	10			37.50	26.00	
	11			27.00	17.00	
	12			32.50	32.67	
LSD (.10)				17.41	11.20	

(Continued)

Table XII Continued...

Treatment		Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
Irrigation	Fertilizer					
5-(ABC-)	1					24.00
	2					16.67
	3					12.67
	4					31.33
	5					39.67
	6					22.67
	7					24.00
	8					32.33
	9					34.33
	10					25.67
	11					33.67
	12					27.33
LSD (.10)						11.20

1/ A dash indicates an omitted irrigation.

2/ See Table I for the fertilizer treatments.

3/ Values are in pounds per acre.

Table XIII. Percent Protein in the Grain. Treatment Means.

Treatment		Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
Irrigation	1/					
1	A B C D		14.30	12.32		12.92
2	- B C D		14.70	12.99		13.30
3	A - C D		13.88	14.75		14.19
4	A B - D			14.10	14.28	
5	A B C -					13.25
LSD (.10)			0.64	0.86		0.69
Fertilizer	2/ 3/					
1	0- 0- 0		13.47	12.78	13.58	12.36
2	0- 0-40		13.46	12.28	12.71	12.29
3	0-40-40		13.15	12.67	14.25	13.43
4	0-80-40		13.17	12.00	11.94	12.51
5	50-40-40		14.63	14.57	14.75	13.43
6	100- 0-40		14.96	14.24	15.36	14.11
7	100-40-40		14.94	13.96	14.54	13.82
8	100-80-40		14.45	13.80	14.54	13.51
9	150-40-40		15.88	14.41	14.71	13.73
10	200- 0-40		15.00	12.58	14.52	13.68
11	200-40-40		13.37	14.47	15.00	14.15
12	200-80-40		15.06	14.71	15.45	13.95
LSD (.10)			1.07	1.11		0.32
Irrigation	Fertilizer					
1-(ABCD)	1		15.13	12.24		12.78
	2		12.88	11.37		11.41
	3		12.93	10.80		12.63
	4		13.10	10.09		11.42
	5		14.08	13.87		12.23
	6		14.93	12.37		14.73
	7		14.56	11.61		12.86
	8		13.55	11.43		12.65
	9		16.81	13.94		13.66
	10		14.28	13.40		13.50
	11		14.11	13.51		13.75
	12		15.28	13.19		13.43
LSD (.10)			1.58	2.22		1.02

Table Continued...

Table XIII Continued...

Treatment		Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
Irrigation	Fertilizer					
2-(-BCD)	1		11.65	12.54		11.80
	2		14.35	11.89		11.75
	3		12.70	12.56		11.65
	4		13.73	12.32		12.50
	5		15.54	14.49		13.71
	6		15.35	13.74		13.68
	7		16.34	14.51		14.55
	8		15.35	13.71		13.87
	9		16.11	14.35		13.88
	10		15.43	6.96		13.54
	11		14.91	14.44		14.21
	12		14.96	14.35		14.45
LSD (.10)			1.85	2.22		1.02
3-(A-CD)	1		13.65	13.84		12.98
	2		13.15	14.39		13.31
	3		13.83	14.51		14.17
	4		12.67	13.01		13.27
	5		14.27	14.99		14.33
	6		14.61	16.30		14.87
	7		13.94	14.96		14.46
	8		14.44	15.23		14.64
	9		14.71	14.39		14.40
	10		15.28	14.97		14.37
	11		11.09	15.09		14.74
	12		14.95	15.31		14.69
LSD (.10)			1.85	2.22		1.02
4-(AB-D)	1			12.50	13.58	
	2			11.46	12.71	
	3			12.84	14.25	
	4			12.56	11.94	
	5			14.91	14.75	
	6			14.56	15.36	
	7			14.74	14.54	
	8			14.83	14.54	
	9			14.97	14.71	
	10			15.00	14.52	
	11			14.84	15.00	
	12			14.98	15.45	
LSD (.10)				2.22	1.02	

(Continued)

Table XIII Continued...

Treatment		Sampling Date			Harvest	
		8/6	9/7	10/5	10/19	10/27
Irrigation	Fertilizer					
5-(ABC-)	1					11.88
	2					12.70
	3					15.28
	4					12.86
	5					13.46
	6					13.14
	7					13.41
	8					12.87
	9					12.96
	10					13.32
	11					13.89
	12					13.21
LSD (.10)						1.02

1/ A cash indicated an omitted irrigation stage.

2/ See Table I for the fertilizer treatments.

3/ Values are in pounds per acre.

Table XIV. Total Grams of Protein in the Grain from One Meter of Row. Treatment Means.

Treatment		Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
Irrigation	1/					
1	A B C D		2.06	5.62		3.67
2	- B C D		1.08	3.47		2.50
3	A - C D		2.07	4.47		3.30
4	A B - D			5.43	3.60	
5	A B C -					3.59
LSD (.10)			0.85	1.39		1.06
Fertilizer	2/ 3/					
1	0- 0- 0		1.39	2.82	3.01	2.45
2	0- 0-40		1.29	3.87	3.90	2.13
3	0-40-40		1.55	4.32	2.80	3.45
4	0-80-40		1.54	4.79	2.80	3.17
5	50-40-40		2.07	4.93	3.52	3.56
6	100- 0-40		1.66	4.36	2.77	3.10
7	100-40-40		2.92	4.97	3.45	3.67
8	100-80-40		1.88	5.33	5.27	3.42
9	150-40-40		2.00	5.14	4.26	3.31
10	200- 0-40		1.17	5.11	3.73	3.30
11	200-40-40		1.71	6.04	2.51	3.98
12	200-80-40		1.66	5.33	5.13	3.65
LSD (.10)			0.62	1.11		0.68
Irrigation	Fertilizer					
1-(ABCD)	1		1.08	1.31		1.77
	2		1.83	1.97		2.09
	3		1.37	6.37		4.22
	4		1.13	3.16		2.10
	5		2.78	7.22		2.89
	6		1.73	4.54		4.87
	7		3.57	6.38		4.44
	8		2.97	7.22		5.54
	9		3.00	3.62		3.23
	10		1.85	9.58		4.05
	11		2.15	8.30		5.20
	12		2.31	7.73		3.65
LSD (.10)			1.07	2.22		1.53

Table Continued...

Table XIV Continued...

Treatment		Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
Irrigation	Treatment					
2-(-BCD)	1		1.24	2.12		1.82
	2		0.29	3.07		1.75
	3		1.06	1.69		2.57
	4		0.84	5.08		2.06
	5		1.04	2.80		2.98
	6		1.72	3.69		2.94
	7		1.72	2.96		3.37
	8		0.47	3.16		1.54
	9		0.89	6.46		3.03
	10		0.71	1.64		2.77
	11		1.70	5.36		1.60
	12		1.24	3.65		3.49
LSD (.10)			1.07	2.22		1.53
3-(A-CD)	1		1.85	3.84		3.34
	2		1.74	5.01		2.59
	3		2.22	5.66		4.95
	4		2.66	6.27		4.38
	5		2.39	3.60		2.98
	6		1.53	1.80		1.53
	7		3.47	4.03		3.72
	8		2.19	4.77		2.44
	9		2.10	3.88		2.44
	10		0.97	3.56		2.95
	11		1.27	6.54		4.37
	12		2.44	4.72		3.90
LSD (.10)			1.07	2.22		1.53
4-(AB-D)	1			4.00	3.01	
	2			5.42	3.90	
	3			3.55	2.80	
	4			4.65	2.80	
	5			6.09	3.52	
	6			7.40	2.77	
	7			6.53	3.45	
	8			6.16	5.27	
	9			6.60	4.26	
	10			5.66	3.73	
	11			3.95	2.51	
	12			5.19	5.13	
LSD (.10)				2.22	1.53	

(Continued)

Table XIV Continued...

Treatment		Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
Irrigation	Fertilizer					
5-(ABC-)	1					2.86
	2					2.07
	3					2.05
	4					4.12
	5					5.37
	6					3.06
	7					3.16
	8					4.15
	9					4.52
	10					3.41
	11					4.76
	12					3.55
LSD (.10)						1.53

1/ A dash indicates an omitted irrigation.

2/ See Table I for the fertilizer treatments.

3/ Values are in pounds per acre.

Table XV. 1000-Kernel Weight. Treatment Means.

Treatment		Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
Irrigation	1/					
1	A B C D		14.94	24.58		26.92
2	- B C D		13.96	20.63		26.75
3	A - C D		17.13	24.21		28.64
4	A B - D			24.21	27.44	
5	A B C -					27.56
LSD (.10)			3.10	3.65		1.23
Fertilizer	2/ 3/					
1	0- 0- 0		12.75	20.63	26.67	27.50
2	0- 0-40		13.67	23.13	29.33	26.59
3	0-40-40		15.50	22.63	26.00	28.00
4	0-80-40		16.00	24.25	28.00	28.92
5	50-40-40		18.08	25.00	28.67	26.92
6	100- 0-40		16.58	23.13	26.67	27.83
7	100-40-40		17.42	24.13	27.00	26.92
8	100-80-40		15.25	25.25	28.33	27.83
9	150-40-40		15.92	25.13	26.67	27.34
10	200- 0-40		12.33	20.50	27.00	25.92
11	200-40-40		15.58	23.75	27.33	28.17
12	200-80-40		13.92	23.38	27.67	27.67
LSD (.10)			2.25	2.69		1.27
Irrigation	Fertilizer					
1-(ABCD)	1		10.75	13.00		27.67
	2		15.75	20.50		23.00
	3		13.50	31.00		27.00
	4		12.75	19.00		27.00
	5		17.25	28.50		25.33
	6		16.50	25.50		27.33
	7		20.00	29.50		25.00
	8		17.25	28.00		31.00
	9		14.75	23.50		27.67
	10		13.00	27.00		25.33
	11		17.25	26.50		28.33
	12		10.50	23.00		28.33
LSD (.10)			3.90	5.40		2.85

Table Continued...

Table XV Continued...

Treatment		Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
Irrigation	Fertilizer					
2-(-BCD)	1		12.50	21.50		25.00
	2		9.50	20.00		27.00
	3		14.50	14.00		28.67
	4		15.00	24.50		29.33
	5		15.25	21.00		25.00
	6		18.25	22.50		28.00
	7		14.00	21.00		25.67
	8		10.50	22.50		25.33
	9		13.00	24.50		26.67
	10		10.50	10.50		25.67
	11		17.75	23.00		28.00
	12		14.50	22.50		26.67
LSD (.10)			3.90	5.40		2.85
3-(A-CD)	1		15.00	22.00		29.33
	2		15.75	26.50		28.67
	3		18.50	23.00		31.33
	4		21.25	29.50		31.00
	5		21.75	25.50		29.00
	6		15.00	21.50		27.67
	7		18.25	21.50		29.00
	8		18.00	25.50		26.33
	9		20.00	25.00		28.67
	10		13.50	21.00		25.33
	11		11.75	25.50		28.67
	12		16.75	24.00		28.67
LSD (.10)			3.90	5.40		2.85
4-(AB-D)	1			26.00	26.67	
	2			26.50	29.33	
	3			22.50	26.00	
	4			24.00	28.00	
	5			25.00	28.67	
	6			23.00	26.67	
	7			24.50	27.00	
	8			25.00	28.33	
	9			27.50	26.67	
	10			23.50	27.00	
	11			20.00	27.33	
	12			24.00	27.67	
LSD (.10)				5.40	2.85	

(Continued)

Table XV Continued...

Treatment		Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
Irrigation	Fertilizer					
5-(ABC-)	1					28.00
	2					27.67
	3					25.00
	4					28.33
	5					28.33
	6					28.33
	7					28.00
	8					28.67
	9					26.33
	10					27.33
	11					27.67
	12					27.00
LSD (.10)						2.85

1/ A dash indicates an omitted irrigation.

2/ See Table I for the fertilizer treatments.

3/ Values are in pounds per acre.

Table XVI. Number of Grain-Bearing Heads from One Meter of Row. Treatment Means.

Treatment		Sampling Date 8/6	9/7	10/5	Harvest 10/19	Harvest 10/27
Irrigation	1/					
1	A B C D		62.44	139.79		
2	- B C D		38.44	109.33		
3	A - C D		55.73	93.63		
4	A B - D			99.63		
5	A B C -					
LSD (.10)						
Fertilizer	2/ 3/					
1	0- 0- 0		51.42	82.50		
2	0- 0-40		47.08	102.13		
3	0-40-40		54.08	102.75		
4	0-80-40		50.50	132.88		
5	50-40-40		55.00	100.88		
6	100- 0-40		48.08	117.63		
7	100-40-40		70.42	116.63		
8	100-80-40		61.00	120.13		
9	150-40-40		49.92	99.63		
10	200- 0-40		38.50	96.88		
11	200-40-40		48.25	129.75		
12	200-80-40		52.17	125.38		
LSD (.10)						
Irrigation	Fertilizer					
1-(ABCD)	1		27.00	78.50		
	2		58.00	77.50		
	3		54.25	141.00		
	4		49.25	147.50		
	5		74.50	137.50		
	6		61.25	168.50		
	7		82.00	142.00		
	8		103.25	155.00		
	9		64.00	88.00		
	10		53.00	167.00		
	11		61.00	177.50		
	12		52.75	197.50		
LSD (.10)						

Table Continued...

Table XVI Continued...

Treatment		Sampling Date			Harvest	
		8/6	9/7	10/5	10/19	10/27
Irrigation	Fertilizer					
2-(-BCD)	1		60.25	79.00		
	2		26.00	122.50		
	3		44.50	82.50		
	4		33.00	148.00		
	5		36.25	86.50		
	6		37.75	142.00		
	7		44.00	130.00		
	8		20.75	127.50		
	9		33.75	126.00		
	10		28.75	42.50		
	11		29.50	109.50		
	12		46.75	116.00		
LSD (.10)						
3-(A-CD)	1		57.00	83.50		
	2		57.25	85.00		
	3		63.50	105.50		
	4		69.25	125.50		
	5		54.25	74.00		
	6		45.25	53.00		
	7		85.25	83.50		
	8		59.00	104.50		
	9		52.00	86.00		
	10		33.75	90.00		
	11		34.25	128.00		
	12		58.00	105.00		
LSD (.10)						
4-(AB-D)	1			89.00		
	2			123.50		
	3			82.00		
	4			110.50		
	5			105.50		
	6			107.00		
	7			111.00		
	8			93.50		
	9			98.50		
	10			88.00		
	11			104.00		
	12			83.00		
LSD (.10)						

(Continued)

Table XVI Continued...

1/ A dash indicates an omitted irrigation.

2/ See Table I for the fertilizer treatments.

3/ Values are in pounds per acre.

Table XVII. F Ratios for Grain and Plant Properties.

Factor	Sampling Date 8/6	9/7	10/5	10/19
Plant Weight				
Irrigation	2.36	9.41* 1/	11.72*	5.40*
Fertilizer	0.60	0.94	.32	1.66
Interaction	1.34	1.25	1.46	1.60*
Grain Weight				
Irrigation		1.66	3.38	1.10
Fertilizer		1.54	1.24	0.93
Interaction		1.21	2.13*	1.41*
Grain Protein Percentage				
Irrigation		1.65	8.51*	3.10*
Fertilizer		2.49*	2.73*	8.33*
Interaction		0.98	1.08	1.31*
1000-Kernel Weight				
Irrigation		1.31	1.40	1.41
Fertilizer		3.07*	1.15	0.84
Interaction		1.73*	1.70*	
Heads Per Meter				
Irrigation		2.37	5.03	
Fertilizer		1.49*	1.28	
Interaction		1.78*	0.98	

1/ Significant at .10.

Table XVIII. Soil Analysis Data. 1/

	Depth	Location			Mean
		Southeast	North	Southwest	
pH (Saturated Paste)	0-6"	7.5	7.5	7.5	7.5
	0-1'	7.6	7.5	7.4	7.5
	1-2'	8.0	8.0	7.9	8.0
	2-3'	7.7	7.6	7.6	7.6
	3-4'	7.7	7.8	7.4	7.6
	4-5'	7.8	7.8	7.7	7.8
Conductivity mmhos/cm^{-1}	0-6"	0.40	0.42	0.48	0.43
	0-1'	0.31	0.37	0.40	0.36
	1-2'	0.34	0.48	0.29	0.37
	2-3'	4.25	3.50	2.60	3.45
	3-4'	4.00	1.40	3.00	2.80
	4-5'	1.75	0.93	1.85	1.51
Organic Matter Percent	0-6"	1.47	2.86	1.47	1.93
	0-1'	2.40	2.40	4.47	3.09
	1-2'	2.16	1.93	3.43	2.51
	2-3'	1.93	1.47	1.93	1.78
Available K kg/ha	0-6"	997	1120+	1120+	1079+
	0-1'	874	750	909	844
	1-2'	795	717	795	769
	2-3'	538	627	694	620
Available P kg/ha	0-6"	72	81	78	77
	0-1'	29	29	12	23
	1-2'	18	29	11	19
	2-3'	7	45	29	27

1/ Samples taken June 12, 1968, during initial site inspection.

Table XIX. Soil Description--Dillon

Avalanche series. Calcisols of the brown soils zone developed in strongly calcareous alluvium in valleys of the northern Rocky Mountain Region.

Distinctive characteristics:

1. Poorly graded character of the parent material with a high silt content, low content of sands and clay and few to common gravels.
2. Thin, light-colored A1 horizon.
3. Distinct or prominent very thick Cca or Dca horizon.

Soil Profile:		Avalanche silt loam (under cultivation)
Ap	0- 7"	Pale brown (10YR 7/3) silt loam; 10YR 5/3 moist; massive structure, slight hard, very friable, non-sticky and slightly plastic; very calcareous; abrupt smooth boundary.
Cca	7-24"	Brown (10YR 7/2) silt loam with a few gravels; 10 YR 4.5/2 moist, moderately coarse prismatic breaking to moderately coarse medium blocks, slightly hard, very friable, nonsticky and slightly plastic; very calcareous; clear wavy boundary.
Dca	24-50"	Very pale brown (10YR 7/3) to white (10YR 8/2) silt loam with some angular gravels. 10YR 5.5/3 to 10YR 6/3.5 moist; massive structure; soft, very friable, nonsticky and slightly plastic; extremely calcareous with thin lime coats on gravels.

Table XX. Precipitation Amounts and Distribution. Dillon Airport Station, 1968.

Day	6 June	7 July	8 Aug.	9 Sept.	10 Oct.
1					T
2	a/			.10	
3	T		.07	T	
4	.02		.02	T	
5					
6	.42	T			
7	T				T
8	.02	.03	T		
9			.08		
10	.40	.04			
11	T	.03		.01	T
12	.03	T		.02	T
13	.03		.41		T
14	.02		.09	T	.27
15	.01		.04	T	.05
16		T	T	T	
17		.07	.15	T	
18			.09	.11	T
19	.28	T	T	.37	
20	.06		.11	.82	T
21			.02	.04	
22	.03		.08		
23	.04				
24					
25					
26				.07	
27					
28					
29					
30					
31					
MONTHLY TOTALS	1.72	0.17	1.20	1.59	.33

a/ T, trace--amount too small to measure. Amounts in inches.

Table XXI. Soil Moisture. Total Inches of Water to Three Feet.

Irr.	Fert.	Dates of Measurement 8/1	8/7	8/14	8/20	9/7	9/18	9/24
ABCD	0- 0-40	5.61	5.05	5.06	5.12	4.37	7.02	7.20
	0-40-40	5.26	5.13	6.44	5.48	4.78	6.16	6.44
	0-80-40	5.72	5.64	6.26	5.78	--	6.98	6.52
	100- 0-40	4.37	3.94	4.24	4.32	3.89	5.00	5.48
	100-40-40	5.38	3.91	4.24	4.49	3.40	6.05	6.00
	100-80-40	6.18	5.64	4.95	4.91	4.29	5.62	5.93
	200- 0-40	5.29	4.29	5.99	5.21	3.43	7.19	6.86
	200-40-40	4.84	4.21	5.37	5.07	4.24	8.29	7.97
	200-80-40	5.33	4.60	--	5.43	4.16	--	5.56
A-CD	0- 0-40	4.50	4.55	4.98	4.38	4.29	7.68	7.14
	0-40-40	4.72	4.45	4.34	4.14	4.13	6.32	6.67
	0-80-40	4.64	4.51	4.44	4.47	4.28	7.45	6.48
	100- 0-40	4.68	5.15	4.69	4.49	4.45	5.31	5.38
	100-40-40	4.61	4.60	4.48	4.50	4.20	5.54	5.43
	100-80-40	4.48	3.99	4.05	3.99	3.57	6.40	6.11
	200- 0-40	4.67	4.26	--	4.01	3.50	5.06	5.64
	200-40-40	4.59	4.65	5.22	4.86	4.62	6.40	6.30
	200-80-40	4.05	3.64	3.80	3.67	3.59	5.90	5.85
AB-D	0- 0-40	5.94	--	5.15	5.13	3.89	4.18	4.66
	0-40-40	6.36	5.23	6.92	6.57	4.55	4.27	4.38
	0-80-40	4.91	4.99	5.41	4.99	3.97	3.62	4.96
	100- 0-40	4.49	4.44	4.88	4.59	3.77	4.07	5.07
	100-40-40	5.43	4.46	4.76	4.75	3.99	3.90	4.72
	100-80-40	4.62	4.41	4.23	4.40	3.62	3.72	4.19
	200- 0-40	4.83	5.18	5.06	4.97	3.67	3.95	4.62
	200-40-40	5.65	4.79	5.11	5.20	3.76	4.19	4.90
	200-80-40	4.78	4.67	4.99	4.41	3.72	3.86	4.80
ABC-	0- 0-40	5.38	--	5.14	4.98	4.07	4.51	4.80
	0-40-40	5.25	4.46	5.77	5.74	4.02	6.47	6.19
	0-80-40	5.11	4.38	5.30	5.10	4.24	6.70	4.40
	100- 0-40	6.30	4.96	5.43	5.37	4.11	5.47	5.54
	100-40-40	5.23	5.01	7.53	6.92	4.65	8.79	8.31
	100-80-40	4.80	4.33	4.65	4.55	3.90	4.36	4.55
	200- 0-40	6.20	5.16	5.74	5.80	4.26	5.50	5.93
	200-40-40	6.59	5.23	6.12	6.04	4.28	6.43	6.96
	200-80-40	5.35	4.23	6.62	6.15	4.10	7.26	6.66

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