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PRODUCTIVITY ENHANCEMENT IN RAINFED AREAS BY WATER CATCHMENT, STORAGE POOL AND DRIP IRRIGATION

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Executive Summary

Dry season production of annual crops is not very successful as during the dry season, annual plants turn yellow and their production is very minimal. Farmers who can manage to own a motorized pump may draw water from shallow wells for irrigation, which may have a negative impact on ground water supply like salt water intrusion. Hence, the agricultural utilization of such areas, for instance in the Philippines, is very much bound to the wet season. In the wet season, farmers have to contend with several environmental constraints such as insect pest and diseases, weeds, water-logging of the soil, flooding, typhoon, and low fertilizer uptake efficiency. As a consequence, the average yield in rainfed areas is also very low.

The approach which was adopted by the present project was to store rainwater on a small scale and use it with high efficiency by means of drip irrigation. A ratio of 1:10 between cultivated and catchment areas would be of high economical value considering the nearly nil production of the dryland. A catchment area of approximately 5 ha grassland with an estimated annual average rainfall of 1700 mm and a surface runoff of 25% were assigned. A reservoir was excavated at the lower part of the catchment along the natural gully to hold approximately 3,000 m^3. The capacity of the reservoir was based on catchment efficiency and evaporation between rainstorm, and was approximately 15% of the theoretical harvestable water. Seepage was considered to be negligible based on the structure of the reservoir bed. Provided 35-40% of the water is lost by evaporation throughout the dry season, the stored water should be sufficient for the irrigation of 0.5 ha if efficient irrigation management is developed.

The project thus included 3 main aspects: Development, training and research.

1. Development of the catchment and storage system

Observations during the 4 years gave the information that average rainfall was 2,053 mm, mainly during June-Sept. The storage reservoir was filled up every year. The stored water in

the pool was, however, not enough to complete the irrigation season of the experimental field. Although the total water consumed was approximately only 1900 m^3, water had to be used from other sources.

Statistical analysis with data of many years on rainfall and runoff is, however, needed in order to obtain more valid conclusions on the ratio between catchment area and storage pool volume. There is probably a need for a larger storage of water per unit area and improved irrigation management to consume water more efficiently.

2. Training of the Philippine team to install and use drip irrigation

The training was fully accomplished. After a visit of the Israeli scientist and technician the local team maintained the entire set-up of drip irrigation very successfully for 3 consecutive seasons. Moreover, an experiment was conducted with this equipment in which the interaction of 4 quantities of water and 2 levels of fertilizers was studied. The use of this equipment is now ready to be duplicated throughout the country.

3. Research aimed to develop an efficient management in order to save irrigation water

Four field trials were conducted in Israel to confront this problem. The important conclusions are that although yield was decreased when the quantities of water are reduced, the losses can be minimized if one adopts the proper management. In non-determinate crops (tomatoes) the damage was minimal if irrigation was withheld during specific growth stages. In determinate crops (corn) the damage was smaller when the amount of water was reduced uniformly throughout the season. Drip irrigation caused less salinity damage as compared with furrow irrigation and should be preferred mainly when low quality water is used. These findings were passed on to the Philippines and will certainly serve their practice of irrigation management.

4. Research Objectives

The overall aim of this study was to develop a simple and inexpensive method of drip irrigation scheme to be applied in rained areas. Irrigation water can be obtained by harvesting rainfall from small catchments and be stored in small pools. The specific objectives were the following:

1. To determine relationships between catchment area and pool size and between pool size and cropping area;
2. To asses the performance of simple drip irrigation techniques using this water resource for various crops;
3. To develop irrigation management which will lead to the most economical and efficient use of the stored water.

5. Detailed Methods and Results

A. Israel

Four field trials were conducted in Israel to deal with Objective 3 which are the main research problems of the project. These were conducted on corn, and on tomatoes for processing. The use of drip irrigation was compared with furrow irrigation (on potatoes) to investigate its advantage, mainly with low quality water. These studies are presented in this report similar to publications in a journal.

One paper based on this study was already accepted for publication by the Israel Journal of Botany. A second paper is about to be submitted to Irrigation Science and a third paper is in preparation. Attached are the front pages of the first two publications.

1. DEVELOPMENT OF OPTIMAL IRRIGATION MANAGEMENT FOR CORN WITH EMPHASIS ON QUANTITY OF WATER APPLIED, WITHHOLDING OF IRRIGATION AND PARTIAL WETTING OF SOIL VOLUME

INTRODUCTION

Water use can be provided more economically if the quantity of applied water is reduced and productivity is not damaged. It can possibly also be obtained by withholding irrigation at specific growth stages and possibly by reducing the volume of soil wetting.

A reduction in the quantity of applied water implies using less water for irrigation than the full requirement of the crop. Evapotranspiration rate is the factor determining irrigation water requirements, and it can be estimated by several direct or indirect methods (Plaut & Meiri, 1994). A very popular indirect method is based on evaporation rates from an evaporation pan, like Class a pan. The ratio between the rate of pan evaporation and the quantity of water to be applied to a particular crop is defined as the crop irrigation coefficient. An outline of the findings of many field trials which determine this coefficient for different crops in various locations is given by Doorenbos & Pruitt (1977). These coefficients usually refer to a fully covered surface, and have to be corrected during early developmental stages. A crop irrigation coefficient of 0.85 was suggested by Shalhevet et al. (1981) for corn during full coverage of the surface. This value was further verified in many field trials conducted in Israel since, and was thus used as our control crop irrigation coefficient.

Another approach to reduce the quantity of irrigation water is based on withholding irrigations at growth stages during which minimal damage occurs. It was shown for several grain crops that flowering and early grain development are critical growth stages and water stress during this period should be minimized (Hiller & Howell, 1983). Moreover, effect of water stress during floral initiation and/or anthesis was reported to be greater than if it occurs during earlier or later developmental stages (Ashley & Ethridge, 1978; Grief, 1987 & Boote, 1983).

The third approach adopted in this project aimed to use irrigation water more economically was by reducing the wetted soil volume. This can be achieved by application of small quantities of water given at high frequencies to avoid severe water shortage. This approach was previously used in our laboratory for cotton (Plaut et al., 1988 & Carmi et al., 1992) and a technique was developed to promote a shallow and restricted root system. Under optimal irrigation management productivity of the restricted-root-volume cotton was similar to cotton grown under common conditions. Since no pre-wetting of a dry soil profile is required and no losses of water due to deep percolation occurs, the total use of water is significantly reduced. This approach was studied by comparing the response of corn to high and low irrigation frequencies.

MATERIALS AND METHODS

A major field trial was conducted in the southern coastal plain of Israel at Kibbutz Givat Brenner. The experimental field was within a much larger field in which corn was planted for

commercial purposes, so that there were no border effects which might sometimes be a serious limitation in field experiments. A preliminary irrigation of approximately 30 mm was applied by sprinklers shortly after sowing to ensure adequate germination. The installation of the drip irrigation system began prior to planting and was terminated within 10 days.

The corn growing period can be divided into 5 periods according to its phenological development:

A = Germination and establishment of final plant stand

B = Vegetative growth

C = Flowering and ear formation

D = Grain filling

E = Maturation

Water stress during period A may result in different plant stand due to stress effects on germination and initial plant growth. Irrigation management and quantities of water applied were thus identical during period A. Evaporation rate from a Class A pan was determined with a pan located west to the corn field to avoid effect of water vapor of the transpiring field on pan evaporation rate. Quantities of irrigation water during period A were equal to the rate of evaporation multiplied by the crop irrigation coefficient of 0.85 and by the relative coverage of the soil surface.

Two approaches were used in order to reduce the amount of irrigation water. The first was partial replenishment of the water lost by evapotranspiration, so that the crop coefficients used were in the range of 0.70 to 1.00 of the common one (0.85 multiplied by relative coverage). The response of corn to a

higher irrigation coefficient (of 1.15) was also studied. Two frequencies of irrigation were compared for each quantity of water: once and three times per week as outlined in Table 1.1. The two frequencies were aimed to change the wetted soil volume.

The second approach was based on withholding of irrigation at one or two of the growing stages B, C and D. One treatment in which irrigation was withheld during all the three stages B + C + D was also included (Table 1.1).

The experimental plot consisted of 6 rows x 12 m long. The space between the center of rows was 96 cm and plants density was 8±1 plants m^{-2}. Measurements were conducted on the two central rows of each plot to avoid possible effects of adjacent plots. Each treatment was replicated five times according to a randomized block design. The detailed layout of the experiment is presented in Fig. 1.1.

The drip laterals were located in the center between two rows and the ratio of laterals to rows was 1:2. Distance between drippers was 1m and discharge rate was 2 l/h at the given water head of 14m. Fertilizers were injected into the irrigation water by means of an Ami'ad fertilizing pump.

Soil moisture content was determined between water applications by means of a neutron probe located at the distance of 20 cm from drippers. These measurements were conducted in triplicates in all treatments of the central block (Fig. 1). Most measurements were to a depth of 120 cm, but several measurements were taken down to 150 cm. The degree of surface coverage by the canopy was determined by measuring the shaded area on plastic measuring bars which were placed along the space

between rows. The shaded areas on these bars were measured at midday on 50 replicates of the control treatments (Treatment no. 7) when the sun was at the zenith (± 15 min).

Records on the rate of plant development were taken by samples removed throughout the growing season. Leaf area was determined by sampling and weighing known samples of leaf discs and total leaf weight. Chemical analysis and other measurements were conducted on samples which were taken in the field and brought to the laboratory. At the time of harvest, grain yield and its components and vegetative yield were determined.

RESULTS AND DISCUSSION

The five growth stages and their timing are outlined in Table 1.2 and harvest was conducted shortly thereafter between August 20 and 24. The quantities of water applied varied between 89 mm in the direst treatment and 573-578 mm in the wettest treatments (Table 1.1). In the treatments which were irrigated 3 times a week and once a week, similar quantities of water were applied according to the given irrigation coefficient. Soil wetting did not exceed the depth of 120 cm except in a few applications of the wettest treatments (Treatments 4 & 8), in which water moved down to 150 cm. Knowing soil moisture content at the initiation and termination of the experiment and the quantities of water applied seasonal evapotranspiration (ET) could be calculated (Table 2.1). As may be expected, the largest difference between ET and the quantity of water applied was in the driest treatment and the smallest difference was in the wettest treatment.

If soil moisture content at field capacity is defined as 0 deficit, then the diversion from this moisture content can be considered as deficit (Fig. 1.2). The deficit to a depth of 120 cm was small and nearly constant in the wettest treatment (#4) for the major part of the season. Similar results were found for low frequent applications (not presented). The control treatment (1.00H) was at a slightly larger water deficit, mainly from 90 days on. The application of water at a lower crop coefficients induced larger soil water deficits which start already much earlier (Fig. 1.2 A). The withholding of irrigation at different growth stages is clearly reflected in the timing of water deficits (Fig. 1.2 B & C). In treatment C+D the development of soil water deficit was more moderate as compared with treatment in which the stress was induced at an earlier stage.

The top soil layer of 30 cm contributed the largest fraction of the total water used by the crop (Fig. 1.3). The two top layers of 60 cm contributed at least 60% of the total water even in the driest treatment. It should be noted that in the wettest treatment the top 30 cm contributed approximately 65% and the top 60 cm over 80% of the total water used up to the age of 75 days (Fig. 1.3). In the dry treatment (0.70H) in which the total water applied was 50% less, water use from the top 30cm was still over 45% and from the top 60 cm above 65%. This indicates that the frequent water application which is possible when drip irrigation is being used enhances water use from the top layers. These layers are probably preferable as they are higher in nutrient and air content.

A comparison between low and high irrigation frequency on water use is presented in Fig. 1.4. At the high frequencies (0.70H, 0.85H and 1.00H), much more water was withdrawn from the top 30 cm as compared with low frequencies (0.70L, 0.85L and 1.00L). This was mostly obvious under the low irrigation coefficient, as the smaller quantities wetted only a restricted soil depth.

The effect of irrigation management on corn production was determined by analyzing the relationship between ET or quantities of water applied and the various yield parameters. The dependence of grain yield on seasonal ET or on quantities of water applied is presented as a linear regression line (Fig. 1.5), and the actual yield values of all 15 treatments are also presented. The lower slope of yield vs. water applied than vs. ET was due to use of stored soil water which was not accounted for in the case of water applied. This was also the reason for the smaller intercept. Corn production is sometimes defined as ear (grain + cob) yield and its dependence on ET and quantities of water applied was thus analyzed in a similar way (Fig. 1.6). The response of ear yield was very similar to that of grain yield and so were the regression equations. The regression coefficient values (R^2) were lower for water applied than for ET.

Grain yield is the result of 5 components: number of plants per unit area, number of ears per plant, average ear size, number of grains per ear and average seed weight. The physiological processes which are responsible for these components are different and occur at different times (see Table 1.2). Since the number of plants per unit area were arranged to be similar, the

number of ears per unit area will depend on the initiation of inflorescence and their early development. Average ear size is determined before and shortly after silking, number of grains will depend on pollination and anthesis and grain size is determined thereafter. There was a clear linear relationship between each of these parameters and ET or quantity of water applied (Fig.s 1.7 & 1.8), but a higher regression coefficient for ET than for water applied. The relative slope (change in slope vs. change in measured parameter) was the highest for average grain weight indicating that this parameter was most sensitive. The lowest slope was obtained for number of seed per ear indicating its lower sensitivity to water application.

Dry weight of vegetative organs was also increased by increasing quantities of water applied or ET (Fig. 1.9). The scatter of the experimental points was, however, large and R^2 values were only 0.52-0.55 as compared with 0.86 or higher in the case of grains and ear yield. The stronger response of grain yield than that of vegetative yield to water, was responsible for the increase in harvest index (dry weight of grain/dry weight of vegetative organs - Fig. 1.10). Dry weight of vegetative organs and ears (ear yield after drying) present total plant dry weight (Fig. 1.11).

The concentration of various ions in plant shoots was determined on plant samples taken shortly after silking, when vegetative development was at its peak (Fig. 1.12). It is very obvious that there was no clear dependence of the concentration of any of the ions on ET values.

A comparison of the effect of the two procedures used for reducing the quantities of irrigation water is presented in Table 1.3. Several treatments are arranged in three groups in which similar quantities of water were applied. In each of these groups, the treatment in which the quantity of water was reduced by lowering the irrigation coefficient gave higher grain and ear yield as compared with withholding water at specific growth stages. This implies that although the crop was probably more sensitive to water stress at specific developmental stages, uniform and mild reduction in water supply throughout the season was less inhibitory. A similar analysis was conducted for total plant and for vegetative organs dry weight (Table 1.4) showing a similar response. Although not all the differences within each group are significant, the trend is clear suggesting a more noticeable reduced production when water was withheld at specific developmental stages than uniformly.

The effect of irrigation frequency and restricted soil volume wetting on corn production was analyzed by calculating the responses of relative yield to reduced water applications (Table 1.5). Ear and grain yield and their components were set as 100% in Treatment 7 (1.00L) which was considered as the reference. In a restricted volume of wetted soil obtained by frequent irrigation with large water quantities higher corn yields were obtained than in a deep wetted soil (compare 1.15H with 1.15L). However, when the quantities of water were reduced the reverse was found (compare 0.70H with 0.70L). The difference between the two frequencies of irrigation were much smaller at the two intermediate irrigation coefficients. This can be explained by

the better performance of the crop when the top soil layer was maintained wet, since nutrient and air are more available. However, under scarcity of water, a larger soil volume which may still supply water to the crop will be preferred. It is of interest that the decrease in both grain and ear yield at the reduced irrigation coefficient are larger than the two yield components and even in many cases more than their product. This is certainly due to the involvement of additional actors which are responsible for the final yield.

Table 1.1. Identification of treatments, quantities of water applied (QWT) and seasonal evapotranspiration (ET).

Treatment no.	Stage of irrigation withholding	Designation of treatment	Number of applications per week	Crop Irrigation Coefficient	Quantities of applied water (mm)	Seasonal Evapotrans-piration (mm)
1	-	0.70H	3	0.70	285	407
2	-	0.85H	3	0.85	383	457
3	-	1.00H	3	1.00	473	550
4	-	1.15H	3	1.15	578	609
5	-	0.70L	1	0.70	322	433
6	-	0.85L	1	0.85	422	479
7	-	1.00L	1	1.00	491	567
8	-	1.15L	1	1.15	573	610
9	B	B	1	1.00	389	449
10	C	C	1	1.00	403	447
11	D	D	1	1.00	358	447
12	B+C	B+C	1	1.00	264	349
13	C+D	C+D	1	1.00	316	464
14	B+D	B+D	1	1.00	271	427
15	B+C+D	B+C+D	1	1.00	89	260

Table 1.2. Outline of 5 growth stages and their time period.

A - Germination and establishment of plant stand	.....	April 8 - May 2
B - Vegetative growth	.....	May 3 - June 15
C - Flowering (male and female	.....	June 16 - June 26
D - Grain filling	.....	June 27 - July 23
E - Maturation	.....	July 24 - August 19

Table 1.3. Grain and ear yield of various treatments in which seasonal evapotranspirations (ET) were similar

Ranges in ET (mm)	Treatment	Grain yield (g/m^2)	Ear yield (g/m^2)
472-433	0.70L (5)*	496 (34)	724 (35)
	B+D (14)	447 (32)	643 (46)
447-457	0.85H (2)	620 (68)	935 (86)
	C (10)	497 (44)	732 (61)
	B (9)	414 (31)	633 (32)
464-479	0.85L (6)	562 (24)	830 (36)
	C+D (13)	501 (47)	754 (62)
	D (11)	447 (63)	655 (89)

* Treatment designation, in parenthesis their serial number (see Table 1.1).

Table 1.4. Whole plant (excluding roots) and vegetative organs dry weight as affected by the reduction of irrigation water in different ways. The reduction in irrigation water also resulted in reduced seasonal evapotranspiration. Standard error of the mean are in parenthesis.

Range in ET (mm)	Treatment	Total dry weight (g/m^2)	Vegetative dry weight (g/m^2)
427-433	0.70L (5)*	1430 (88)	713 (40)
	B+D (14)	1218 (126)	585 (71)
447-457	0.85H (2)	1691 (116)	770 (82)
	C (10)	1527 (120)	826 (73)
	B (9)	1100 (92)	474 (79)
464-479	0.85L (6)	1689 (90)	869 (68)
	C+D (13)	1456 (119)	715 (72)
	D (11)	1325 (115)	677 (59)

* Treatment designation in parenthesis (see Table 1.1).

Table 1.5. The effect of irrigation frequency resulting in different soil volume wetting on relative corn yield and relative yield components. The values in Treatment 1.00L were set as 100%.

Treatment no.	Treatment designation	Ear yield (%)	Grain yield (%)	Av. grain weight (%)	No. of seeds per ear (%)
1	0.70H	63.1	61.7	87.6	72.5
2	0.85H	82.0	77.9	93.6	88.2
3	1.00H	95.6	85.1	94.6	91.6
4	1.15H	113.2	116.3	106.8	111.3
5	0.70L	71.1	70.3	90.9	96.6
6	0.85L	81.6	79.7	96.5	85.4
7	1.00L	100	100	100	100
8	1.15L	107.3	112.1	102.8	102.6

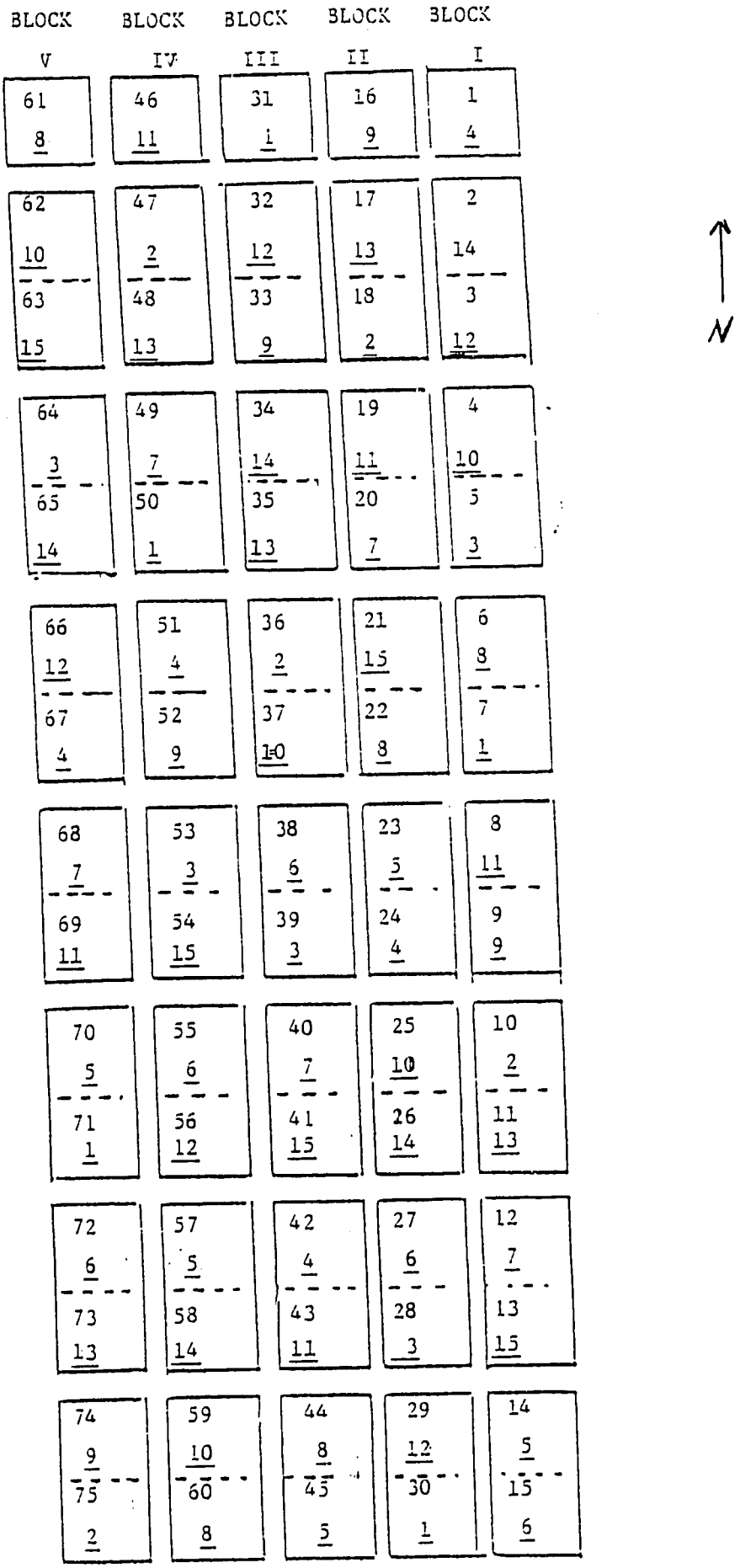


Fig. 1.1: Outline of experimental field for corn irrigation management. Underlined numbers represent number of treatment as defined in Table 1.1, other numbers represent serial number of plot.

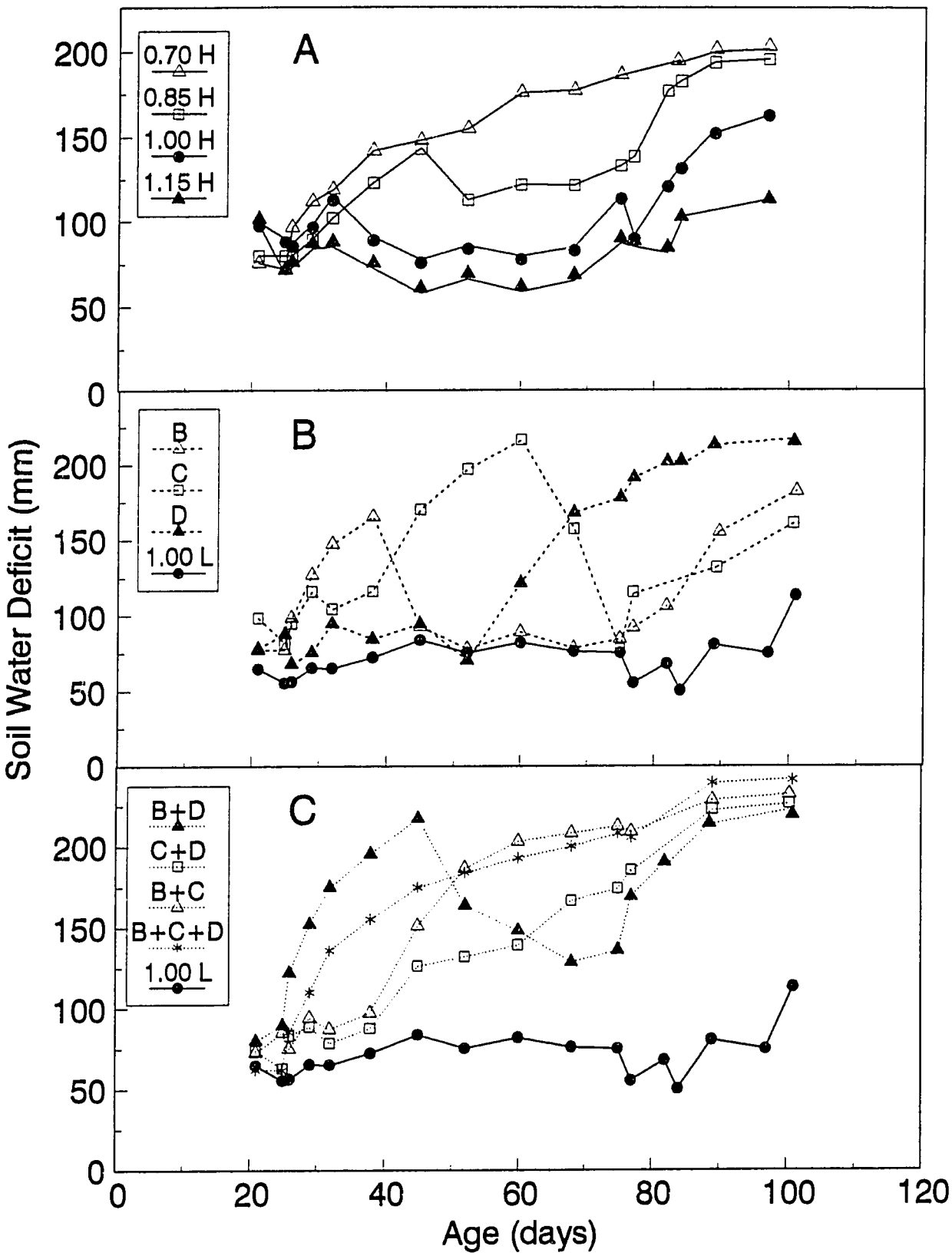


Fig 1.2: Floctuation throughout the season in soil water deficit to a depth of 120 cm.

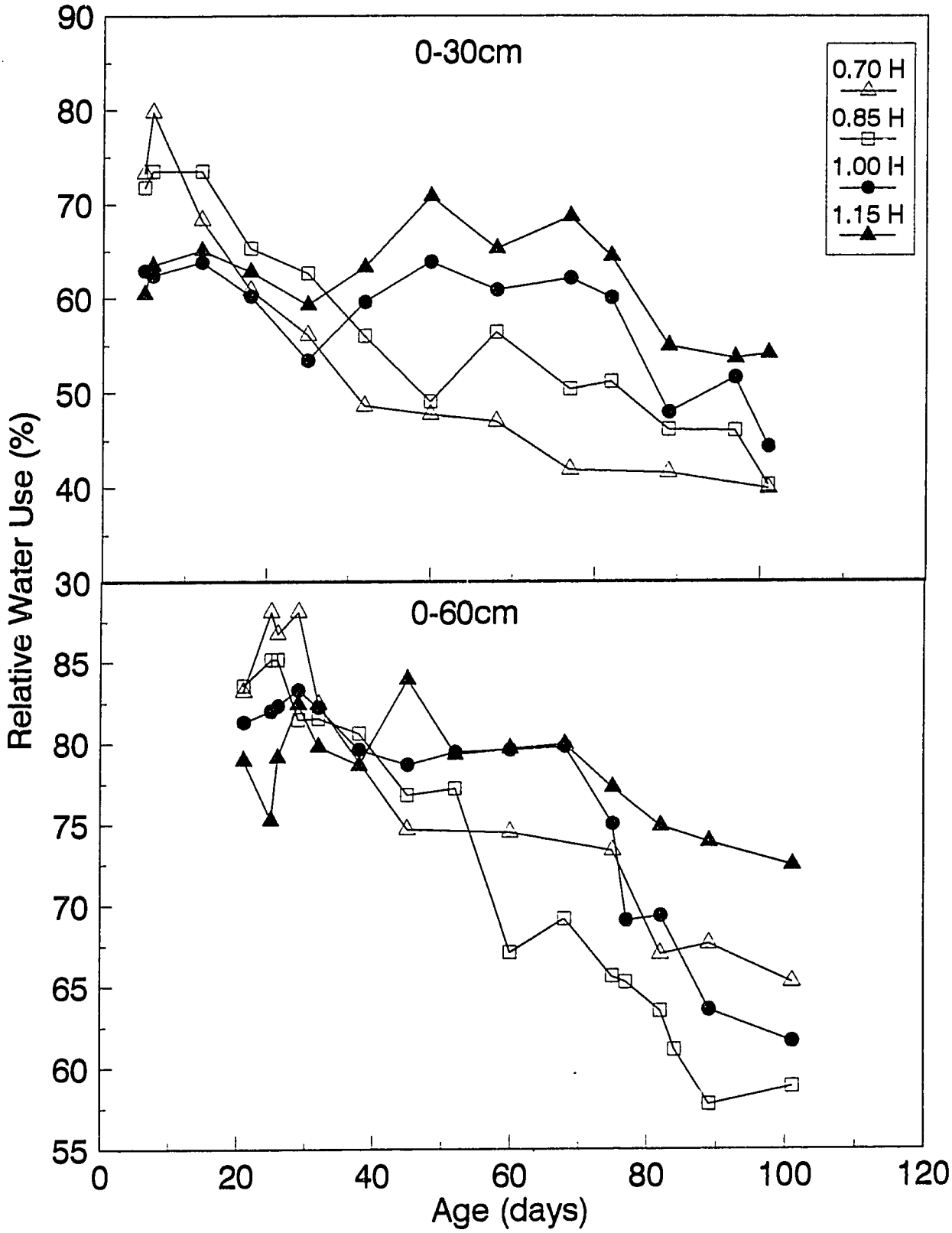


Fig 1.3: Relative water use throughout the season from a soil layer of 0-30 and 0-60 cm out of total water used by the crop.

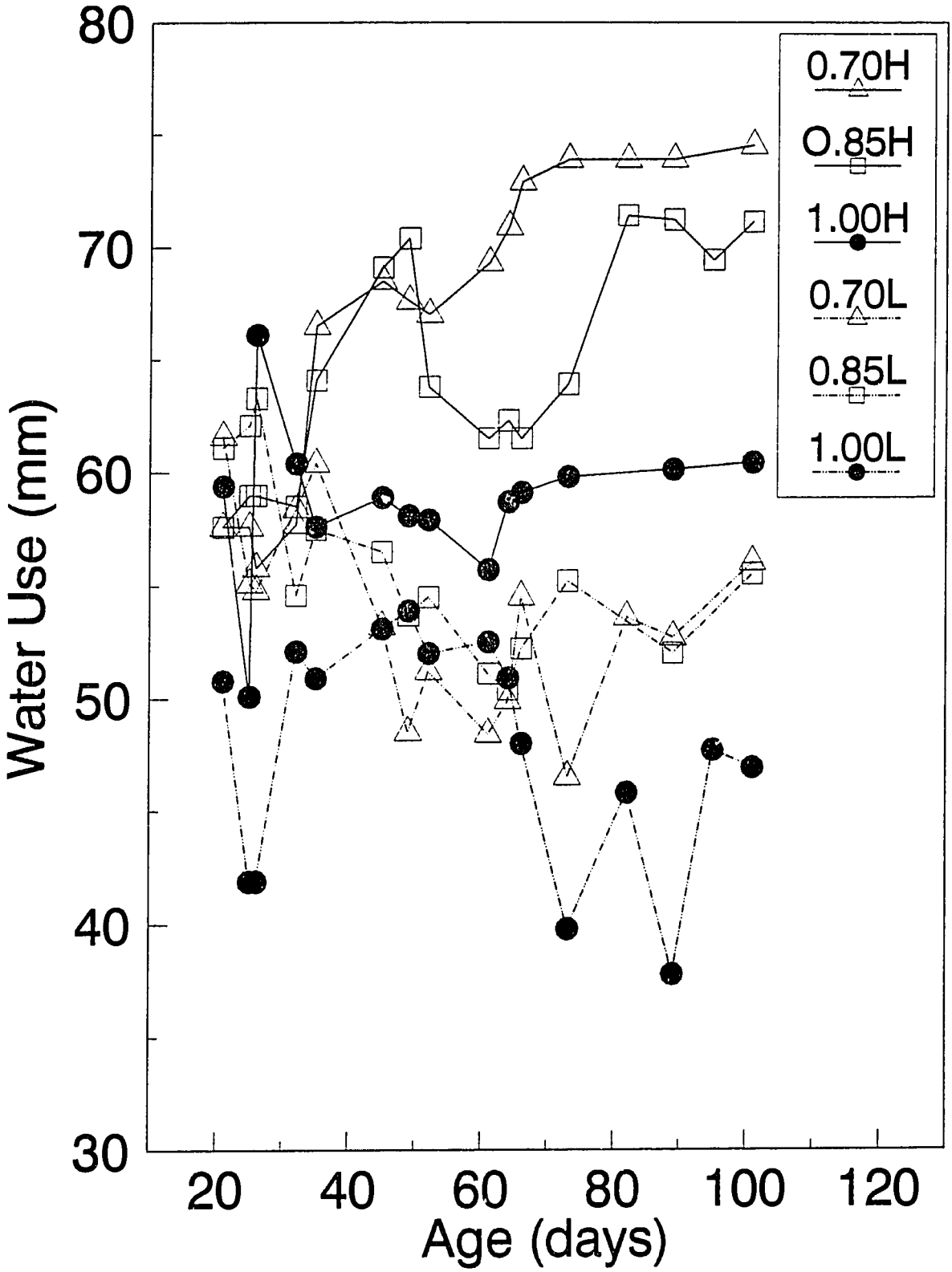


Fig 1.4: Water use by the corn crop throughout the season, from the depth of 0-30 cm.

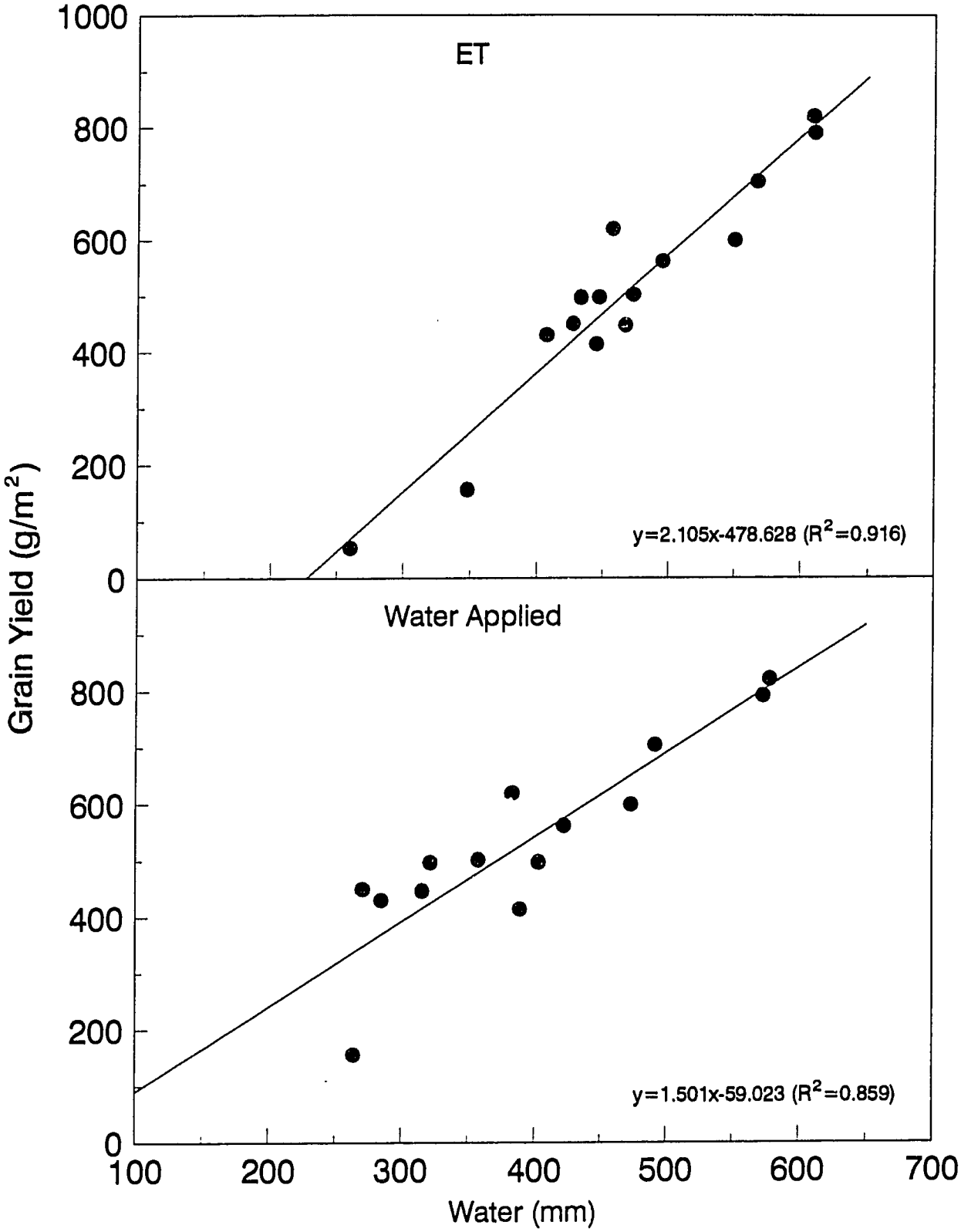


Fig 1.5: Dependence of corn grain yield on ET and quantities of water applied.

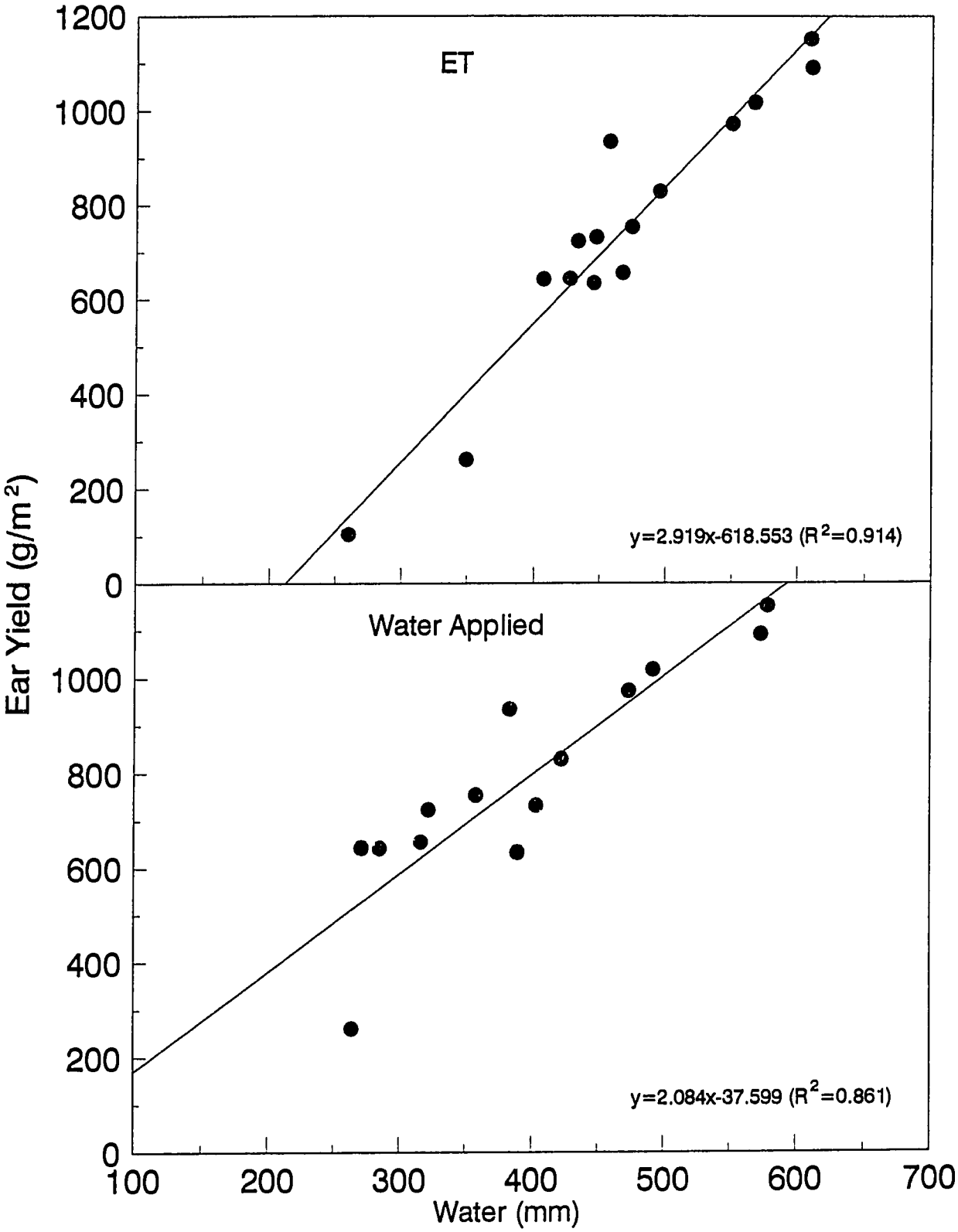


Fig 1.6: Dependence of corn ear yield on ET and quantities of water applied.

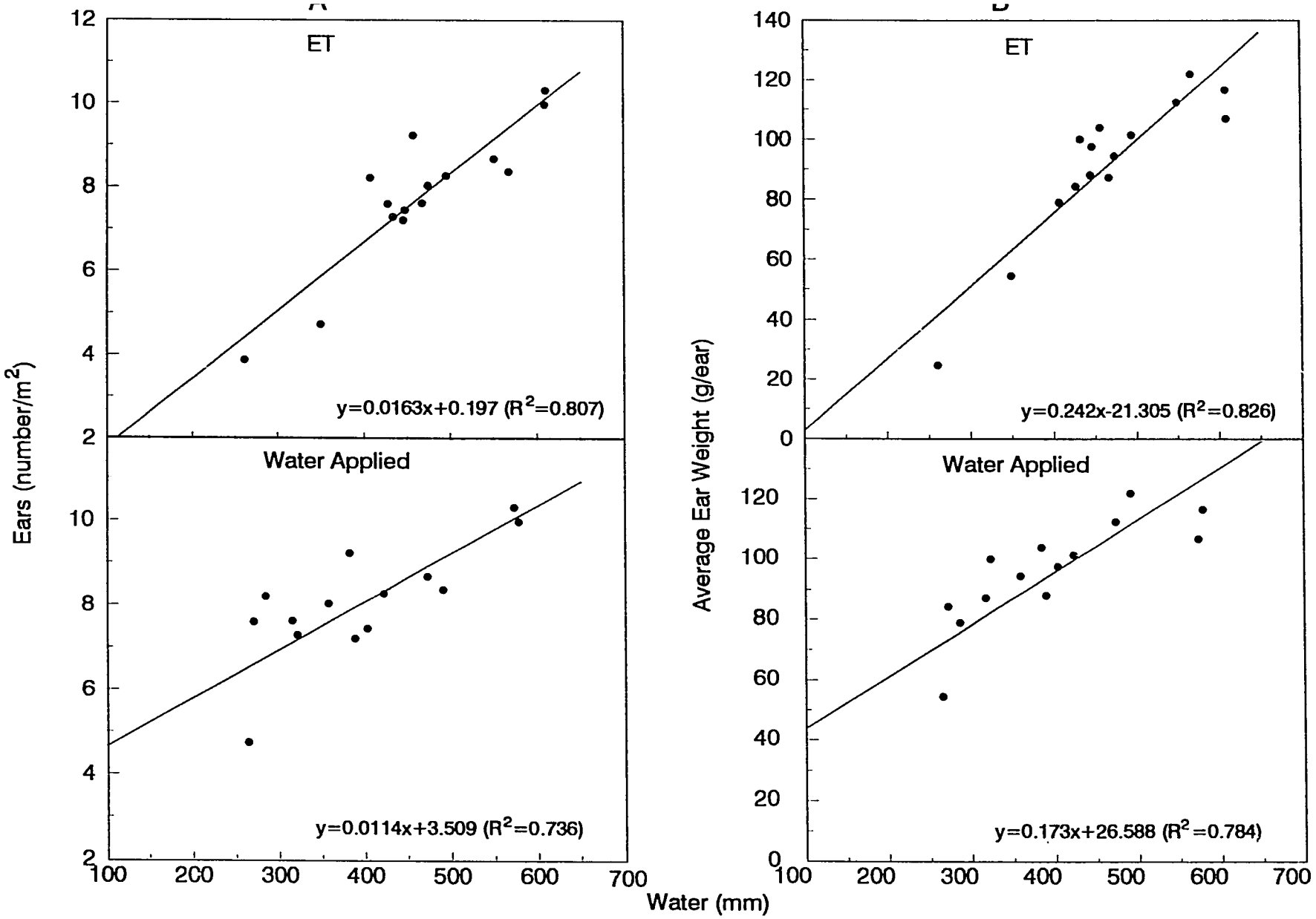


Fig 1.7: The effect of ET and quantities of water applied on corn grain yield components.
A: Number of ears per unit area. B: Average ear size.

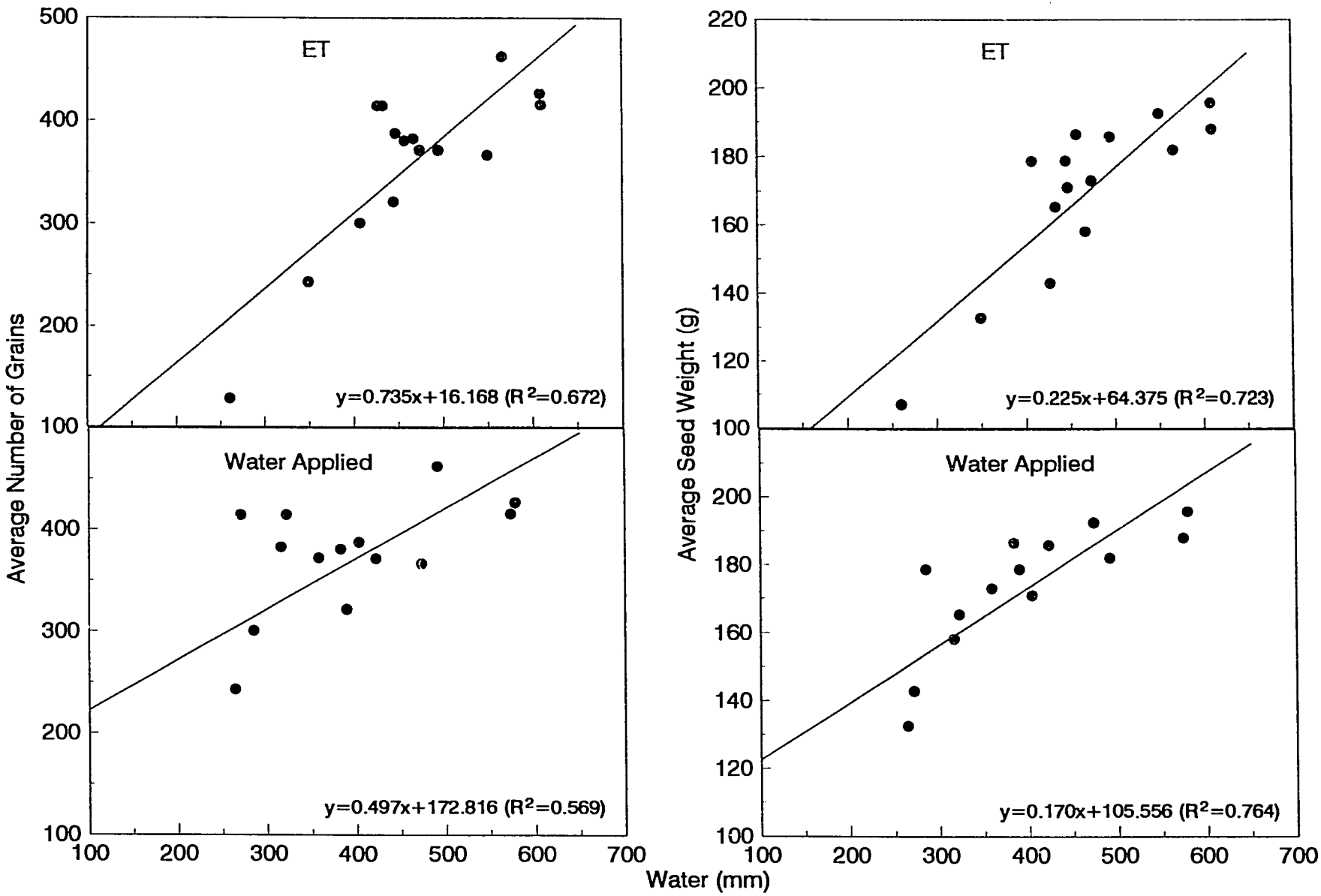


Fig 1.8: The effect of ET and quantities of water applied on corn grain yield components.
C: Average number of grain per ear. B: Average grain weight.

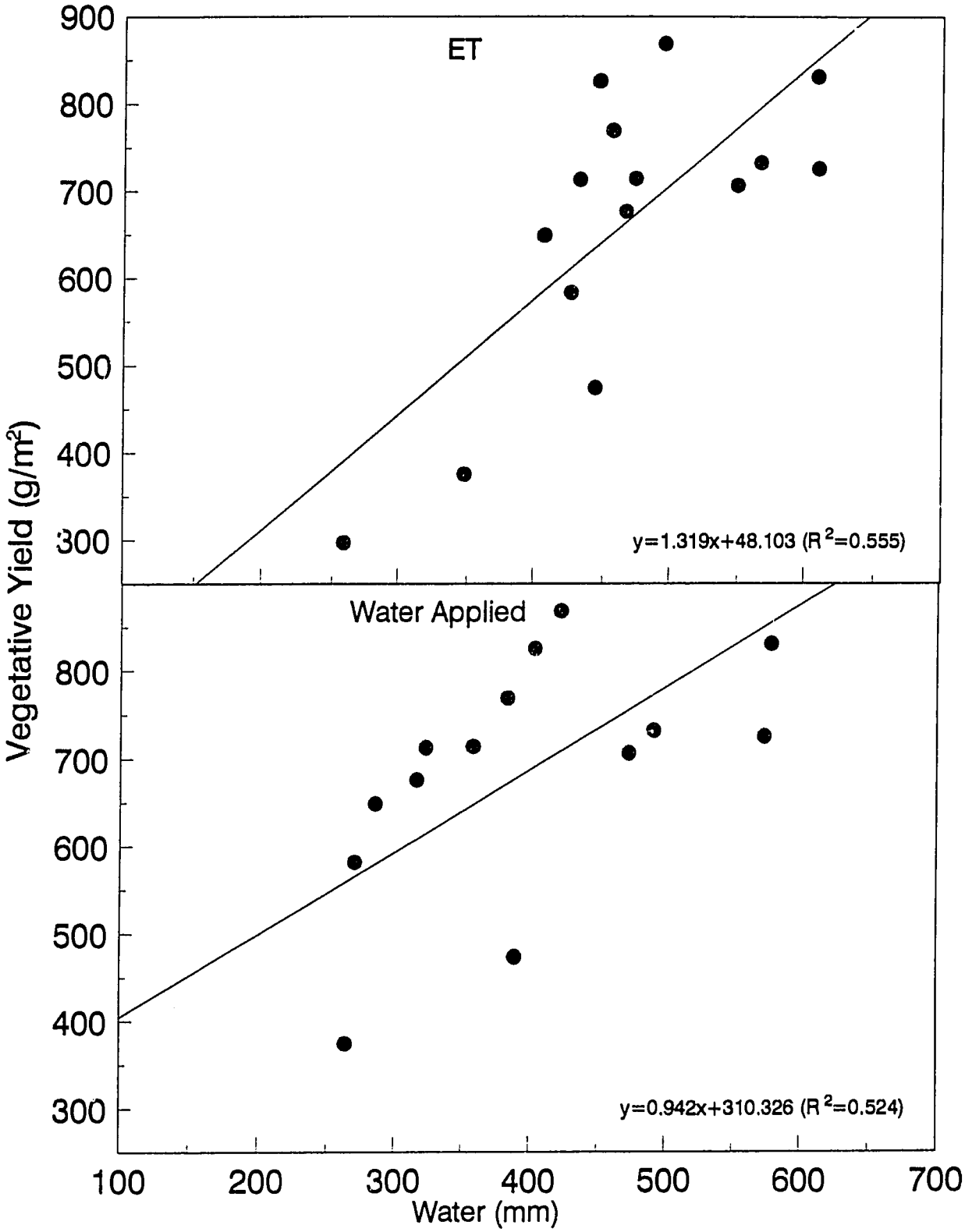


Fig 1.9: Dependence of corn vegetative organs dry weight (excluding roots), on ET and quantities of water applied.

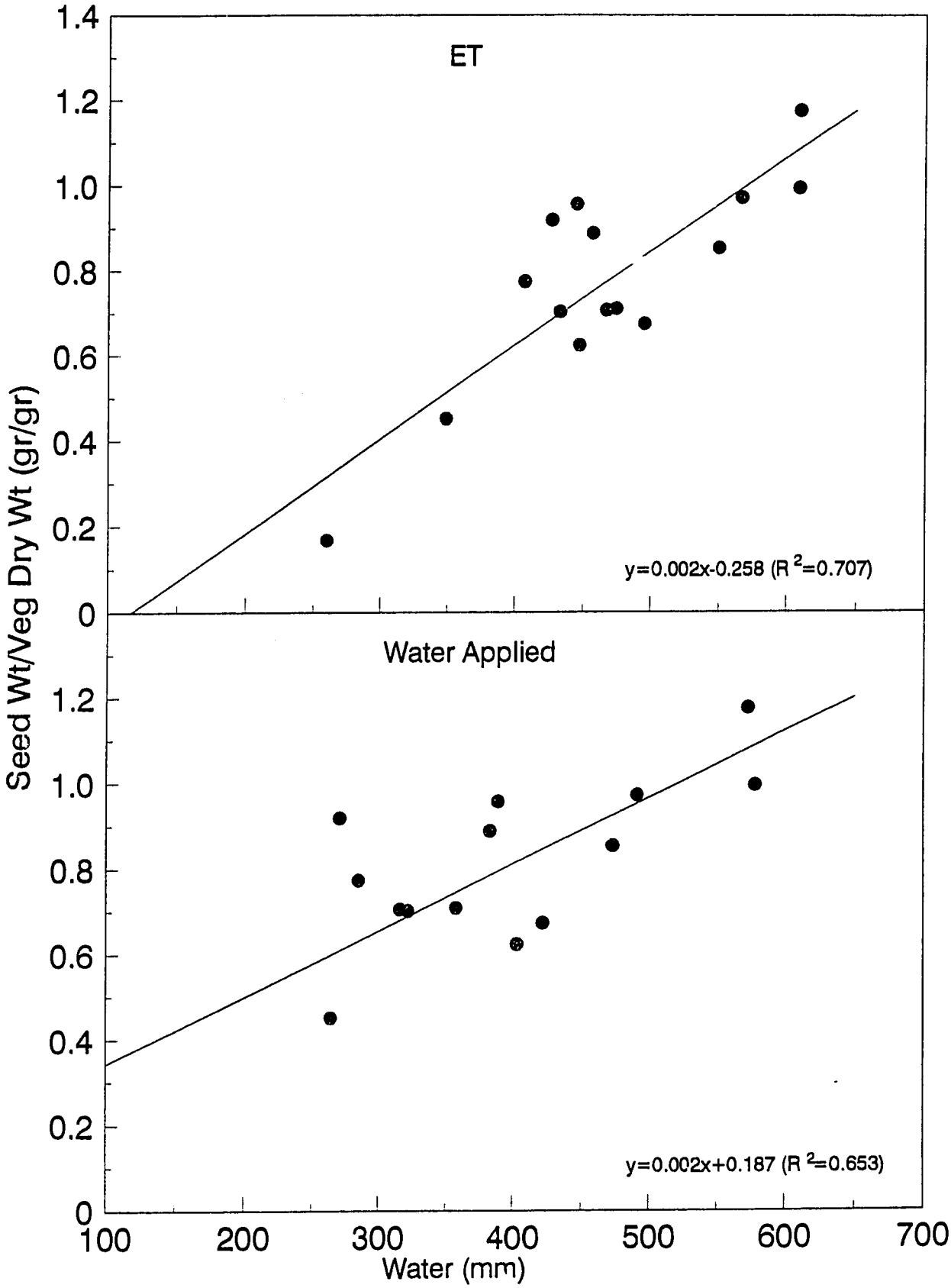


Fig 1.10: Dependence of Harvest index on ET and quantities of water applied.

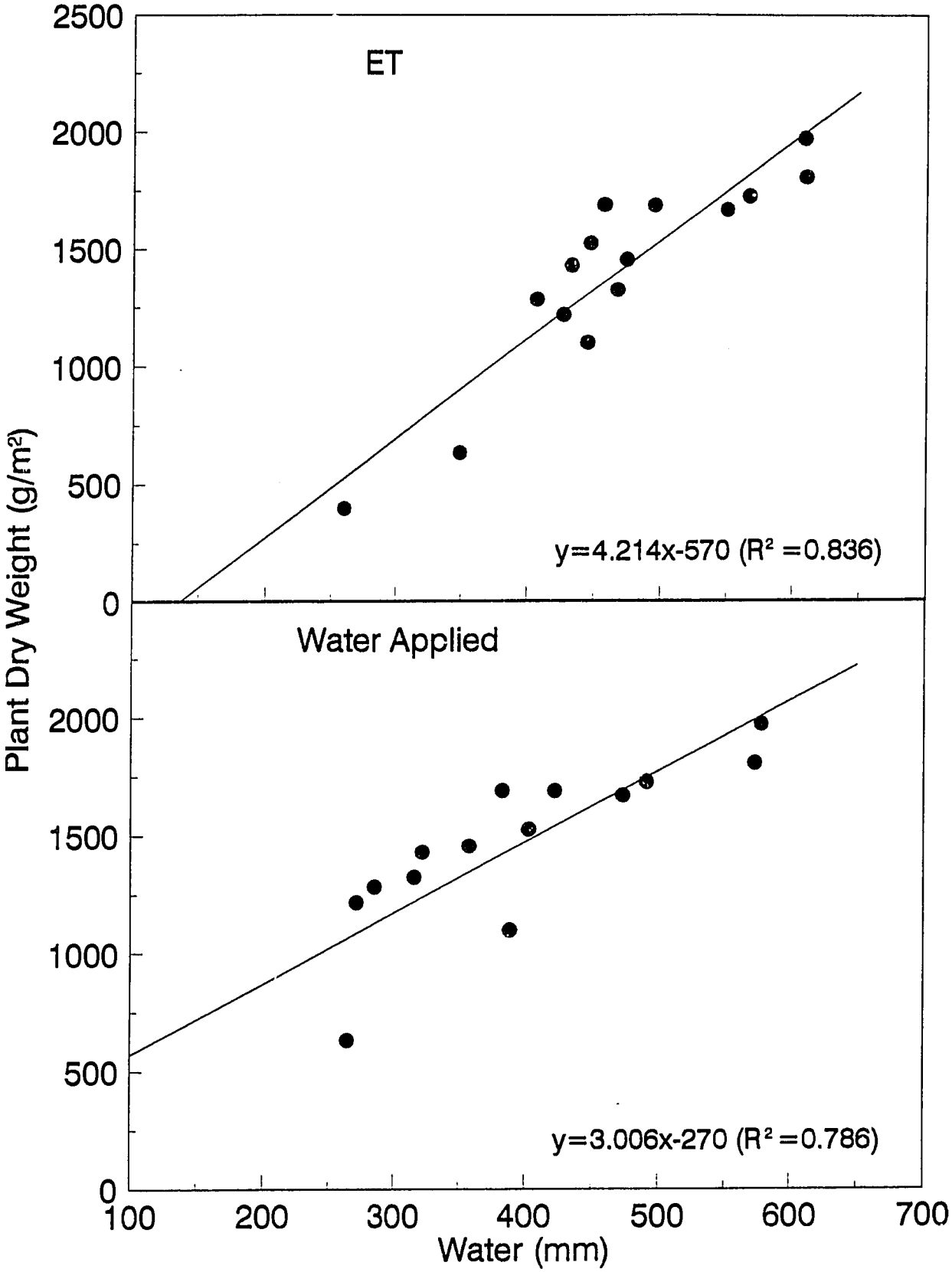


Fig 1.11: Dependence of average dry weight per plant on ET and quantity of water applied.

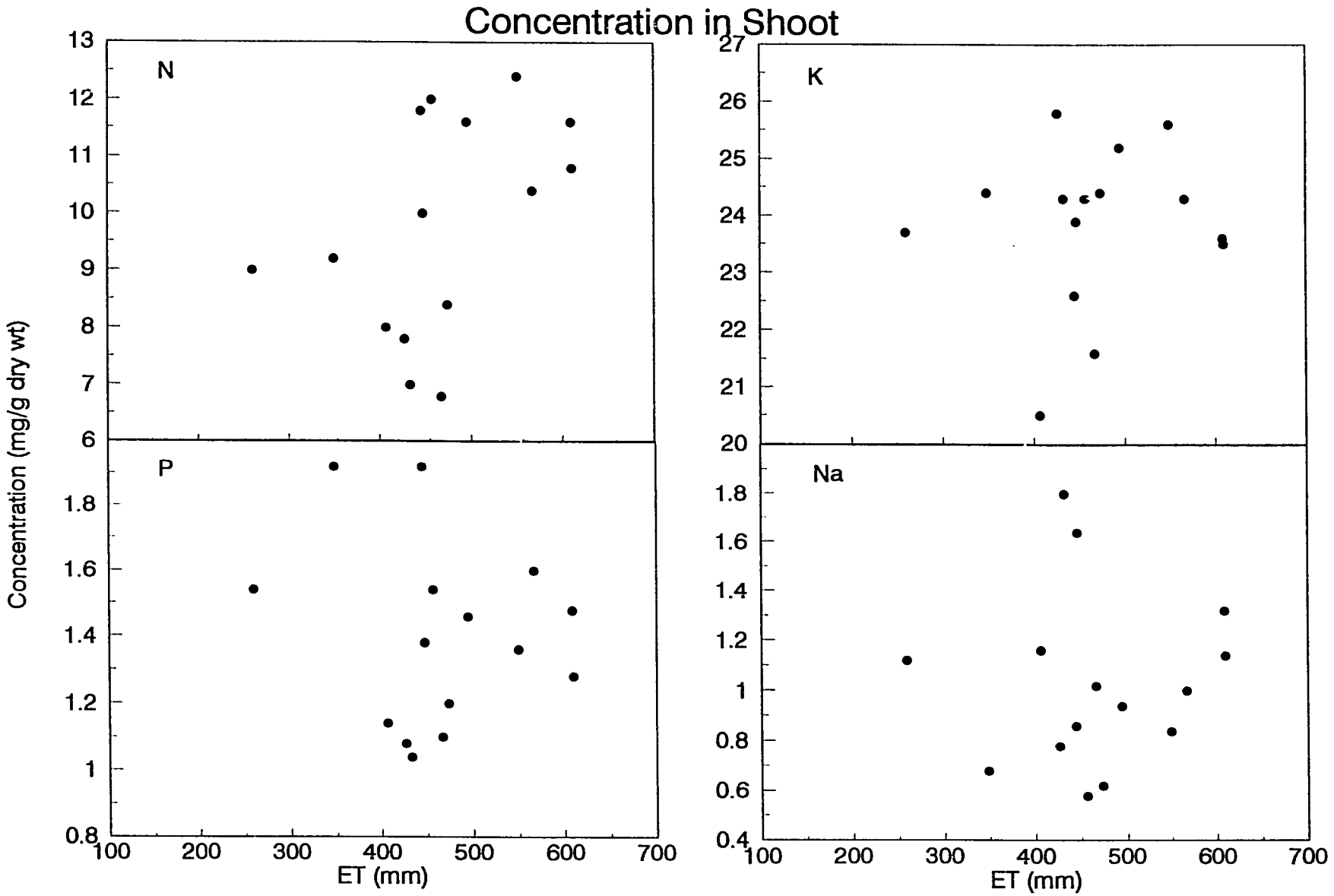


Fig 1.12: Concentration of 4 ions in plant shoot. Samplrs were taken shortly after silking.

2. PRODUCTION OF PROCESSING TOMATOES UNDER DRIP IRRIGATION USING TWO WATER QUALITIES AND RESTRICTED QUANTITIES

INTRODUCTION

In drip irrigation water is applied to the soil through emitters at a very low discharge rate as compared with surface irrigation and at a low pressure as compared with sprinkling. The main advantage of drip irrigation is the high degree of control of water application. An application efficiency of 90% can easily be achieved with drip irrigation, while the efficiency of sprinkling is 60-80% and of surface irrigation 40-50% (Wu and Gitlin, 1975). In row crops and orchards which are the crops irrigated by drip irrigation, only a fraction of the soil surface is usually wetted. Although part of the water migrates laterally below the soil surface, only part of the soil volume is wetted. Since this volume is mostly where the majority of the roots exist, drip irrigation will lead to significant savings in water with minimal reduction in yield.

The higher efficiency of water use by drip irrigation as compared with other irrigation systems was outlined for several crops. In cotton the yield of drip irrigated crops were found to be higher than sprinkler irrigated crops, provided the same amount of water was applied (Plaut, 1983). Drip was found as a preferred irrigation method for several vegetable crops (Phene & Beadle, 1976; Dasberg & Bresler, 1985) and for sugar-cane (Gillespie, 1980). In citrus, water could be saved with no yield reduction using drip irrigation (Bielorai, 1982). Similar results were obtained for grapevines, namely, similar yields with

drip as with sprinklers or flood irrigation, but a marked decrease in water use (Peacock, 1977). In apples, growth and yields were much better under drip than under sprinkler irrigation (Middleton, 1979).

An important advantage of drip irrigation is a decrease in the damage to crops when low-quality water is used. The better production under drip irrigation with brackish water was contributed to the avoidance of foliar absorption of salts, to a lower salt concentration in the soil solution as water is being applied at higher frequencies and to the leaching of salts out of the root zone (Dasberg & Bresler, 1985).

When the quantities of irrigation water are limited, for instance, when the only source of water is storage pools, drip irrigation is certainly the preferred irrigation system. An optimal irrigation management should be developed which will lead to the most efficient water use so that maximal production will be obtained with the limiting quantities of available water. Another aspect to be studied is the response of the drip irrigated crop to salinity. Low quality water is an important source of water in arid or semiarid regions. Storage of water in a pool for an extended period of time will lead to an increase of salt concentrations due to evaporation.

Tomatoes are an important crop both as a vegetable crop used for fresh fruit production and as a field crop used for processing. The latter was used in the present project in order to develop an optimal irrigation management with drip irrigation. the response of tomatoes to saline irrigation water was also determined in the same experiment.

MATERIALS AND METHODS

The experiment was conducted in the fields of Kibbtuz Nahal-Oz in the northern Negev. The soil is a loess-type loam (Calcic Haploxeralf) and has been in use for intensive irrigated agricultural production for over 30 years. Some of the physical and chemical properties of the soil are presented in Table 2.1. The soil is slightly basic and has a low hydraulic conductivity, considering the high sand content. The previous crop was cotton which was grown on this field for 4 consecutive years. The field was prepared for, planting during the fall of 1989 by plowing, smoothing and adding 30 m^3/ha manure, and 400 kg/ha superphosphate. Tomato (Lycopersicum esculentum) C. Peto 81 was grown on double-hedged rows at a distance of 40 cm between individual rows. One pair of double hedged rows was arranged for each 1.92 cm-wide bed. Seedlings were planted at mean distances of 33 cm along the row on March 25, 1990. Water was applied twice on March 25 and on March 30 (15 mm at each application) to ensure full establishment of the field. There was rain of approximately 40 mm on April 1 and an additional preliminary irrigation of 30 mm on April 23. All preliminary irrigations were given by sprinkling. The irrigation water was from the National Carrier at an EC of 0.8-1.0 $dS.m^{-1}$.

The crop was fully established during the last week of April and flowering started on April 25. Differential treatments were given by drip irrigation starting on April 30. One drip lateral (Netafim) was placed at the center of each double-hedged row. The distance between drippers along the lateral was 1 m. The first application by drippers, of 40 mm, was identical for all

treatments and in order to obtain full overlapping of wetting fronts. Differential treatments started on May 6 and are outlined in Table 2.3. A control treatment was included in the experimental design, which was irrigated according to a crop irrigation coefficient which varied between 0.6 and 0.9 of Class A pan evaporation. It was 0.6 during the second week of May, and increased gradually reaching 0.9 at the first week of June. The coefficient was 0.85-0.9 until the third week of June and then gradually decreased to 0.5 at the end of the irrigation season (Table 2.2).

A detailed outline of the experimental design is outlined in Table 2.3. Treatment 5 represents the control treatment in which the relative crop was defined as 1.00. In the first 4 treatments the factor was less than 1.00 and in treatments 6-7 the factor was above 1.00. Treatments 8-10 were irrigated according to the same irrigation coefficient as the control but no water was applied during various parts of the irrigation season. In Treatment 8 irrigation water was withheld during vegetative development (early). In Treatment 9 during flowering and beginning of fruit expansion (medium) and in Treatment 10 during ripening (late). This resulted in reduced quantities of seasonal irrigation water. Irrigation continued until July 8, excluding Treatment 11 in which irrigation was extended until July 21. Total quantities of water applied in the various treatments was between 200 and 550 mm including the preliminary water applications.

Another set of treatments was conducted on the same field using saline irrigation water, with an EC of 4.8-52 $dS.m^{-1}$ and

SAR of 23-27. Seven of these treatments were conducted using different quantities of saline water for tomato irrigation. Six out of them were equivalent to Treatment 1 through 6 of Table 2.3, namely, applying water at relative crop coefficients between 0.25 and 1.15. The seventh treatment was equivalent to Treatment 11 of Table 2.3, namely a delay in the termination of water application. The total amounts of saline water used was similar to the amount of good quality water at each irrigation coefficient.

Plant samples from an area of 1.0 m^2 were taken at approximately 10 day intervals throughout the experimental period. Fresh and dry weight of the vegetative organs (excluding roots) and of fruits were taken at 8-10 day intervals for the determination of fresh and dry weight and for chemical analysis of their constituents.

Since the treatments influenced the rate of plant development, fruit formation and ripening, three harvests had to be conducted, each for different treatment. At the first harvest (July 11, 1990) treatment which were irrigated according to a relative coefficient of 0.25 and 0.45 (non-saline and saline water) were harvested. At the second harvest (July 23) treatments which were irrigated at a coefficient of 0.65, 0.85, 1.00 (saline and non-saline and Treatment 8, 9 & 10 were harvested. At the third harvest (July 30), the rest of the treatment, namely, those irrigated at a coefficient of. 1.15, 1.30 and Treatment 11 were harvested.

RESULTS AND DISCUSSION

The entire soil profile down to a depth of 120 cm (and even deeper) was fully-charged with water at the beginning of the season (Fig. 2.1). In fact, soil water content in the treatment irrigated at a crop coefficient of 0.25 was even slightly higher than those irrigated at higher coefficients. As may be expected, nearly the entire available water was depleted from the measured profile at the end of the season, approaching wilting percentage, which was 12-14%. It should be noted that even in the control treatment, irrigated at a relative crop coefficient of 1.00, water was fully depleted only from the top layer of 30 cm. In the wettest treatment, irrigated at a relative coefficient of 1.30, substantial quantities of water were left in the soil profile at the end of the season.

During the initial 45 days after planting, soil moisture was retained nearly at its initial level even in the driest treatment (coefficient = 0.25) (Fig. 2.2). This can be attributed to the small water requirement during the initial growing stage.

Thereafter, the differences between treatments became very significant and soil moisture was maintained near its initial content for an additional 60, 30 and 0 days in the wettest, intermediate and dry treatments, respectively. The use of saline irrigation water decreased the depletion of soil water in each of the treatments maintaining a higher soil moisture content for a more extended period.

The EC profile in the soil (Fig. 2.3) can serve as a tool to determine relative water utilization from the profile. Most of the soil water was withdrawn from a depth of 0-40 cm as EC was

significantly higher than in the deeper layers. Accumulation of salts in the vicinity of the dripper (sampled at 20 cm from dripper) was probably because substantial quantities of salts were pushed to the wetting front. In the top 70 cm, no difference in soil EC between the plots irrigated with saline and nonsaline water was found at the time of planting. Leaching was, however, not sufficient to remove the salts of previous season from the deeper soil layers. The distribution of Cl in the soil profile (Fig. 2.4) is very similar to that of EC, as most of the salts were chlorides. The concentration of sodium in the soil profile at the time of planting increased gradually with depth, unlike Cl which was leached out of the top three layers (Fig. 2.5). At harvest, the distribution of both ions became much more similar, although the concentration of Na was nearly 70% of that of Cl. The soil SAR at the time of planting indicates the residue of ions in the soil of presalinized plots (Fig. 2.6). The SAR rose significantly in those plots throughout the irrigation season reaching the values of the saline irrigation water.

Yield response curves of tomatoes for water show that maximum fresh fruits was obtained when approximately 470 mm of nonsaline water was applied (Fig. 2.7). Larger amounts of water did not increase fresh fruit yield. However, since the residual water at the end of the season was less than the storage at planting (Fig. 2.1), and no water was lost by deep percolation, the true consumption was higher than this figure. The yield response curve for saline water was very similar to that of nonsaline water, but it was significantly lower at intermediate

water quantities. There was a clear response curve of the number of harvested fruits to water with no difference between the two water qualities (Fig. 2.7). The increase in the number of harvested fruits between the lowest and highest amounts of water was by 72% and 47%, respectively, for nonsaline and saline water, indicating a better response to good water quality. The size of individual fruits determined by weight of single fruits was also increased by increasing quantities of irrigation water (Fig. 2.8A). The increase in size was also more marked with nonsaline water than with saline water. However, the effect of water quantities on fruit number was larger than its effect on fruit size at both water qualities (compare Fig. 2.7 and 2.8).

The increase in the quantities of applied water according to different crop coefficients delayed fruit ripening. As outlined in Materials and Methods, most of the treatments irrigated with both water qualities were harvested on July 23 (after 120 days of growth). The two driest treatments had to be harvested 12 days earlier and the two wettest treatments 7 days later. In spite of this the percentage of pink fruit was higher in the wet treatments (Fig. 2.8 B). The percentage of high-quality red fruits was 78-85% in the various treatments excluding the two wettest treatment in which it was 65-70% only.

The response of tomatoes to the second approach for reducing the quantities of irrigation water by withholding irrigations during various growth stages is shown in Fig. 2.9. Withholding irrigation during the vegetative stage or during flowering (early and medium) resulted in similar yield as under full irrigation. Withdrawal of irrigation during ripening (late) even increased

the yield which was similar to a delayed termination of the irrigation season. The effect of reducing the quantities of water applied on fresh fruit and on TSS yields are outlined in Table 2.4. It can be seen that when irrigation was withheld during flowering, fruit yield was increased by 10% and TSS yield by 20%. The use of water was thus much more efficient. The same phenomenon was obtained when larger quantities of water were applied, for instance, when Treatments 10 and 4 are compared. An increase of 20% in fruit and in TSS yield were obtained when water was withheld during part of the season. This management seems therefore to be much more efficient in water use, as compared with the control (Treatment 5).

The effect of irrigation withholding in contrast to a uniform decrease in water quantities was not by affecting fruit number (compare Fig. 2.9 with 2.8). Average fruit weight was not related to the quantities of water applied but to the timing of irrigation withholding (Fig. 2.10). Withholding of irrigation during fruit expansion reduced average fruit weight very significantly, while withholding during ripening had no effect on fruit size.

Delayed termination of the irrigation season caused a delay in ripening and although harvest was 7 days later, only 65% of the fruits were fully ripe as compared with 80% in the non-delayed termination.

An important parameter of processing tomatoes quality is the concentration of total soluble solids (TSS) in the fruit. An increase in water applied or in water consumed by evapotranspiration reduced the content of TSS in the fruit (Fig.

2.11) TSS was close to 7% of the juice when approximately 200 mm of water were applied and was only 5.4% when 550 mm were applied. The calculated TSS yield (TSS per unit area) was, however, increased by approximately 65% when the amount of water was raised from 200 to 500 mm (Table 2.4). This was due to its more intensive effect on fruit yield than on TSS concentration. The effect of water quantities on TSS was similar for nonsaline and for saline water, but TSS content in saline water irrigated plants was 1.2-1.3% higher.

Another parameter, developed in the present study for the evaluation of fruit quality was fruit specific weight. Data of fruit weight was available, and fruit volume was determined by water displacement when fruits were put into water. Fruit volume was then correlated with fruit diameter which could more easily be measured (Fig. 2.12). Although the diameter of nonsaline grown fruits was larger than that of saline grown fruits, the relation between diameter and volume was very similar, so that this regression could be used to determine average fruit volume.

The ratio of fruit volume to weight was not 1:1 through the entire range of water applied when measured on 200 fruits of various treatments (Fig. 2.13A). The specific weight of fruits was significantly higher when irrigated with saline water (Fig. 2.13B). Specific fruit weight was also increased in the driest treatment at both salinity levels.

Table 2.5 presents properties of fruit juice. The properties which were determined were TSS, pH, EC, osmotic potential K^+ and Na^+ content. Young fruits were tagged after anthesis to determine the time of their development. Juice

properties were then determined for ripe fruits which developed during different parts of the season. This was conducted on the driest treatment and on the control (Treatments 1 & 5 of Table 2.3). The most marked difference between treatments was in TSS osmotic potential and Na^+ content.

The effect of the irrigation regimes on dry weight formation by tomato plants and its allocation in the fruit was determined by measuring dry weight accumulation throughout the season. During flowering and at the beginning of fruit expansion, the highest rate of dry weight accumulation in fruits was in the dry treatment, indicating the high activity of the fruit sink (Fig. 2.14). However, water stress which developed with time reduced this ability and the rate of dry weight accumulation was severely reduced. In plants irrigated with saline water the rate of dry weight accumulation in fruits was proportional to the quantities of water applied throughout the season. Accumulation of dry weight in vegetative organs was also affected by the quantities of water applied, but only during the last 30 days of the experiment (Fig. 2.15).

Vegetative dry weight formation by the tomato plant was proportional to the quantities of water applied, in both saline and nonsaline water (Fig. 2.16). In order to evaluate the relative sensitivity of vegetative organs and of fruit to salinity and to the quantities of water applied, an apparent harvest index was calculated. The yield of fresh fruit, of TSS and of total dry matter per unit vegetative dry weight was calculated (Table 2.6). Harvest index for fresh fruit was not

affected by the quantity of water applied while TSS yield and fruit dry weight were slightly increased.

In most cases the apparent harvest index was higher with saline water than with nonsaline water, indicating that vegetative growth was more sensitive to salinity.

Stomatal resistance determined at the peak of vegetative development was with nearly the same among most treatments (Fig. 2.17). Only in the driest treatment which was irrigated at a crop irrigation coefficient a significant increase in stomatal resistance was observed.

Table 2.1 Chemical and physical properties of the loess-type soil at Nahal-Oz and chemical analysis of the national carrier used for irrigation

Soil:	Mechanical Composition			CEC	pH	EC	$CaCO_3$	Field capacity	Hydraulic conductivity
	Sand %	Silt %	Clay %	(meq/100gr)		dS/m^{-1}	%	(% by volume)	($mm.hr^{-1}$)
	53.3	25.7	15.0	16.0	8.4	0.8	13.4	27-29	7.5
Water:	Ion concentration (meq/lit)						EC		SAR
	Cl^-	CO_3^-	HCO_3^-	$Ca^{++}+Mg^{++}$	Na^+		dS/m^{-1}		
	6.7	-	-	5.4	4.1		0.95		2.5

Table 2.2 Class A pan evaporation and amount of water applied in the control treatment (crop factor = 1.00) 6/5 - 8/7

Date	Daily pan evaporation rate (mm)	Daily water applied (mm)	Date	Daily pan evaporation rate (mm)	Daily water applied (mm)
6/5-12/5	6.0	3.6	10/6-16/6	6.9	5.9
13/5-19/5	6.0	4.2	17/6-23/6	7.4	6.3
20/5-26/5	5.8	4.8	24/6-30/6	7.2	4.3
27/5-2/6	7.1	6.0	1/7-8/7	7.3	3.7
3/6-9/6	6.9	6.2	8/7-19/7	7.4	3.7
			15/7-21/7	7.3	3.7

Table 2.3 Irrigation of processing tomatoes Nahal-Oz 1990. Design of experiment and quantities of water applied

Treatment number	Relative crop irrigation coefficient	Irrigation withhold or extended	Water applied (mm)
Nonsaline			
1	0.25	-	202
2	0.45	-	243
3	0.65	-	312
4	0.85	-	386
5	1.00	-	415
6	1.15	-	498
7	1.30	-	548
8	1.00	6/5 - 2/6	308
9	1.00	2/6 - 17/6	311
10	1.00	17/6 - 1/7	381
11	1.00	Delayed 21/7	476
Saline			
12	0.25		186
13	0.45		244
14	0.65		311
15	0.85		396
16	1.00		422
17	1.15		480
18	1.00	Delayed	470

Table 2.4 Yield of fresh tomato fruits and of total soluble solutes (TSS) in the juice as affected by reducing the quantities of irrigation water. The supply was reduced either by withholding irrigations at specific developmental stages or by a uniform reduction in water supply throughout the season according to different crop irrigation coefficients

Treatment number	Total water applied (mm)	Stages of irrigation withdrawal	Relative crop coefficient	Fresh fruit yield (kg/m^2)	TSS yield (g/m^2)	Yield per unit water (kg/mm) Fruit	TSS
8	310 ± 2	Vegetative &	1.00	10.8	533	35.1	1.73
9		fruit expans.	1.00	10.9	643	35.1	2.07
3		No withholding	0.65	9.9	538	31.7	1.72
10	384 (±3)	Ripening	1.00	12.2	666	31.9	1.75
4		No withholding	0.85	9.9	555	25.7	1.44
5	415	No withholding	1.00	12.8	574	26.9	1.38
6	498	No withholding	1.15	13.2	660	26.5	1.33

Table 2.5 Properties of tomato fruit juice

Parameter	Treat-ment	Days from beginning of flowering						
		22	26	31	36	45	56	63
TSS	Dry	6.5	6.5	6.5	6.5		6.5	8
	Wet		4.5	4.1	4	4.5	5	
pH	Dry	4.7	4.57	4.62	4.60		4.75	4.15
	Wet		4.77	4.46	4.46	4.46	4.57	
EC	Dry	3.5	4.3	4.5	4.5		4.5	4.5
	Wet		4.5	4.3	4.2	4.0	4.3	
Osmotic potential	Dry	4.8	3.4	5.2	5.4		9.4	11.6
	Wet		3.6	3.5	2.2	2.7	2.5	
K^+ content meq.lit^{-1}	Dry	83	86	86	82		83	90
	Wet		83	76	73	71	78	
Na^+ content meq.lit^{-1}	Dry	6.5	5.0	6.0	6.5		4.5	9
	Wet		2.7	3.1	3.0	3.6	3.4	

Table 2.6 Apparent harvest index of tomato fruits calculated as fresh fruit yield, TSS yield and fruit dry weight yield per unit of vegetative yield

Relative crop coefficient	Water applied (mm)	Apparent harvest indices (gr/gr.veg.dry wt.)		
		Fruit yield	TSS yield	Fruit dry weight
Nonsaline				
0.25	202	17.8	0.78	1.25
0.45	243	18.2	0.80	
0.65	312	16.8	0.83	
0.85	386	18.1	0.98	
1.00	415	18.0	0.95	1.40
1.15	490	17.4	0.91	1.78
1.30	548	17.6	1.06	
Saline				
0.25	186	15.5	0.83	1.38
0.45	244	19.5	1.17	
0.65	311	19.2	1.01	
0.85	396	18.2	1.00	
1.00	422	15.6	0.97	1.70
1.15	480	15.7	1.19	1.75

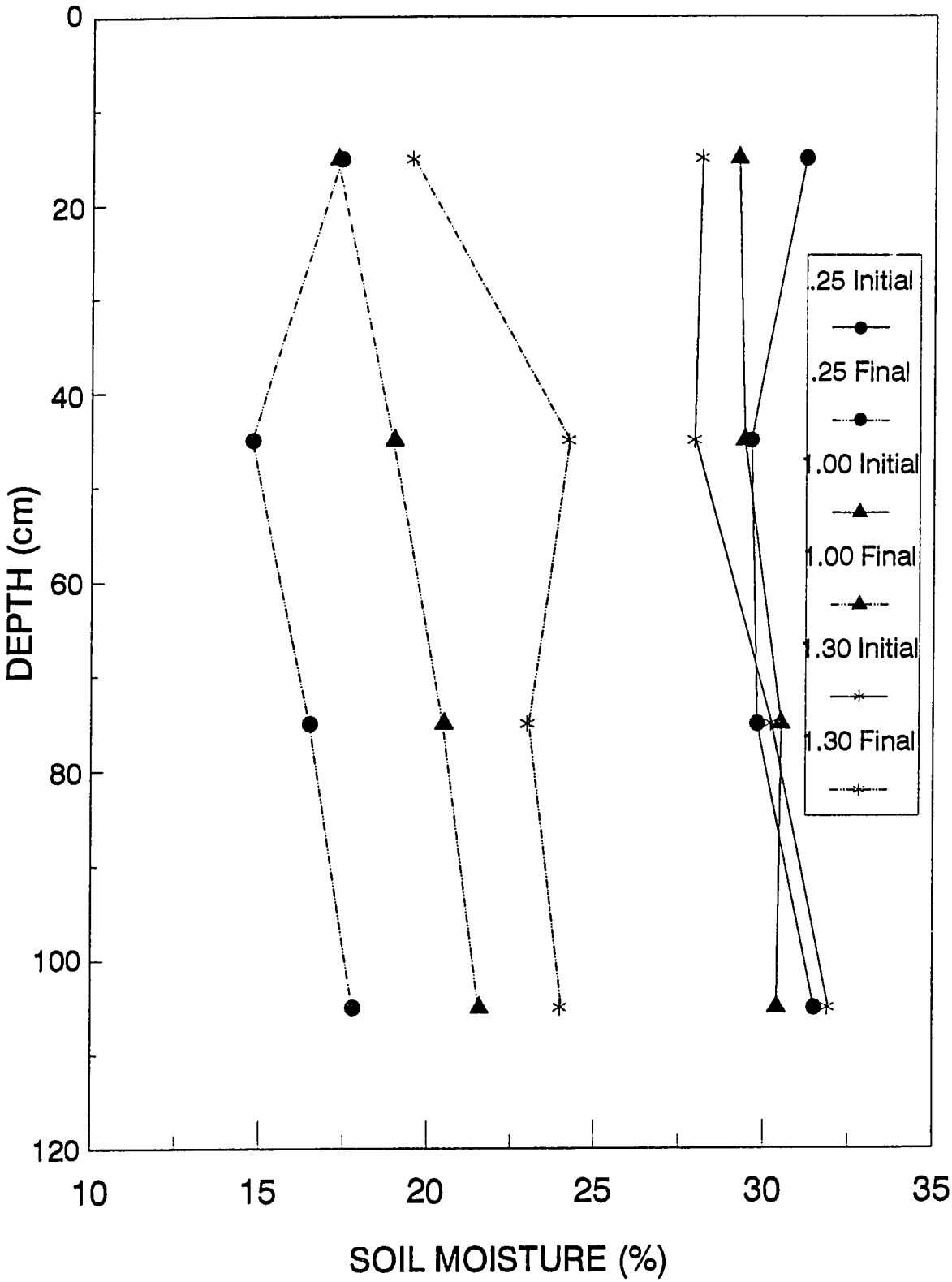


Fig 2.1: Profile of soil moisture (by volume) at three relative crop coefficient using non-saline water at initial and final stages of the season.

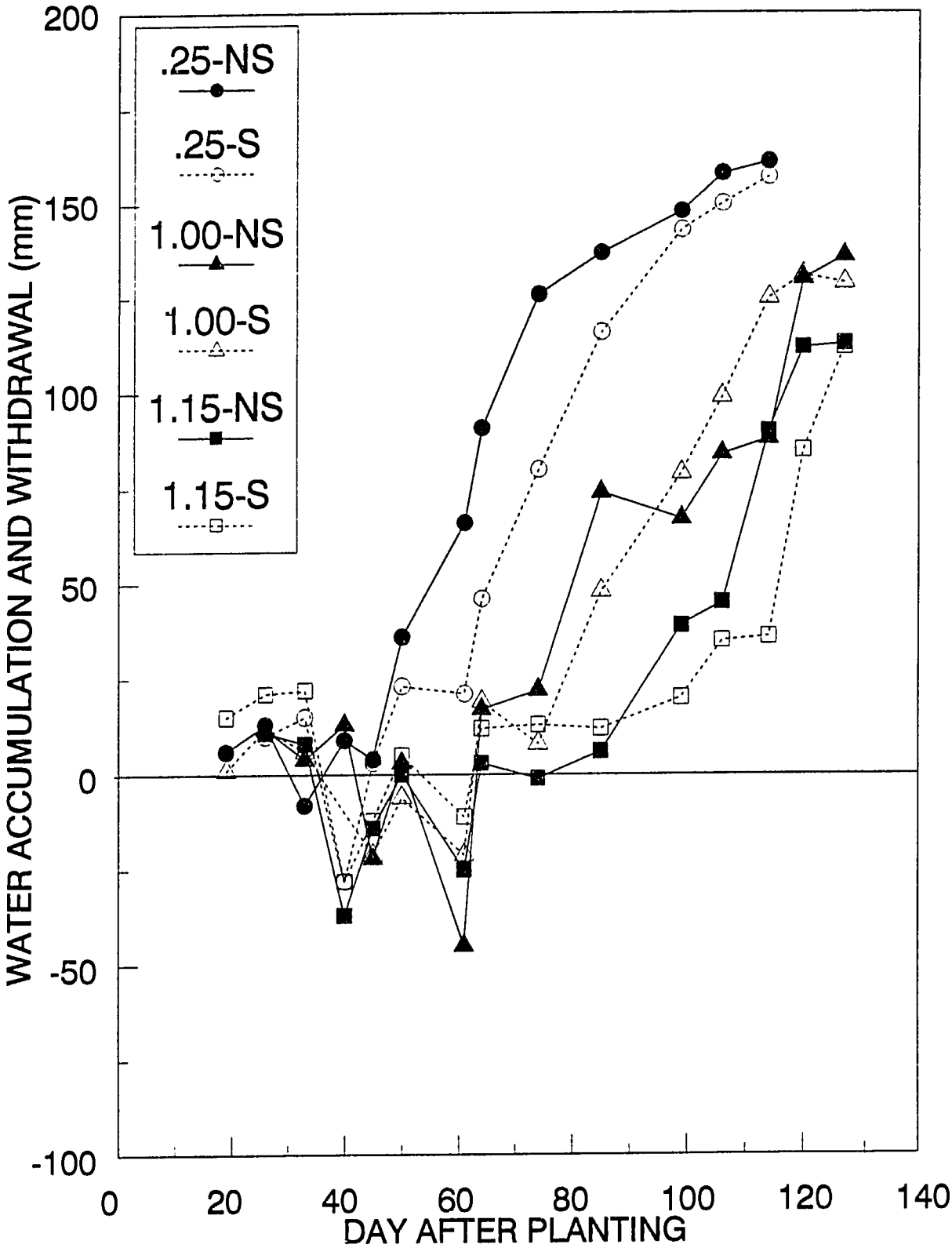


Fig 2.2: Fluctuation in moisture content of the soil profile with time. Positive = withdrawal. Negative = accumulation.

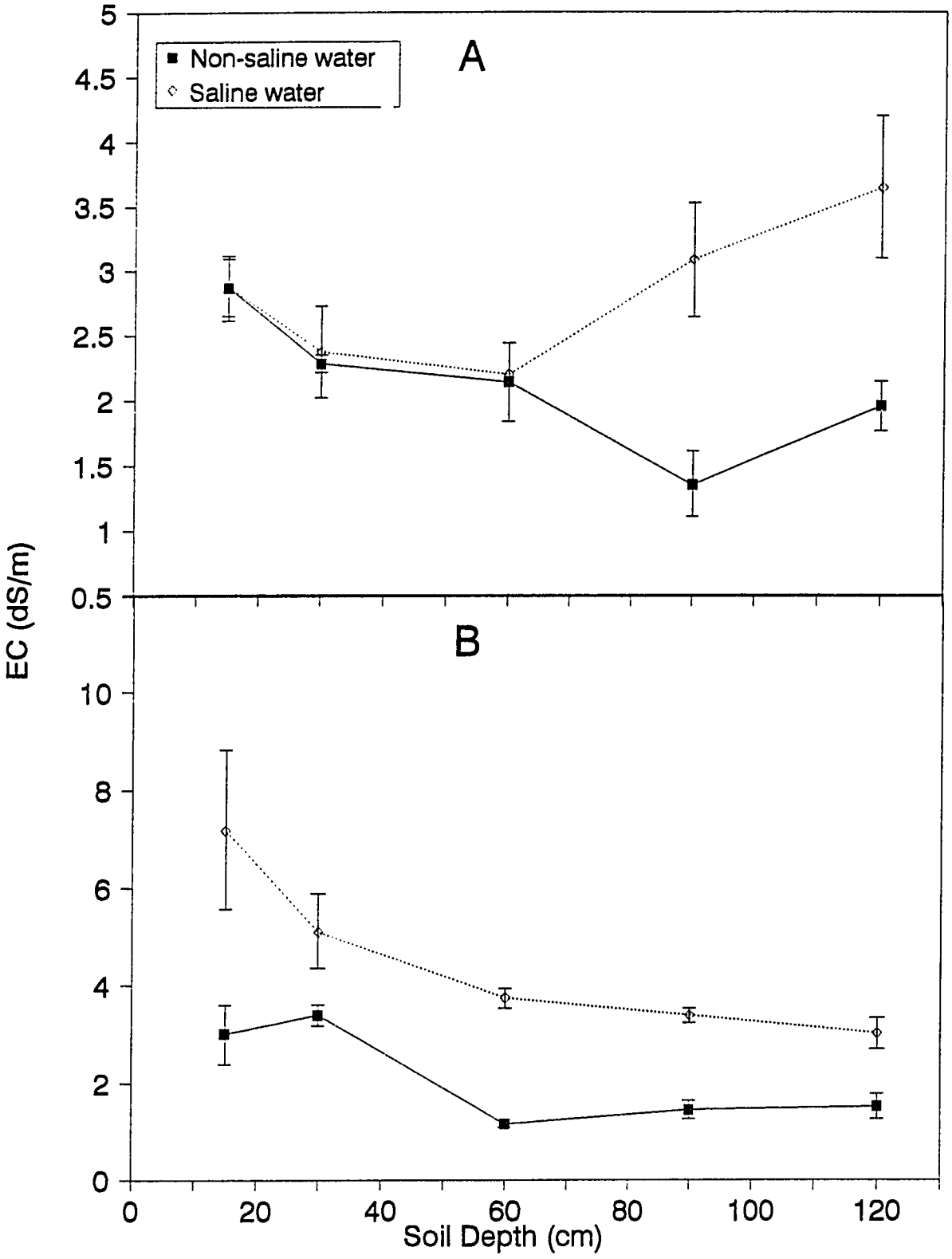


Fig 2.3: EC in soil profile at planting (A) and at harvest (B).
EC was determined in saturated soil extract.
The 5 points represent 0-20,20-40,40-70,70-100 and 100-130 cm.

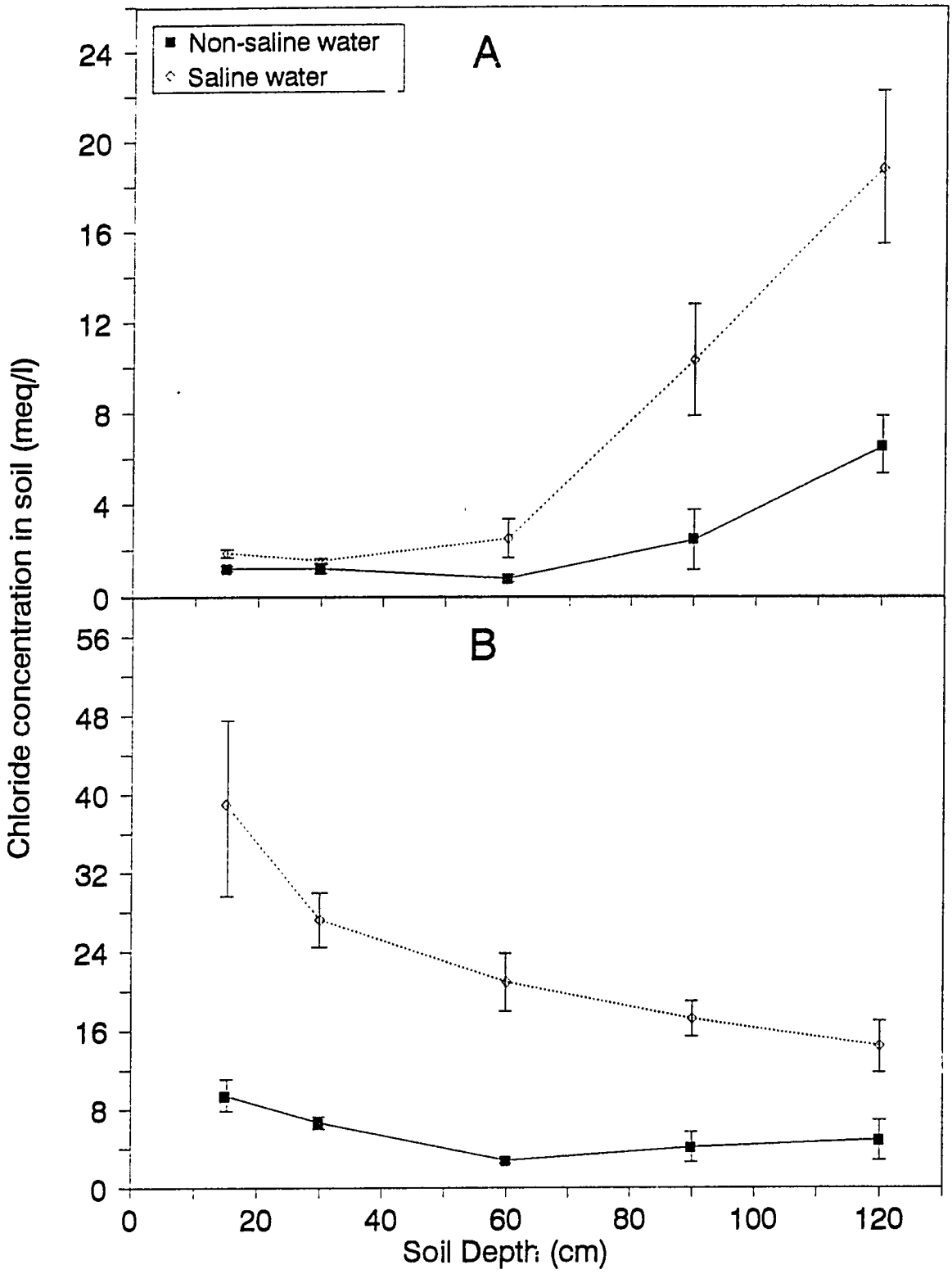


Fig 2.4: Chloride concentration in soil profile at planting (A) and at harvest (B).
Details as in Fig. 2.3.

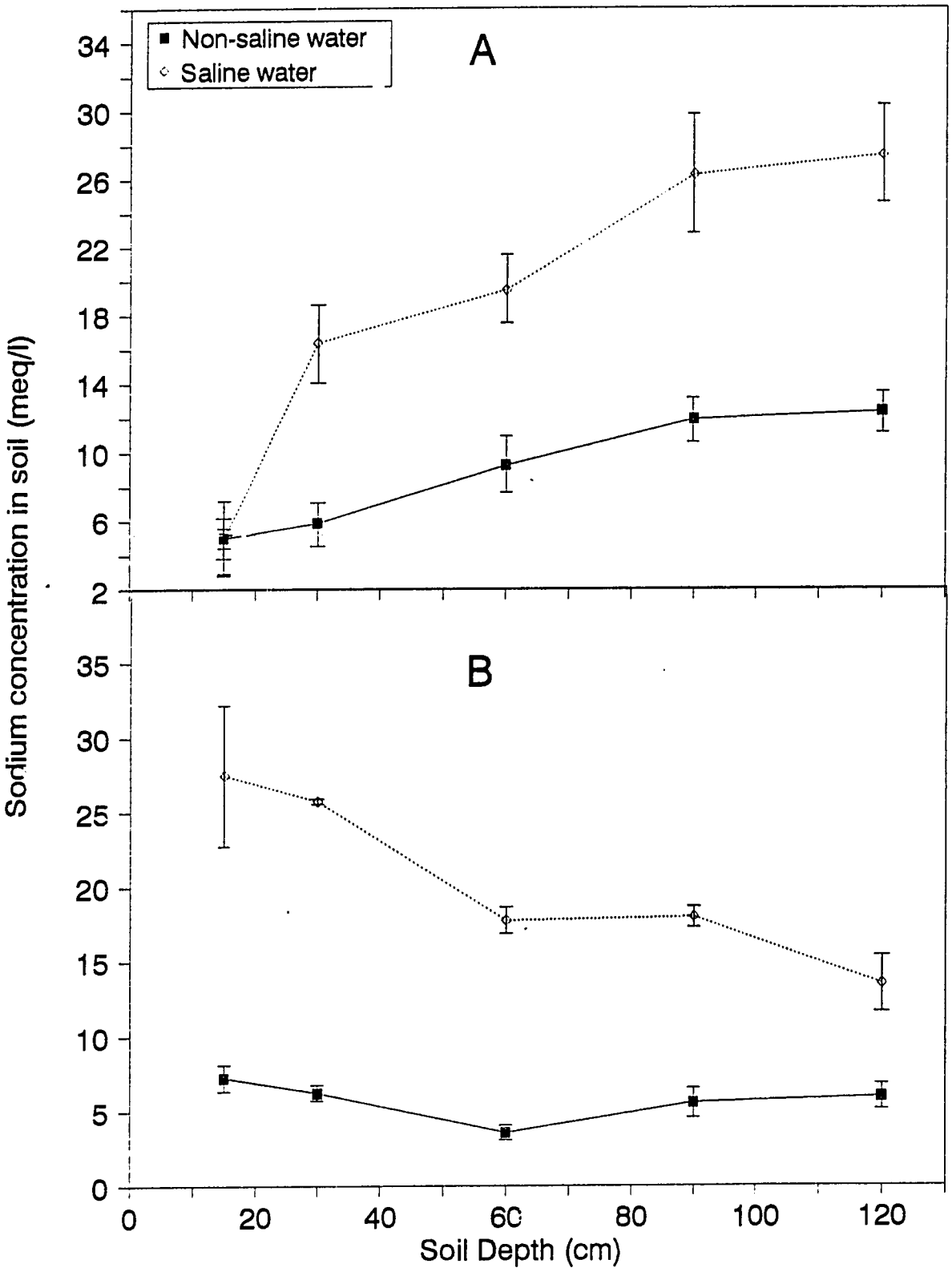


Fig 2.5: Sodium concentration in soil profile at planting (A) and at harvest (B).
Details as in Fig. 2.3.

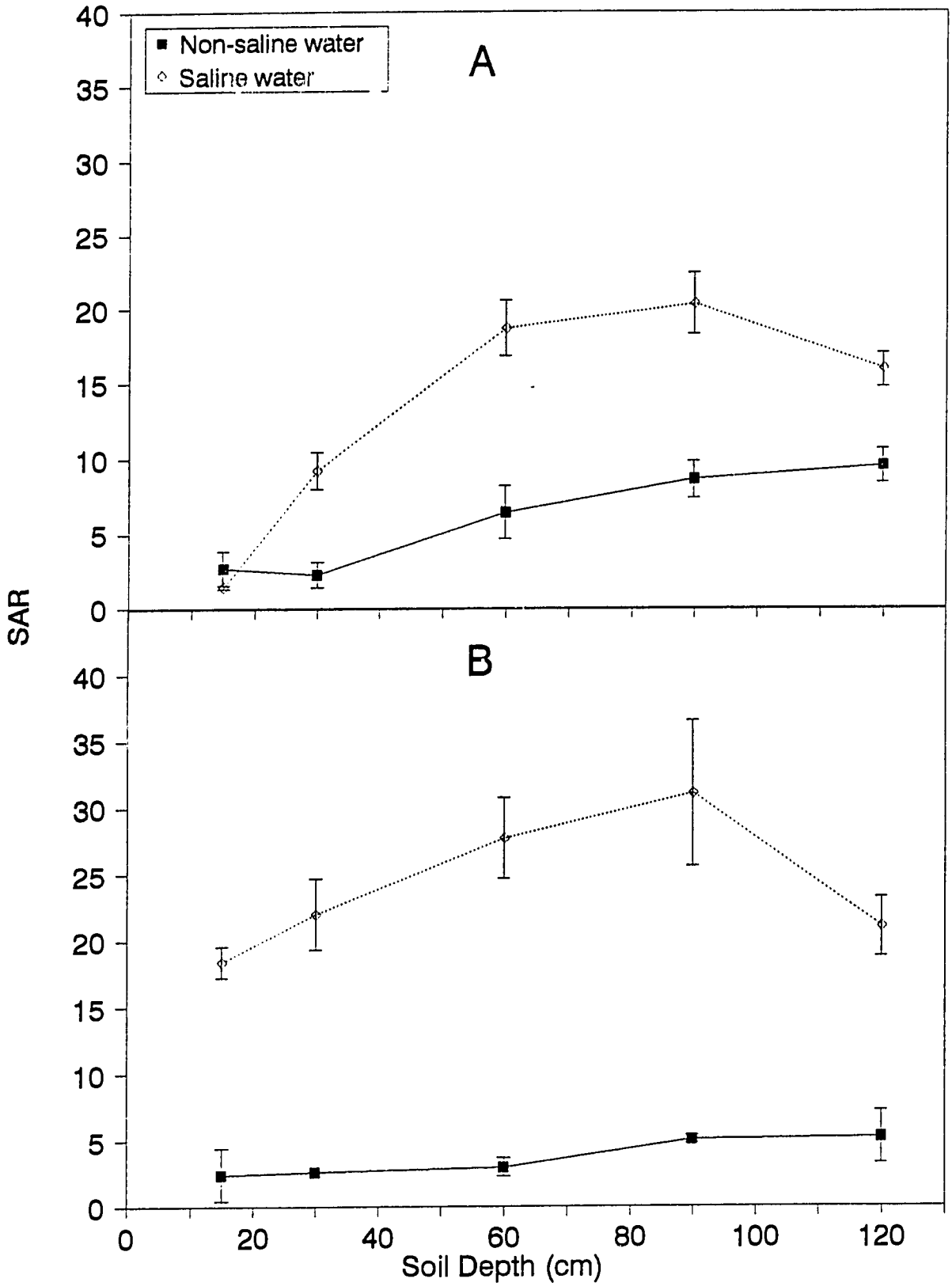


Fig 2.6: SAR in soil profile at planting (A) and at harvest (B). Details as in Fig. 2.3.

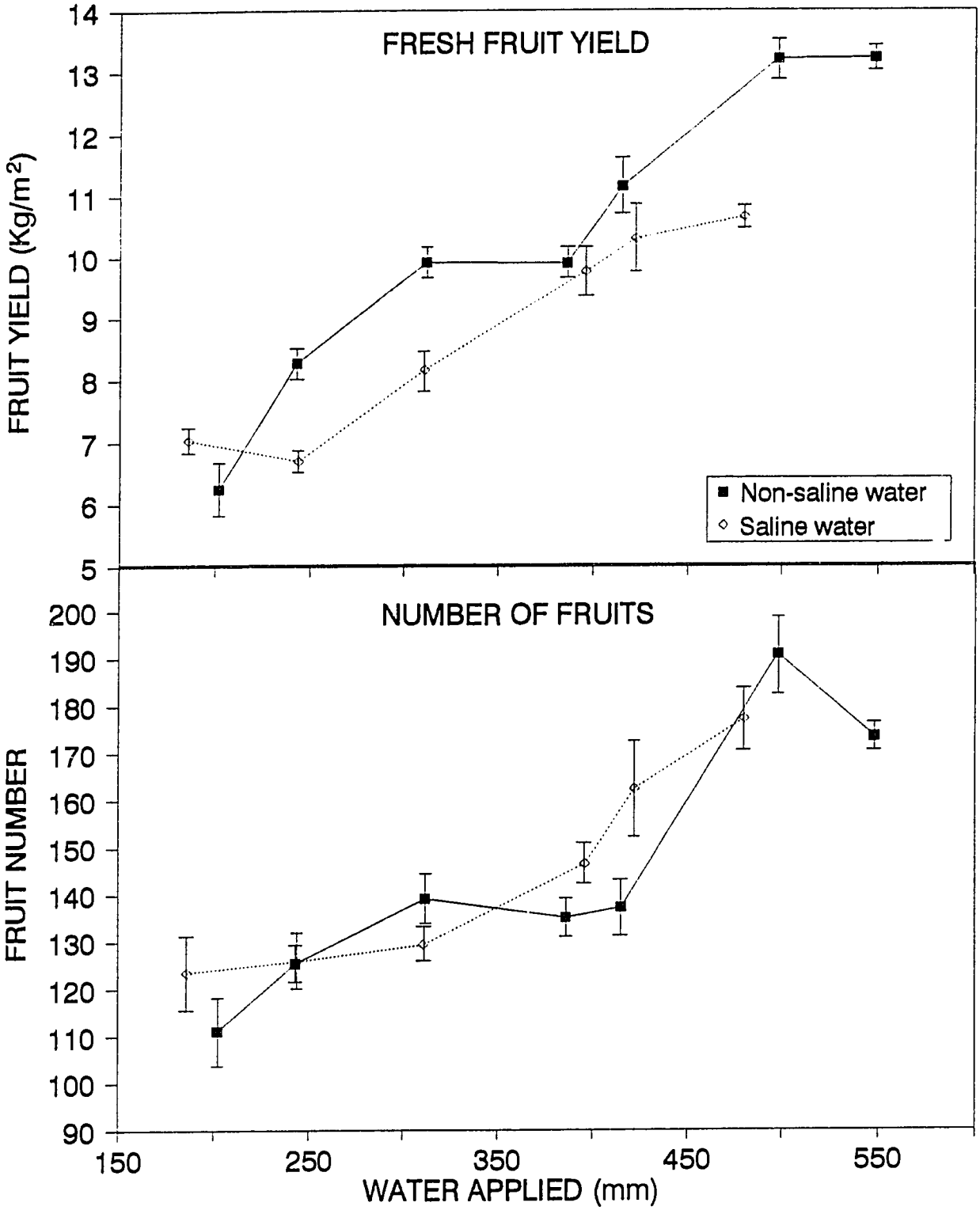
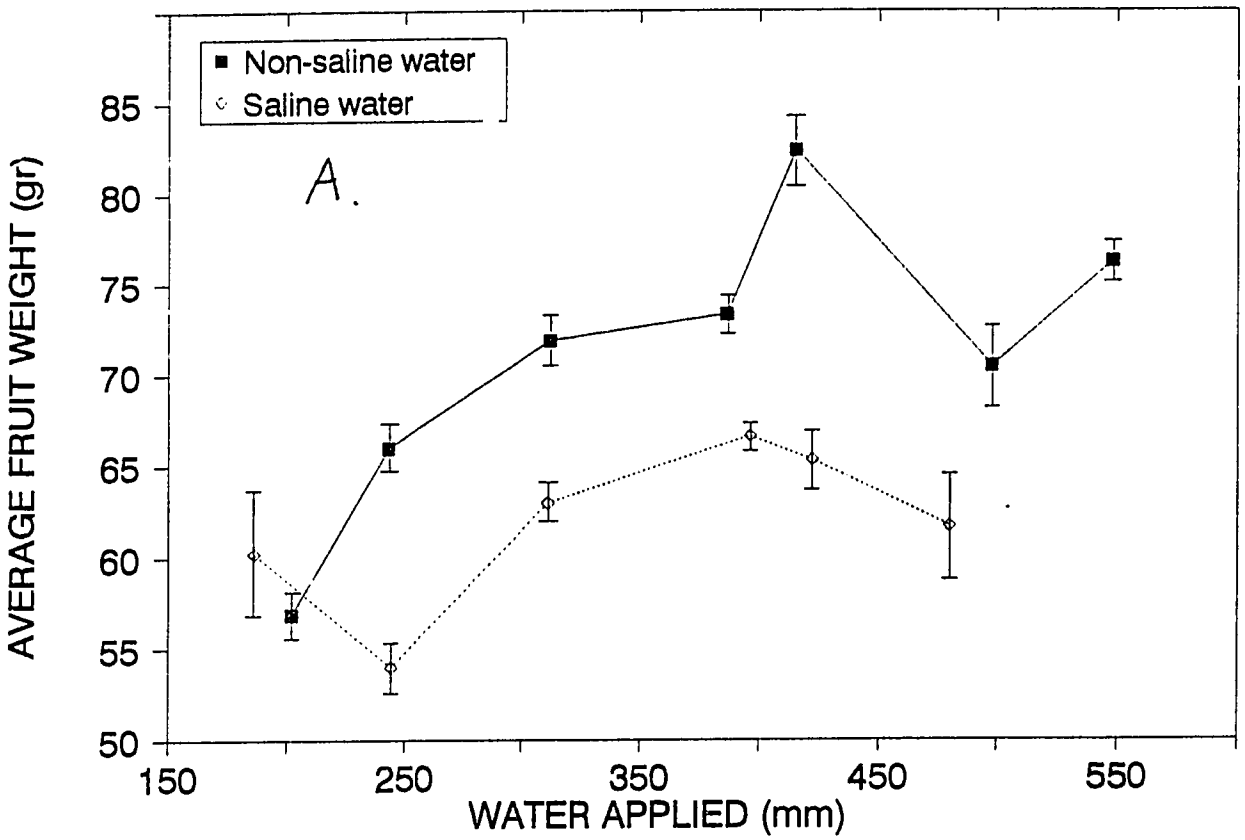


Fig 2.7: Effect of quantities of applied irrigation water on fresh tomato fruit yield and on number of fruits.



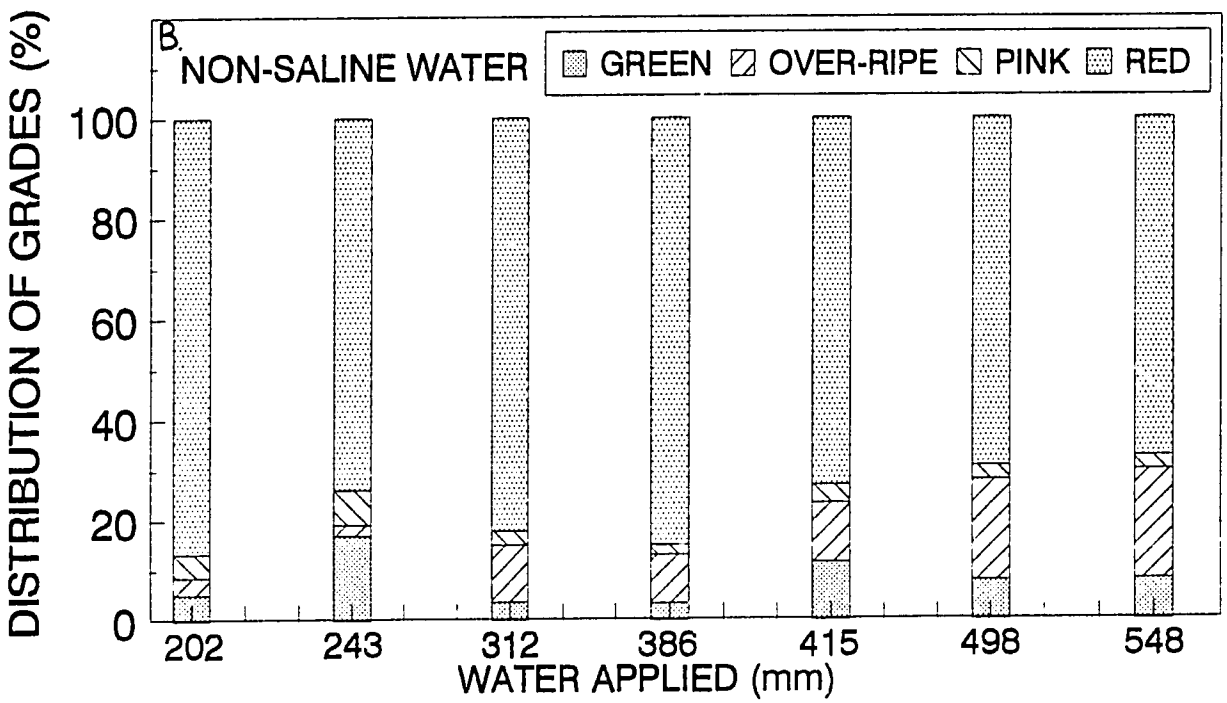


Fig 2.8:Effect of quantities of applied irrigation water on average fruit weight and on fruit ripening.

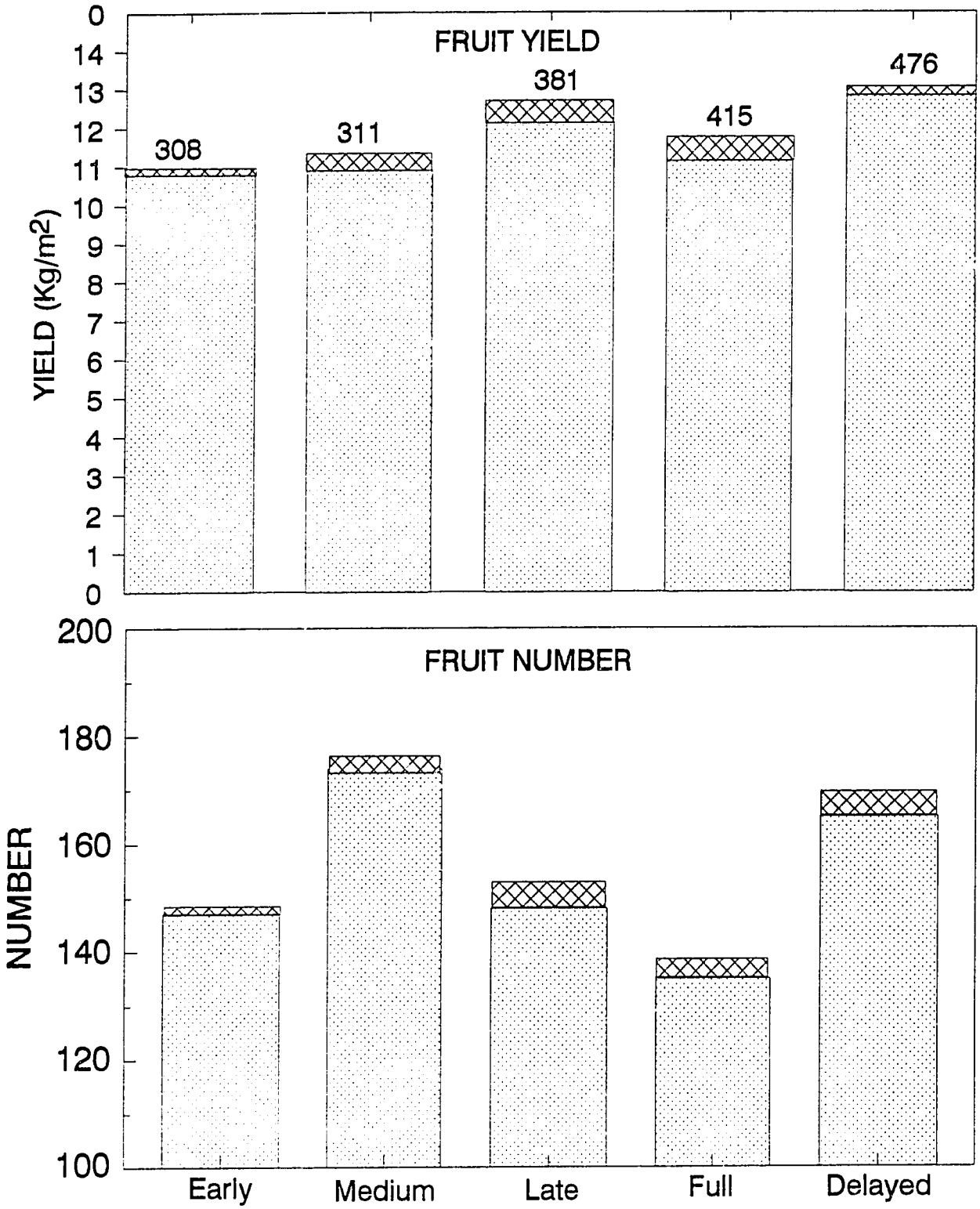


Fig 2.9: Effect of withholding of irrigation water at different growth stages on fresh tomato fruits yield and on number of fruits. (Full=no withdrawal, Delayed=delayed termination). Upper bar=SE of the means. Quantities of water applied (mm) shown at top.

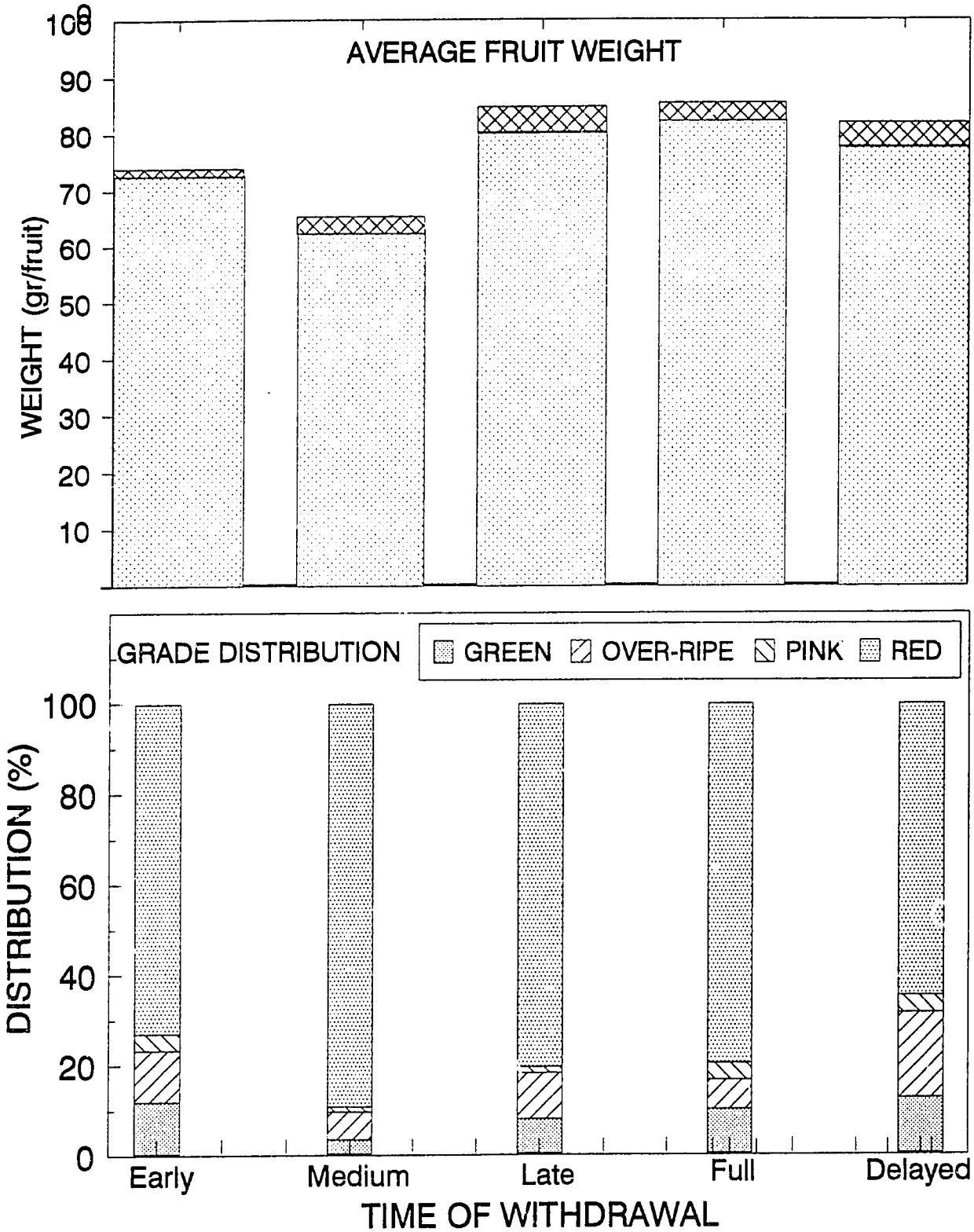


Fig 2.10: Effect of withdrawal of irrigation water and delayed termination on average fruit weight and on tomato fruit ripening. Details as in Fig.2.2.

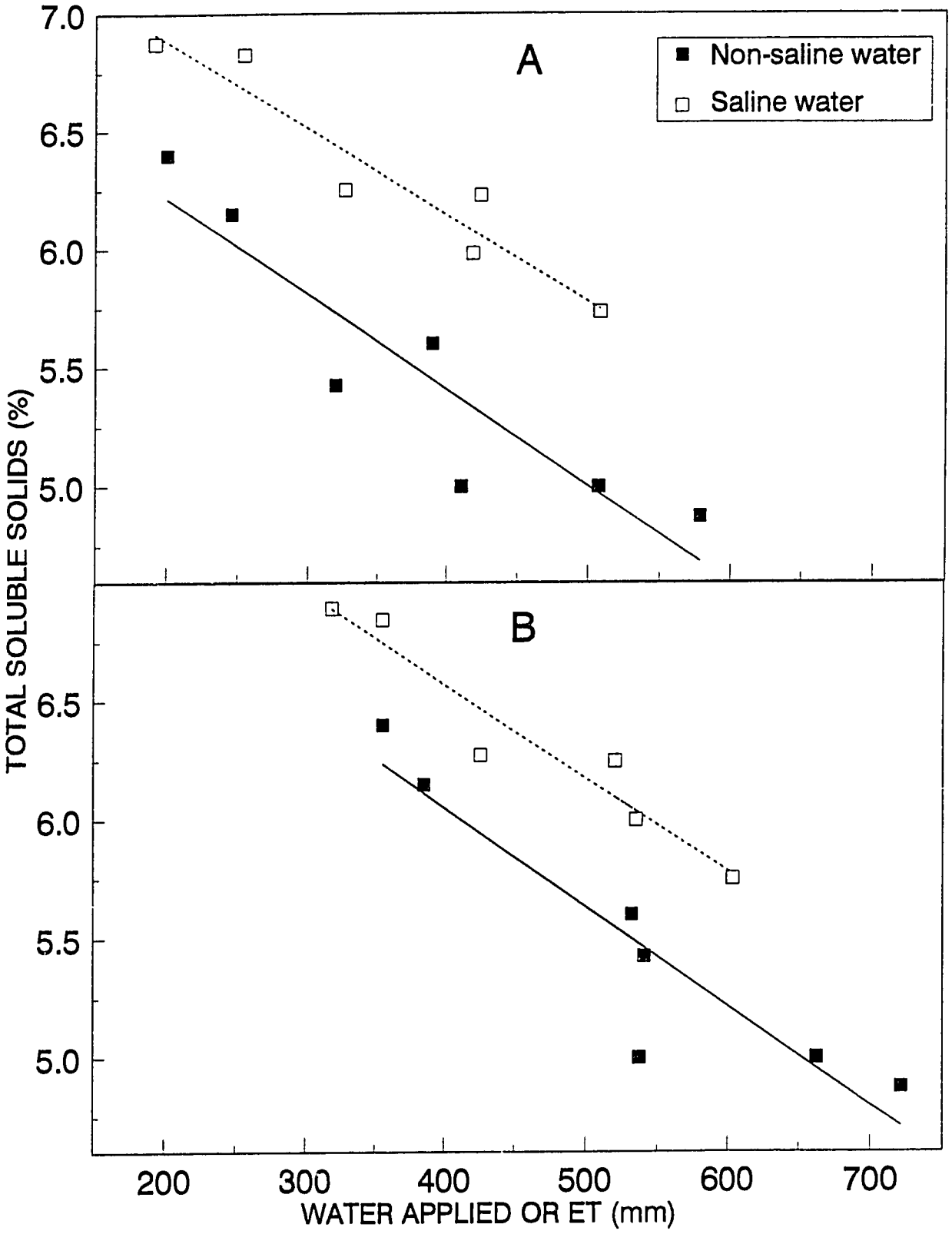


Fig 2.11: Effect of quantities of irrigation water (A) or evapotranspiration (B) on total soluble solids (TSS) in tomato fruits.

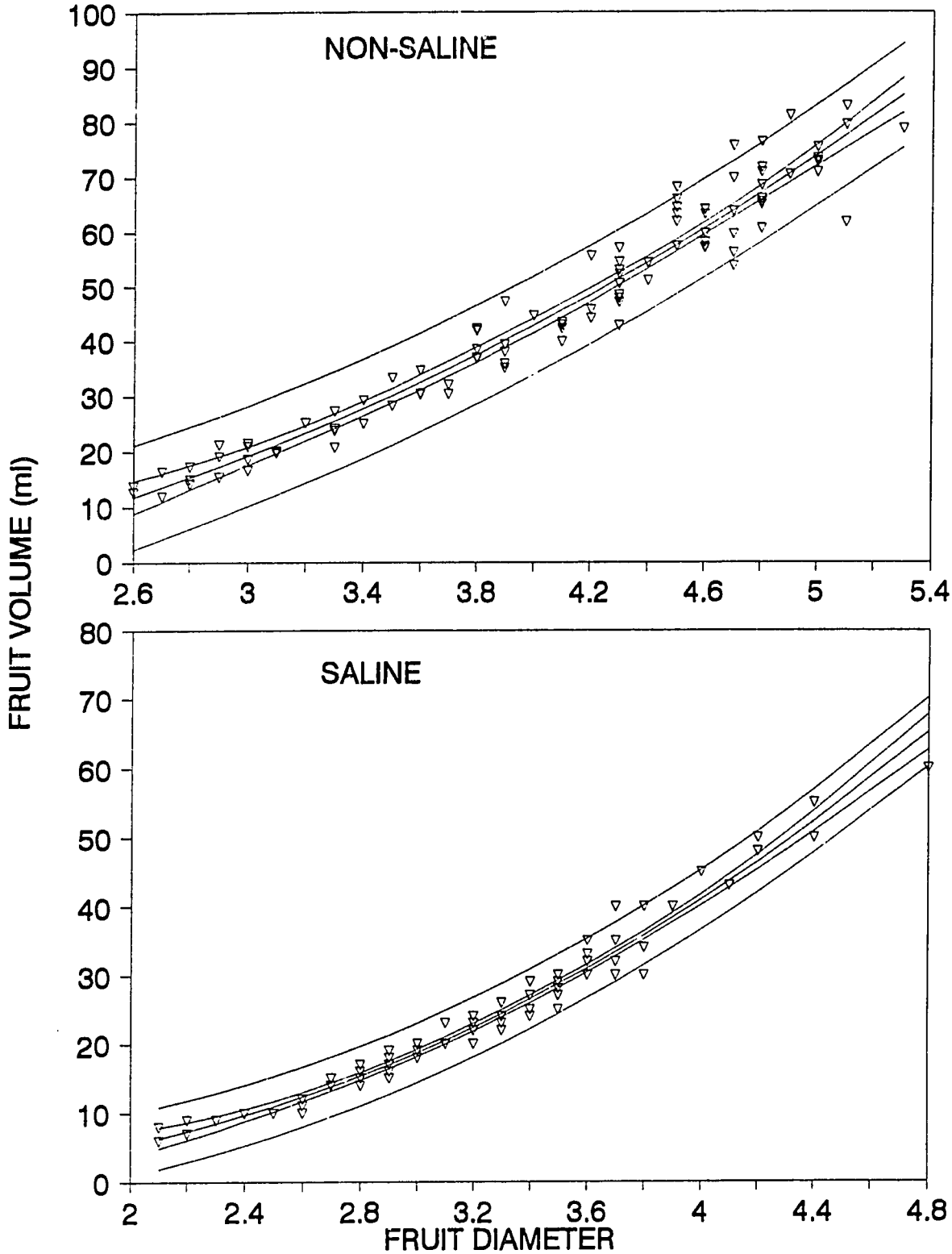


Fig 2.12: Parabolic regression of fruit volume against diameter.
Central line is the calculated function.
Other lines are ±0.2 SE and ±1.0 SE.

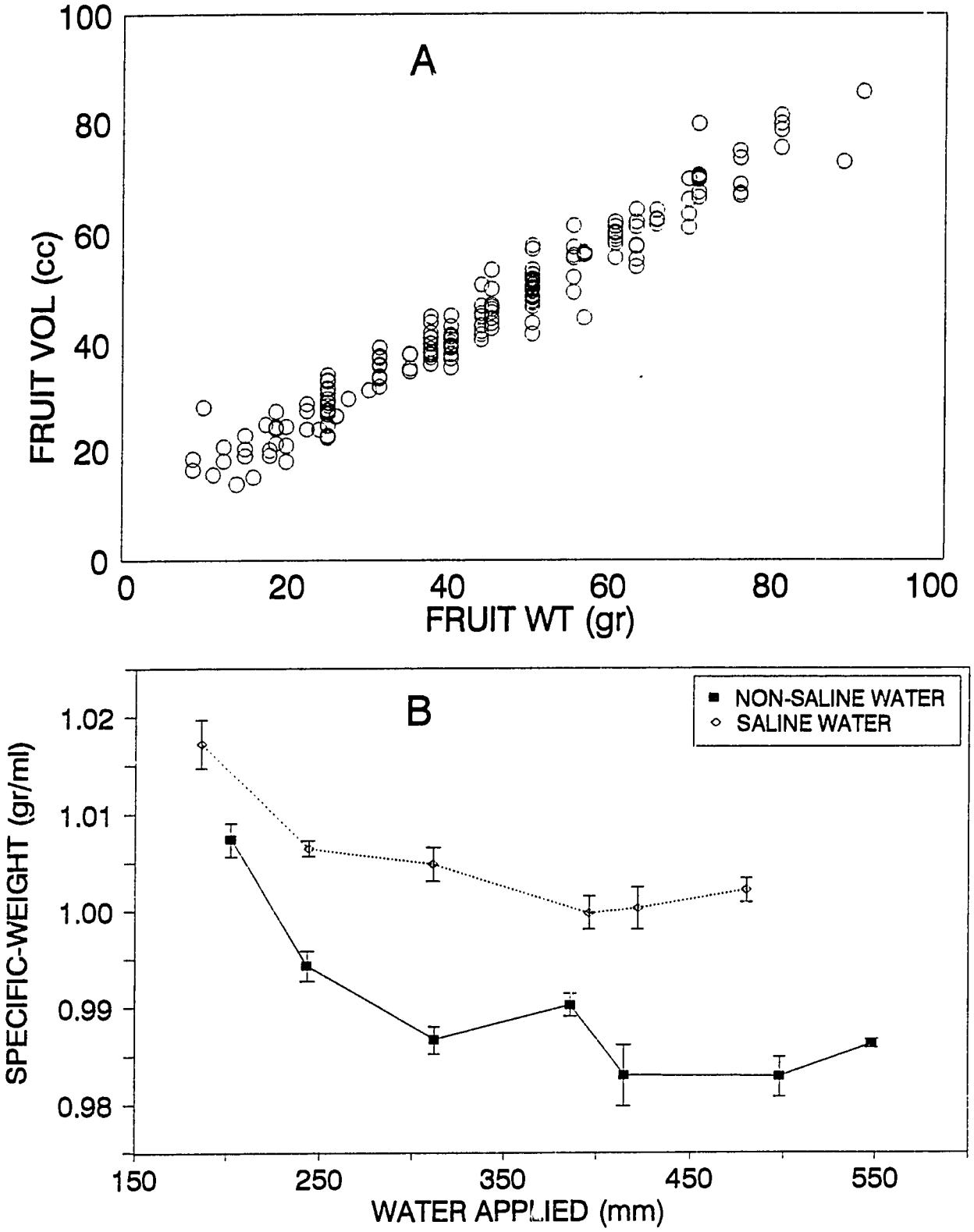


Fig 2.13: A.Relation between tomato fruit weight and volume.
B.Effect of quntities of water applied on specific fruit weight.

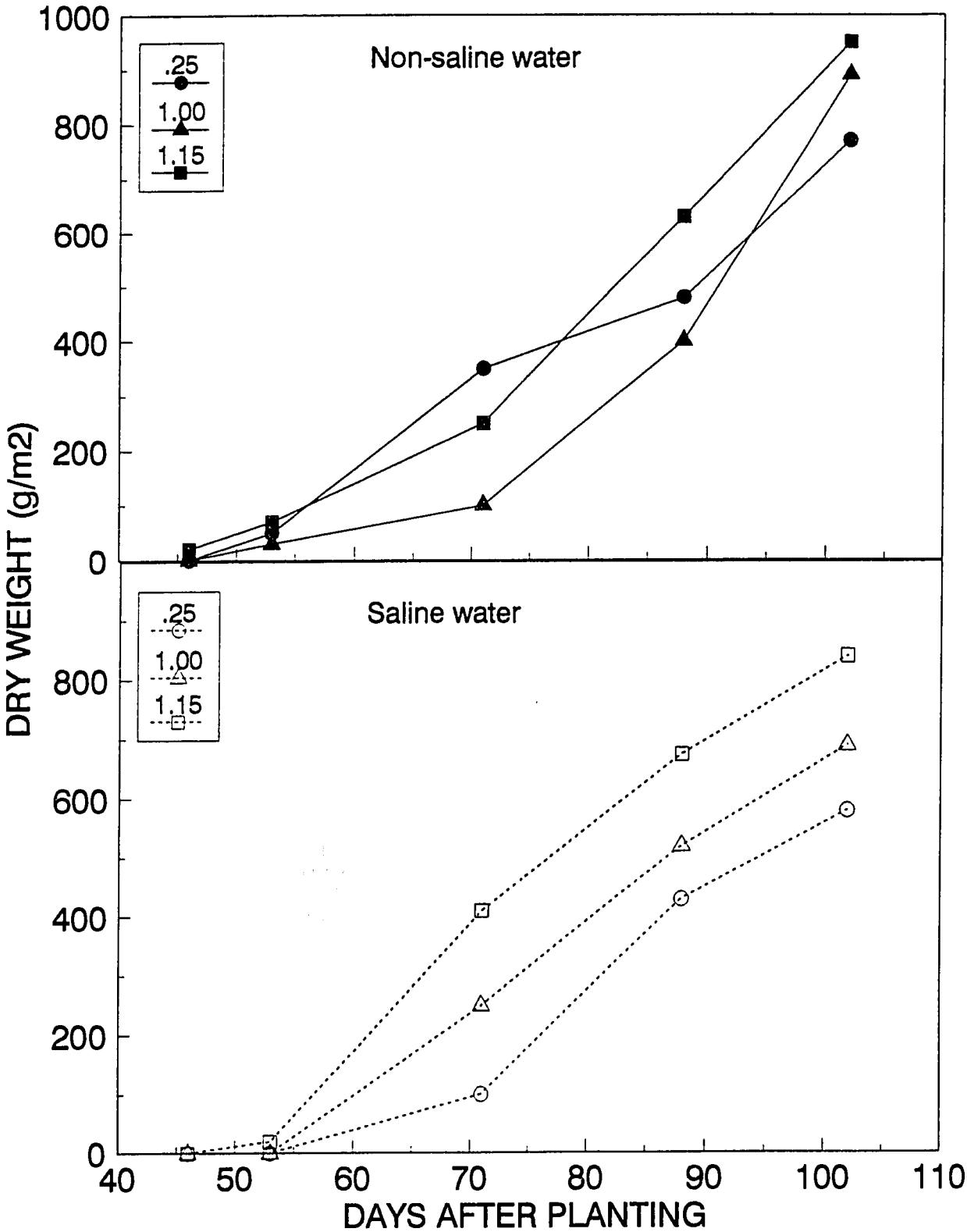


Fig 2.14: Effect of irrrigation management on total dry weight accumulation in tomato fruits.

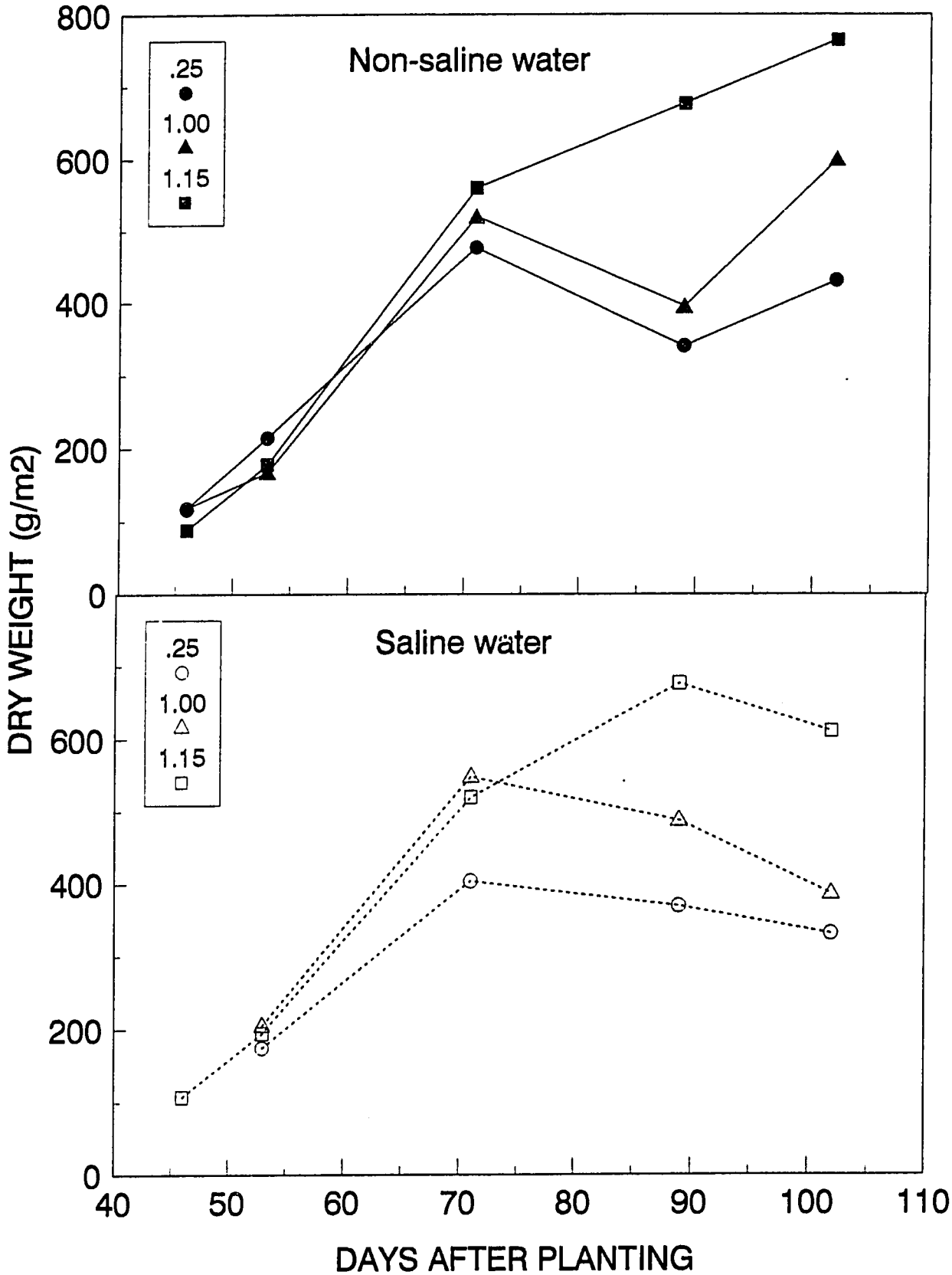


Fig 2.15: Effect of irrigation management on dry weight accumulation in tomato vegetative organs.

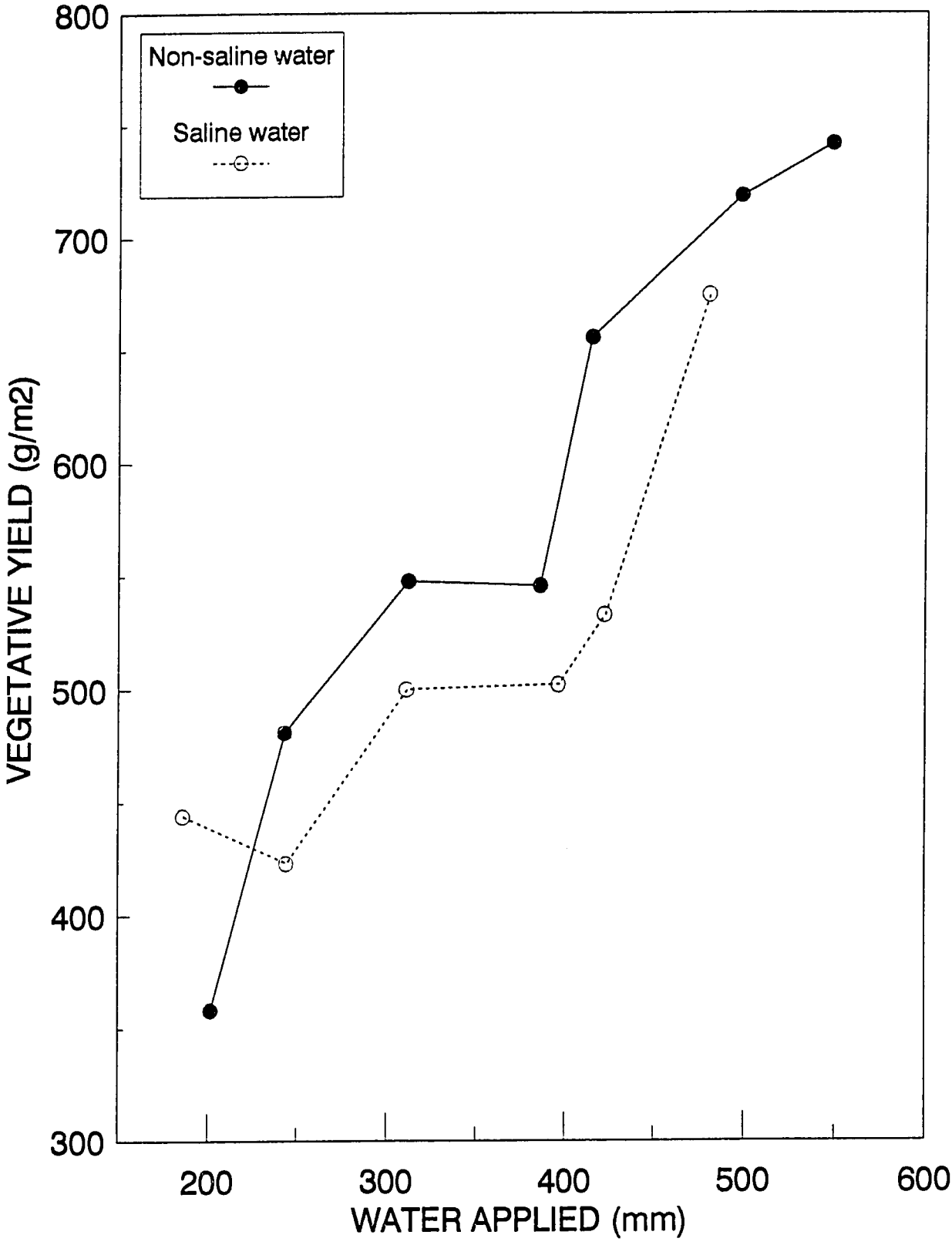


Fig 2.16: Dependance of vegetative dry weight on quantity of water applied.

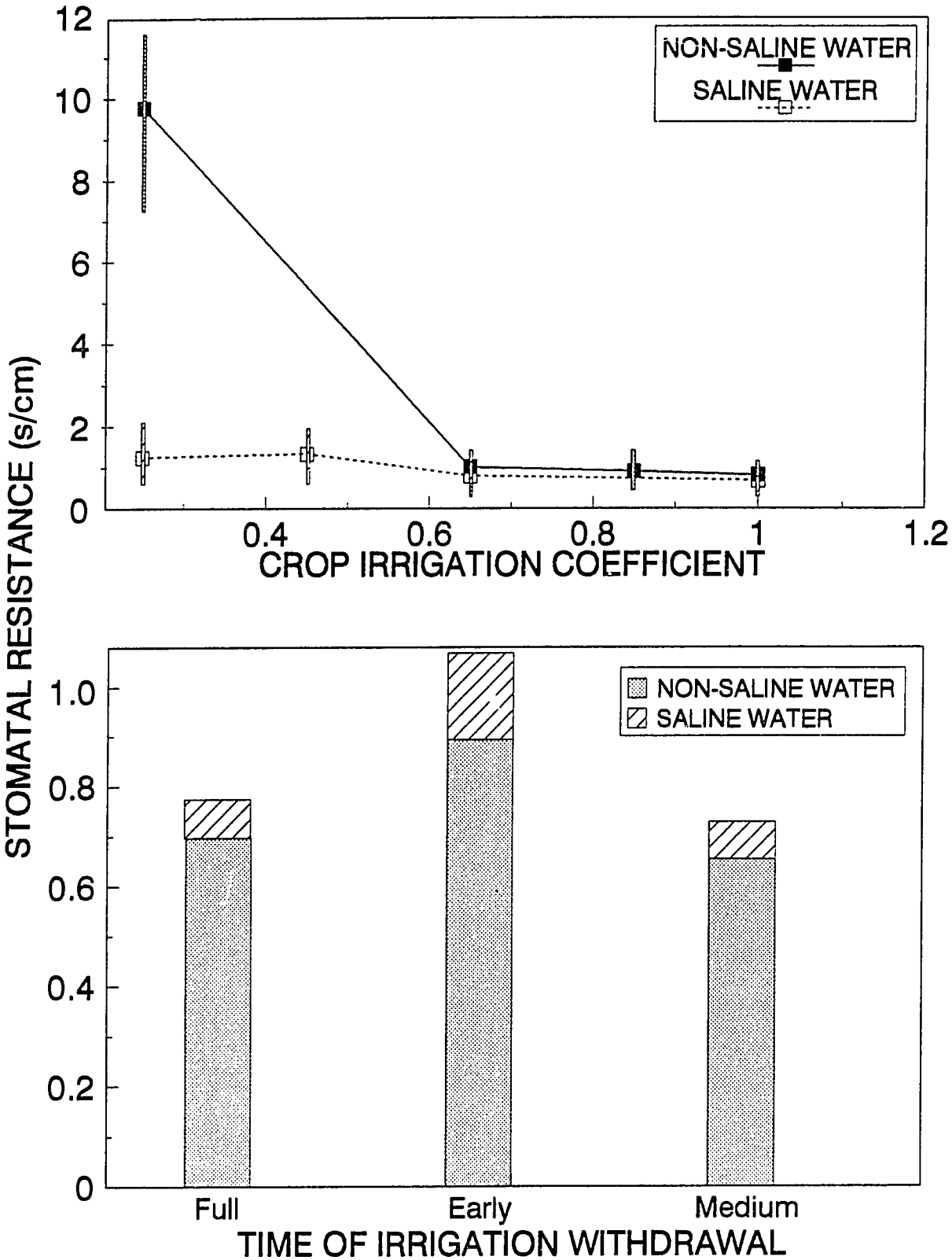


Fig 2.17: Effect of irrigation management on stomatal resistance of tomato leaves.

3. RESPONSE OF TWO CULTIVARS OF PROCESSING TOMATOES TO THE RESTRICTION OF IRRIGATION WATER

INTRODUCTION

The purpose of the second field trial on tomatoes was also to determine their response to the restriction of water quantities applied by drip irrigation. The original objective (according to the Research Proposal) was to reduce the quantities of water according to plant water potential. Scheduling irrigation of processing tomatoes according to plant water potential was found to be not very successful, as there was no response of water potential to irrigation regimes. In fact the response of production and fruit quality was not well-reflected in the history of plant water potential during the various growth stages. It was thus decided to obtain more data and confirm the evidence on positive response of fruit quality to withholding irrigation water during specific growth stages. This experiment was conducted in the summer of 1991.

MATERIALS AND METHODS

Two cultivars - Peto 81 and Alumim 9 were planted on April 4, 1991 at Kibbutz Nahal-Oz in the southern coastal plain of Israel, in the vicinity of last year's experimental site. The tomatoes were planted in double-hedged rows, on a bed 1.92 m wide, with similar distances to previous year, giving a total of 32,500 plants/ha. The preliminary irrigations with sprinklers applied 55 mm within 10 days after planting.

The differential irrigations started thereafter using a drip irrigation system. One lateral per bed with a distance between drippers of 75 cm. Total amount of water applied during the season is presented in Table 3.1. The amounts of water for identical treatments were slightly less than in 1990 due to a high rate of rainwater (approximately 550 mm) during the preceding winter. This filled the entire soil profile up to field capacity and reduced water requirement at the beginning of the season. Water was applied twice a week.

Seven different irrigation regimes were applied to each of the two cultivars (Table 3.1). The control plots (Treat. 1) were irrigated according to a crop irrigation coefficient which varied between 0.6 and 0.9 depending on coverage of the soil surface by the canopy. The coefficient was reduced to the range of 0.45 - 0.7 (Treat. 5) and 0.3 - 0.45 (Treat. 7). In other treatments, water was withheld during 3 different stages of development which were vegetative growth, flowering and fruit expansion and ripening (Treatments 2, 3 & 4), or during 2 stages (Treat. 6). Water was applied as in the control during the rest of the season.

Soil water content and salt concentrations were determined throughout the season. Development of the canopy dry weight formation was determined throughout the growing season. Yield and quality were determined at the final picking.

RESULTS AND DISCUSSION

The differences among treatments in soil moisture content was predominant in the top 30 cm of soil as shown in Fig. 3.1.

In the control treatment soil water content (by volume) was between 20 and 22% for the first 60 days of plant development and gradually decreased thereafter down to 12% at harvest time. A reduction of the crop irrigation coefficient by 25% resulted in a decrease of 24% in the quantity of water applied but the moisture in the top soil layer was not depleted below 19% during the first 60 days. In contrast, withholding irrigation during various growth stages (Treatments 2, 3 & 4) resulted in severe depletion of soil moisture and in an average decrease of 30% of the total water applied. This difference between a uniform decrease in water application and the temporal withholding of water was, in fact, detected in fruit production (Table 3.2).

A more severe depletion of soil moisture was found when the irrigation coefficient was reduced by 50% or when water was withheld at 2 growth stages (Fig. 3.1B). The integration of time and moisture depletion of the soil was similar in the two treatments of deficient water supply.

The rise in soil EC and Cl^- concentration in the top soil layer (Fig. 3.2) indicates that most of the water was withdrawn from this layer. It is interesting that Ca+Mg and also K but not Na, were depleted from the top soil layers much more than from the deeper layers. The SAR values were reduced at the top layer.

The rate of soil surface coverage by the canopy was very similar for both cultivars in all treatments in which 25% of the water was reduced, except when withholding was during vegetative growth (Fig. 3.3). When 50% of the water was reduced the rate of canopy coverage was severely inhibited.

The inhibition of plant development when water was withheld at an early developmental stage (Treat. 2) was also found for vegetative dry matter production (Fig. 3.4). In the cv Alumim 9 but not in Peto 81, a recovery was obtained at a later stage of development. It is interesting that withholding of irrigation water at a later stage resulted in an enhanced growth rate of vegetative organs after removal of the stress, mainly in Peto 81. In general, the plant of cv Peto 81 produced more dry weight in vegetative organs as compared with Alumim 9.

The response of fruit yield to withholding irrigation water did not confirm previous year's results. In both cultivars a uniform reduction in irrigation water throughout the growing season resulted in smaller reduction of fruit yield as compared with withholding irrigation water at any part of the growing season (compare Treatment 5 with Treatments 2-4 in Table 3.2). The yield was by 9-23% in Peto 81 and by 18-20% in Alumim 9. This is probably a result of the sever water stress under conditions of water withholding in the present season. It is very possible that in the control treatment water was given in excess and as indicated, the treatment of uniform decrease in irrigation coefficient was probably only slightly stressed. In contrast, the treatments in which water was withheld were under much more severe stress.

Fruit quality was, however, positively affected by withholding irrigation water, similar to previous experiments. Withholding irrigation water during fruit expansion or ripening, increased TSS and dry weight content of fruit of both cultivars. It also enhanced fruit ripening and improved fruit color.

Table 3.1. Design of 2nd experiment with processing tomatoes (1991). The same treatments were applied to both cv Peto 81 and cv Alumim 9. Growth stages A, B and C refer to vegetative growth, flowering and fruit expansion and ripening stages, respectively.

Treatment number	Relative crop irrigation coefficient	Irrigation withheld during: Weeks	Growth stage	Water applied
1	1.00	-	-	398
2	1.00	5→8	A	304
3	1.00	8→11	B	279
4	1.00	11→14	C	278
5	0.75	-	-	301
6	0.75	5→8, 11→14	A+C	238
7	0.50	-	-	219

Table 3.2. Fruit yield and quality of two cultivars of tomato for processing as affected by irrigation regimes. Significant improvement over the control is underlined.

Treat-ment	Fruit yield (kg/m^2)	TSS content (%)	Dry weight of fruit (%)	Intensity of color
Peto 81				
1	11.6	5.7	4.57	2.5
2	9.0	5.2	4.49	3.0
3	7.5	6.9	5.55	4.5
4	8.7	6.1	4.73	3.5
5	9.7	6.3	6.18	4.0
6	7.5	5.6	4.59	1.5
7	7.0	7.1	6.29	1.5
Alumim 9				
1	13.1	5.0	5.06	3.0
2	9.7	4.7	4.19	3.0
3	9.5	6.0	6.94	4.5
4	9.5	5.5	6.18	3.0
5	11.7	5.3	5.12	3.0
6	8.8	4.7	5.12	2.5
7	8.4	6.2	5.81	3.0

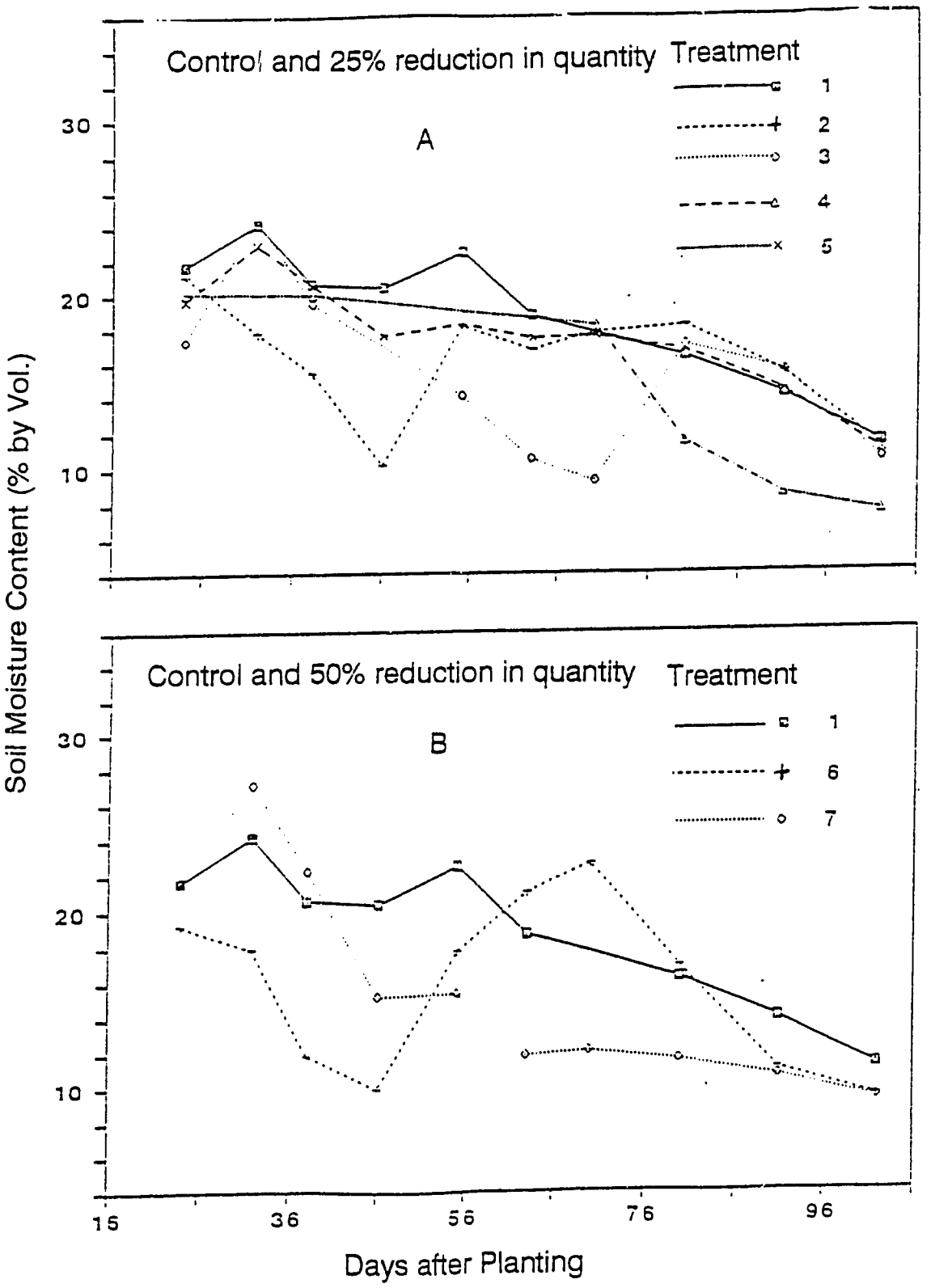


Fig 3.1: Effect of reducing quantities of water at various growth stages on soil moisture content at a depth of 0-30 cm. Treatments outlined in Table 3.1.

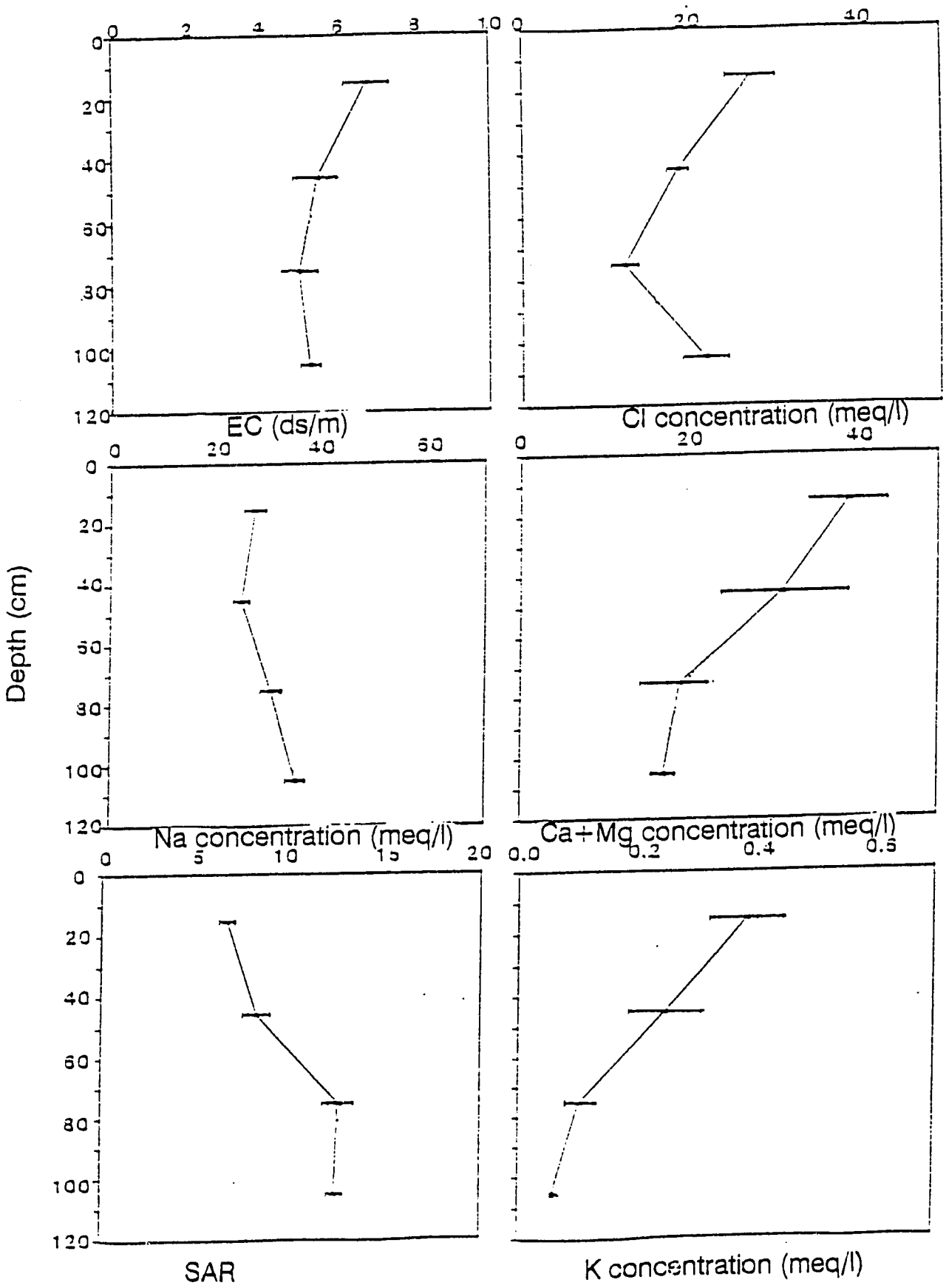


Fig 3.2: Profile of EC and ion concentrations in the soil at the end of the growing season. The figures are averages and SE of all treatments and replicates.

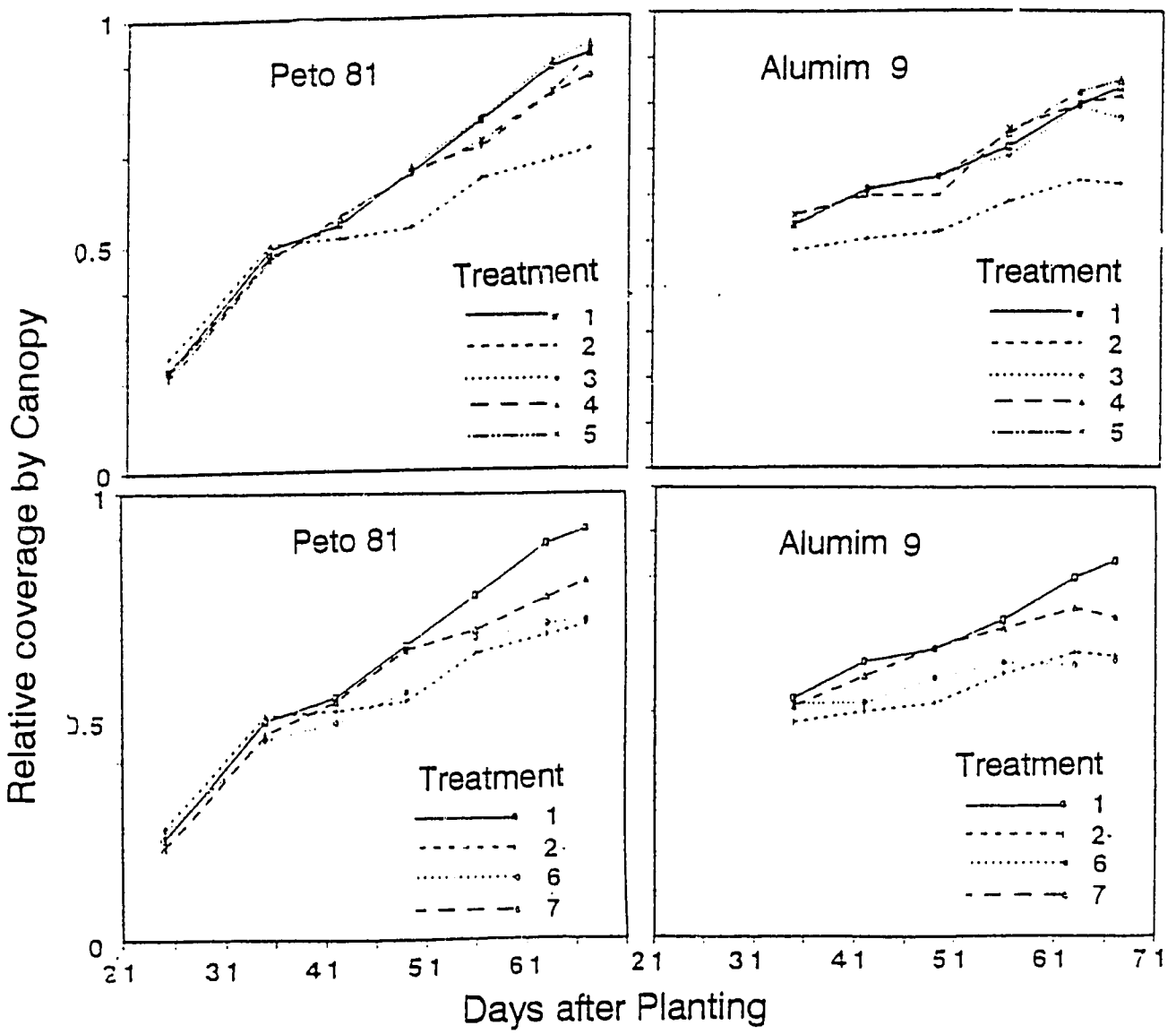


Fig 3.3: Effect of irrigation regimes on rate of soil coverage by the plant canopy. Treatment outlined in Table 3.1.

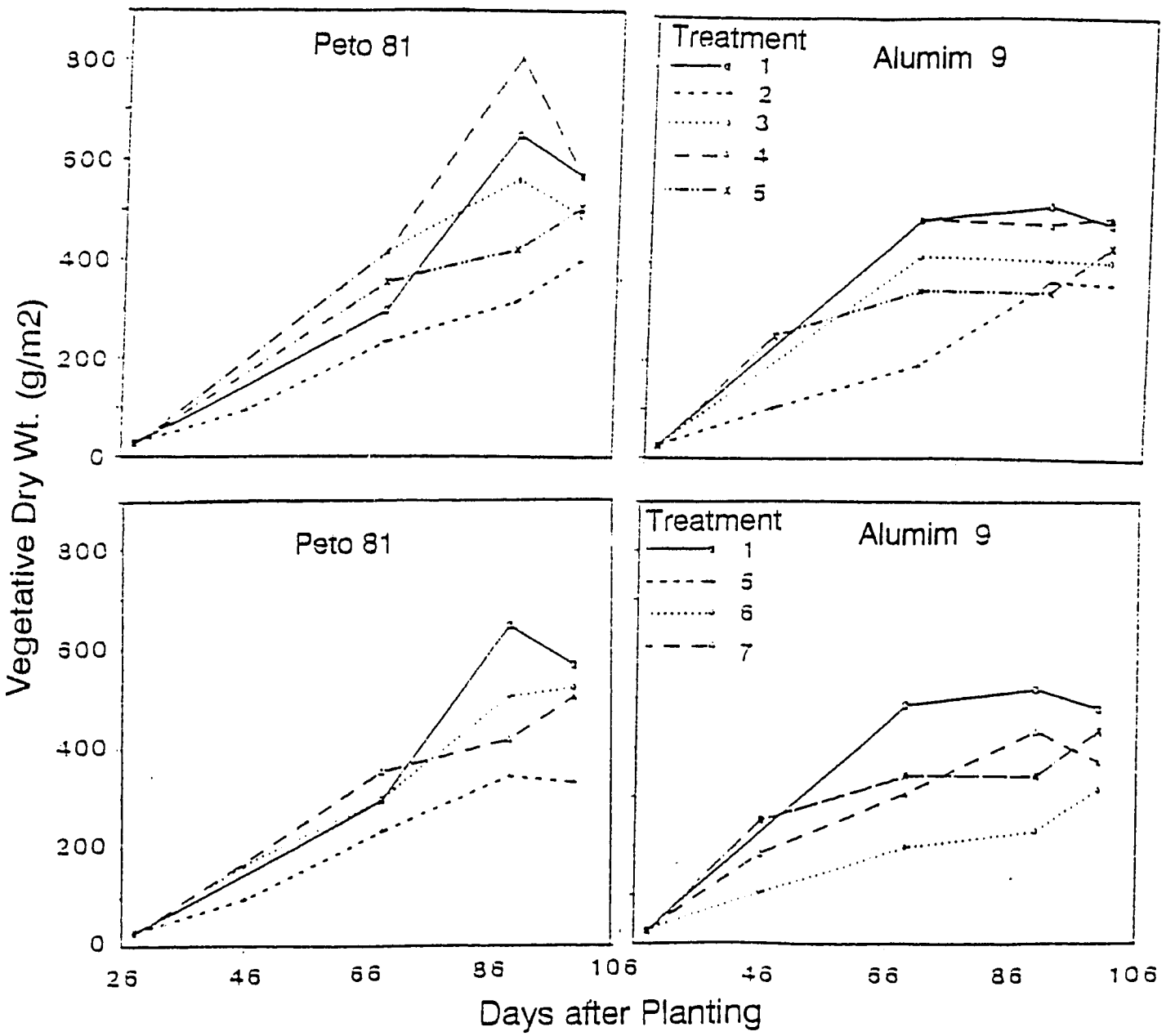


Fig 3.4: Effect of irrigation regimes on dry weight accumulation rate in vegetative organs. Treatments as outlined in Table 3.1.

4. A COMPARISON BETWEEN DRIP AND FURROW IRRIGATION WITH THREE WATER QUALITIES AND THEIR EFFECT ON PRODUCTION OF POTATOES

Most row crops are irrigated very successfully with drip irrigation in Israel. Higher production can be achieved with drip irrigation than with open irrigation with similar quantities of water (Dasberg & Bresler, 1985). The advantage of drip irrigation may even be greater when brackish water is used for irrigation (Goldberg, 1976; Shalhevet et al., 1983). This is usually attributed to at least three factors: (a) damage to the canopy due to direct wetting which is the case with sprinkling, (b) avoiding fluctuations in soil matrix potential due to frequent water applications and (c) a possibility to push the salinity front away from the majority of the root system.

Potatoes are known as a salinity sensitive crop (Maas & Hoffman, 1977). When the EC of the irrigation water was in the range of 5.0 - 7.0 dS/m a significant decrease in productivity was found using any irrigation system (Meiri et al., personal communication and earlier reports, 1986 1987).

The purpose of the present study was thus to determine the effect of salinity on growth, yield ion uptake and water relations of potatoes irrigated by drip and furrow systems. This comparison was conducted with EC levels between 1.0 and 5.0 dS/m in the irrigation water.

MATREIALS AND METHODS

A field trial was conducted in the spring of 1993 in an

experimental field at Kibbutz Nahal-Oz as previous experiments. Organic manure (45 m^3/ha) and superphosphate (900 kg/ha) were added during the preceeding fall. Planting of Desiree potatoes was conducted on February 25, 1992, at a depth of 14 cm, in the center of ridges which were 1 m apart and separated by furrows. The distance between planted tubers was 26 cm, and their average weight was 85 gr/tuber (ϕ= 40-45 mm). The total weight of planted tubers was 0.325 g/m^2.

Emergence started on March 21-23 and first irrigation was applied on March 28. Irrigation was according to the experimental design (Table 1) and water with the different salinity levels was applied from the first irrigation onwards. The quantity of water was determined on the basis of Class A pan evaporation using a crop coefficient of 1.0, corrected according to soil surface coverage by the canopy. Quantities of water were identical for all experimental treatments. Urea as N source dissolved in water was applied twice weekly. The rate of nitrogen dressing varied according to crop development; 4.0 gr/m^2.week during March 28 through April 24, 8.0 gr/m^2.week during April 25 through May 8, and again 4.0 gr/m^2.week during May 9 through May 30.

One drip line (Netafim) with emitters every 60 cm was placed along the top of each ridge at a depth of 3-5 cm. This practice and their low discharge rate of 2.2 l/hr (3.6 l/m^2.hr) avoided runoff. Furrow irrigation was obtained by placing drip lines with discharge rate of 16 l/m^2.hr along the furrow. As the field was nearly level, this high discharge rate filled the furrow with water and simulated furrow irrigation. Three EC levels 1.0, 3.0

and 5.0 dS/m of the irrigation water were used. The low salinity level was the national carrier water and the high EC was that of a local well. In fact, it was used up to June 10 by injecting a salt solution into the good quality water. After June 10 a local well was operating and supplied water with an EC of 5 dS/m. The intermediate EC was obtained by mixing water of the two salinity levels at a 1:1 ratio. The chemical composition of the artificially prepared saline water and the well water was similar. Both contained 38, 5.4 and 1.6 meq/l of Na^{++}, Ca^{++} and Mg^{++} salts, respectively. The experiment was coducted in both a nonsaline and a presalinized soil in which saline water was used for irrigation for the last 8 years.

Each experimental plot consisted of 6 rows x 12 m long out of which 10 m x 2 central rows were used for the final harvest.

Shoots were sampled 3 times during the experiment at 22.4, 11.5 and 15.6. Ion analysis was conducted on the 3 sampling dates, dry weight was determined on the last two. Tubers were sampled at the final harvest. Fresh and dry weight of the tubers, ion content, EC and osmotic potential of the sap were determined on samples. The final harvest was conducted on July 7 and the tubers were sorted according to size and regularity.

RESULTS AND DISCUSSION

At the beginning of the season, prior to planting, the EC of saturated soil extracts was low throughout the entire soil profile of 120 cm (not shown). After 5 weeks of irrigation with water of different salinity levels, there was a rise in EC but only at the top soil layer (Fig. 4.1a). However, as the EC was

determined in a saturated extract prepared with distilled water, the EC under field-capacity was approximately twice as high. SAR values were very low in the top layer but raised along the profile when 5.0 dS/m water was used. These values were, however, significantly lower than the SAR values of the irrigation water which was 22-26.

At the end of the growing season, the EC of the top 30 cm of soil was 7-8 dS/m in the saturated soil extract of both non-salinized and presalinized soils, when irrigated with 5.0 dS/m water. At deeper soil layers of these plots and at the top layer of the plots irrigated with 1.0 dS/m water, soil EC was in the range of 1-4 dS/m. The irrigation method had no effect on soil EC determined at this distance (10 cm) from drippers. The horizontal and vertical distribution of soil EC for drip and furrow irrigation methods are compared in Figure 4.2. Under drip irrigation the EC was 8.5 dS/m in the furrow at a soil depth of 0-30 cm when saline water was used, while in the ridges along the laterals EC did not exceed 4.5 dS/m (Fig. 4.2a). A build-up of salinity was found at the top layer in the furrow when non-saline water was applied. Under furrow irrigation similar high EC levels were found in the top layer of the ridges and in the furrow when saline water was used (Fig. 4.2b). In the deeper layers, the EC in the ridge even exceeded that in the furrow. These findings indicate that by furrow irrigation a notable part of the salts were pushed into the ridges where the tubers were developing, while by drip irrigation they were pushed away from the ridges. The SAR values along the ridges and furrow of both irrigation methods are outlined in Fig. 4.3 for the end of the season and

give more details on ion distribution.

An early determination of tuber yield was conducted on May 11, shortly before the switch in salinity levels (Fig. 4.4a). Higher yield was already found at this stage under drip as compared with furrow irrigation under most soil or water salinities. Salinity in the irrigation water reduced tuber yield only under furrow irrigation when applied in non-salinized soil. Average tuber weight was not affected significantly by the different treatments and reached an average weight of 60-70 gr at this stage of development (Fig. 4.4b).

Final tuber yield at final harvest, was significantly decreased under furrow irrigation even at the intermediate salinity level (Fig. 4.5a). There was, however, no significant decrease even at 5 dS/m under drip irrigation. The history of field exposure to salinity had no significant effect on tuber yield in both irrigation methods. It is interesting that the average tuber weight in contrast to yield was only slightly decreased by furrow irrigation with saline water (Fig. 4.5b). This indicates that the decrease in yield must largely be attributed to the number of tubers per plant unit area.

At the first shoot sampling on May 16 only a slight decrease in shoot dry weight was found under drip irrigation with saline water. The difference in both soil types was insignificant (Fig. 4.6). At the time of peak shoot development (15.06) the decrease of shoot dry weight by saline irrigation water was more significant (Fig. 4.6b). The effect under furrow irrigation was again more marked than under drip irrigation.

The salt ions Cl^- and Na^+ in the shoot were determined on leaf sampled on 24.04, 11.05 and 15.06 (before shoot senescence). The terminal leaflet of the youngest fully-expanded leaf was always sampled (Figures 4.7 & 4.8). A significant increase in Cl concentration in the leaf material was found in all treatments and at all sampling dates under increased salinity of the irrigation water. There was also a gradual increase in leaf Cl concentration with time at all salinity levels. This increase can be attributed to the rise in soil Cl content and not accumulation of Cl in the leaf with time, as different leaves of a similar age were always sampled. Irrigation method and soil presalinization had no effect on leaf Cl^- concentration. The accumulation of Na in leaves was 30-40 times less than that of Cl throughout the entire season. These low concentrations are probably responsible for the large error in assays and the high standard errors (Figs. 4.8 b &c). It seems, however, that at 5 dS/m drip irrigation of presalinized soil there was a large increase in leaf Na, mainly at the later samplings.

Osmotic potential of tuber sap collected at final harvest was clearly decreased, and EC of the sap was increased by salinity of the irrigation (Figs. 4.9 a & b). Irrigation method and presalinization of the soil had no significant effect on these parameters. The increase in EC was approximately by 3 dS/m while the irrigation water at the highest salinity level was practically increased by 4 dS/m, but much more in the soil solution. This indicated that the salt ions were excluded to a large extent by the tubers. A comparison between leaf and tuber water potentials (Table 4.2) indicates a similar or slightly more

negative potential in tubers except under furrow irrigation with 5 dS/m water. This implies the difficulty of tuber to compete with the shoot for water under these conditions.

The concentration of Cl and Na in tubers was determined once on 11.05 and at the final harvest 7.07. The concentration of Cl in the tubers as in shoots was significantly increased by salinity in the irrigation water at both samplings (Figs. 4.10 a & b). The concentration of Cl in the tubers was approximately lower by one order of magnitude than its concentration in the shoots. In contrast to shoots, there was almost no increase in tuber Cl in the later harvest, although the tubers remained in the soil and were exposed to salinity. The Na concentration was 5-25 times lower than Cl concentration in tubers (Figs. 4.11 a & b). In contrast to shoots, the accumulation of Na was strongly stimulated by salinity in the irrigation water. It seems also that the accumulation of Na was much higher under drip than under furrow irrigation.

Table 4.1. Design of the experiment treatments

	EC of Irrigation water	Irrigation Method
1	1.0	Drip
2	3.0	Drip
3	5.0	Drip
4	1.0	Furrow
5	3.0	Furrow
6	5.0	Furrow

Table 4.2. Leaf and tuber water potentials as determined on 09.05. SE of the means in paranthesis.

Treatment		Leaf water potential (MPa)	Tuber water potential (MPa)
Non-saline soil:			
Drip-irrig.	1 dS/m	-0.31 (0.02)	-0.30 (0.02)
	5 dS/m	-0.48 (0.01)	-0.49 (0.02)
Furrow-irrig.	1 dS/m	-0.38 (0.03)	-0.40)0.03)
	5 dS/m	-0.53 (0.04)	-0.47 (0.04)
Presalinized Soil:			
Drip-irrig.		-0.33 (0.01)	-0.36 (0.03)
1 dS/m		-0.46 (0.02)	-0.50 (0.02)
	5 dS/m		
		-0.46 (0.07)	-0.47 (0.05)
Furrow-irrig.	1 dS/m	-0.53 (0.02)	-0.44 (0.02)
	5 dS/m		

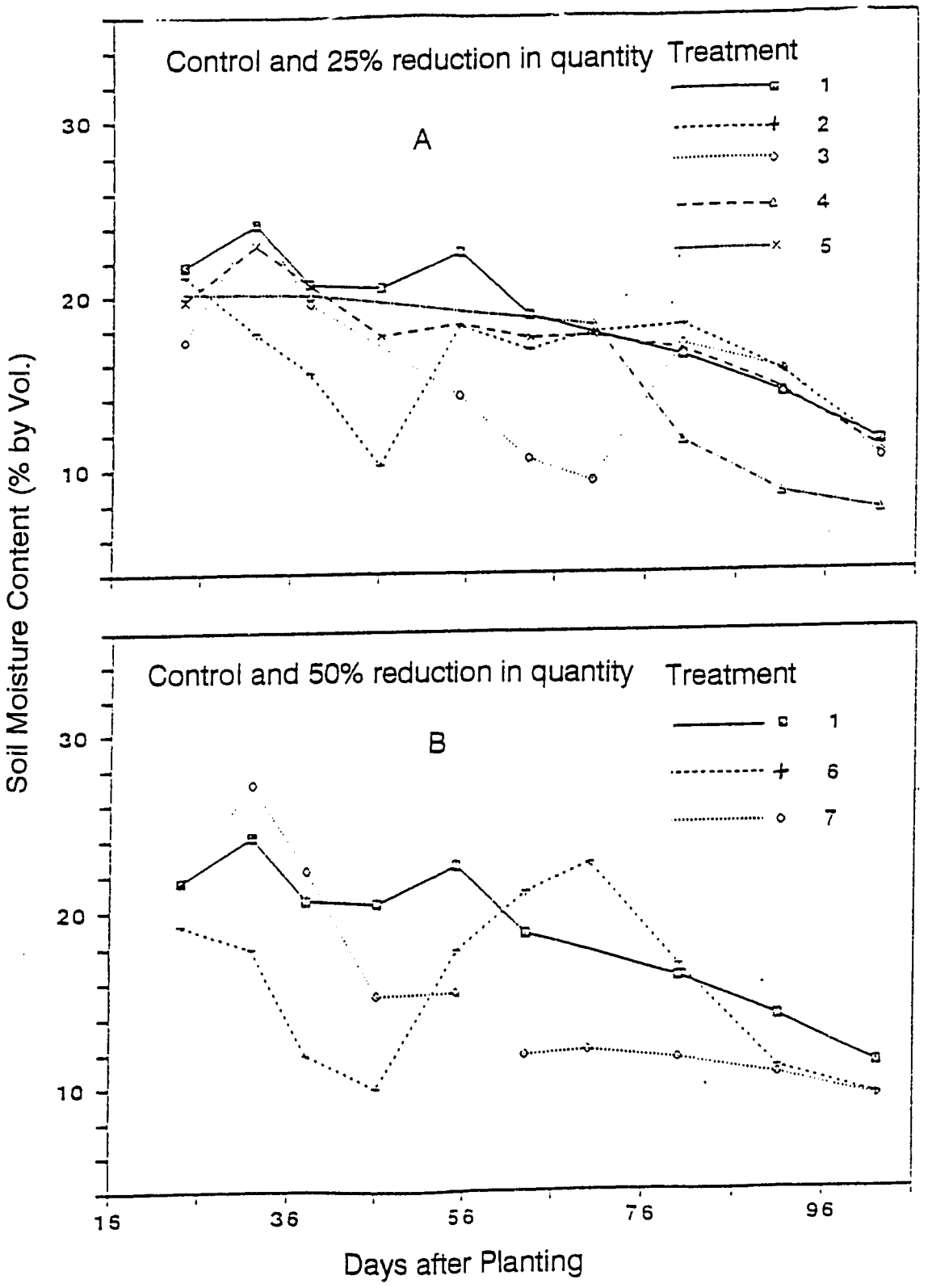
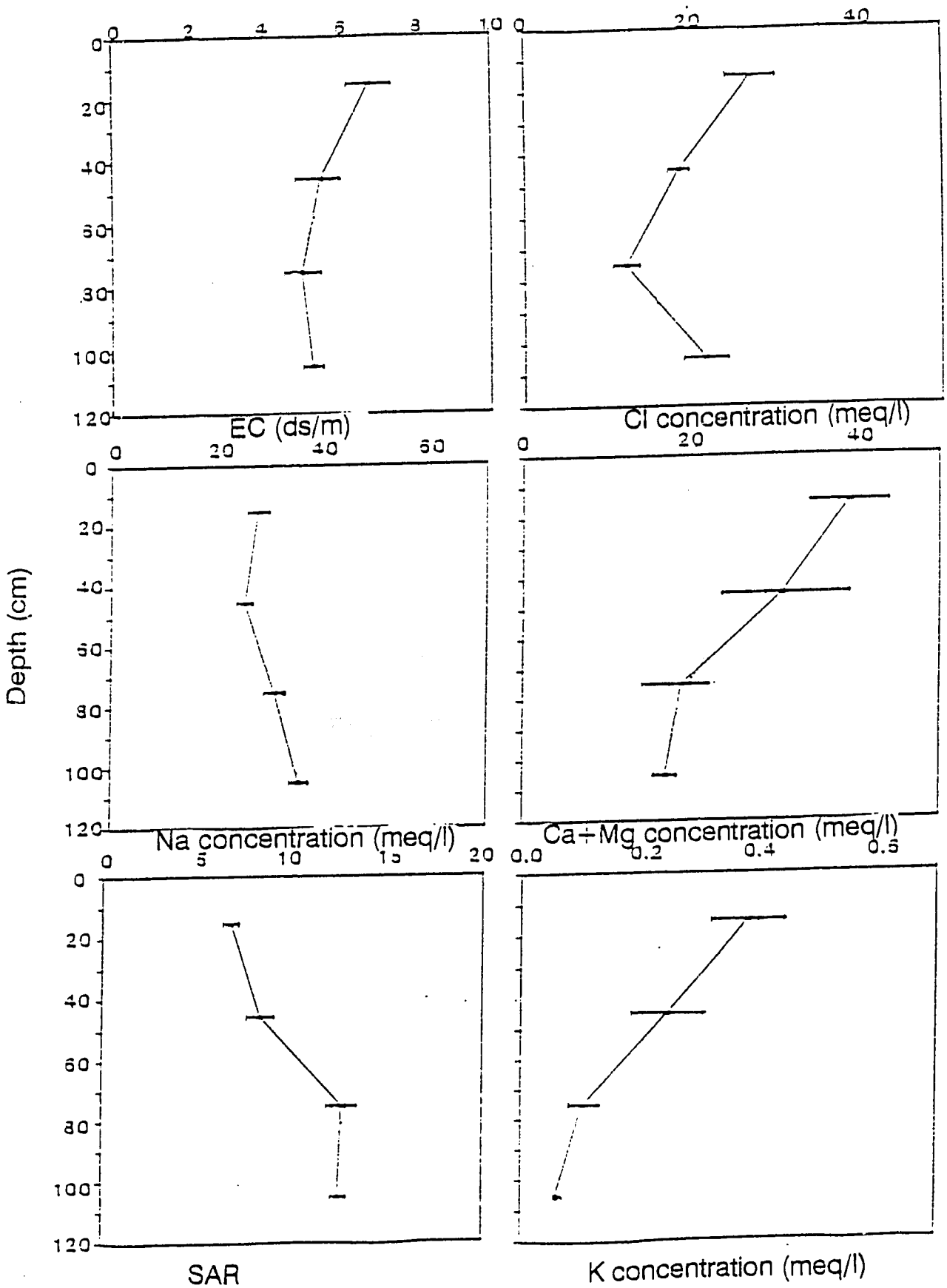


Fig 3.1: Effect of reducing quantities of water at various growth stages on soil moisture content at a depth of 0-30 cm. Treatments outlined in Table 3.1.



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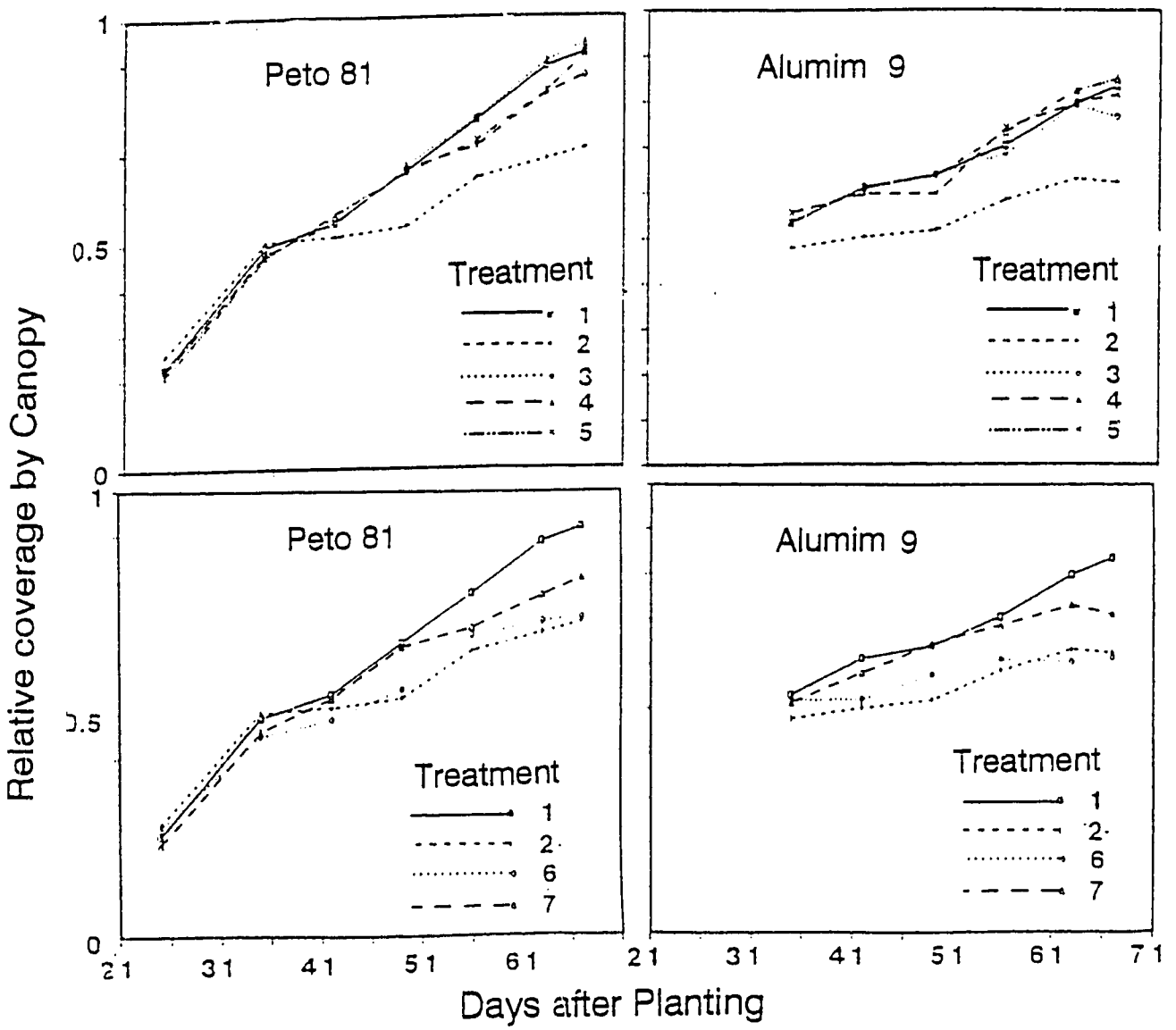

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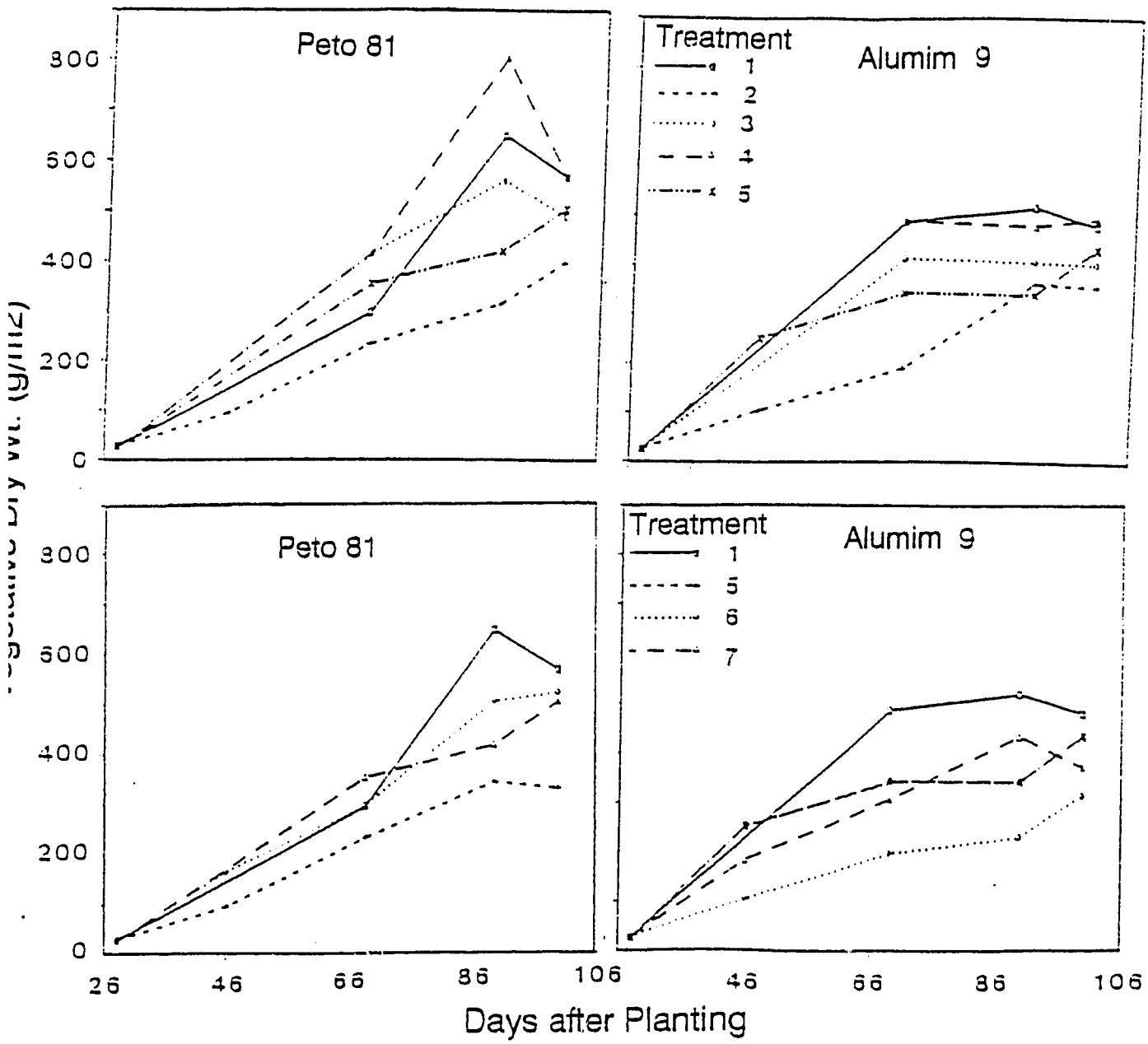

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At the end of the growing season, the EC of the top 30 cm of soil was 7-8 dS/m in the saturated soil extract of both non-salinized and presalinized soils, when irrigated with 5.0 dS/m water. At deeper soil layers of these plots and at the top layer of the plots irrigated with 1.0 dS/m water, soil EC was in the range of 1-4 dS/m. The irrigation method had no effect on soil EC determined at this distance (10 cm) from drippers. The horizontal and vertical distribution of soil EC for drip and furrow irrigation methods are compared in Figure 4.2. Under drip irrigation the EC was 8.5 dS/m in the furrow at a soil depth of 0-30 cm when saline water was used, while in the ridges along the laterals EC did not exceed 4.5 dS/m (Fig. 4.2a). A build-up of salinity was found at the top layer in the furrow when non-saline water was applied. Under furrow irrigation similar high EC levels were found in the top layer of the ridges and in the furrow when saline water was used (Fig. 4.2b). In the deeper layers, the EC in the ridge even exceeded that in the furrow. These findings indicate that by furrow irrigation a notable part of the salts were pushed into the ridges where the tubers were developing, while by drip irrigation they were pushed away from the ridges. The SAR values along the ridges and furrow of both irrigation methods are outlined in Fig. 4.3 for the end of the season and

give more details on ion distribution.

An early determination of tuber yield was conducted on May 11, shortly before the switch in salinity levels (Fig. 4.4a). Higher yield was already found at this stage under drip as compared with furrow irrigation under most soil or water salinities. Salinity in the irrigation water reduced tuber yield only under furrow irrigation when applied in non-salinized soil. Average tuber weight was not affected significantly by the different treatments and reached an average weight of 60-70 gr at this stage of development (Fig. 4.4b).

Final tuber yield at final harvest, was significantly decreased under furrow irrigation even at the intermediate salinity level (Fig. 4.5a). There was, however, no significant decrease even at 5 dS/m under drip irrigation. The history of field exposure to salinity had no significant effect on tuber yield in both irrigation methods. It is interesting that the average tuber weight in contrast to yield was only slightly decreased by furrow irrigation with saline water (Fig. 4.5b). This indicates that the decrease in yield must largely be attributed to the number of tubers per plant unit area.

At the first shoot sampling on May 16 only a slight decrease in shoot dry weight was found under drip irrigation with saline water. The difference in both soil types was insignificant (Fig. 4.6). At the time of peak shoot development (15.06) the decrease of shoot dry weight by saline irrigation water was more significant (Fig. 4.6b). The effect under furrow irrigation was again more marked than under drip irrigation.

The salt ions Cl^- and Na^+ in the shoot were determined on leaf sampled on 24.04, 11.05 and 15.06 (before shoot senescence). The terminal leaflet of the youngest fully-expanded leaf was always sampled (Figures 4.7 & 4.8). A significant increase in Cl concentration in the leaf material was found in all treatments and at all sampling dates under increased salinity of the irrigation water. There was also a gradual increase in leaf Cl concentration with time at all salinity levels. This increase can be attributed to the rise in soil Cl content and not accumulation of Cl in the leaf with time, as different leaves of a similar age were always sampled. Irrigation method and soil presalinization had no effect on leaf Cl^- concentration. The accumulation of Na in leaves was 30-40 times less than that of Cl throughout the entire season. These low concentrations are probably responsible for the large error in assays and the high standard errors (Figs. 4.8 b &c). It seems, however, that at 5 dS/m drip irrigation of presalinized soil there was a large increase in leaf Na, mainly at the later samplings.

Osmotic potential of tuber sap collected at final harvest was clearly decreased, and EC of the sap was increased by salinity of the irrigation (Figs. 4.9 a & b). Irrigation method and presalinization of the soil had no significant effect on these parameters. The increase in EC was approximately by 3 dS/m while the irrigation water at the highest salinity level was practically increased by 4 dS/m, but much more in the soil solution. This indicated that the salt ions were excluded to a large extent by the tubers. A comparison between leaf and tuber water potentials (Table 4.2) indicates a similar or slightly more

negative potential in tubers except under furrow irrigation with 5 dS/m water. This implies the difficulty of tuber to compete with the shoot for water under these conditions.

The concentration of Cl and Na in tubers was determined once on 11.05 and at the final harvest 7.07. The concentration of Cl in the tubers as in shoots was significantly increased by salinity in the irrigation water at both samplings (Figs. 4.10 a & b). The concentration of Cl in the tubers was approximately lower by one order of magnitude than its concentration in the shoots. In contrast to shoots, there was almost no increase in tuber Cl in the later harvest, although the tubers remained in the soil and were exposed to salinity. The Na concentration was 5-25 times lower than Cl concentration in tubers (Figs. 4.11 a & b). In contrast to shoots, the accumulation of Na was strongly stimulated by salinity in the irrigation water. It seems also that the accumulation of Na was much higher under drip than under furrow irrigation.

Table 4.1. Design of the experiment treatments

	EC of Irrigation water	Irrigation Method
1	1.0	Drip
2	3.0	Drip
3	5.0	Drip
4	1.0	Furrow
5	3.0	Furrow
6	5.0	Furrow

Table 4.2. Leaf and tuber water potentials as determined on 09.05. SE of the means in paranthesis.

Treatment		Leaf water potential (MPa)	Tuber water potential (MPa)
Non-saline soil:			
Drip-irrig.	1 dS/m	-0.31 (0.02)	-0.30 (0.02)
	5 dS/m	-0.48 (0.01)	-0.49 (0.02)
Furrow-irrig.	1 dS/m	-0.38 (0.03)	-0.40)0.03)
	5 dS/m	-0.53 (0.04)	-0.47 (0.04)
Presalinized Soil:			
Drip-irrig.		-0.33 (0.01)	-0.36 (0.03)
1 dS/m		-0.46 (0.02)	-0.50 (0.02)
	5 dS/m		
		-0.46 (0.07)	-0.47 (0.05)
Furrow-irrig.	1 dS/m	-0.53 (0.02)	-0.44 (0.02)
	5 dS/m		

LEGENDS TO FIGURES

Fig. 4.1: EC and SAR of saturated soil extracts after application of approximately 40% of the total irrigation water (on 05.05). NSS = non-saline soil, SS = presalinized soil. 1 dS/m and 5 dS/m were the planned EC levels of the nonsaline and the highest salinity levels in the irrigation water (see text).

Fig. 4.2: Horizontal and vertical distribution of EC in saturated soil extracts at the end of the season. Samples were taken from ridges and furrows of plots irrigated with 1.0 dS/m and 5.0 dS/m water. a = drip irrigated, b = furrow irrigated.

Fig. 4.3: SAR of saturated soil extracts determined at the end of the season. SAR was determined in the same samples as EC outlined in Figure 2.

Fig. 4.4: Tuber yield determined on May 11. NSS-Dr = non-saline soil, drip irrigated NSS-Fr = non-saline soil, furrow irrigated, SS-Dr = presalinized soil, drip irrigated, SS-Fr = presalinized soil. Furrow irrigated. Small bars on top of the large bars present SE of the means. a = tuber yield b = average tuber weight.

Fig. 4.5: Tuber yield at final harvest (07.07). Abbreviations and symbols as outlined in Fig. 4.4. a = tuber yield b = average tuber weight.

Fig. 4.6: The effect of continuous use of saline irrigation water on shoot dry weight of potatoes plants. Dry weight was determined on 16.05, and again shortly before shoot senescence on 15.06. Abbreviations and symbols as outlined in Fig. 4.2. a = sampling on 16.05 b = sampling on 15.06.

Fig. 4.7: The effect of saline irrigation water on Cl content in potato shoots. Shoot samples were taken on 22.04, 11.05 and 15.06 data for each sampling is presented separately. Abbreviations and symbols as outlined in Fig. 4.2.

Fig. 4.8: The effect of saline irrigation water on Na content in potato shoots. Shoot samples were taken on 22.09, 11.05 and 15.06, data for each sampling is presented separately. Abbreviation and symbols as outlined in Fig. 4.2.

Fig. 4.9: The effect of saline irrigation water on osmotic potential and EC of tuber sap, as determined on 07.07. Abbreviations and symbols as outlined in Fig. 4.2. a = osmotic potential b = EC.

Fig. 4.10: The effect of saline irrigation water on Cl content in potato tubers as determined on 11.05 and at the final harvest on 07.07. Abbreviation and symbols as outlined in Fig. 4.2. a = sampled at 11.05 b = sampled at 07.07

Fig. 4.11: The effect of saline irrigation water on Na content in potato tubers as determined on 11.05 and at final harvest on 07.07. Abbreviations and symbols as outlined in Fig. 4.2. a = sampled at 11.05 b = sampled of 07.07.

Figure 4.1

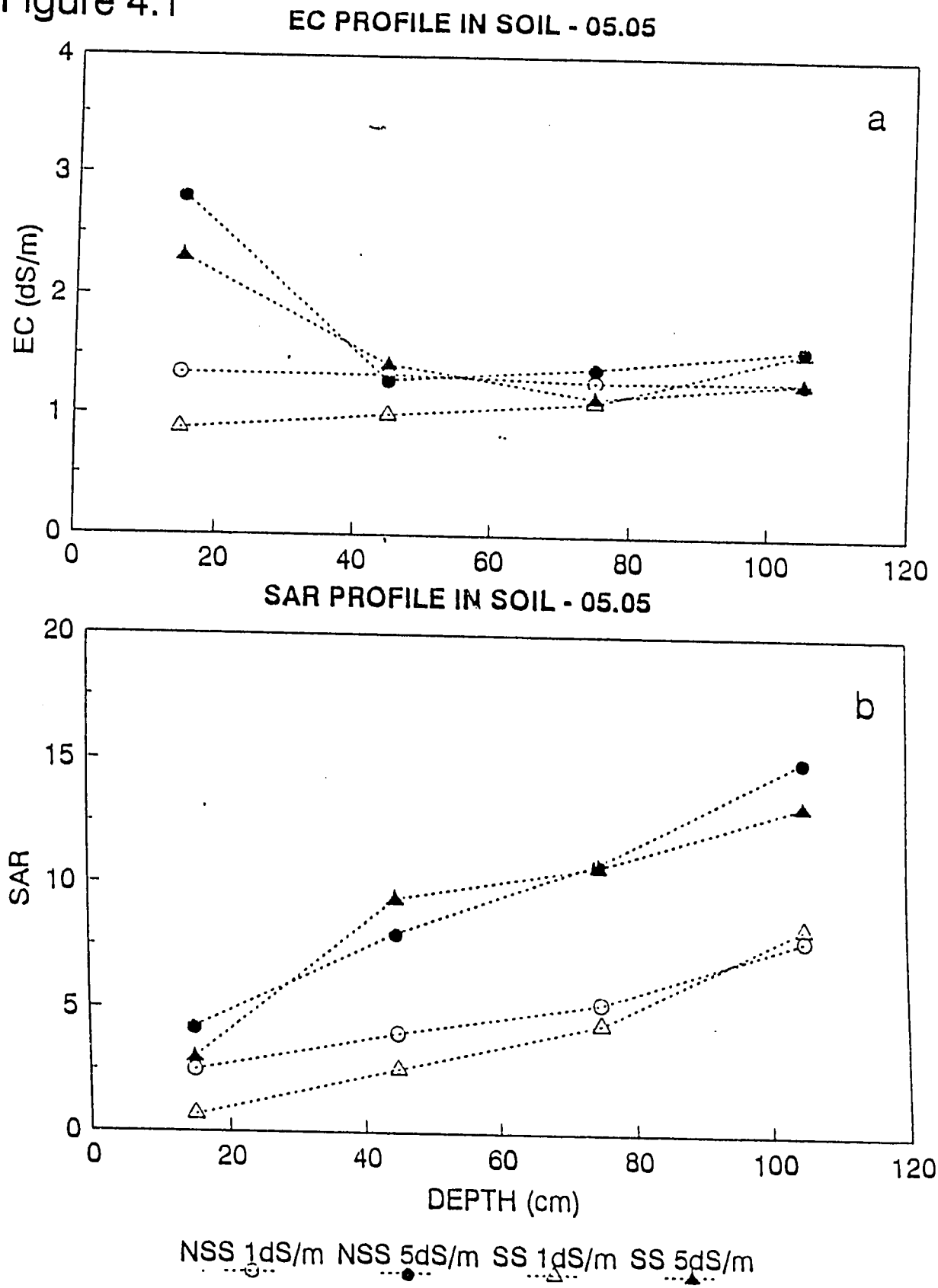

EC PROFILE IN SOIL - 05.05
a
EC (dS/m)
0
1
2
3
4
0
20
40
60
80
100
120
SAR PROFILE IN SOIL - 05.05
b
SAR
0
5
10
15
20
0
20
40
60
80
100
120
DEPTH (cm)
NSS 1dS/m
NSS 5dS/m
SS 1dS/m
SS 5dS/m

Figure 4.2

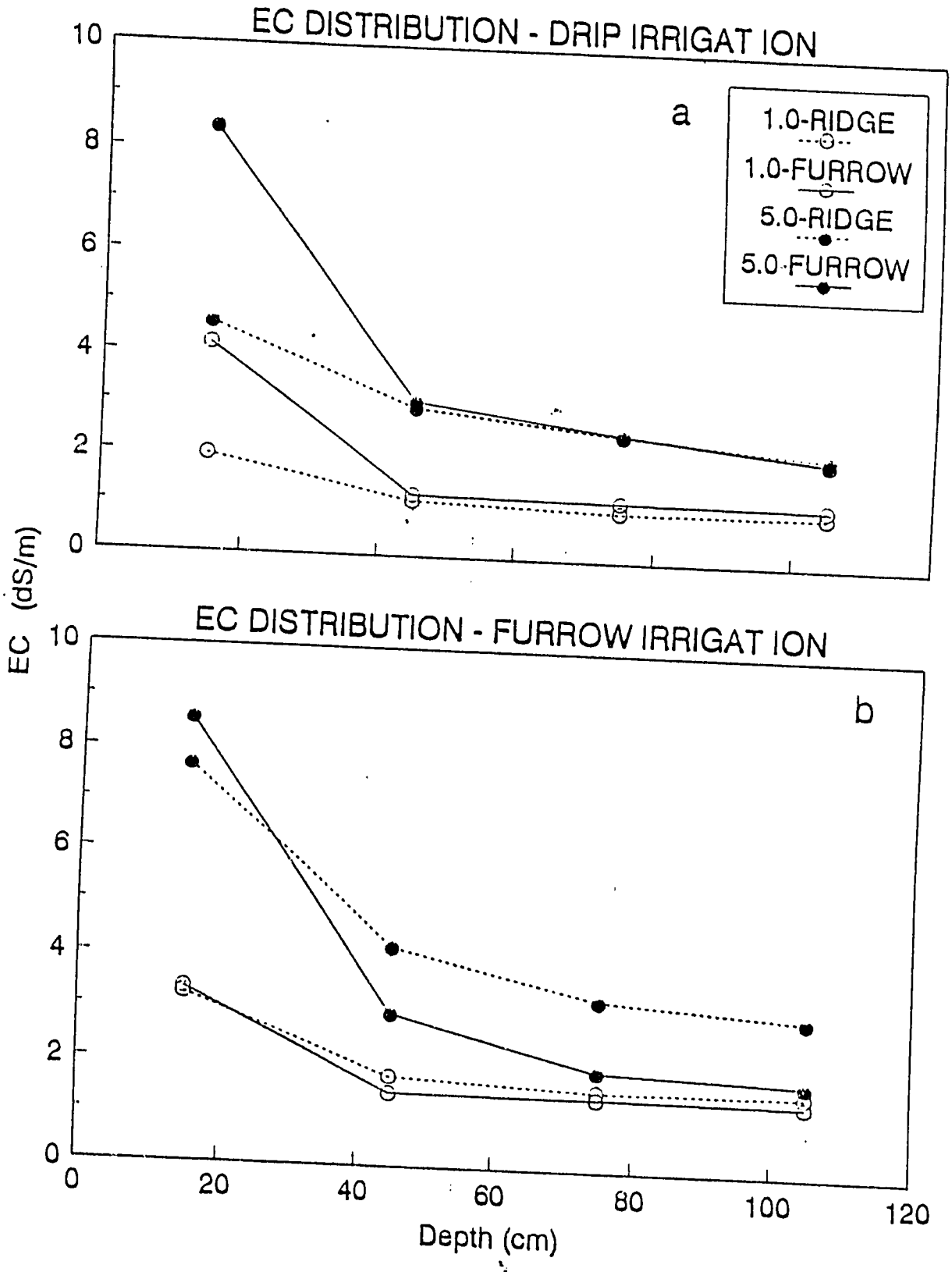
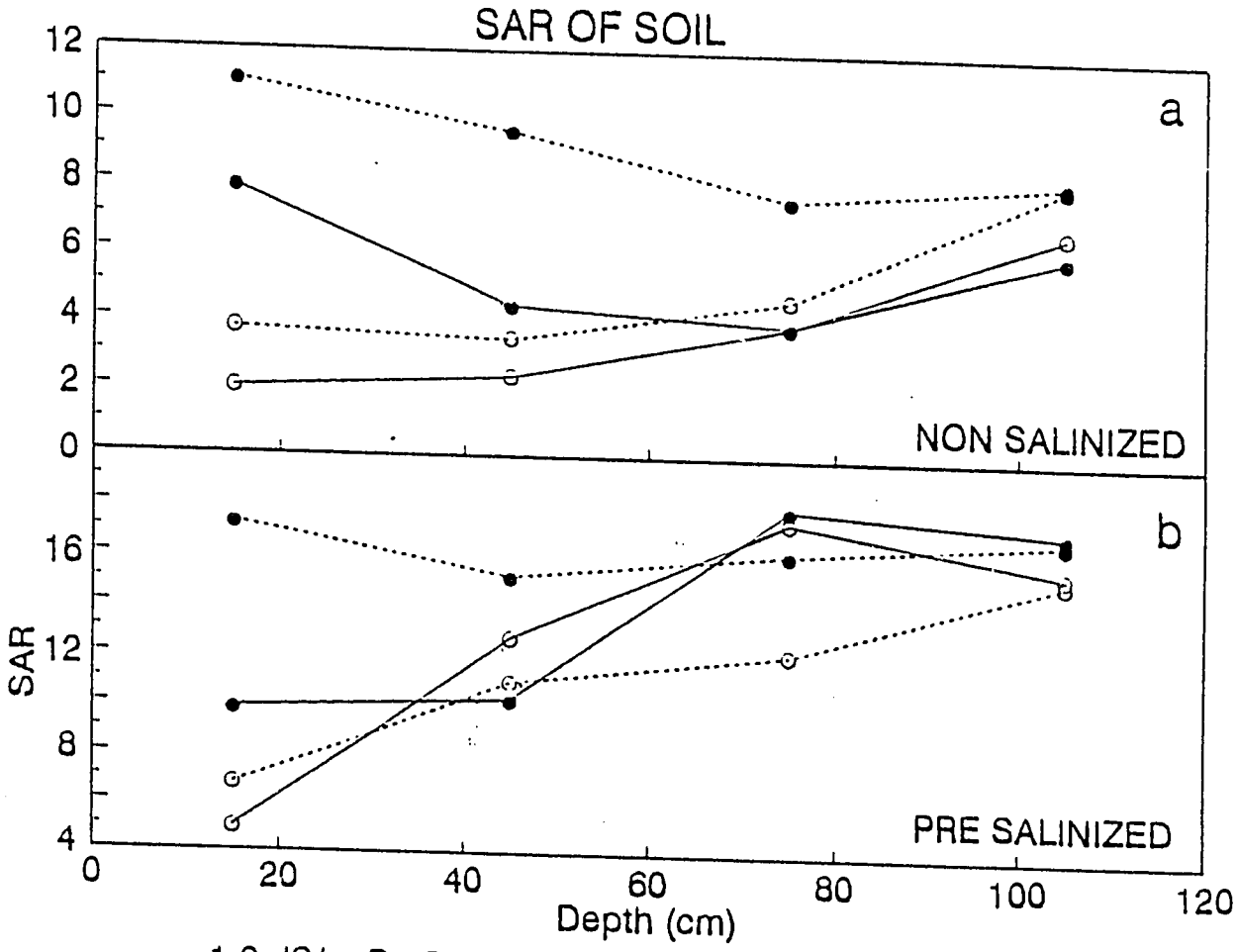

EC DISTRIBUTION - DRIP IRRIGAT ION
a
1.0-RIDGE
1.0-FURROW
5.0-RIDGE
5.0-FURROW
EC DISTRIBUTION - FURROW IRRIGAT ION
b
EC (dS/m)
Depth (cm)
0
2
4
6
8
10
0
20
40
60
80
100
120

Figure 4.3


SAR OF SOIL
a
NON SALINIZED
b
PRE SALINIZED
SAR
Depth (cm)
1.0 dS/m-Dr 5.0 dS/m-Dr 1.0 dS/m-Dr 5.0 dS/m-Fr

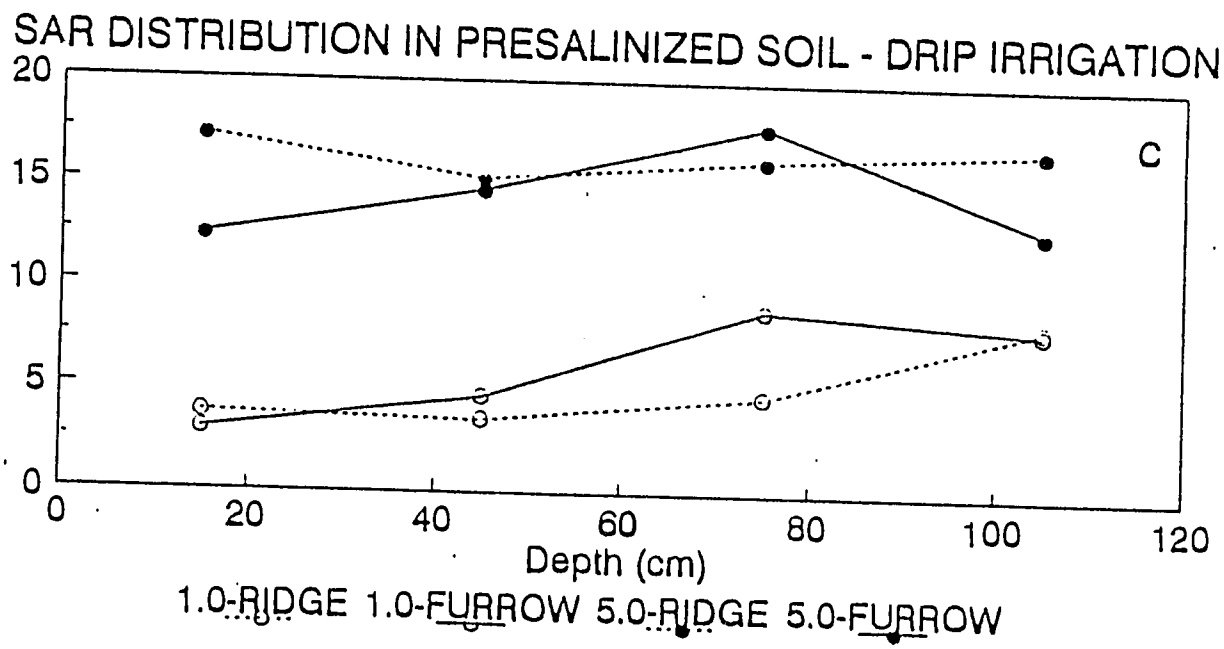

SAR DISTRIBUTION IN PRESALINIZED SOIL - DRIP IRRIGATION
c
Depth (cm)
1.0-RIDGE 1.0-FURROW 5.0-RIDGE 5.0-FURROW

Figure 4.4

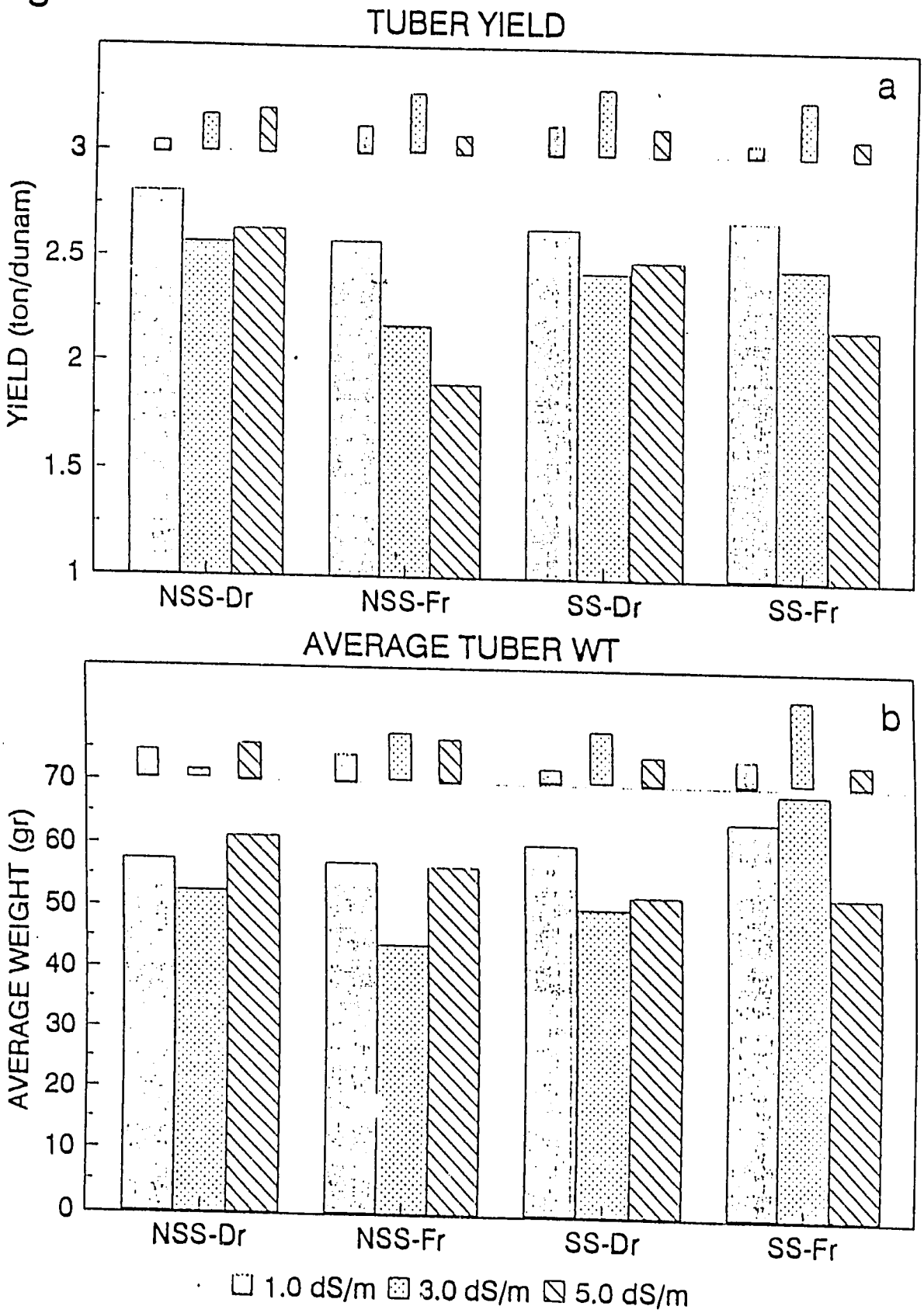

TUBER YIELD
a
YIELD (ton/dunam)
3
2.5
2
1.5
1
NSS-Dr
NSS-Fr
SS-Dr
SS-Fr
AVERAGE TUBER WT
b
AVERAGE WEIGHT (gr)
70
60
50
40
30
20
10
0
NSS-Dr
NSS-Fr
SS-Dr
SS-Fr
1.0 dS/m
3.0 dS/m
5.0 dS/m

Figure 4.5

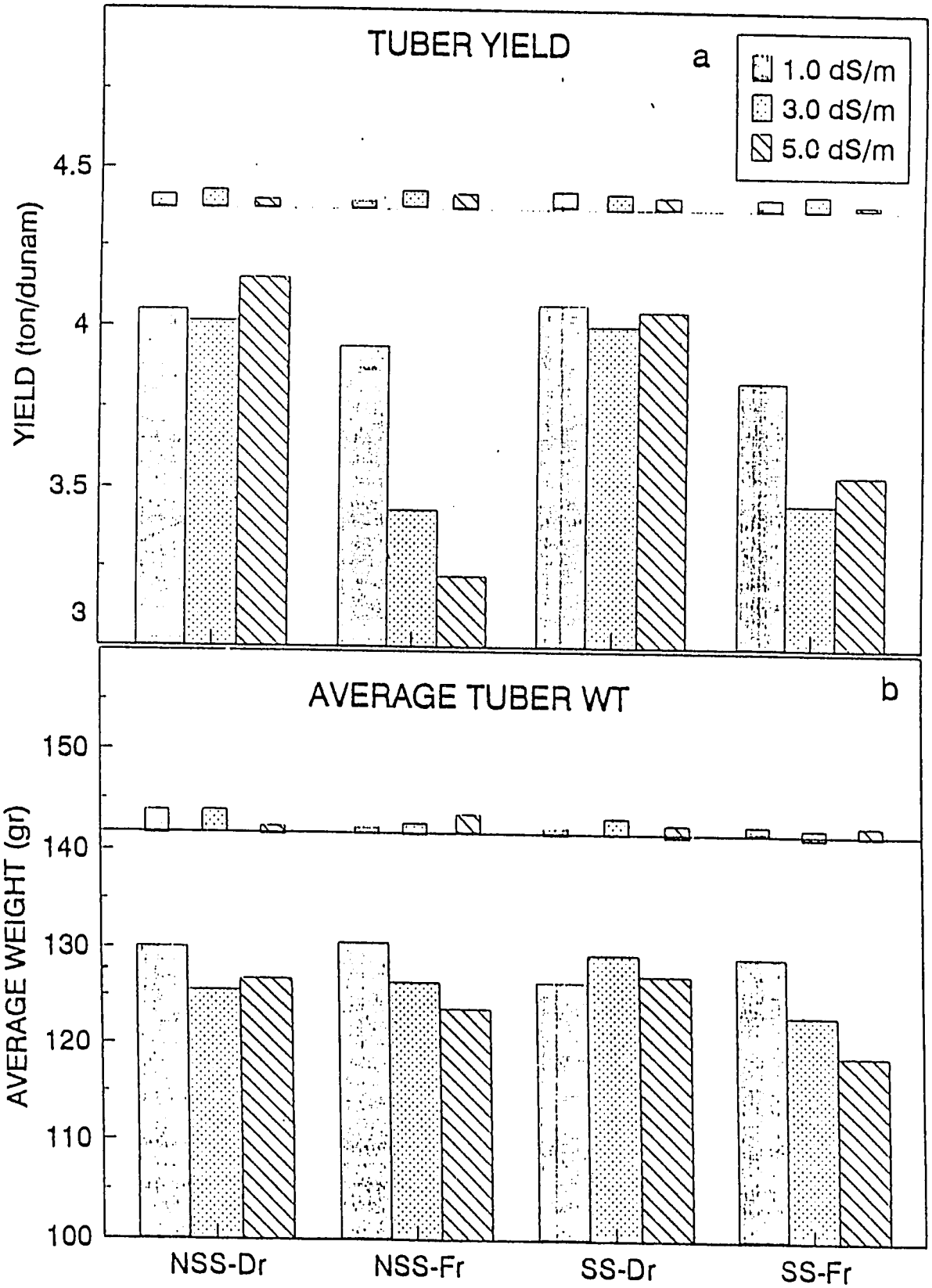

TUBER YIELD
a
1.0 dS/m
3.0 dS/m
5.0 dS/m
YIELD (ton/dunam)
4.5
4
3.5
3
AVERAGE TUBER WT
b
AVERAGE WEIGHT (gr)
150
140
130
120
110
100
NSS-Dr
NSS-Fr
SS-Dr
SS-Fr

Figure 4.6

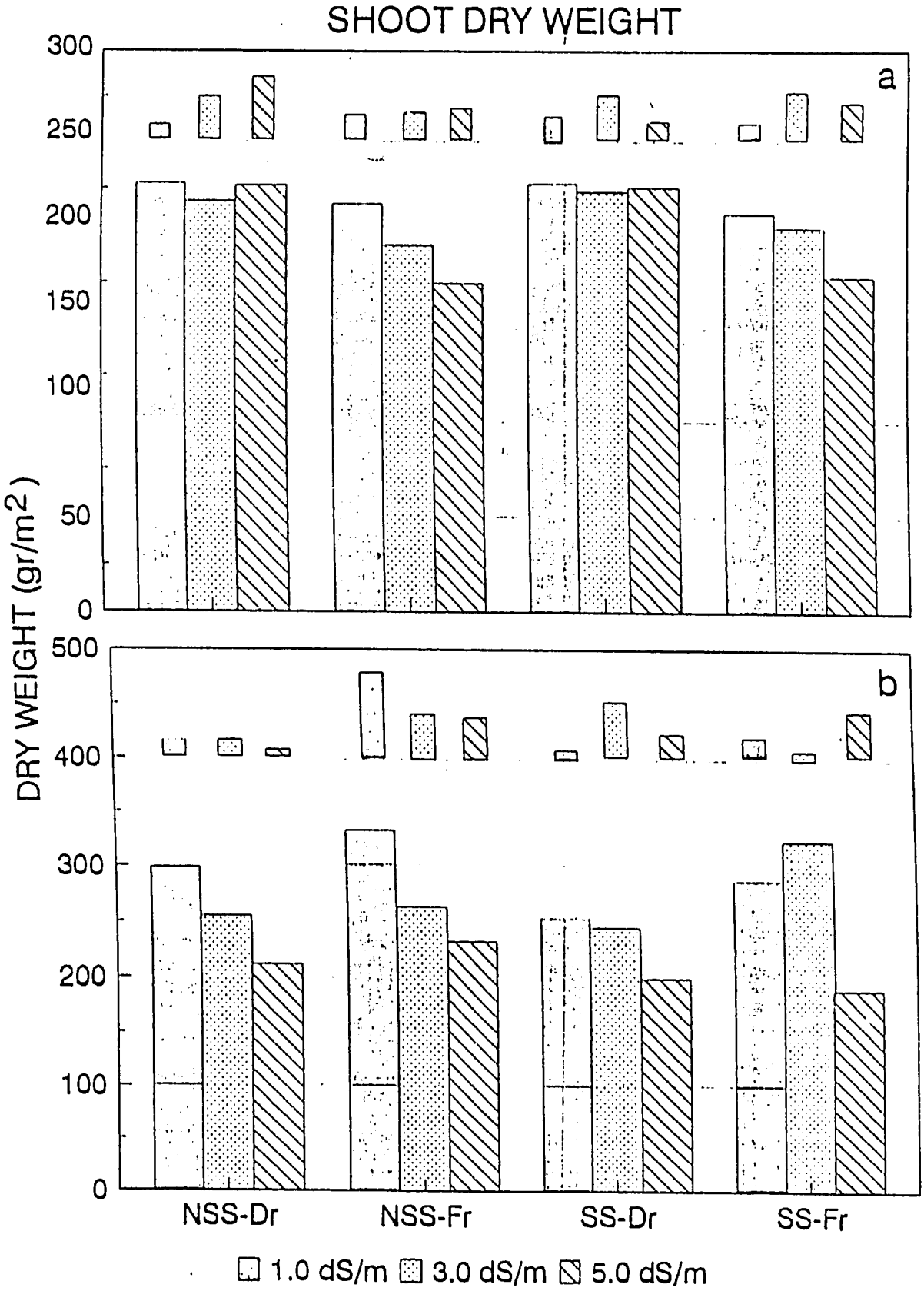

SHOOT DRY WEIGHT
DRY WEIGHT (gr/m2)
a
b
300
250
200
150
100
50
0
500
400
300
200
100
0
NSS-Dr
NSS-Fr
SS-Dr
SS-Fr
1.0 dS/m
3.0 dS/m
5.0 dS/m

Figure 4.7

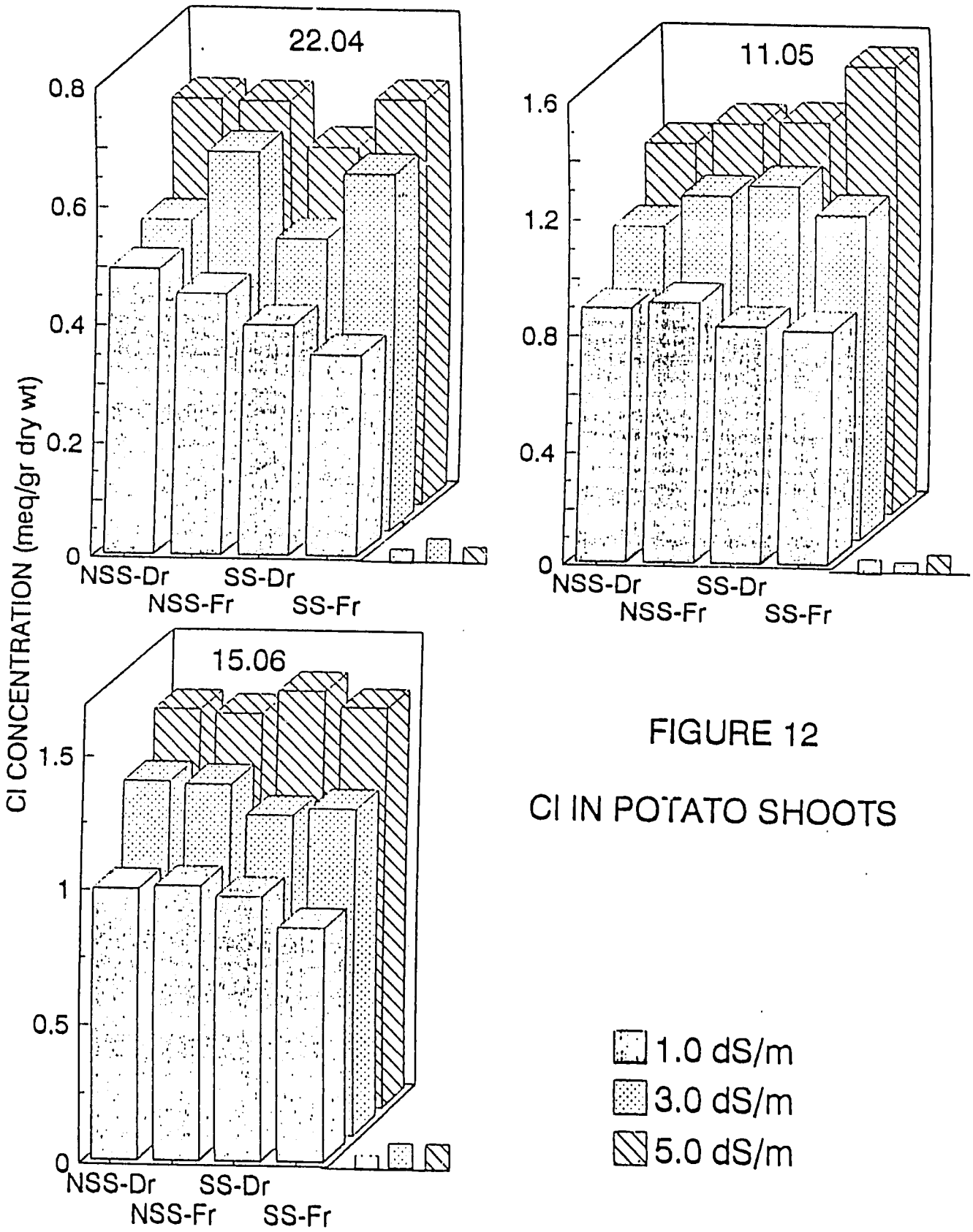


FIGURE 12

Cl IN POTATO SHOOTS

Figure 4.8

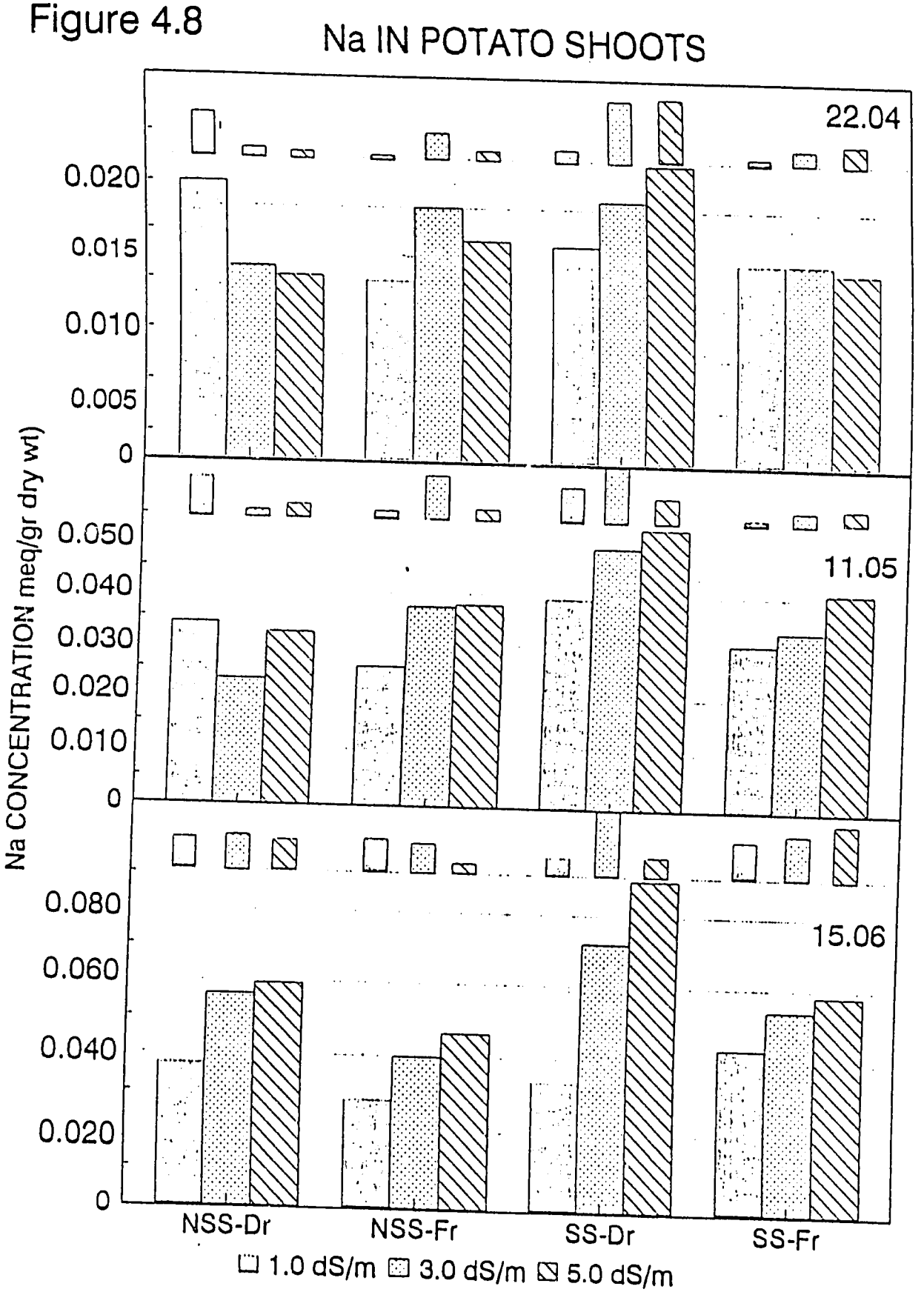
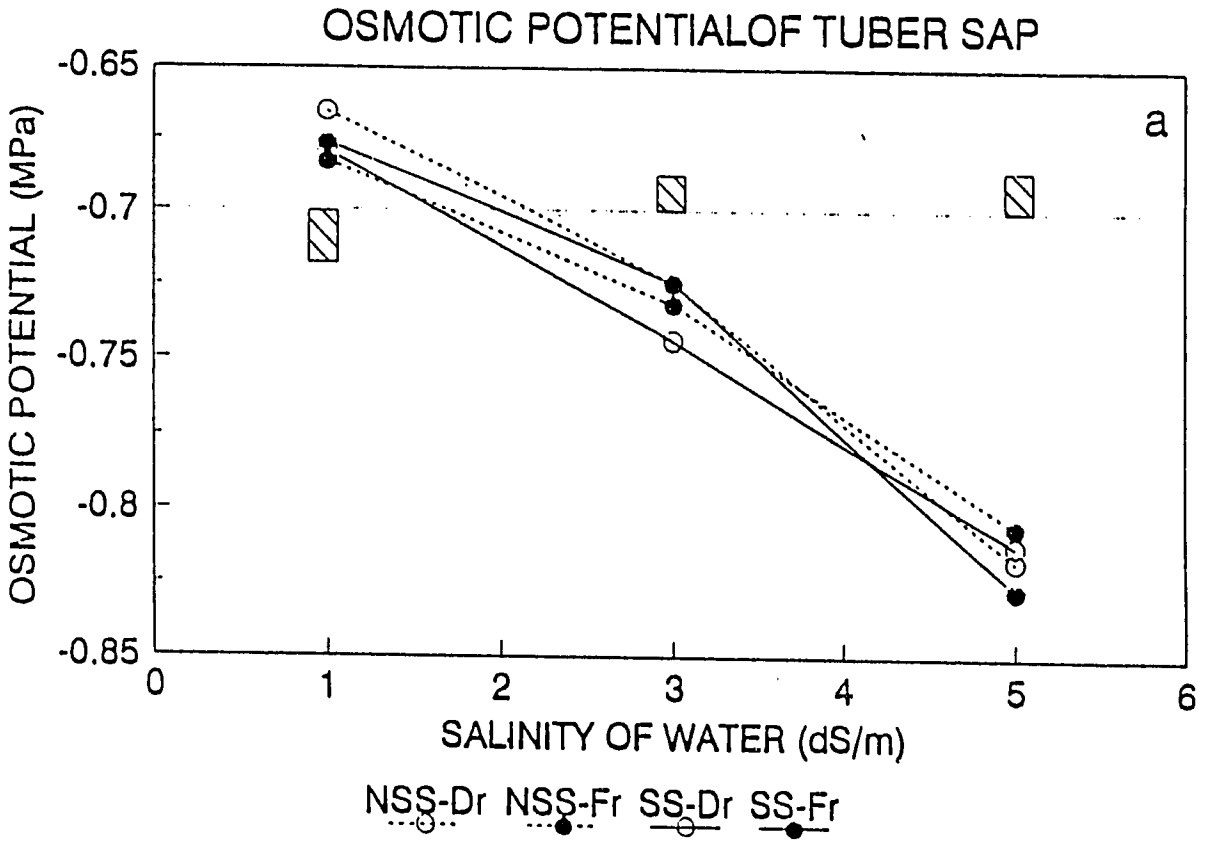

Na IN POTATO SHOOTS
22.04
11.05
15.06
0.020
0.015
0.010
0.005
0
0.050
0.040
0.030
0.020
0.010
0
0.080
0.060
0.040
0.020
0
Na CONCENTRATION meq/gr dry wt)
NSS-Dr
NSS-Fr
SS-Dr
SS-Fr
1.0 dS/m
3.0 dS/m
5.0 dS/m

Figure 4.9


OSMOTIC POTENTIALOF TUBER SAP
a
OSMOTIC POTENTIAL (MPa)
-0.65
-0.7
-0.75
-0.8
-0.85
0
1
2
3
4
5
6
SALINITY OF WATER (dS/m)
NSS-Dr NSS-Fr SS-Dr SS-Fr

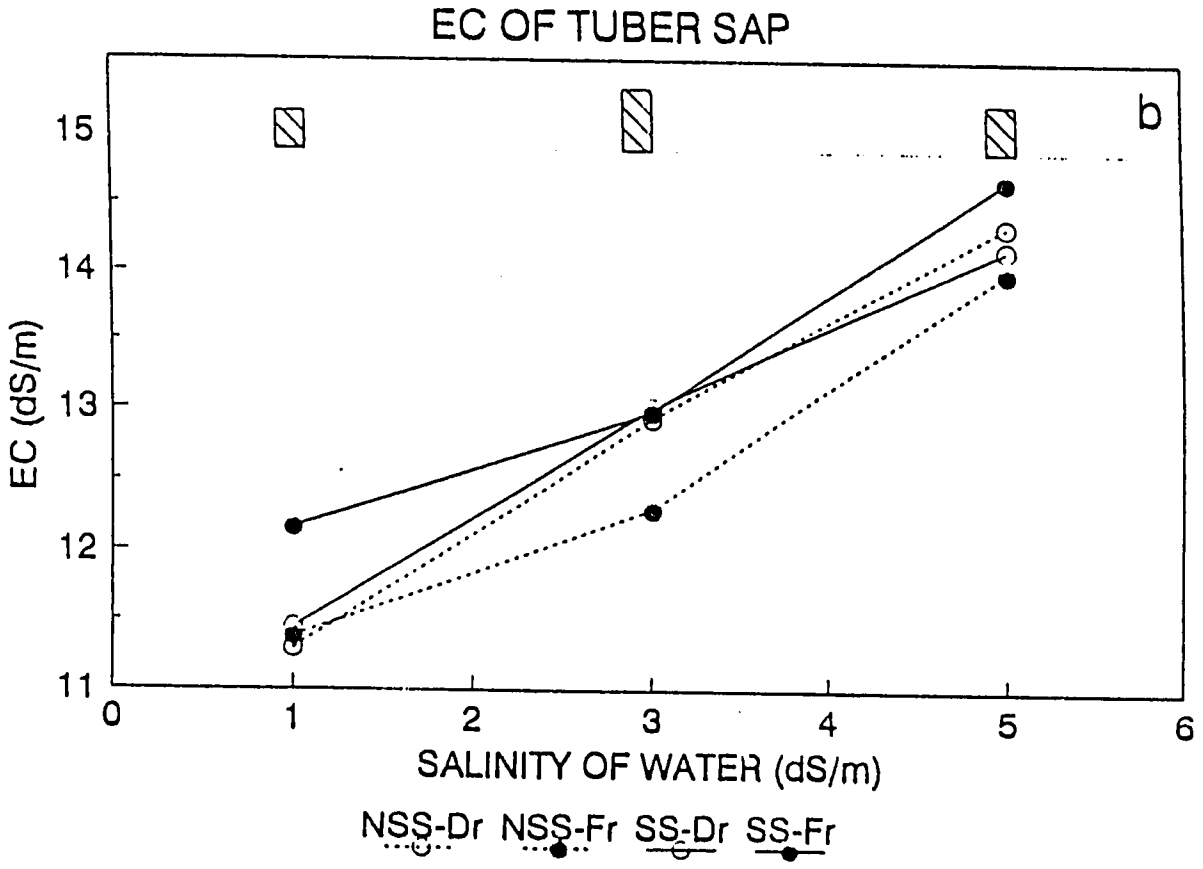

EC OF TUBER SAP
b
EC (dS/m)
15
14
13
12
11
0
1
2
3
4
5
6
SALINITY OF WATER (dS/m)
NSS-Dr NSS-Fr SS-Dr SS-Fr

Figure 4.10

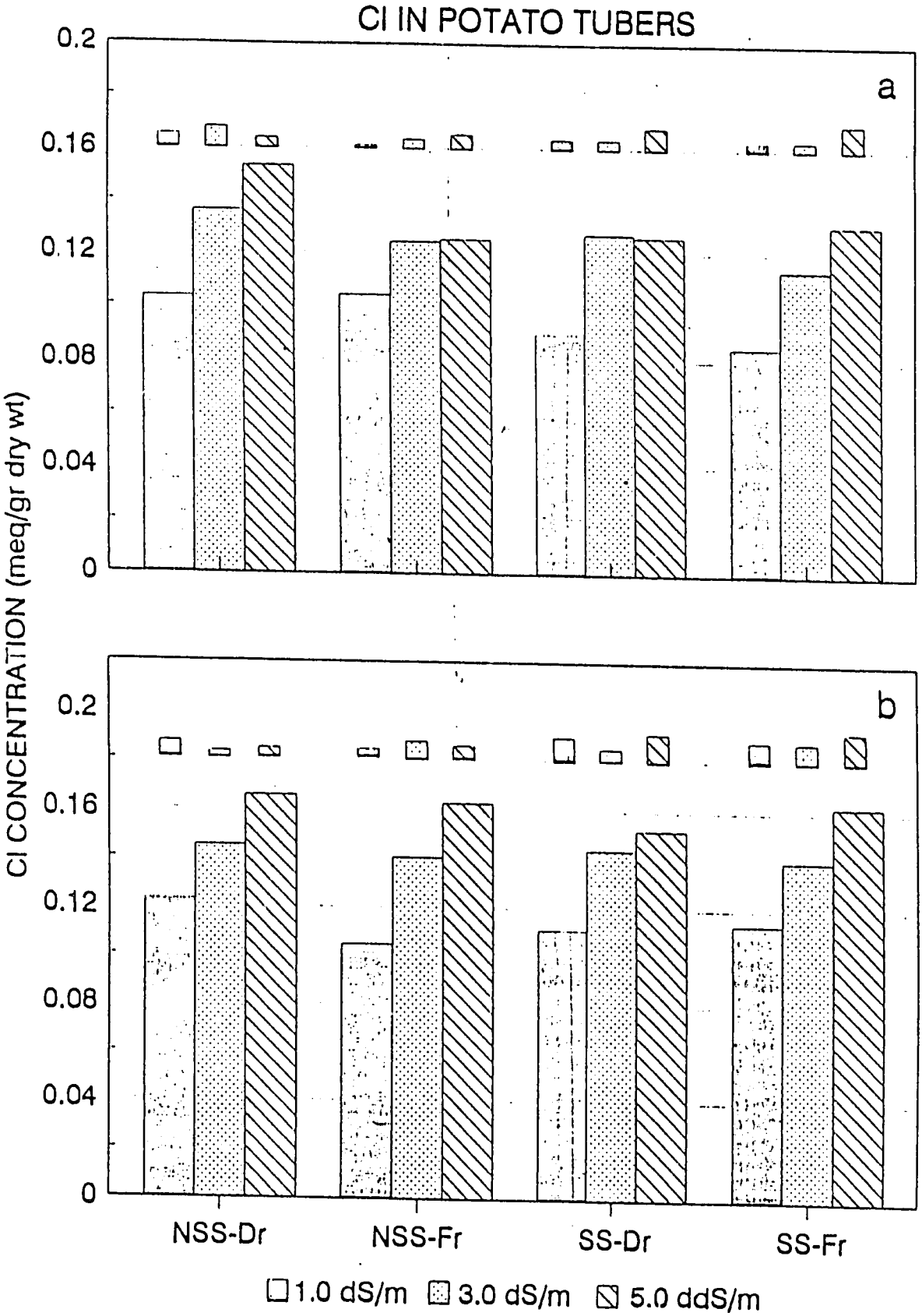
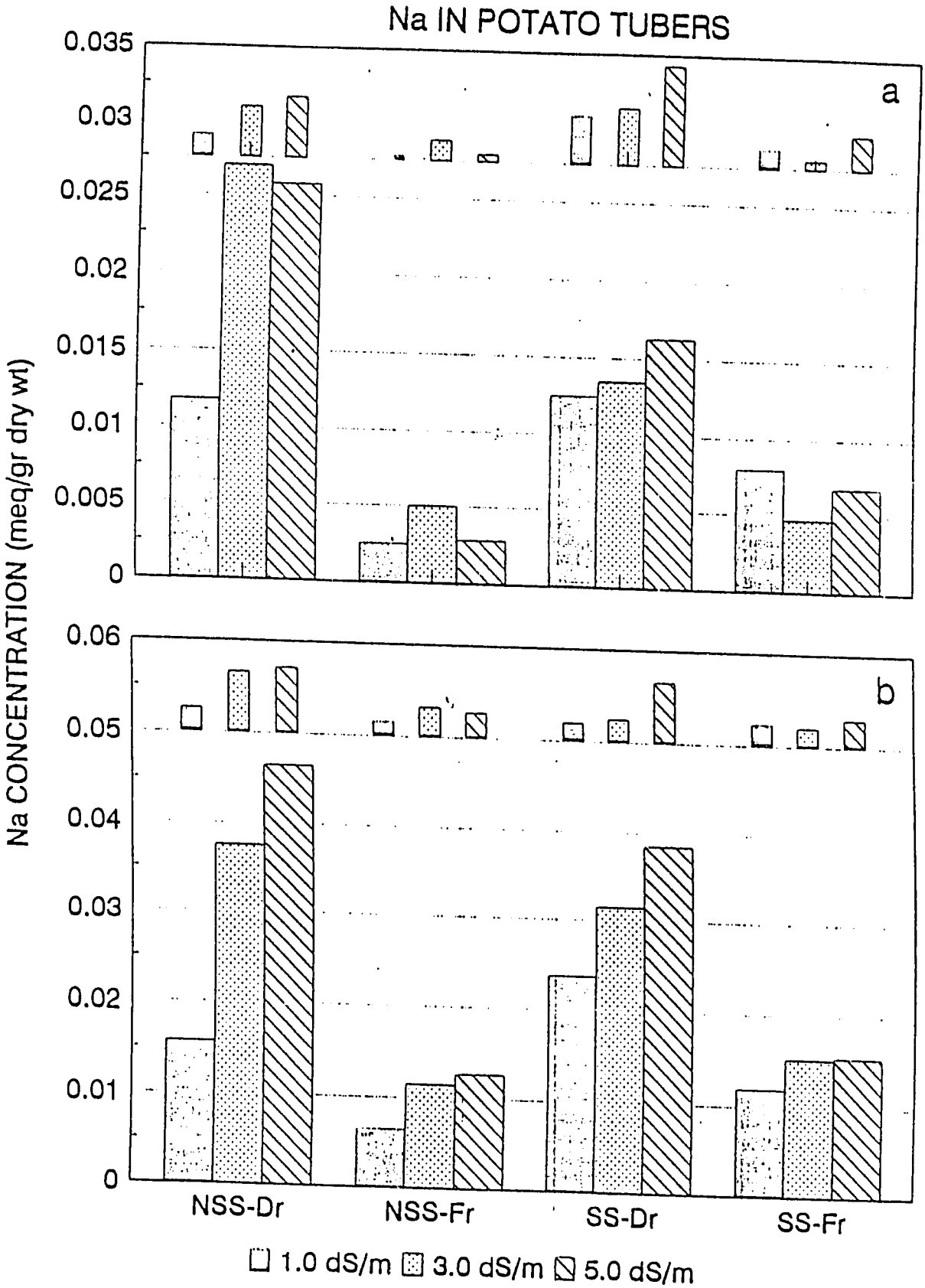

Cl IN POTATO TUBERS
a
b
0.2
0.16
0.12
0.08
0.04
0
Cl CONCENTRATION (meq/gr dry wt)
NSS-Dr
NSS-Fr
SS-Dr
SS-Fr
1.0 dS/m
3.0 dS/m
5.0 ddS/m

Figure 4.11


Na IN POTATO TUBERS
Na CONCENTRATION (meq/gr dry wt)
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
a
0.06
0.05
0.04
0.03
0.02
0.01
0
b
NSS-Dr
NSS-Fr
SS-Dr
SS-Fr
1.0 dS/m
3.0 dS/m
5.0 dS/m

B. Philippines:

The operation of a catchment area, storage of water and its use for corn irrigation with a drip irrigation system.

Introduction

A small pioneer project which can be demonstrated to farmers and then be distributed on a larger scale is described. Rainwater is stored in a small reservoir and is then used for irrigation by a drip system. The investigation was carried out in a climatic condition characterized by a long, dry season of 5-6 months.

MATERIALS AND METHODS

The project component which was the subject of research in the Philippines was to conduct field experiment to test the method of impounding run-off water during rainy season and the consequent application of this water to row crops by drip/trickle method during dry months. The site chosen as the catchment area is a part of the experiment station of the Industrial Technology Development Institute (ITDI formerly NIST) of the Department of Science and Technology located in barrio Molino, Bacoor, Cavite. The province of Cavite falls under Type I climate which is characterized as having ____ distinct wet season* of 5-6 months duration and a dry season of 5-6 months also. This type of climate prevail in all provinces in the western half of Luzon and western Mindoro, Panay and Palawan (Oldeman, 1984)

The catchment area was approximately 5 hectare grasslands (Fig. 1) with patches of leguminous trees mostly Glyricidia sepium. It was estimated that given an annual rainfall of around 1,700 mm and a surface run-off of 25%, the 5-hectare

area would yield about 21,000 cu m which would readily fill up the storage reservoir.

Storage Reservoir

A straight embankment type of reservoir was excavated at the lower portion of the catchment along the natural gully using a back hoe machine. It has a dimension of 15 m wide, 50 m long and 4 m deep (Fig. 2). If full, this reservoir could hold 3,000 cu m of run-off water. The size of the reservoir was determined based on the estimate of crop water requirements including surface evaporation from the reservoir but excluding seepage and percolation losses. These were assumed to be negligible on the basis of the structure of the reservoir bed which is composed of hard unconsolidated material with very low permeability.

Experimental Field

The experimental field used in the study was located within the catchment area at about 50 m away and above the reservoir. Its total area was 0.5 hectare but the actual experiment was only 4,000 sq. m. Every cropping season, the field was thoroughly cultivated as early as first week of December using a disc plow and rotary harrow pulled by a tractor.

Meteorological Record

A standard USDA pan evaporimeter and a non-recording rain gauge were set up at the experimental station. A daily observation on evaporation and rainfall was made for 4 years.

The pan evaporation data were used to estimate the weekly irrigation rates for the crop (Fig. 3).

Test Crop

During the 3-year period of field study, one hybrid and two varities of *Zea mays* (corn) were planted on three different dry cropping seasons in 1990, 1991 and 1992. These are the Hybrid Pioneer Y8G64, IPB Var 1 and IPB Var 5. Corn is a major cereal crop grown in the Philippines for food and feeds. Due to inadequate local production, the country has been importing corn for feeds.

Experimental Design and Lay-out

In order to assess the performance of simple drip irrigation techniques using stored water, a combinations of 4 rates of irrigation and 2 levels of nitrogen fertilizer were tried. The 4 rates of irrigation were based on percentage of total pan evaporation (Ep) a week before water application. These were 55%, 70%, 85% and 100%. The nitrogen levels were 90 and 180 Kg N per hectare.

The experimental design was intended to be a 4 x 2 factorial in split-plot design wherein the irrigation rates would be the main plot and the N fertilizer would be the sub-plot but, because of the impractical way of randomizing irrigation rates by drip system, the resulting design was modified split-plot. The whole experimental field was divided into 5 blocks according to the slope gradient to represent 5 replications. Each block were subdivided into 4 main plots

for the 4 rates of irrigation. Then each main plot was further sub-divided into 2 sub-plot where the 2 levels of nitrogen fertilizer were randomly distributed.

Before corn seed were planted, the drip irrigation system was installed all over the service area. The system consisted of the following components:

1. Head (control consisting of the motorized pump which drew water from the reservoir for distribution to the service area, a filter and a fertilize tank with injector. (Fig. 4)
2. Main lines made of plastic pipes
3. Sub lines
4. Laterals with emitters with capacity 2 l/hr.
5. Check values and flow regulators to deliver water of 2 l/hr.

The field lay-out can be seen in Fig. 5. The sub-plot was 100 sq m containing 7 laterals with a length of 10 m and spaced at 1.4 m. Each lateral contains 20 emitters spaced at 50 cm. interval. Since there were 20 emitters in each lateral and 7 laterals per sub -plot, each sub-plot contains 140 emitters. For the whole service area, there were 2,600 emitters.

System of Planting

The field experiments were conducted only during dry season which starts in December. All field preparation were finished at the beginning of planting started in early January. January each year.

The method of planting was by double-row. Two rows of corn seeds were drilled (one seed/hill) on each side of the

lateral (Fig. 6). The distance of planting between hills was 0.165 m giving a population density of m 84,000 plants per hectare. There were two varieties and one hybrid corn used in the experiment. Hybrid Y8G64 was planted in the first season of 1990, IPB Var 1 in the second year (1991)and IPB Var 5 in the third year (1992).

Irrigation Schedule

Water application was done on a weekly basis. The amount of water applied for the week was calculated based on the total Class A pan evaporation for the past week multiplied by the predetermined rates: 55%, 70%, 85%, and 100%. Weekly irrigation was done from planting stage up to 90 days. Stored water in the reservoir was pumped up using Kirloskar coupled to a 16 HP Briggs & Stratton . The operating pressure during irrigation 2.5 atmosphere. With a timing device, the amount of irrigation was accurately given.

Nitrogen in the form of ammonium sulphate solution was applied in stages. One third of the total amount was applied 15 days after planting. Another one third was given at 30 days and the remaining amount was given at 45 days after planting. A fertilizer injector was used in controlling the application. Thus device was attached at the Head component of the drip irrigation system.

Data Gathered

The standard data sets gathered during the 3-year cropping experiments were growth and yield response, soil

moisture conditions and weather data. The equipment bought for measuring field photosynthesis and transpiration did not work very well until 90 days after planting.

Growth was measured in terms of change iin height of the crop over a certain time intervals. Five one-week old seedlings were randomly identified and marked in the experimental unit consisting of 7 double hedge rows.

Relative Water Content. Relative water content is a measure of the water status of the plant. It is the ratio of the actual water content of the leaf tissue to the water content of the same tissue when fully turgid (Eq.1)

$$R = \frac{FW - DW}{TW - DW} \times 100 \quad (1)$$

where R is the relative water content of the leaf disc, FW and TW are fresh weights and turgid weight respectively. It was determined by cutting small size leaf disk (5 mm dia) on fully expanded corn leaves and measured their fresh weight on analytical balance sensitive to 0.1 mgm. And then the disk were floated in the petri dish containing water until they become turgid. Then they were surface dried and weighed to give turgid weight (TW). The disks were then oven-dried at 80 ^{o}C. DW is the oven dry weight. R was measured at 1:00 PM.

Grain Yielld. At 100-105 days after planting, the crop was harvested. Five samples plants which were randomly identified and tagged 5 days after germination and from which other measurements such as height and leaf width were made were harvested to estimate yield. The grain/kernel were

separated from the cob, sun-dried to 14% moisture and weighed. The other yield estimate was made by harvesting the 3 center double rows having an area of 280 sq m. Corn ears were shelled and sun-dried to 14% moisture and weighed. In both estimates, the yield was extrapolated to a hectare basis.

Width of leaves.. Size of the leaves could reflect the effect of treatments. In this study the width of sample leaves was measured at their widest margin. Leaves which were sampled were the first fully expanded ones from the top.

Length of corn ears. This parameter was measured on corn ears of five sample plants in each replicate at harvest.

Soil moisture profiles. The dynamics of soil moisture in time and space was determine in irrigation level 80% Ep. At mid-vegetative stage, soil moisture was determined by standard method on soil samples taken at various distances from the dripper and at different depths just after water was applied and 7 days later. Soil samples were oven dried to constant weight at 105 deg C.

RESULTS AND DISCUSSION

Rainfal Pattern

The rainfall pattern during the 4 year period from 1989 to 1992 is shown in Fig. 7. Two distinct seasons are indicated: Wet from May to November, dry from Dec. to April. The rainfall events in the months of May and November which are the beginning and the tail-end of the rainy season respectively, are highly variable. In some years, the start

of rainfall is delayed until the last week of May. Out of 4-year observations, there was zero and 2 rainy days in May of 1991 and 1992, respectively (Fig. 8 and Table 1). The average annual rainfall is 2,053 mm. With this quantity, the 5-hectare catchment was more than sufficient to yield surface run-off for the reservoir.

Evaporation Pattern

Standard pan evaporation is also variable as shown in Fig. 9. The highest evaporation occurs in dry season ranging from 5 to 91 mm per day in Jan. and April, respectively. The average daily evaporation from Jan to May is 7 mm. as 5 mm per day which was used in estimating the water requirements of the crop, hence the size of the reservoir.

An analysis of rainfall/evaporation pattern such as this is important in developing water resource management scheme for dry season agriculture. By plotting rainfall and pan evaporation on the same scale as done in Fig. 10 it is obvious that the highest pan evaporation coincides with the lowest rainfall and high temperature. Areas between two curves represent water deficit or excess water supply period.

Water Impoundment

The water reservoir which was built to store run-off water equivalent to the water requirement of crops was easily filled up at the early part of rainy season. However, the stored water was not enough to complete the irrigation needs of the crops up to maturity. It has to be augmented by other

sources like stream and dam. Obviously, water losses due to surface evaporation and percolation were under estimated.

Grain Yield

The yield response of corn varieties to drip irrigation under two levels of nitrogen is shown in Tables 2-4. Table 2 is the yield data for hybrid pioneer Y8G64. Under 90 Kg/ha the yield increases from 5.4 to 6.6 t/ha although the difference is not statistically significant. At 180 Kg N/ha, the yield at 100 Ep is significantly higher than that at 55% Ep. Also, at the highest irrigation rate, the yield at 180N is higher than that at 90 N. Obviously there was interaction of irrigation rate and nitrogen fertilizer at the highest irrigation scheme.

Table 3 shows the response of IPB Var 1 to irrigation and nitrogen. The yield at 55% Ep which is 2.5 t/ha is obviously lower than that at 100% Ep under lower nitrogen level. At higher nitrogen, the yield is statistically the same in all levels of irrigation.

The yield of IPB Var 5 is shown in Table 4 to be significantly lower at 55% Ep than the rest of irrigation rates at both nitrogen levels.

Although not statistically significant, the trend is clear that the yield of all corn varieties increased with increasing rates of drip irrigation. Of course it is needless to say that without irrigation no single plant could survive drought. Except for Pioneer Y8G64, the response to nitrogen was not significant. The yield response curves for the 3

varieties of corn is given in Fig. 11-13. It is clear that from 70% Ep upwards the corn yields were statistically the same. In other words 70% Ep seemed to be the optimum level of irrigation for corn. Any further increase in water application would not result to increase yield significantly. The ratio of water applied to the amount of grain yield in kg. water per kg grain yield was calculated for the 3 corn varieties and the result is shown in Table 5. Of the 3 varieties, IPB Var 5 gave the lowest ratio of 427 in response to irrigation rates and in nitrogen level which is 407. These figures are lower than the reported values elsewhere. The ratio is indicative also of the amount of transpiration needed to produce a unit of grain yield.

The amount of grain yield that may be produced by applying a unit of irrigation water was calculated and shown in Table 6. This ratio, called water use efficiency, (WUE) is higher toward a lower level of irrigation, but higher in higher nitrogen level. The highest WUE of 2.5 gm grain yield per kg of water applied is found in IPB Var 5. In general, this variety has a higher WUE than the other two varieties with respect to irrigation and nitrogen fertilization.

Length of Corn Ears

The length of corn ears in IPB Var 5 irrigation rates and nitrogen level (Table 7). Beyond 55% Ep, variation in corn ears was not obvious. In the case of nitrogen effect, corn ears were longer at higher nitrogen level.

Width of Leaves

Measurement of the width of leaves at their widest margin are reported in Table 8. Width is narrow at 55% Ep for all irrigation is 9.3 cm. Plants applied with 180 Kg N had wider leaves and apparently wider surface area.

Relative Water Conduct

Relative water content reflects the water status of plants during sampling time. A spot determination of this parameter in IPB Var 5 at vegetative stage at 1:00 PM shows that plants at higher irrigation rates (85, 100%) had higher relative water content or less water deficit than those at the lower level of irrigation (Table 9). Nitrogen application did not cause difference in relative water content. In other words, plants were able to maintain a good water status even at mid-day, when evapotranspiration at this time is maximu, at higher levels of drip irrigation.

Crop Growth

The pattern of growth at various ages is shown in Fig. 14. The shift of growth rate from linear (up to 45 DAP) to experimental rate started at 45 DAP onwards. Take note that the separation of effects due to irrigation took place at the latter stage of growth. There seems to have only 2 populations between 76-90 DAP: those which were irrigated 55% Ep and those crops irrigated beyond 55%.

Soil Moisture

Soil moisture depletion profile shows that the plant draws more water in soil volume under the dripper and near the surface. Regions further from the dripper point contributed less to the water needs of the plant.

Corn crop grown under dry season has responded exceedingly well to drip irrigation in this study. Exhibiting a very high yield of 4-8 tons per ha. in marginal soil which is not agriculturally used during dry season is totally unexpected. The yield performance is consistent with the other morpho-physiological parameters such as leaf width, ear length and relative water content. The ears and kernel are of very good quality as they look robust and shiny.

The response curve of corn appears to indicate that irrigation rate at 70% Ep is the optimum level with regards to water use efficiency (WUE) for all varieties studied and for both N level. Beyond 70%, WUE declined. Producing 1-8 g grain per Kg of water applied is quite high. The high efficiency may be largely due to the drip method of water applications and also to the combination of environmental factors such as high solar radiation, absence of insect pests and diseases and excellent soil moisture condition.

The good performance of the simple drip system is an attribute of the technology inspite of the poor quality of the water impounded. The impounded water was turbid due to suspended silt. This material came from the nearby road construction. The excellent filtering system may have contributed a great deal.

The coupling of the drip system to water impoundment makes the latter an attractive proposition. Small water impoundment is a currently done in many places in Central Luzon, but they are mainly for fish culture. Transporting this water to the farm is another matter, especially if it requires muscle exercise. But with the drip system to convey the water to the cultivated farm, it is now possible to grow crops even in marginal lands during dry season.

Table 1. Number of rainy days with 5 mm or more per day rainfall.

	1992	1991	1990	1989	TOTAL	MEAN
Jan	0	0	0	0	0	0.0
Feb	1	0	1	3	5	1.3
Mar	0	2	1	1	4	1.0
Apr	0	0	0	[illegible]	0	0.0
May	2	0	12	8	22	5.5
Jun	6	8	16	7	37	9.3
Jul	16	14	15	16	61	15.3
Aug	20	21	18	15	74	18.5
Sep	17	10	13	11	51	12.8
Oct	4	2	8	9	23	5.8
Nov	6	4	6	2	18	4.5
Dec	1	0	1	0	2	0.5
SUM	73	61	91	72	297	74.25
MEAN	6.1	5.1	7.6	6.0	24.8	6.2

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Table 2.Yield of corn hybrid Pioneer Y8G64 at various levels of irrigation during dry season in 1990.

Rate-irrigation (%Ep)	Total water applied (CM/ha)	Yield (t/ha)* 90kg N/ha	180kg N/ha
55	2820	5.4 b	6.7 b
70	3460	5.7 b	7.9 ab
85	4060	6.4 b	7.9 ab
100	4700	6.6 b	10.4 a

* at 14% moisture content

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Each value is the average of 5 replication

Table 3. Yield of Corn Variety IPB Var 1 at various levels of drip irrigation during the dry season, 1991.

Rate-irrigation (%Ep)	Total water applied (CM/ha)	Yield (t/ha)*	
		90kg N/ha	180kg N/ha
55	2960	2.5 b	3.9 ab
70	3420	4.1 a	4.3 a
85	4080	4.3 a	4.0 ab
100	4720	4.3 a	4.7 a

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Each value is the average of 5 replication

Table 4. Yield of Corn Variety IPB Var 5 at various levels of drip irrigation during the dry season, 1992

Rate-irrigation (%Ep)	Total water applied (CM/ha)	Yield (t/ha)*	
		90kg N/ha	180kg N/ha
55	2360	4.6 b	5.1 b
70	2880	7.5 a	8.2 a
85	3420	7.8 a	8.4 a
100	3900	8.4 a	9.4 a

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Each value is the average of 5 replication

Table 5. Ratio of water applied to the amount of grain yield (Kg. water applied per Kg of grain yield.)

WATER APPLIED (% Ep)	NITROGEN LEVEL 90 N	180 N	Mean
A. Hybrid Pioneer Y8G64			
55	525	418	471
70	601	437	519
85	636	510	573
100	711	457	584
Mean	618	455	537
B- IPB Var 1			
55	1172	755	963
70	836	797	816
85	956	1016	986
100	1086	999	1042
Mean	797	892	844
C. IPB Var 5			
55	508	462	485
70	384	350	367
85	438	404	421
100	461	413	437
Mean	448	407	427

Table 6. Water use efficiency at various irrigation and nitrogen levels of three corn varieties (in kg grain yield per kg wateer applied)

WATER APPLIED (% Ep)	NITROGEN LEVEL 90 N	180 N	Mean
A. Hybrid Pioneer Y8G64			
55	1.9	2.4	2.1
70	1.7	2.3	2.0
85	1.6	2.0	1.8
100	1.4	2.2	1.8
Mean	1.6	2.2	1.9
B. IPB Var 1			
55	0.8	1.3	1.4
70	1.2	1.3	1.25
85	1.0	1.0	1.0
100	0.9	1.0	0.95
	0.97	1.1	1.15
C. IPB Var 5			
55	2.0	2.2	2.1
70	2.6	2.8	2.7
85	2.3	2.5	2.4
100	2.2	2.4	2.3
Mean	2.3	2.5	2.4

Table 7. Average length of IPB Var 5 corn ears (cm) at various levels of irrigation and nitrogen

RATE OF IRRIG. (% Ep)	NITROGEN LEVEL 90 N	180 N	MEAN
55	13.8	14.2	14.0
70	15.5	17.7	16.6
85	15.8	16.8	16.3
100	15.6	17.4	16.5
MEAN	15.2	16.5	15.8

TABLE 8. Average width of IPB Var 5 leaves at their widest margin (in cm).

RATE OF IRRIG. (% Ep)	NITROGEN LEVEL		
	90 N	180 N	MEAN
55	8.9	8.7	8.8
70	8.9	10.1	9.5
85	9.1	9.8	9.4
100	9.1	10.1	9.6
MEAN	9.0	9.7	9.3

Table 9. Relative water content of IPB Var. 5 corn crop at vegetative stage under various irrigation and nitrogen levels taken at 13:00 hours.

RATE OF IRRIG. (% Ep)	NITROGEN LEVEL		
	90 N	180 N	MEAN
55	94.5	92.5	93.3
70	93.7	94.7	94.7
85	98.9	99.8	99.3
100	98.5	97.0	97.7
MEAN	96.4	96.0	

Table 10. Soil moisture profile at various distances from the point zero of the dripper. Just irrigation after and 7 days later. Data are in per cent dry weight

DEPTH (cm)	DISTANCE FROM DRIPPER (cm)			
	0	10	20	30
	Just after irrigation			
0	71	58	41	19
10	56	53	45	44
20	55	51	37	52
30	51	27	60	62
	7 Days after irrigation			
0	30	24	21	22
10	28	31	25	26
20	27	22	27	28
30	23			

Fig. 1 The catchment area with grass cover

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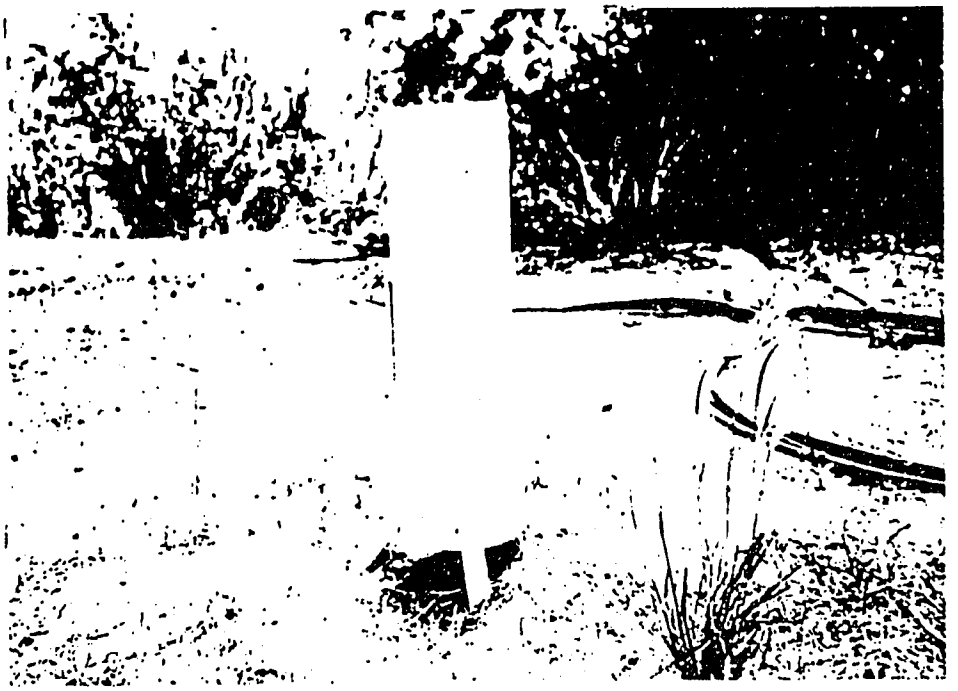
Fig. 2. The water reservoir



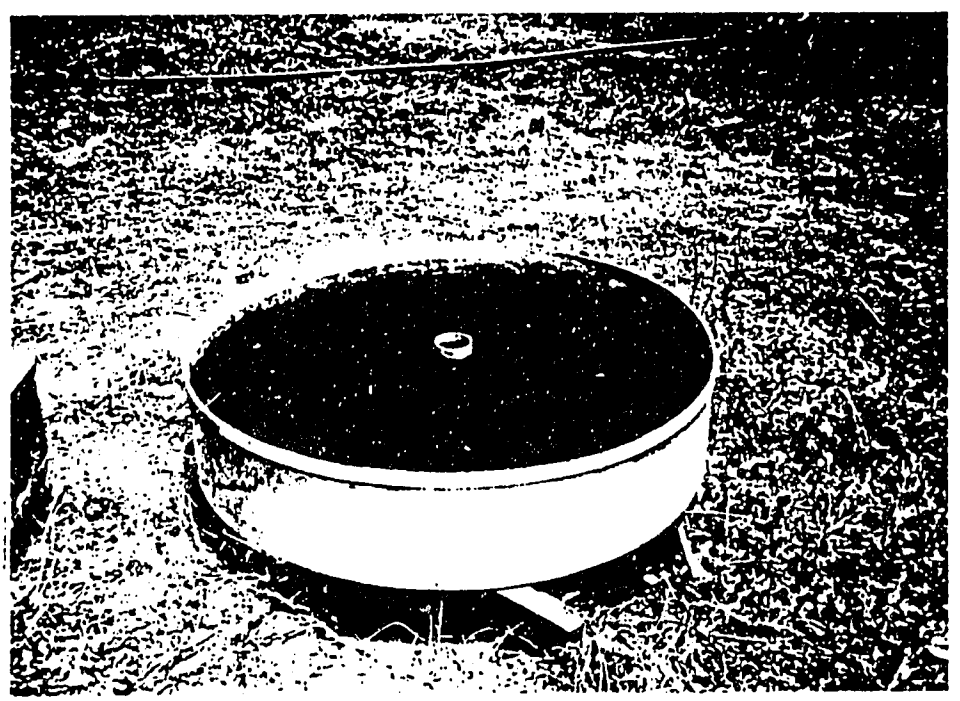


Fig. 3. Raingauge and standard pan evaporimeter

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Fig. 4. A motorized pump

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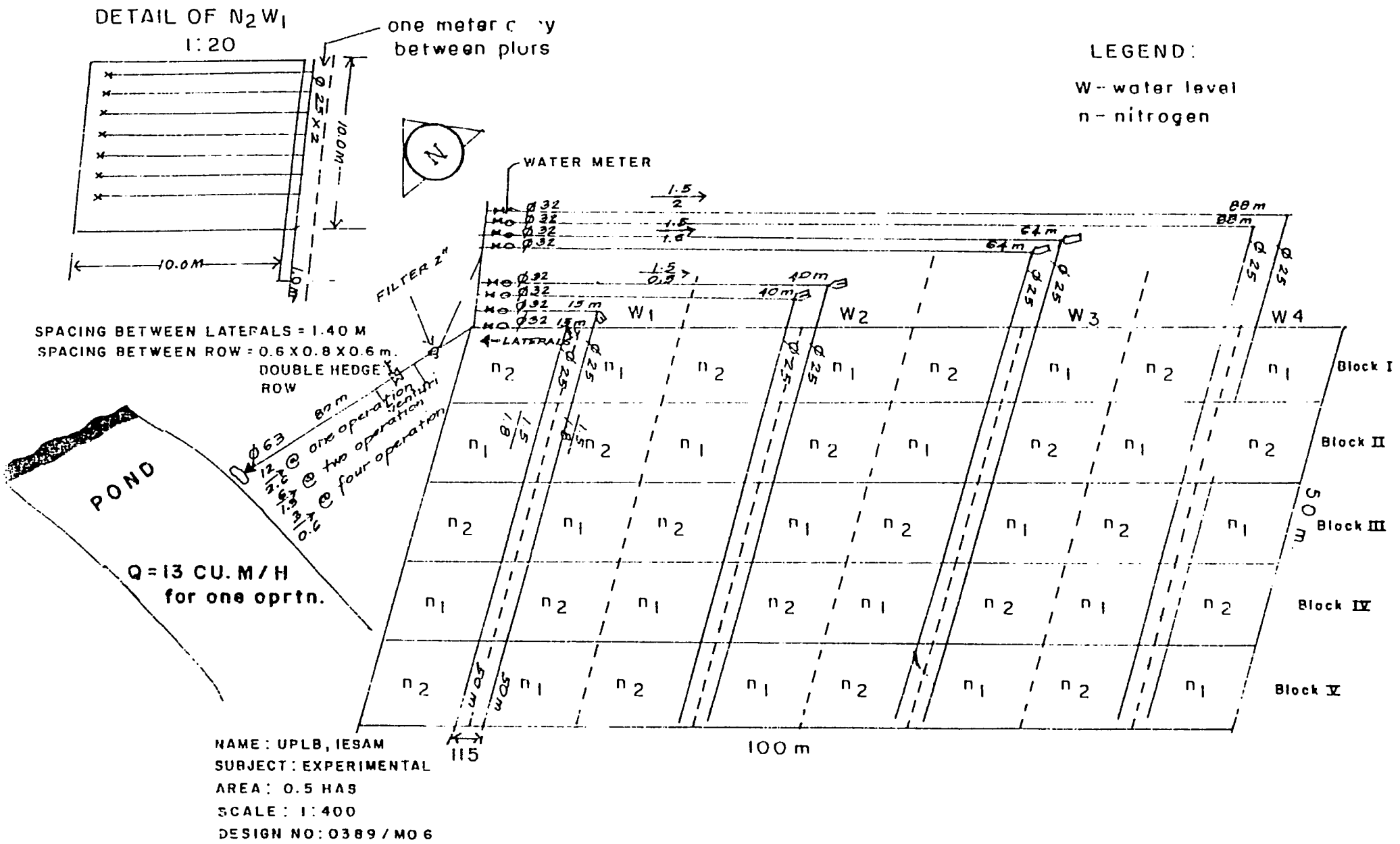

Figure 5. Design and Lay out of Field Experiment

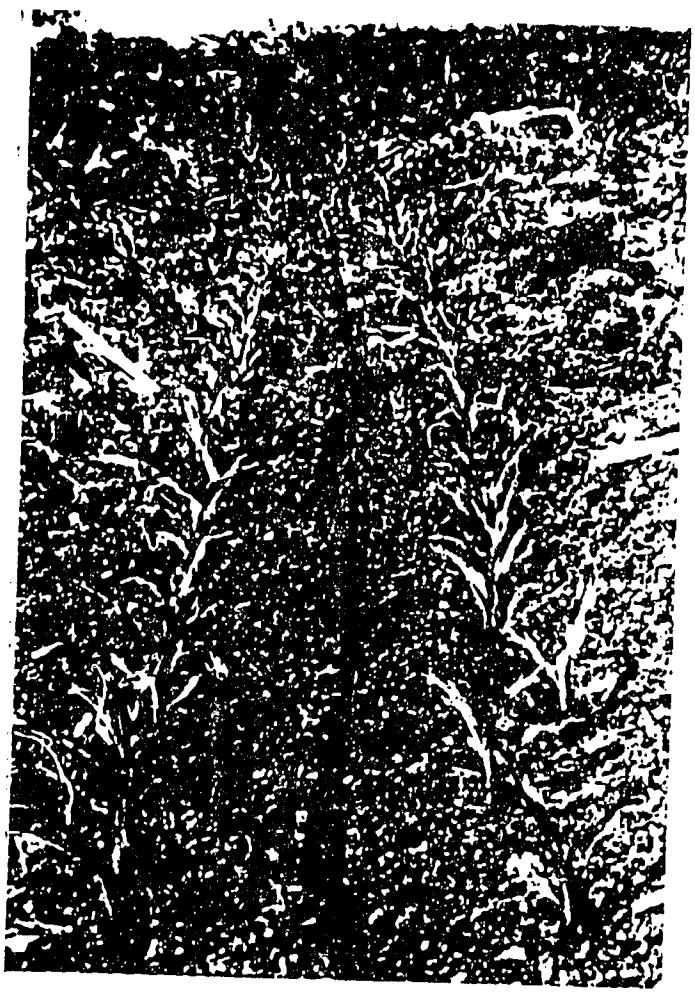

Fig. 6 A double-hedge row planting of corn seeds

Fig. 7 Rainfall pattern at Molino Bacoor, Cavite. The data are average of 3 years period. (1989-1992)

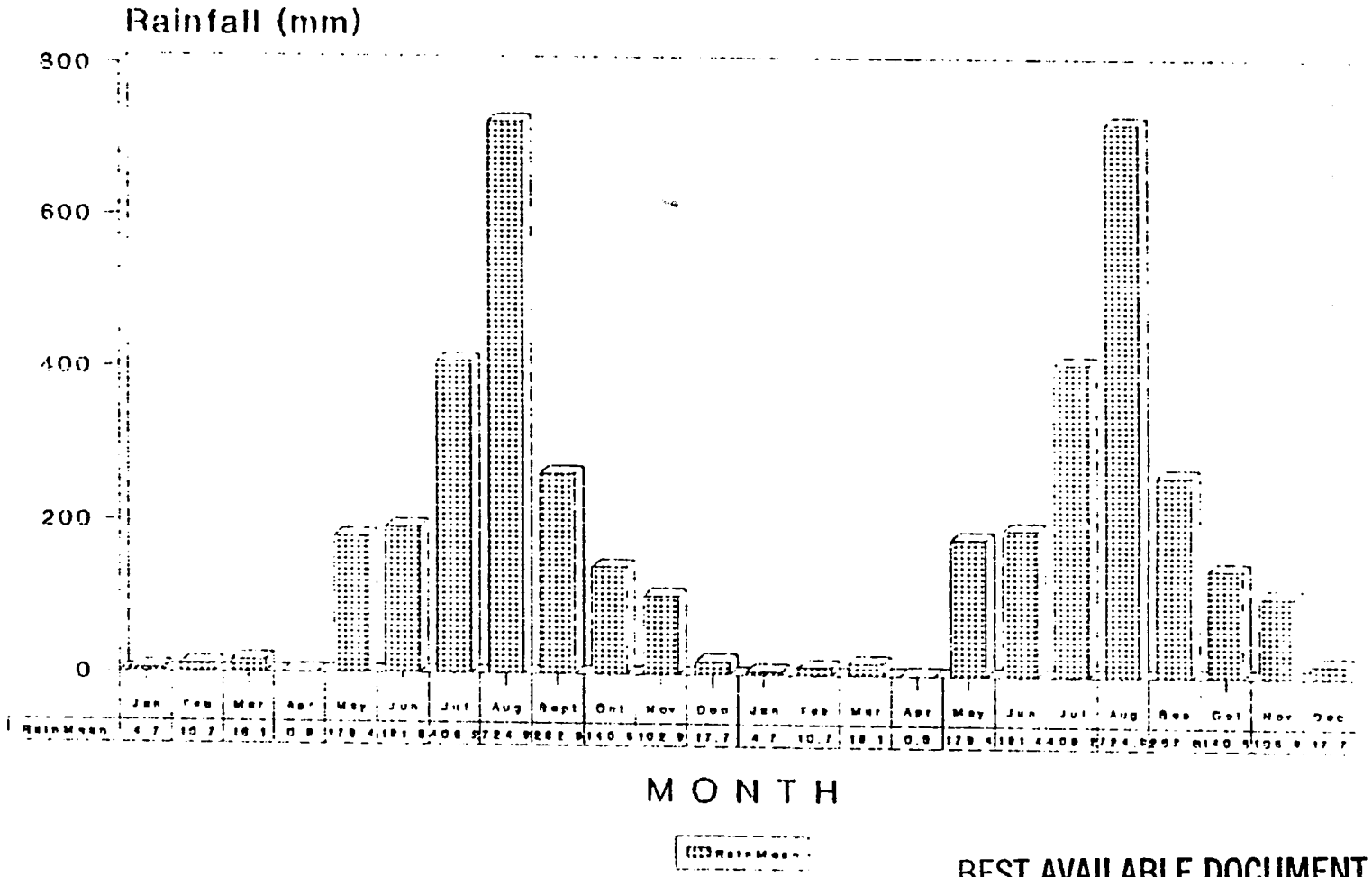

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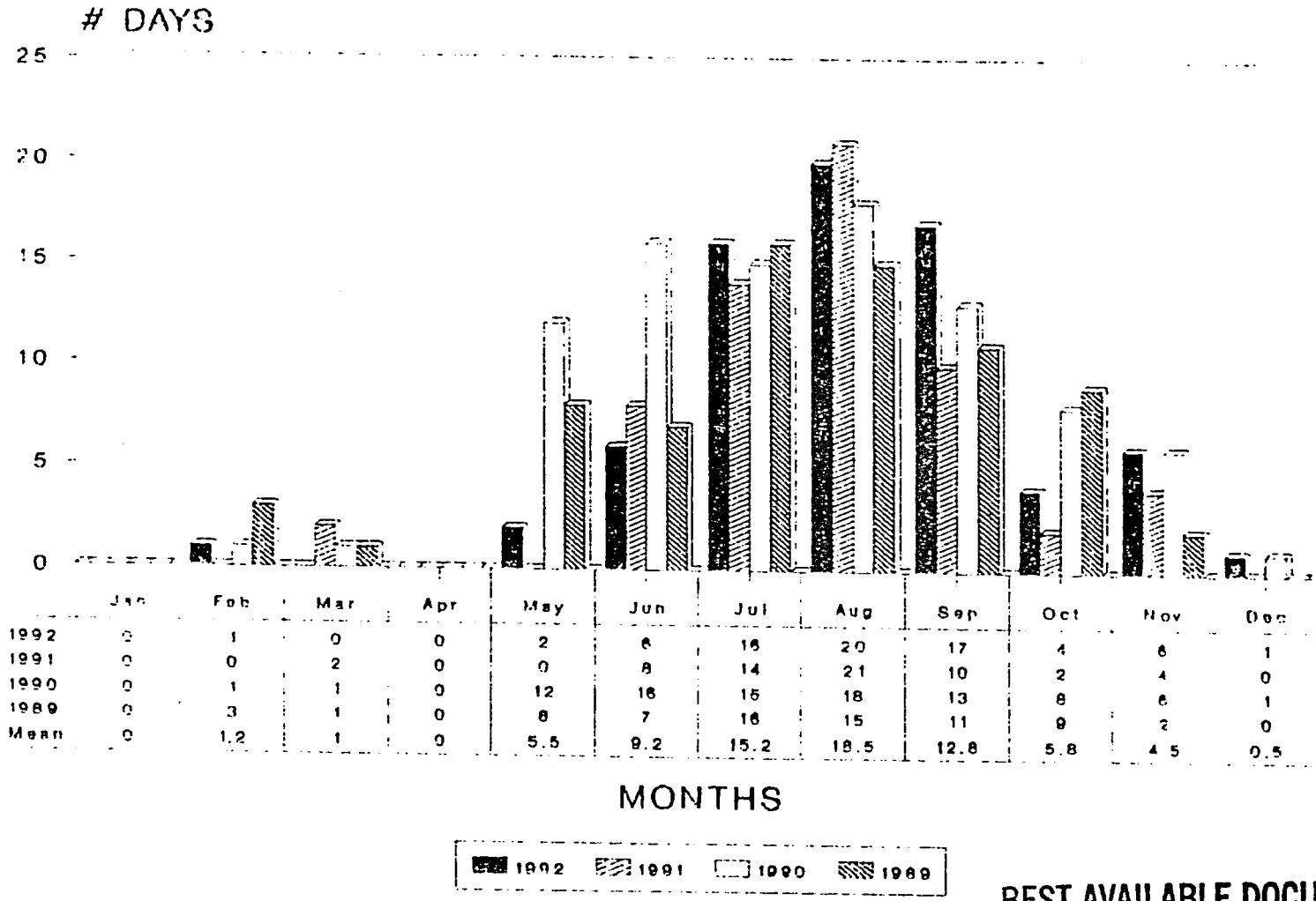
Fig. 8 Average number of days in which the daily rainfall is 5 mm or more.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1992	0	1	0	0	2	6	16	20	17	4	6	1
1991	0	0	2	0	0	8	14	21	10	2	4	0
1990	0	1	1	0	12	16	15	18	13	8	6	1
1989	0	3	1	0	8	7	16	15	11	9	2	0
Mean	0	1.2	1	0	5.5	9.2	15.2	18.5	12.8	5.8	4.5	0.5

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Fig. 9 Pan Evaporation pattern at Molino Bacoor, Cavite. The data are average of 3 years. (1989 - 1992)

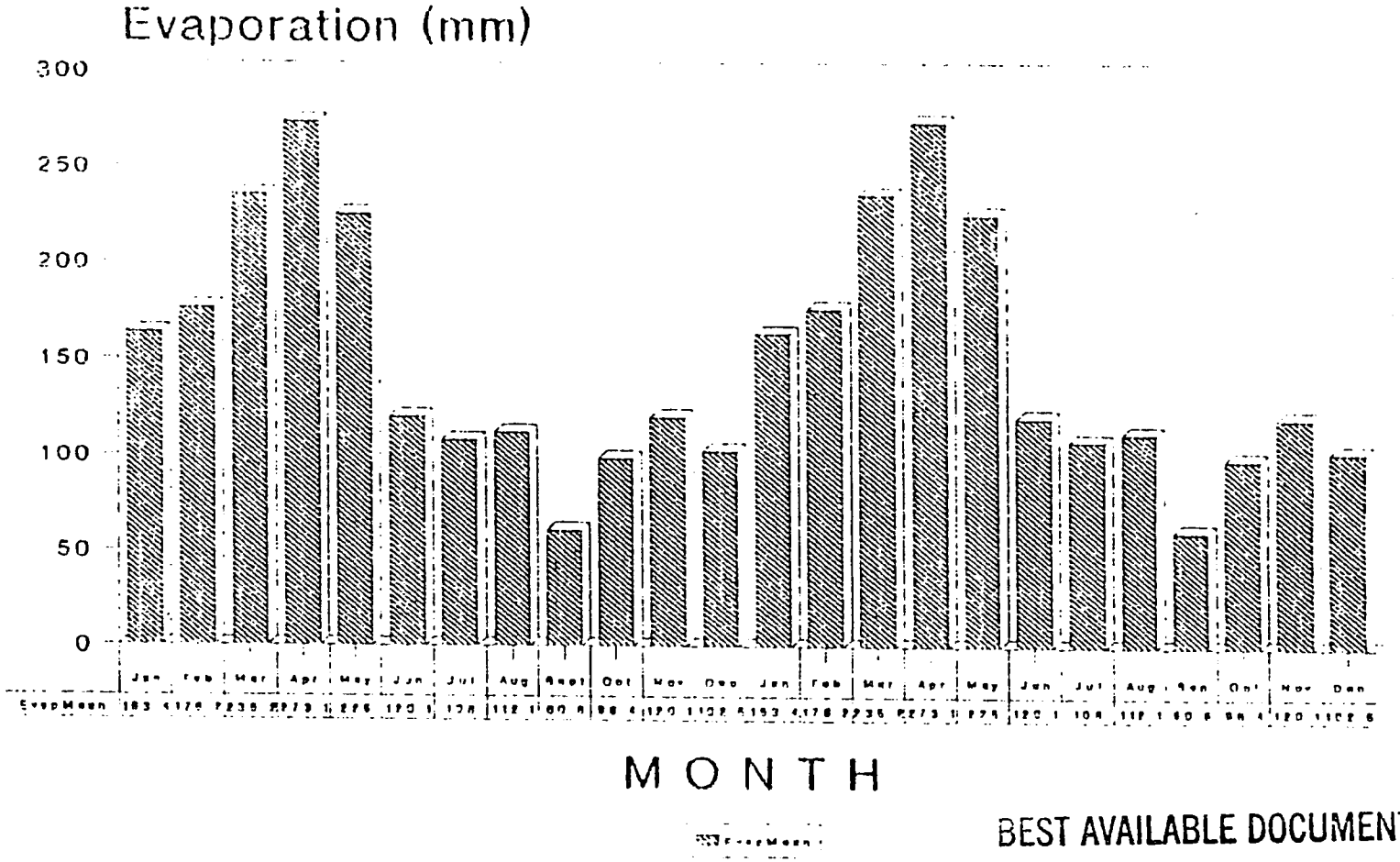

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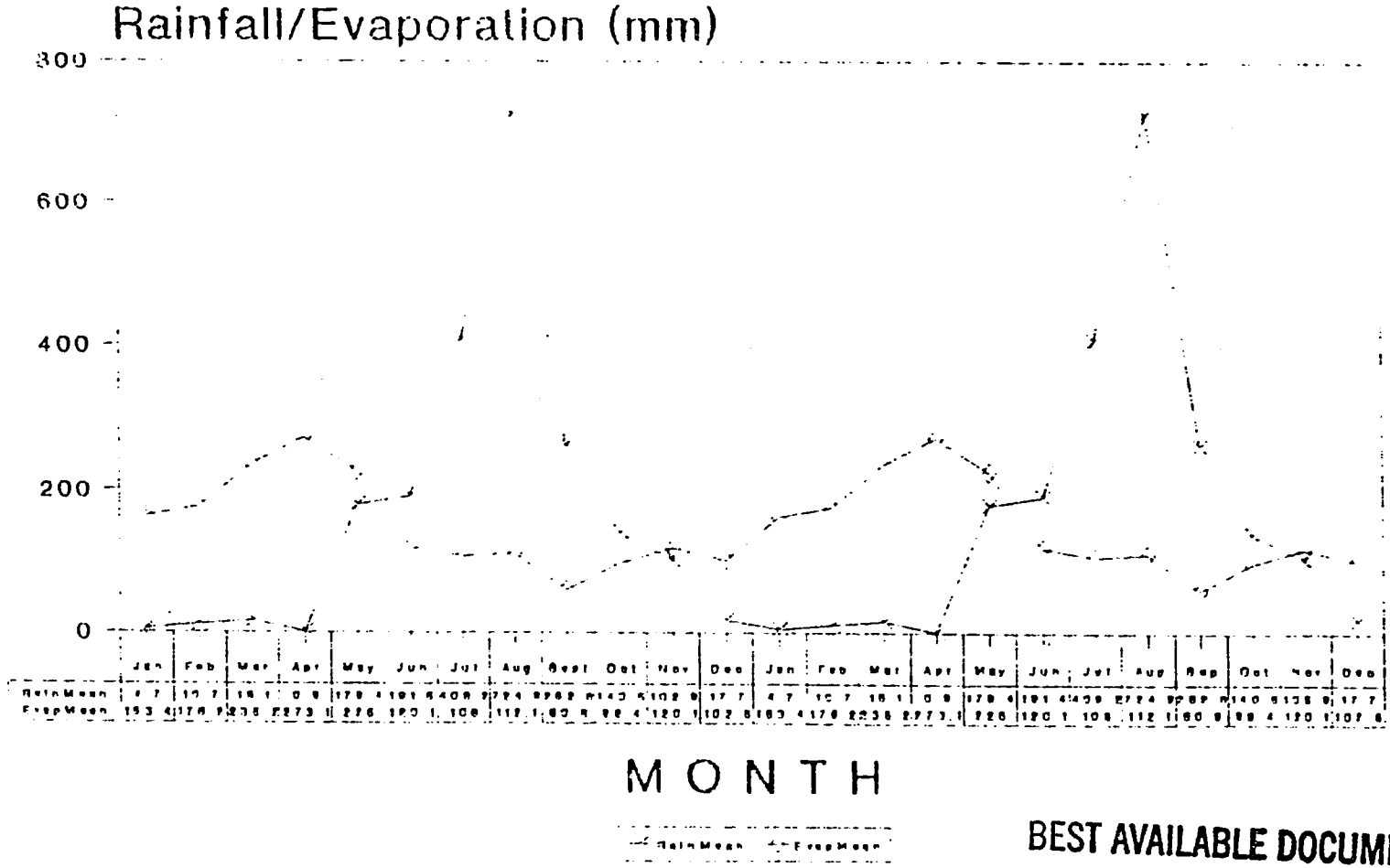
Fig. 10 Mean Rainfall/Evaporation
at Molino, Bacoor, Cavite
(Jan 1989 - Dec 1992)



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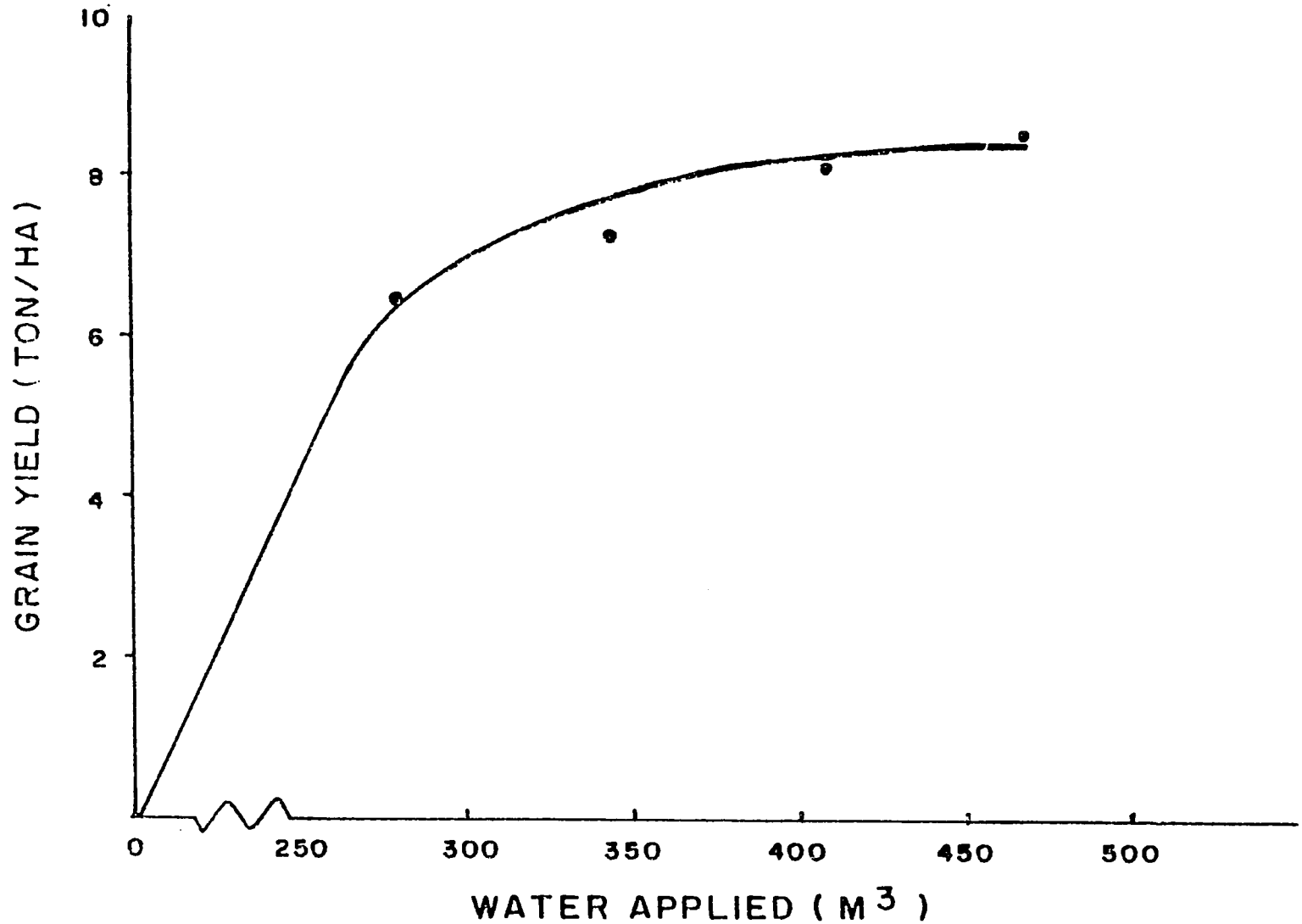


Figure 11. Yield response of corn hybrid Pioneer Y 8664 to various levels of water applied and average nitrogen level.

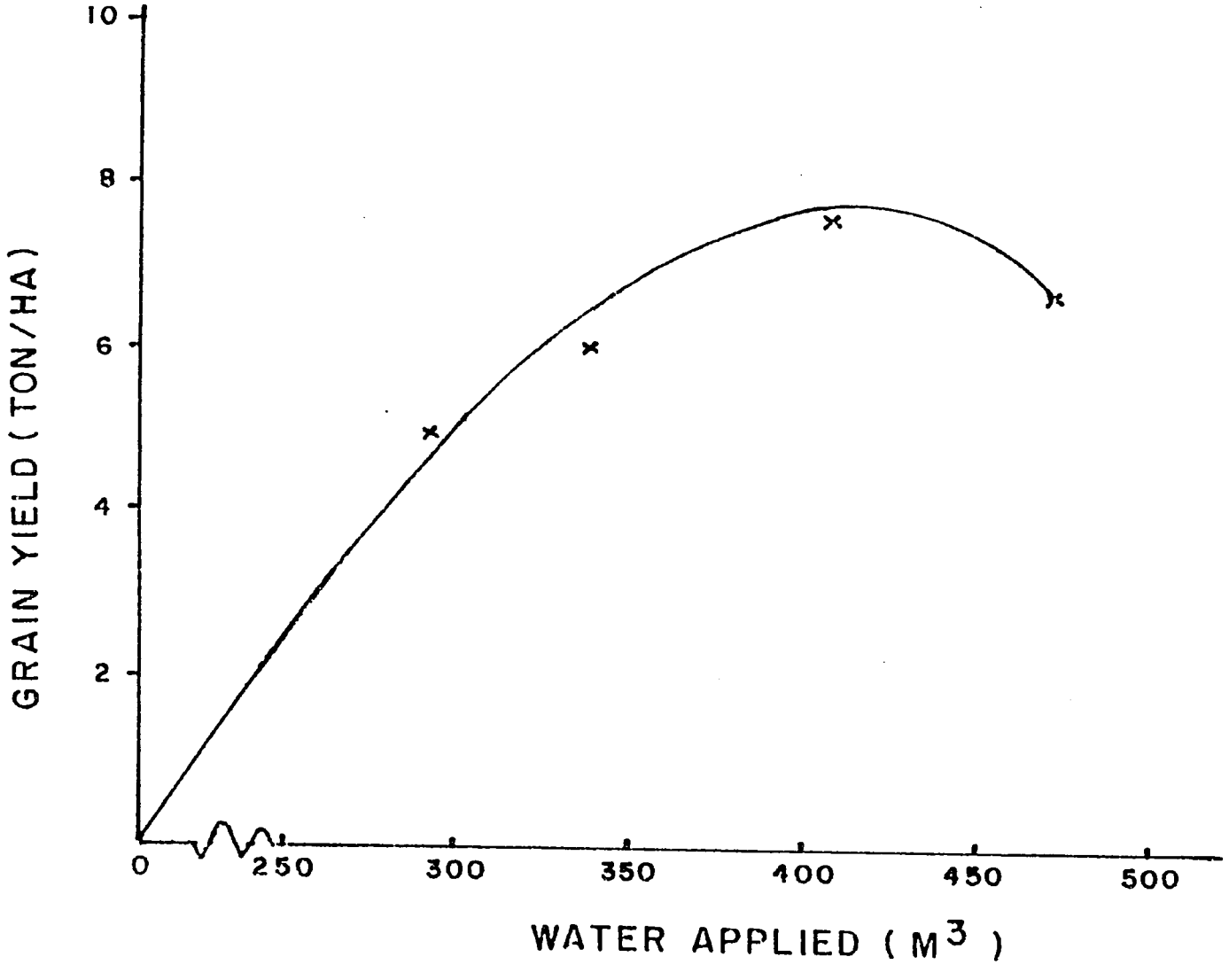


Figure 12. Yield response of corn variety IPB Var I to various amount of water applied.

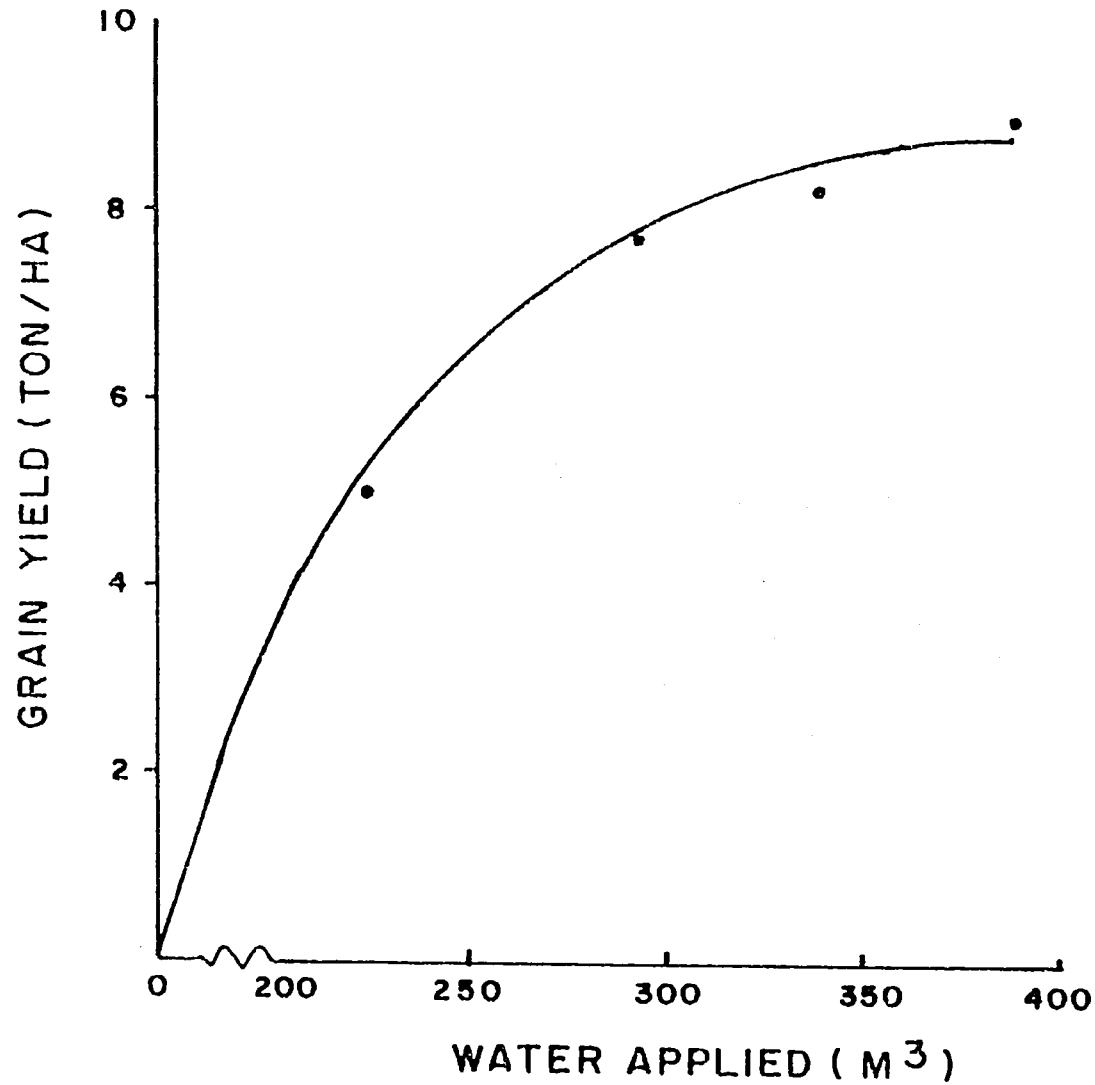


Figure 13. Yield response of corn variety IPB Var. 5 to various amount of water applied.

Fig. 14a Accumulated growth of corn at various irrigation levels & 90 kg N/ha.

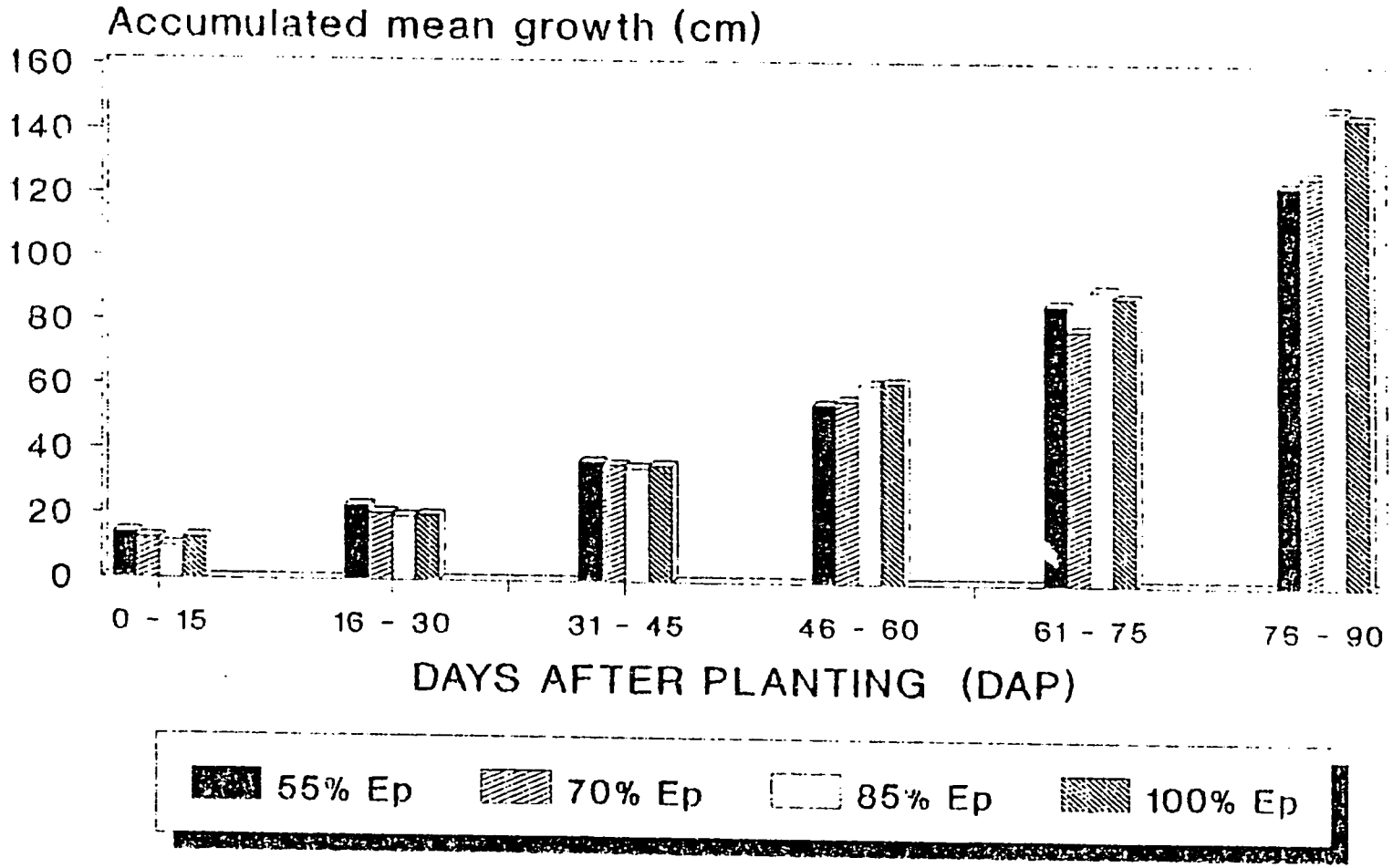
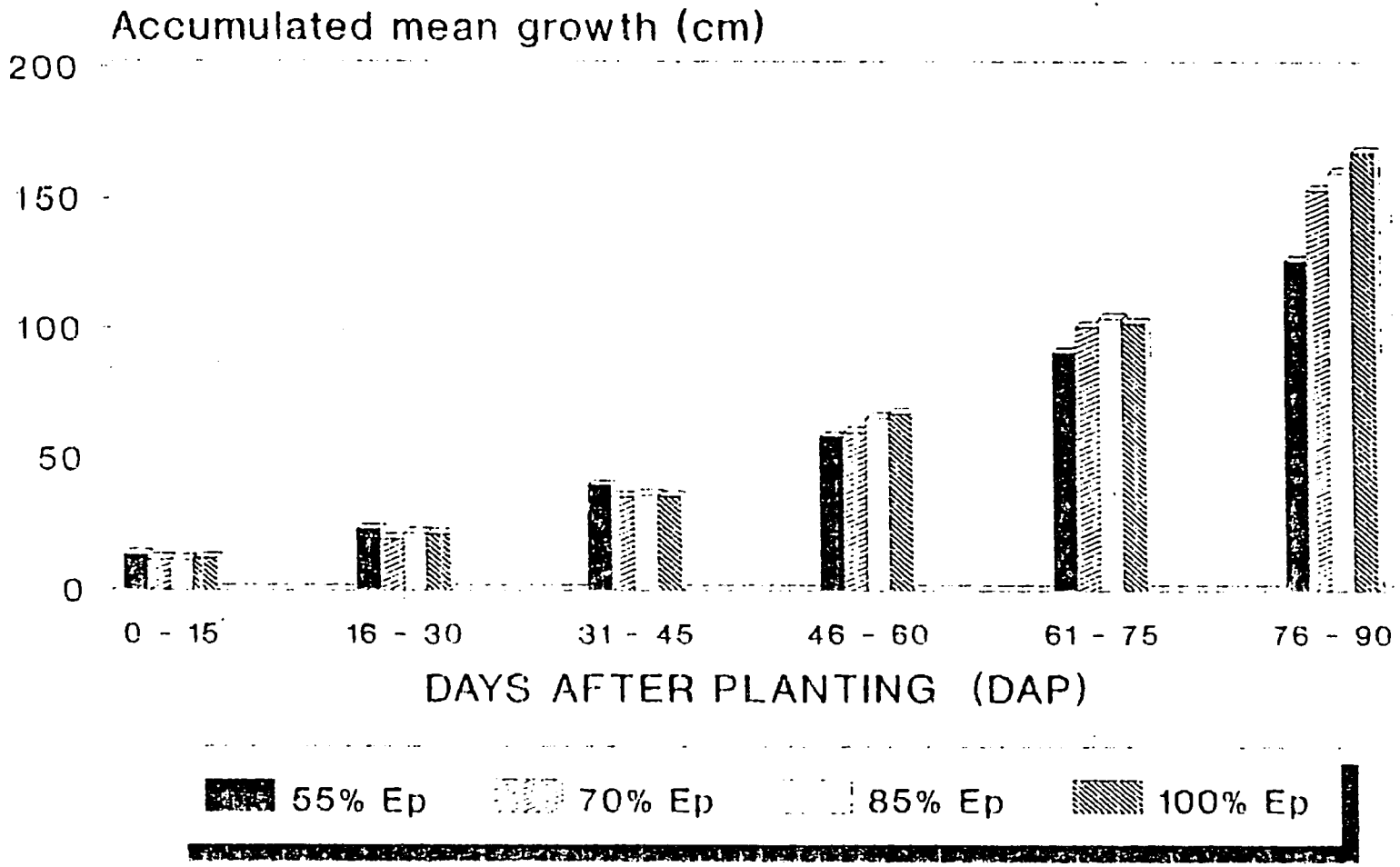


Fig. 14b Accumulated growth of corn at various irrigation levels & 180 kg N/ha



6. IMPACT, RELEVANCE AND TECHNOLOGY TRANSFER

The impact of the project was in three main directions:

a. It demonstrated to agricultural scientists, extension service personnel and farmers the potential of cropping during the dry season mainly in Western Luzon of the Philippines. Farmers are usually not occupied with agricultural production during this dry season and the findings of this project may open up many new possibilities for them. They will be able to grow the crop on crops like corn during this season based on the findings of this project. This will increase their annual income which is very low and will keep them busy during a period when they are idle.

b. A small team of technician were trained to install and use successfully drip irrigation for irrigation of row-crops. This is very important because limited quantities of water which will be available from water catchment systems during this dry season. This implies high efficiency of water use which can hardly be obtained by the conventional open irrigation methods. the expertise gained by the local team which was engaged in the project can now be transferred to additional people so that the Experimental Station of the University of the Philippines at Los Banos can serve as a demonstration and training center for this purpose.

c. The scientific capabilities of the Institute of Environmental Science and Management at the University Los Banos was enriched with expertise and equipment needed for the conduction of further

studies on crop water and fertilizer requirements, soil-plant-relationships and stress physiology.

The Institute is now in a position to conduct trials on a small scale determining soil and plant water status, evapotranspiration, plant development and productivity. The Institute can now serve as a center for irrigation research in the Philippines and conduct studies which are extremely necessary for many parts of the country.

7. PROJECT ACTIVITIES/OUTPUTS

Prof. Enrique P. Pacardo visited the Volcani Center at Bet Dagan for 3 weeks in the summer of 1990 and participated in the studies conducted at the Volcani Center (see Section 5.A.3). The discussion we held during this period and his direct involvement in the lab and field work were important to bring the work conducted at Los Banos and at Bet Dagan to a uniform standard.

Prof. Plaut and Mr. Grava visited Los Banos for 3 weeks during January, 1991, when the main field trial was being conducted. This was a very fruitful period as the equipment just arrived shortly beforehand (after many delays). the visit was used for training (see Section 6.C) and for discussion of future work.

Six semi-annual reports were regularly prepared by the Principal and Collaborating Investigators in common and were submitted to CDR.

Two publications in the form of scientific articles were prepared after the conclusion of the project. One was already

accepted by the Israel Journal of Botany and the second was submitted to Irrigation Science (Attached first page of both publications). A third publication is presently under preparation, based mainly on the present report.

8. PROJECT PRODUCTIVITY

The project accomplished most of the proposed goals, but there are two main drawbacks. One is related to the insufficient information on potential evaporation rate and seepage from the storage reservoir before the beginning and throughout the irrigation season. This led to insufficient water available even for efficient irrigation needs. Water had thus to be used from additional sources and irrigation could not be based exclusively on harvested rainwater.

The second drawback was the selection of crops in the Philippines. Corn is certainly a very important crop in Western Luzon, however for expensive water as the harvested and stored rainwater high value crops should have been used. Such crops would have benefitted much more from this expensive water. The use of the water for such crops would have been a real challenge and would have a much stronger impact on the state economy as well as a stronger persuasion on local farmers.

9. FUTURE WORK

In light with the significant success impact and relevance of the project Phase II of the project should be implemented in which more significant accomplishment will certainly be achieved. Based on all the information collected in this project Phase II

should be directed to high value crops mainly fresh vegetable crops like: table-tomatoes, peppers, cucumbers, melons, water-melons, etc. The crops to be studied should carefully be selected on the basis of a marketing and economical survey. Another criterion for crop selection is its potential to benefit from deficient use of irrigation water. We have recently collected relevant information on tomatoes and melons concerning their ability to be grown under conditions of limiting water supply producing economical yield with outstanding fruit quality. This information can be sued for Phase II of the project.

In addition, new techniques which can be used to determine deficient irrigation management are already in an advanced stage of development. These ought to be adopted in this study and will certainly promote the scientific and technical abilities of the staff of the University of the Philippines.

Thirdly, time was not sufficient to produce a center for training personnel from more remote locations to use drip irrigation and the scientific equipment. Phase II will allow this important function to be carried out.

An additional aspect is the contribution of deficient irrigation management to sustainable agriculture. The promotion of such management procedures have high relevance for the future agriculture in development countries.

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SENSITIVITY OF CROP PLANTS TO WATER STRESS AT SPECIFIC DEVELOPMENTAL STAGES: RE-EVALUATION OF EXPERIMENTAL FINDINGS

Z. Plaut

Abstract

Many investigators have suggested that in many crops different sensitivity to water stress can be found at different growth stages. Since identical amounts of water may be applied, irrespective of whether a crop is exposed to relatively severe and short periods of stress or to extended periods of mild stress, the responses to such differing conditions should be compared. Unfortunately, such a comparison was not conducted in most studies on sensitivity to water stress at different growth stages. In the present study, such a comparison was made for three crops: corn, sunflower and tomato. The study is based on three field experiments conducted for different purposes.

In corn, distinct responses of ear and kernel yields to the timing of water stress was found. Withdrawal of irrigation water during flowering and cob formation resulted in greater yield losses than during other stages, indicating that this is a critical growth stage. However, slight and uniform reduction of water during the entire growth period, resulted in significantly less damage to kernel or ear production, although the total amount of water applied was similar to that under staged

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THE RESPONSE OF POTATOES TO CONTINUOUS AND NON-CONTINUOUS USE OF SALINE WATER FOR IRRIGATION

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Most row crops are irrigated very successfully with drip irrigation in Israel. Higher production can be achieved with drip irrigation than with open irrigation with similar quantities of water (Dasberg & Bresler, 1985). The advantage of drip irrigation may even be greater when brackish water is used for irrigation (Goldberg, 1976; Shalhevet et al., 1983). This is usually attributed to at least three factors: (a) damage to the canopy due to direct wetting which is the case with sprinkling, (b) avoiding fluctuations in soil matrix potential due to frequent water applications and (c) a possibility to push the salinity front away from the majority of the root system.

Potatoes are known as a salinity sensitive crop (Maas & Hoffman, 1977). When the EC of the irrigation water was in the range of 5.0 - 7.0 dS/m a significant decrease in productivity was found using any irrigation system (Meiri et al., personal communication and earlier reports, 1987). A decrease in salt damage can be achieved either by blending the brackish water with good quality water or by exposing the crop to salinity during part of the growing season.

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