Title
Salinity and Boron Control Under High-Frequency Low-Volume Irrigation

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SALINITY AND BORON CONTROL
UNDER HIGH-FREQUENCY LOW-VOLUME IRRIGATION

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TECHNICAL COMPLETION REPORT

MARCH 1983

SALINITY AND BORON CONTROL UNDER HIGH-FREQUENCY LOW-VOLUME IRRIGATION

A B S T R A C T

A 3-year study of the accumulation of soluble salts and boron in a soil profile following trickle irrigation with well water is completed. Irrigation treatments consisted of three levels of water applications based on estimated evapotranspiration (ET) requirements of grape vines. Estimates of ET were obtained from soil data using a neutron (CPN) meter. Soil water potentials obtained by tensiometers at different soil depths provided information about soil water movement. Analyses of soil samples taken in late 1981 showed slow but continued salt and boron accumulation during irrigation periods. Plant samples showed boron accumulation in the grape leaves during the irrigation season. Leaves from the lowest irrigation level (2/3 ET) showed higher boron contents than did 3/3 ET level which was higher than the 4/3 ET irrigation treatment. Chloride accumulation in the plant leaves increased similar to that of boron, however, sodium did not, although it did accumulate in leaf petioles during the irrigation season in all treatments. In general, plant tissues reflected the sodium, chloride, and boron concentrations found in the soil. Grape yields in 1982 responded to the higher irrigation levels and yields were considerably larger than the local area average.

A. Research Project Accomplishments

The 3-year study of salt and boron accumulation in the soil profile when grapes were trickle (drip) irrigated with well water is completed. The experiment was actually established on a Panoche clay loam soil in the San Joaquin Valley of California in 1977 and continued to some degree through 1982. Treatments consisted of different amounts of water by applying 2/3, 3/3, and 4/3 of estimated evapotranspiration (ET) requirement for grapes. Two nonweighing lysimeters were installed, each containing two vines and were located in the 4/3 ET irrigation treatment. These lysimeters were initially used to estimate the ET requirement for the study. In 1981 a chamber method (new) was used to estimate ET along with lysimeter data, but the results were unsatisfactory. Neutron access tubes located in all treatments to a soil depth of 270 cm were used in conjunction with a Campbell Pacific Neutron meter to determine the water content of the soil on a volume basis. In addition, Mercury-type tensiometers placed in all treatments furnished water movement data in the soil following irrigations. The tensiometers were located at different soil depths and at variable distances from the trickle emitters as were the neutron access tubes.

Irrigation treatment 3/3 ET was the best estimate and appeared very close to the evapotranspirational needs of the grape vines. Evaporation measured in a class-A pan located within the experiment was recorded and the results compared with those from an adjacent grass-covered weather station site. The relationship between the irrigation needs of the vines and the evaporation from the vine area shown in Figure 1 was close to the value observed in 1980 and 1981.

Water contents in the soil profile for the three irrigation treatments were followed throughout the recent growing season. From February to September 1982 soil water contents at the 30 to 120-cm depth ranged from 20.5 to 24.5 percent by volume for irrigation treatment 2/3 ET, from 21.0 to 27.0 percent for treatment

3/3 ET and from 22.5 to 31.0 percent for treatment 4/3 ET (Figure 2). These results showed trends in soil water contents close to what was intended by the three levels of irrigation. The 2/3 ET level indicated a decrease in soil water content with time, the 3/3 showed essentially no change in water content, and the 4/3 ET treatment level of irrigation showed an increase in soil water over time.

Evidence of water movement in the soil was shown by the tensiometer data in terms of flux or movement within the soil profile between the 90-and 120-cm depth. June-September data show that very little water flux occurred in irrigation treatments 2/3 and 3/3 ET, but there was downward water movement (flux) in treatment 4/3 ET (Figure 3), thus evidence of excess water application.

Since 1979, contour maps have been constructed by computer showing mean water contents at different soil depths for irrigation treatments from February or March to September. In conjunction with the contour maps, soil-water/profiles showing isolines (lines of equal water content) 30, 65, and 120 cm from the vines were also constructed by computer. Other computer-treated data included soil-water fluxes for all irrigation levels, contour profiles for soil-salt (EC), Cl, and boron from soil samples taken up to and including November 1981.

Contour maps depicting salt concentrations in the soil for the three irrigation levels starting in November 1979 to November 1981 are shown in Figures 4 to 6 for the 2/3 ET irrigation treatment. The contour lines showing electrical conductivity (EC) near the point of water application in the upper left corner of the graphs indicate the measure of salt present following a season's irrigation of only 2/3 of estimated evapotranspiration for each year. These data and the following for the 3/3 and 4/3 ET irrigation treatments should be observed along with irrigation amounts presented in Table 1 and the leaching effect of rainfall in Table 2. Table 4 shows EC levels of over 4.0 dS/m or mmho/cm at about the 15-

cm soil depth near the vine. The EC concentrations decreased with soil depth until it reached 1.0 dS/m at the 120-cm soil depth. In Figure 5 (1980) the EC concentrations were somewhat lower near the soil surface (3.67 dS/m) but remained above 1.0 dS/m throughout the soil profile. Figure 6 (1981) showed a buildup of salt not only in upper soil levels but also down to the 120-cm soil depth.

Table 1. Water applications - 1979-1982

Irrigation* Treatments	cm 1979	1980	1981	1982
2/3 ET	26.4	32.3	27.9	22.6
3/3 ET	36.1	40.4	35.8	30.2
4/3 ET	54.9	51.3	49.0	42.4

*Irrigation water: EC = 1.5 dS/m
Boron - 0.6 ppm

Table 2. Winter Rainfall - WSFS

	cm
1978-79	21.1
1979-80	23.4
1980-81	16.5
1981-82	17.8

Similar graph for irrigation level 3/3 ET (Figure 7) show EC values for 1979 ranged from 5.0 dS/m near the vine down to 1.0 dS/m at the 120-cm soil depth. Data for 1980 (Figure 8) show the level of EC was less at the upper soil level for this irrigation level but higher concentrations of salt was found at deeper soil depth than in 1979. Data for 1981 shown in Figure 9 are quite similar to that of 1980.

Electrical conductivity data shown in Figures 10 to 12 are for the 4/3 ET irrigation level in which some leaching of salts (EC) were intended to be accomplished. In 1979, November EC values of 5.0 dS/m were observed very near the vines (upper left corner of graph). This high concentration of salts gradually decreased with soil depth until it was only about 1.0 dS/m at the 150-180-cm soil depth. 1980 data in Figure 11 showed a marked decrease in salt in the upper soil levels but a slight increase below. Figure 12 shows data following a irrigation season in 1981. The EC content near the soil surface is near that found in 1980 but not as high as that found in 1979.

It is apparent from these data that the quality and amount of water used in irrigations and the amount of rainfall during the winter months in this area play a large role in salt accumulation under these cultural conditions. Trends in chloride concentrations, one of the primary constituents of salt, were found to be almost identical to that of EC and were not included.

Boron contents of soil, being associated intimately with the clay fraction, change considerably slower than salt content under the same irrigation conditions. As noted in Table 1 the boron content of the irrigation water was 0.6 parts per million. The source of water was from a deep (700 - 1800 ft.) well and little change in boron content was expected during the course of the study.

The profile of boron contents in the soil in the 2/3 ET irrigation treatment is shown in Figure 13. In 1979, the highest boron content (2.38 ppm) was found at the 15-cm soil depth and 15-cm from the vine. However, the boron content increased to above 3 ppm in the upper soil level and also increased considerably some distance from the vine (Figure 14).

At the 3/3 ET irrigation level a somewhat different picture of the change in boron content of the soil was in evidence. Figure 15 depicts boron contents as high as 3.25 ppm at the 15-cm soil depth and distance from the vine in 1979. However, in 1981 (Figure 16) the boron contents in the upper soil level decrease but tended to increase at lower soil depths.

frequent irrigations from a point source (trickle system) it is conceivable that within the almost continually wetted soil volume and limited root zone the boron in the water is readily taken up by the vines before it has a chance to be fixed by the clay fraction of the soil. This could explain why the boron in the vine leaves reaches levels higher than would be expected based on the water-boron content.

Since grape yields obtained were considerably above the average for this area in 1982, the level of salt and boron in the soil and irrigation levels had very little detrimental effect on crop production at this site. Significant differences in grape yield were found only between the lowest (2/3 ET) and highest (4/3 ET) levels of irrigation.

B. Application of Research Results

The results obtained have been presented at various conferences dealing with salinity and drip irrigation, two of which are W-128, Trickle Irrigation to Improve Crop Production and Management, and W-160, the Physio-Chemical Basis for Management of Salt Affected Soils. Numerous visitors, domestic and foreign have observed the field experiment on site.

In general, the results obtained from the trickle irrigation research in the San Joaquin Valley of California will be used as a guide toward greater water use efficiency and soil salinity and boron control in irrigated areas where considerable amounts of soluble salts and boron are present in irrigation waters. The results so far give an estimate of the evapotranspiration requirements for grapes. As the research progresses, the results should allow management decisions to be made on the minimum amount of water that must be applied through a trickle system in order to maintain sufficiently low salt and boron concentrations to not affect growth or yield of grapes. County farm advisors and farmers would utilize the results of this study to maintain high crop production while minimizing the danger of soil salinity and boron buildup under a system of high water use efficiency.

Providing funds from other sources are available, studies of salt, boron, and water balance in the trickle-irrigated vineyard will be continued with measurements of salt and boron concentrations, water content, and water potential distributions in the soil. The effect of different amounts of salt and water on yield will continue to be evaluated. Experiments will be continued on methods of determining actual evapotranspiration from trickle-irrigated grapes.

C. Publications

Results published in limited circulation reports for Regional Projects W-128 (Trickle Irrigation to Improve Crop Production and Management) and W-160

(The Physio-Chemical Basis for Management of Salt Affected Soils) during the years 1979 to 1982 and 1981-82, respectively. Formal publications following completed chemical analyses are contemplated.

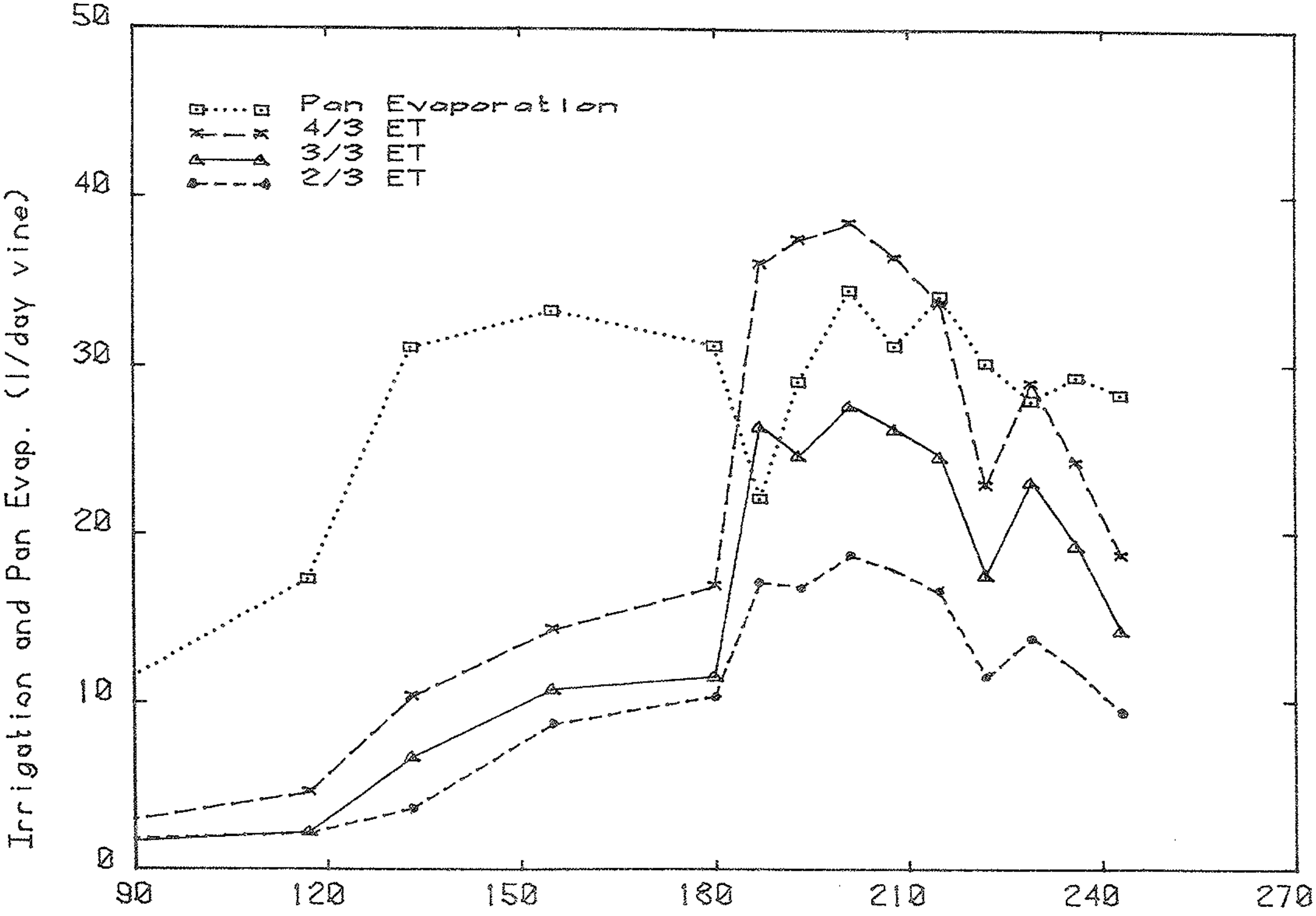


Figure 1.

GRAPE'82

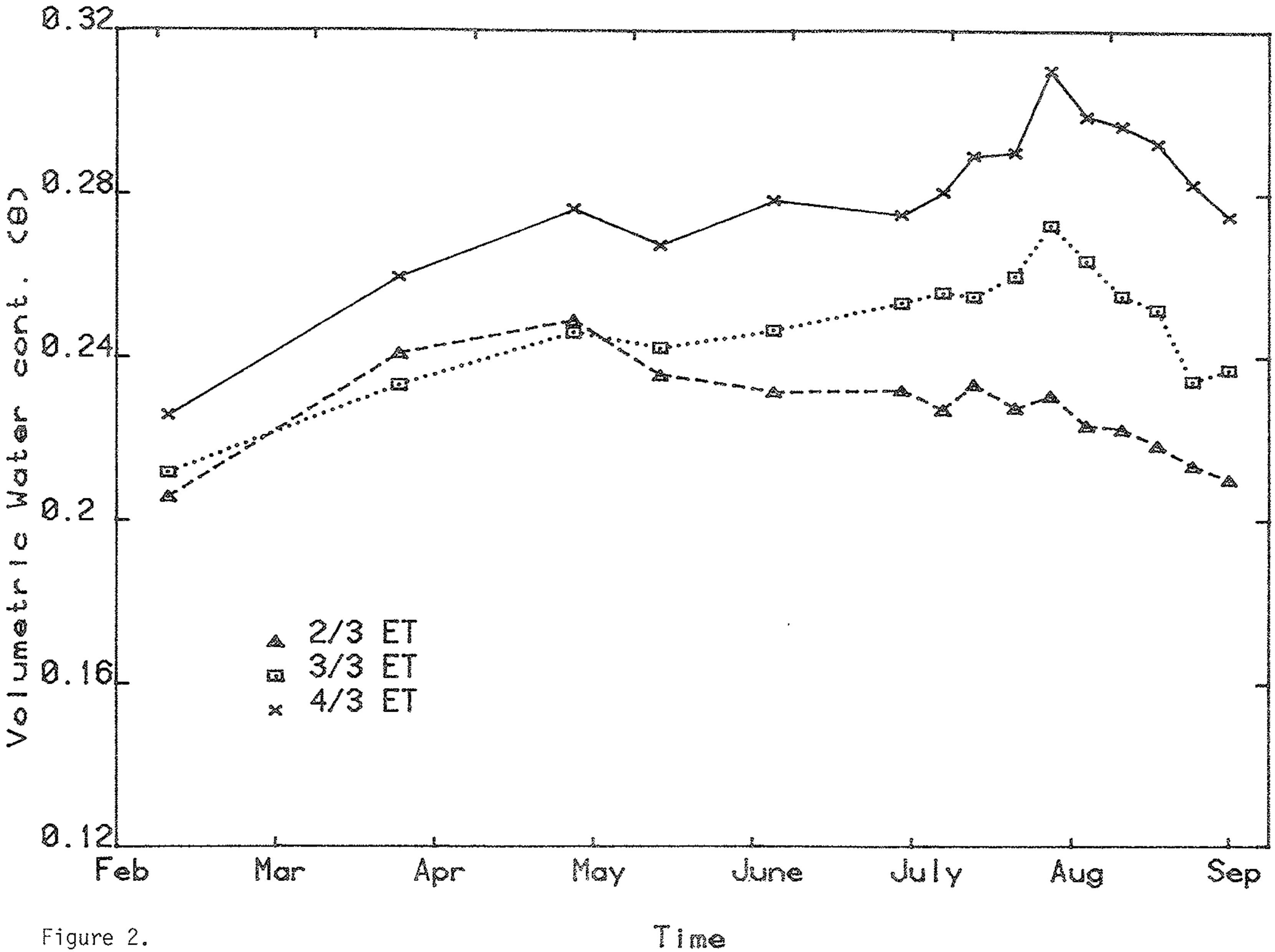


Figure 2.

GRAPE'82-Variation of soil-water content for three Irrigation Treatments. Average between 30 to 120 cm depth. (between vines).

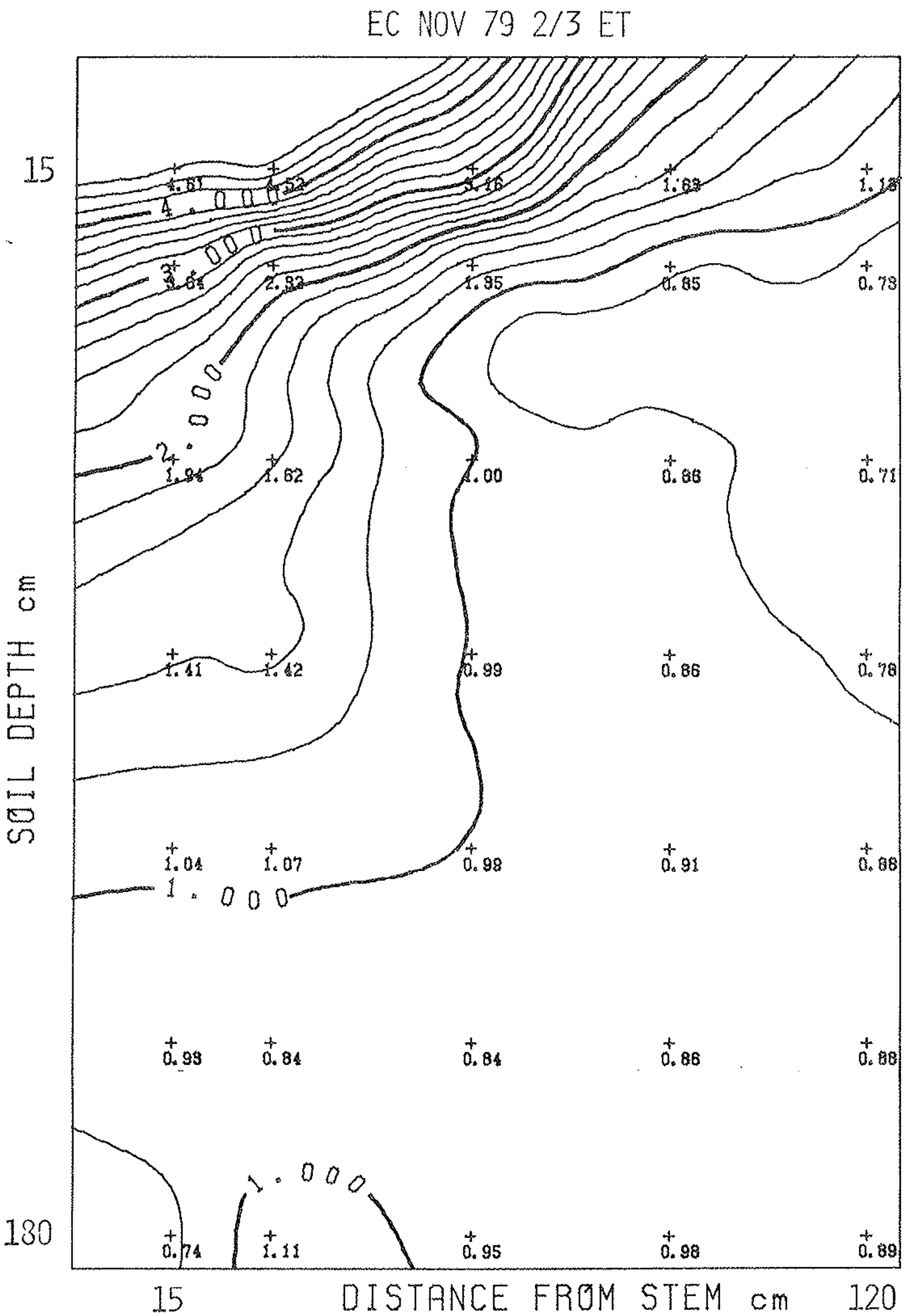

EC NOV 79 2/3 ET
SØIL DEPTH cm
DISTANCE FRØM STEM cm
15
180
15
120
4.000
3.000
2.000
1.000
1.000
2.32
1.95
0.85
0.78
1.94
1.62
1.00
0.86
0.71
1.41
1.42
0.99
0.86
0.78
1.04
1.07
0.98
0.91
0.88
0.93
0.84
0.84
0.86
0.88
0.74
1.11
0.95
0.98
0.89

Figure 4.

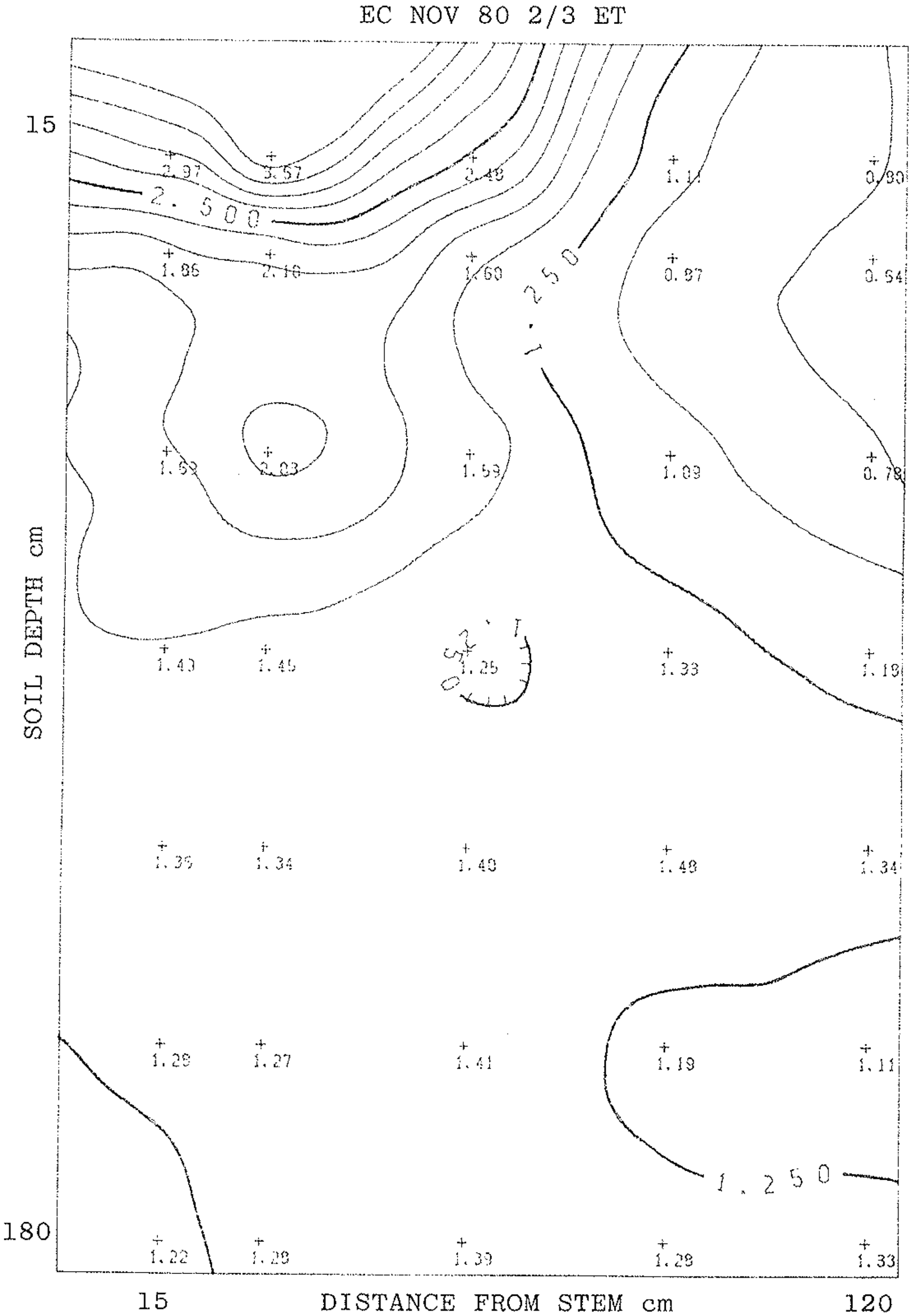

EC NOV 80 2/3 ET
15
180
SOIL DEPTH cm
15
120
DISTANCE FROM STEM cm
2.500
1.250
1.250

Figure 5.

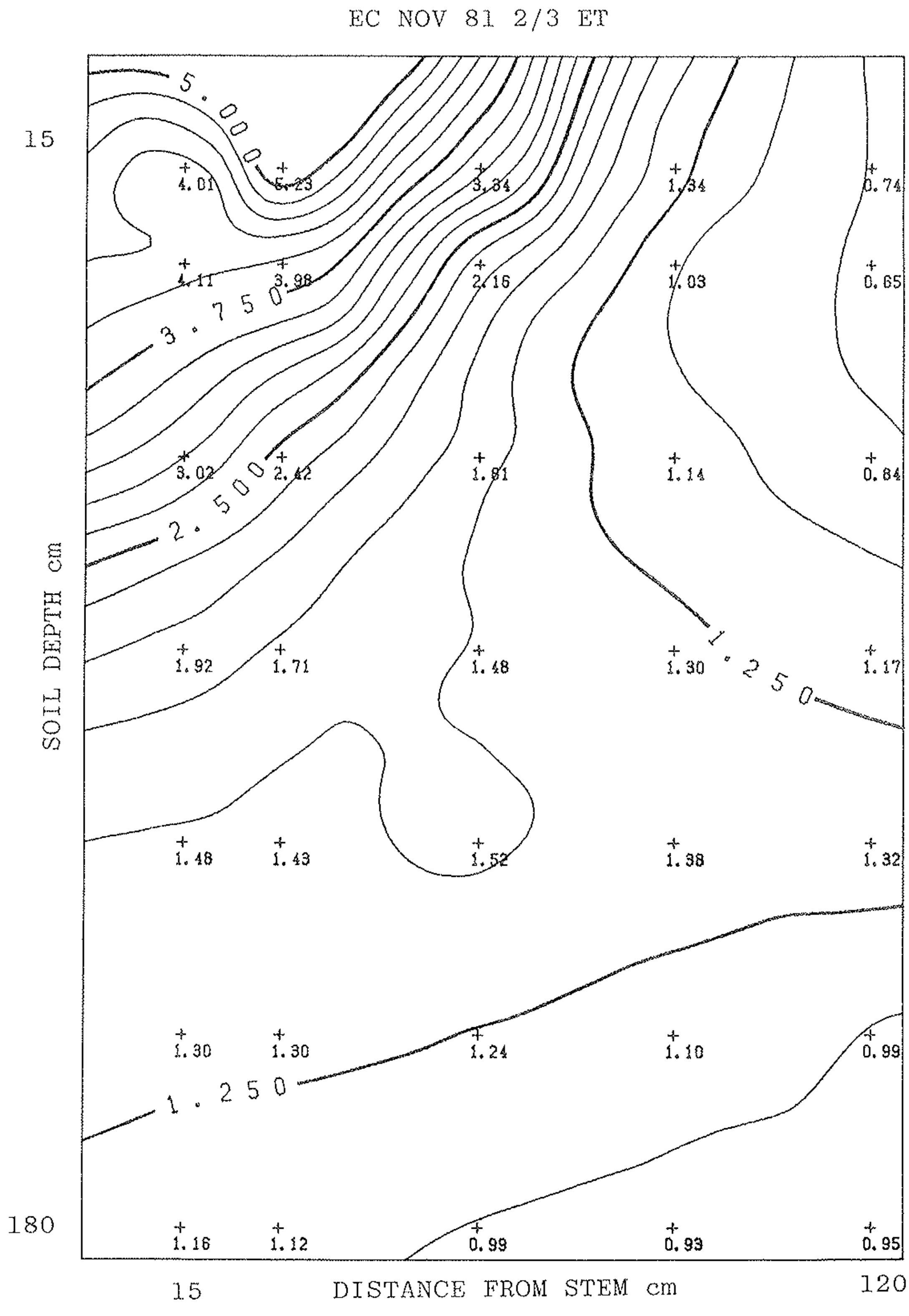

EC NOV 81 2/3 ET
15
180
SOIL DEPTH cm
15
DISTANCE FROM STEM cm
120
5.000
3.750
2.500
1.250
1.250
4.01
5.23
3.34
1.34
0.74
4.11
3.98
2.16
1.03
0.65
3.02
2.42
1.81
1.14
0.84
1.92
1.71
1.48
1.30
1.17
1.48
1.43
1.52
1.38
1.32
1.30
1.30
1.24
1.10
0.99
1.16
1.12
0.99
0.93
0.95

Figure 6.

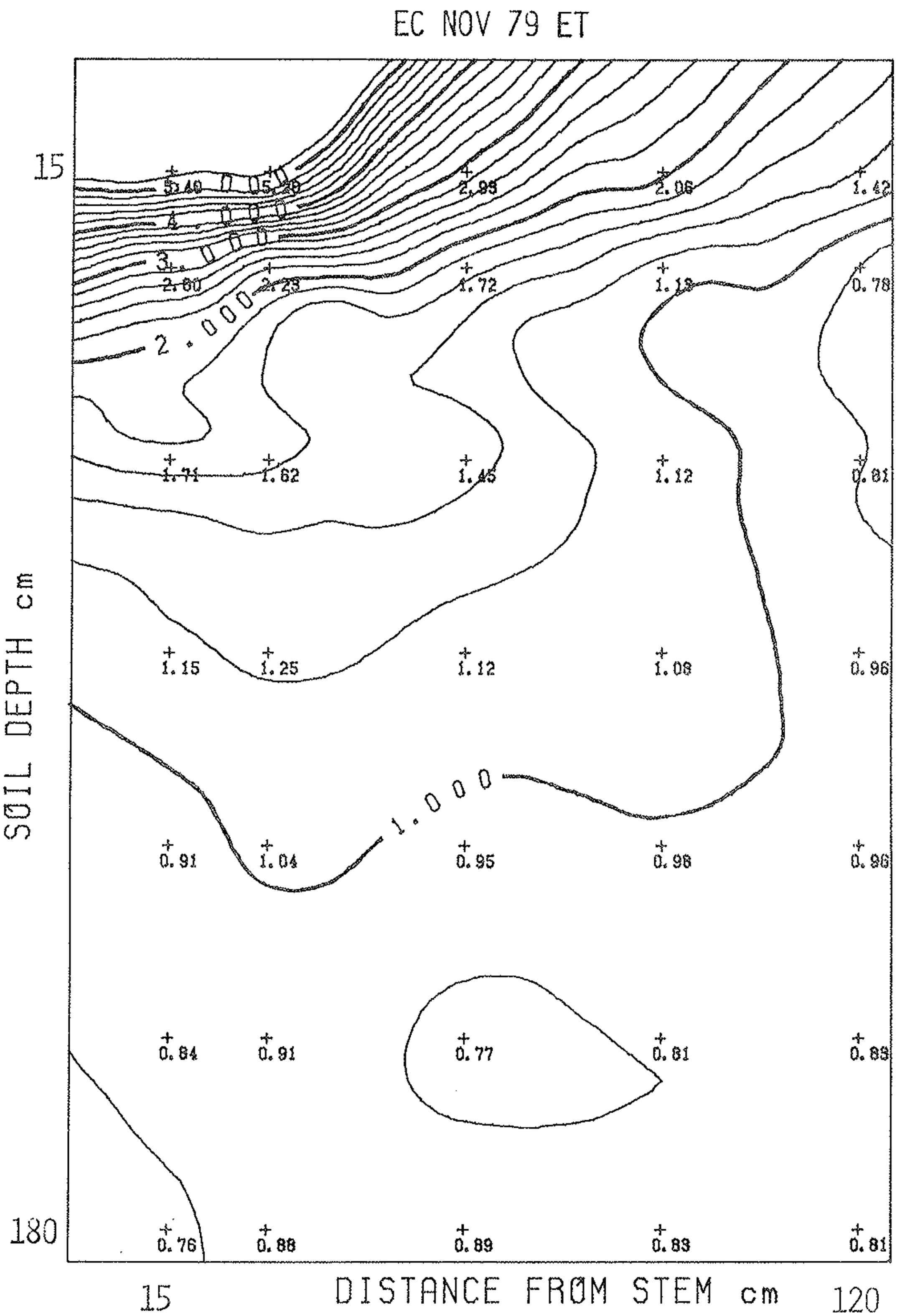

EC NOV 79 ET
15
180
SOIL DEPTH cm
15
DISTANCE FROM STEM cm
120
5.40
5.20
2.99
2.06
1.42
4
3.
2.60
2.23
1.72
1.13
0.78
2.000
1.71
1.62
1.45
1.12
0.81
1.15
1.25
1.12
1.08
0.96
1.000
0.91
1.04
0.95
0.98
0.96
0.84
0.91
0.77
0.81
0.83
0.76
0.88
0.89
0.83
0.81

Figure 7.

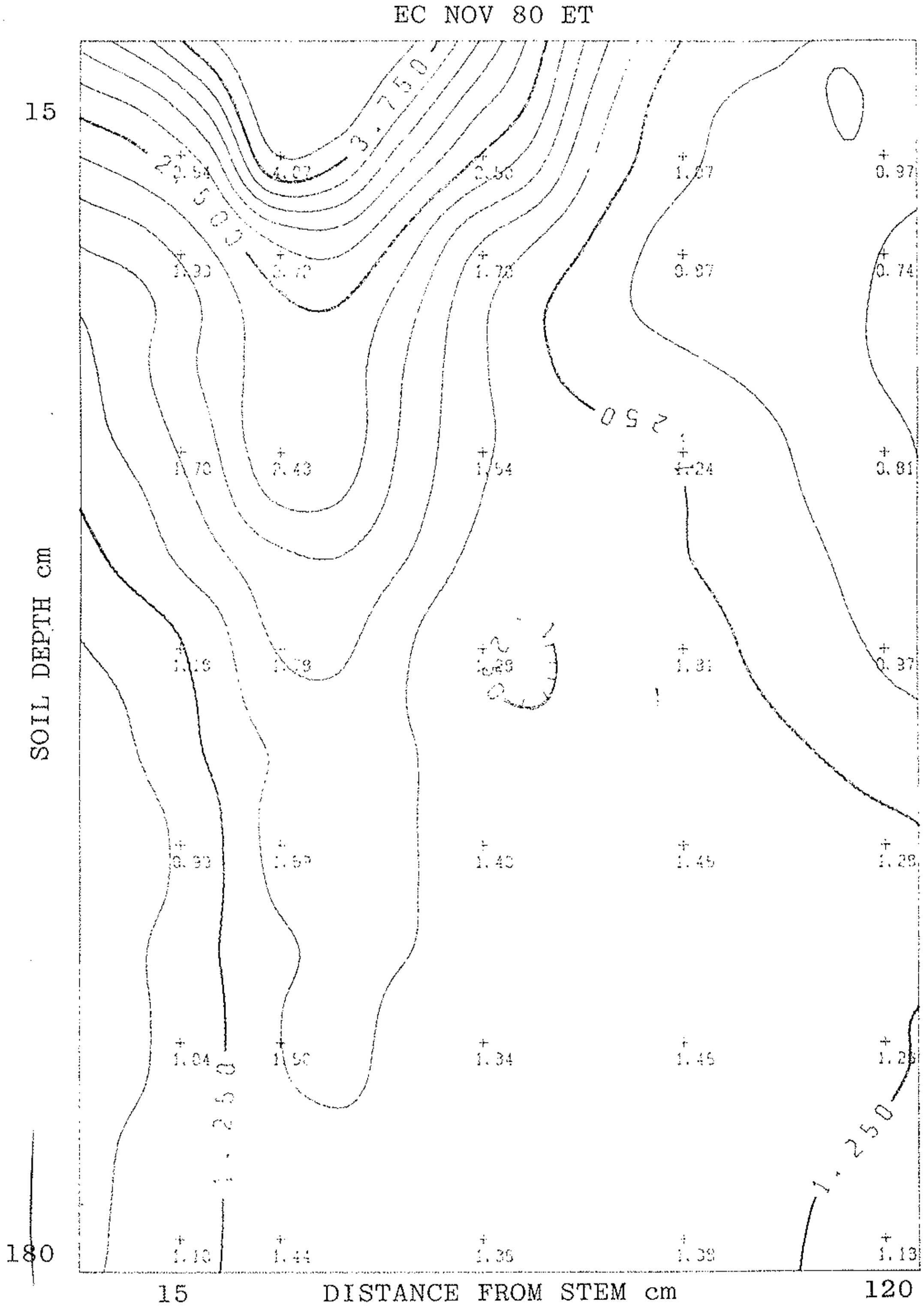

EC NOV 80 ET
SOIL DEPTH cm
15
180
DISTANCE FROM STEM cm
15
120
3.750
2.500
2.250
1.250
1.250

Figure 8.

EC NOV 81 ET

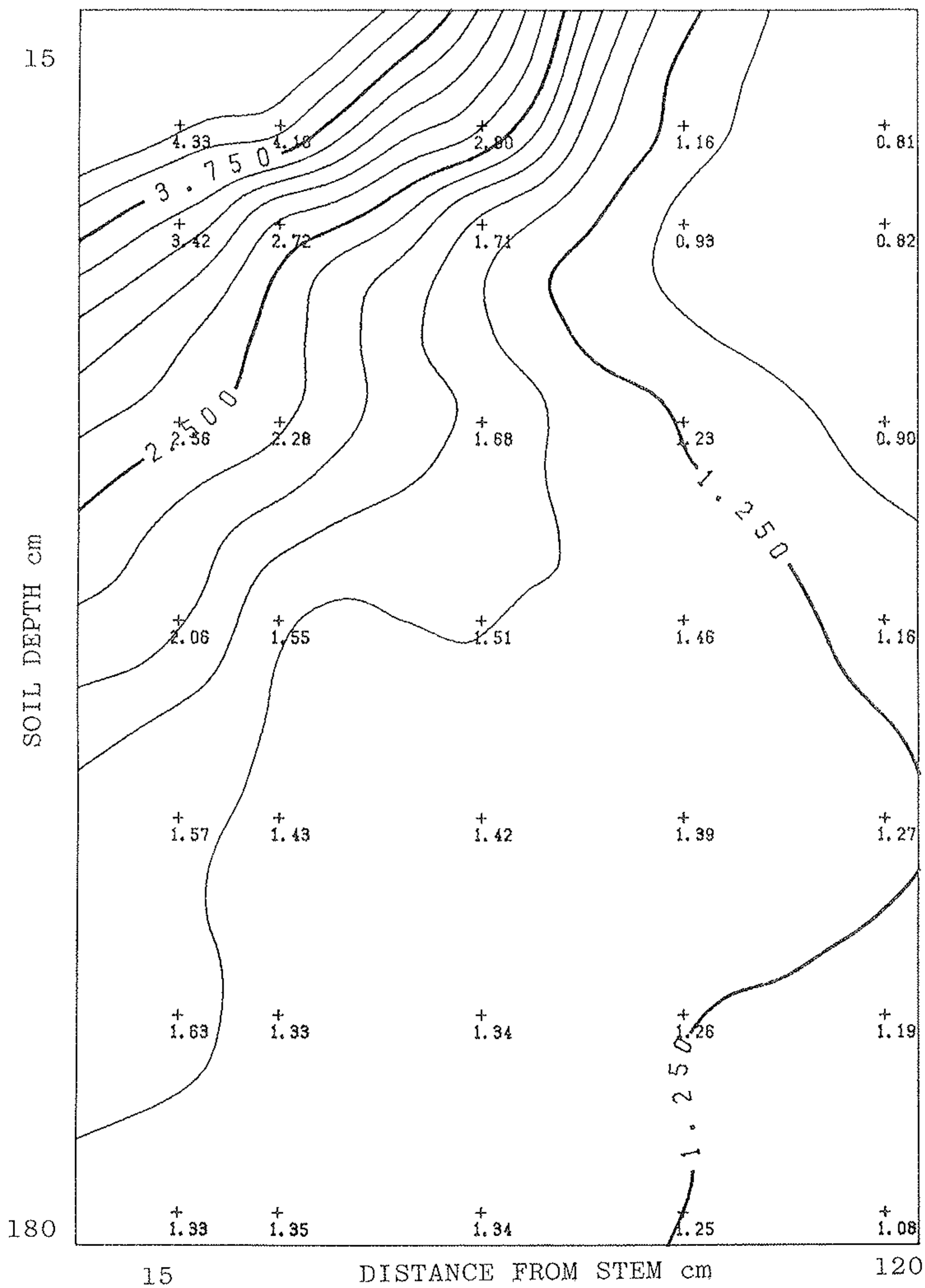


Figure 9

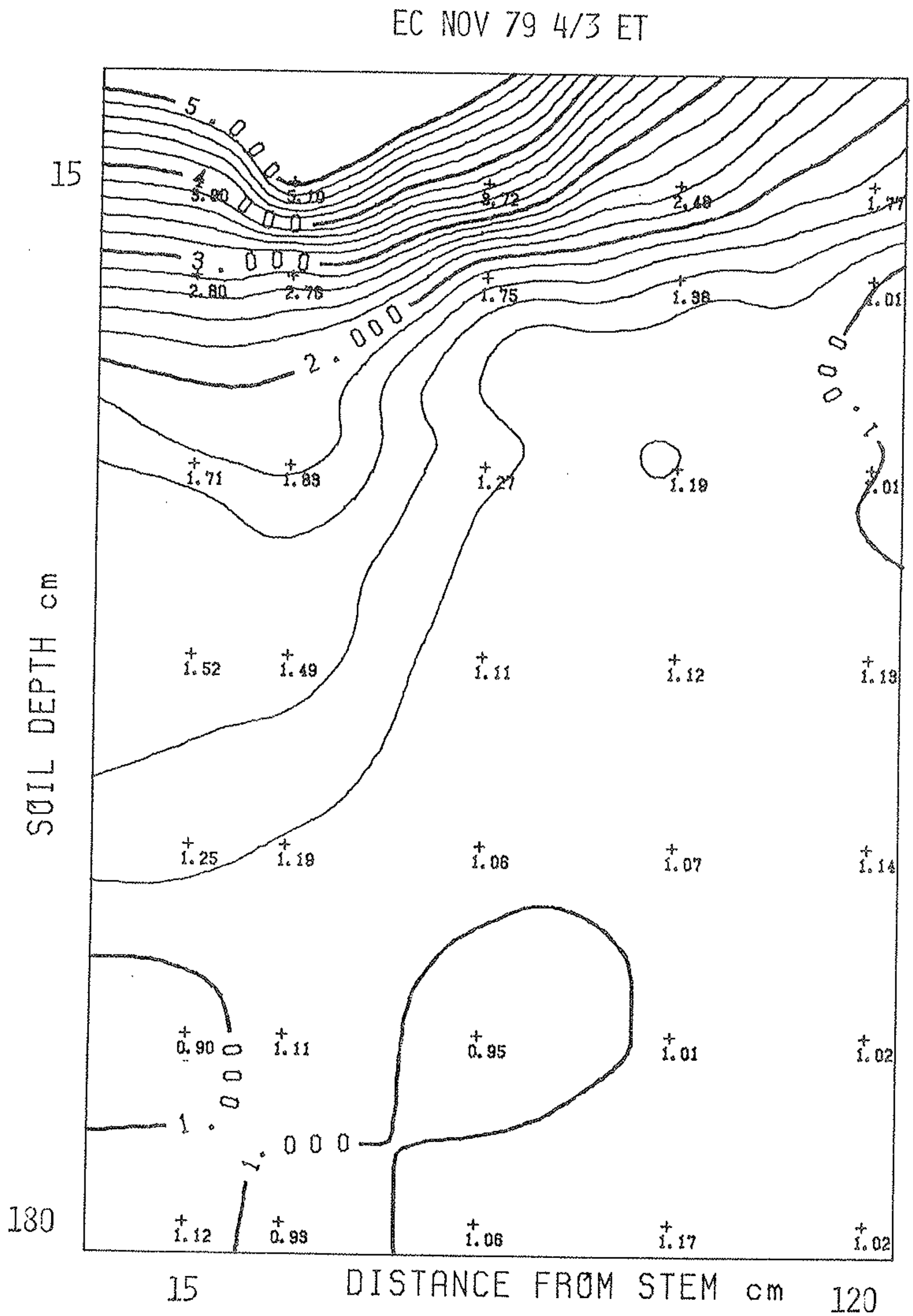

EC NOV 79 4/3 ET
SØIL DEPTH cm
DISTANCE FRØM STEM cm
15
180
15
120
5.000
4.000
3.000
2.000
1.000
1.000
1.000
1.000
5.80
5.10
3.72
2.48
1.77
2.80
2.76
1.75
1.38
1.01
1.71
1.83
1.27
1.19
1.01
1.52
1.49
1.11
1.12
1.13
1.25
1.19
1.06
1.07
1.14
0.90
1.11
0.95
1.01
1.02
1.12
0.99
1.06
1.17
1.02

Figure 10.

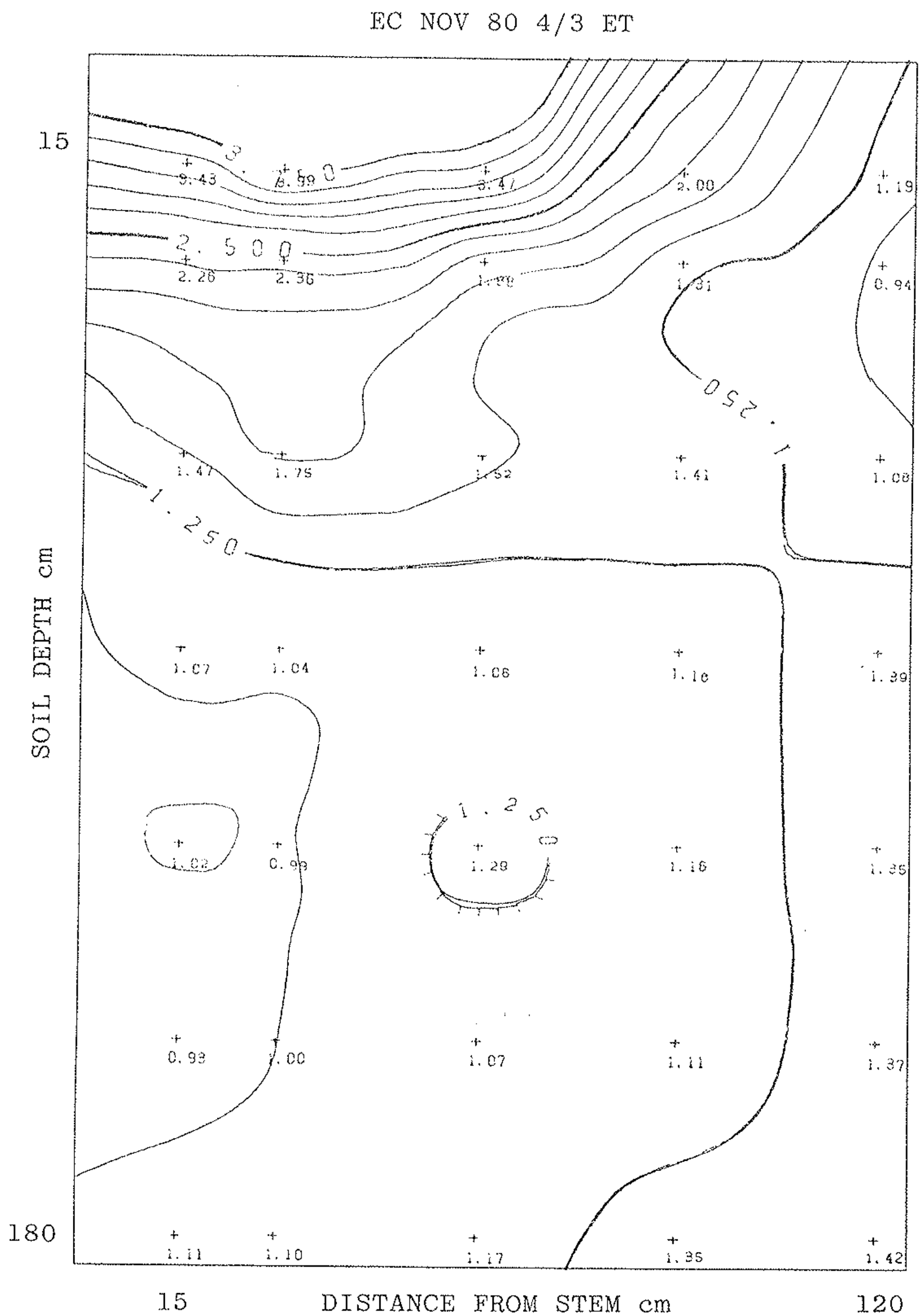

EC NOV 80 4/3 ET
15
180
SOIL DEPTH cm
15
DISTANCE FROM STEM cm
120
2.500
1.250

Figure 11.

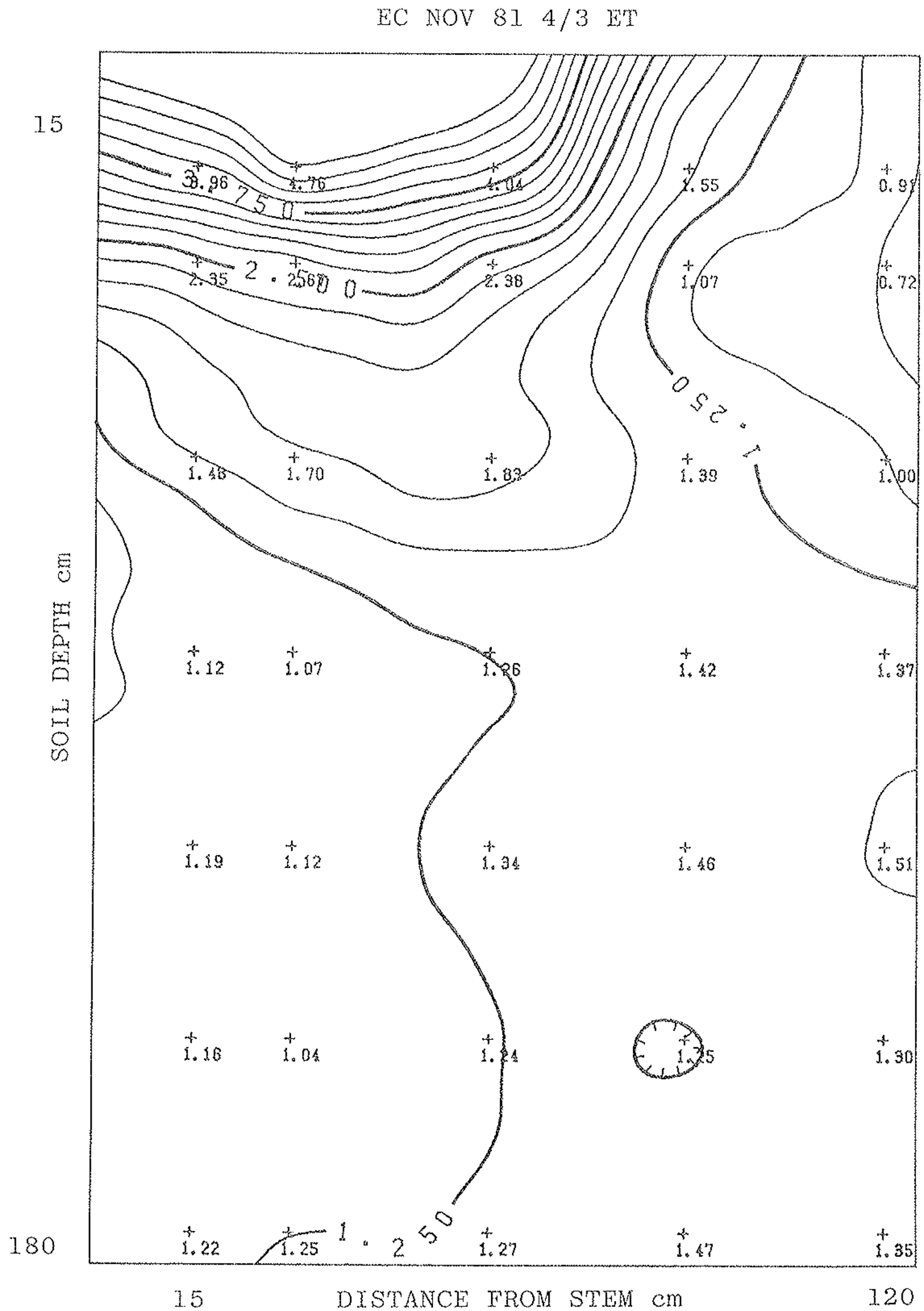

EC NOV 81 4/3 ET
15
180
SOIL DEPTH cm
15
DISTANCE FROM STEM cm
120
3.96
4.76
4.04
1.55
0.91
2.35
2.56
2.38
1.07
0.72
1.48
1.70
1.83
1.39
1.00
1.12
1.07
1.26
1.42
1.37
1.19
1.12
1.34
1.46
1.51
1.16
1.04
1.24
1.25
1.30
1.22
1.25
1.27
1.47
1.35
3.750
2.500
1.250
1.250

Figure 12.

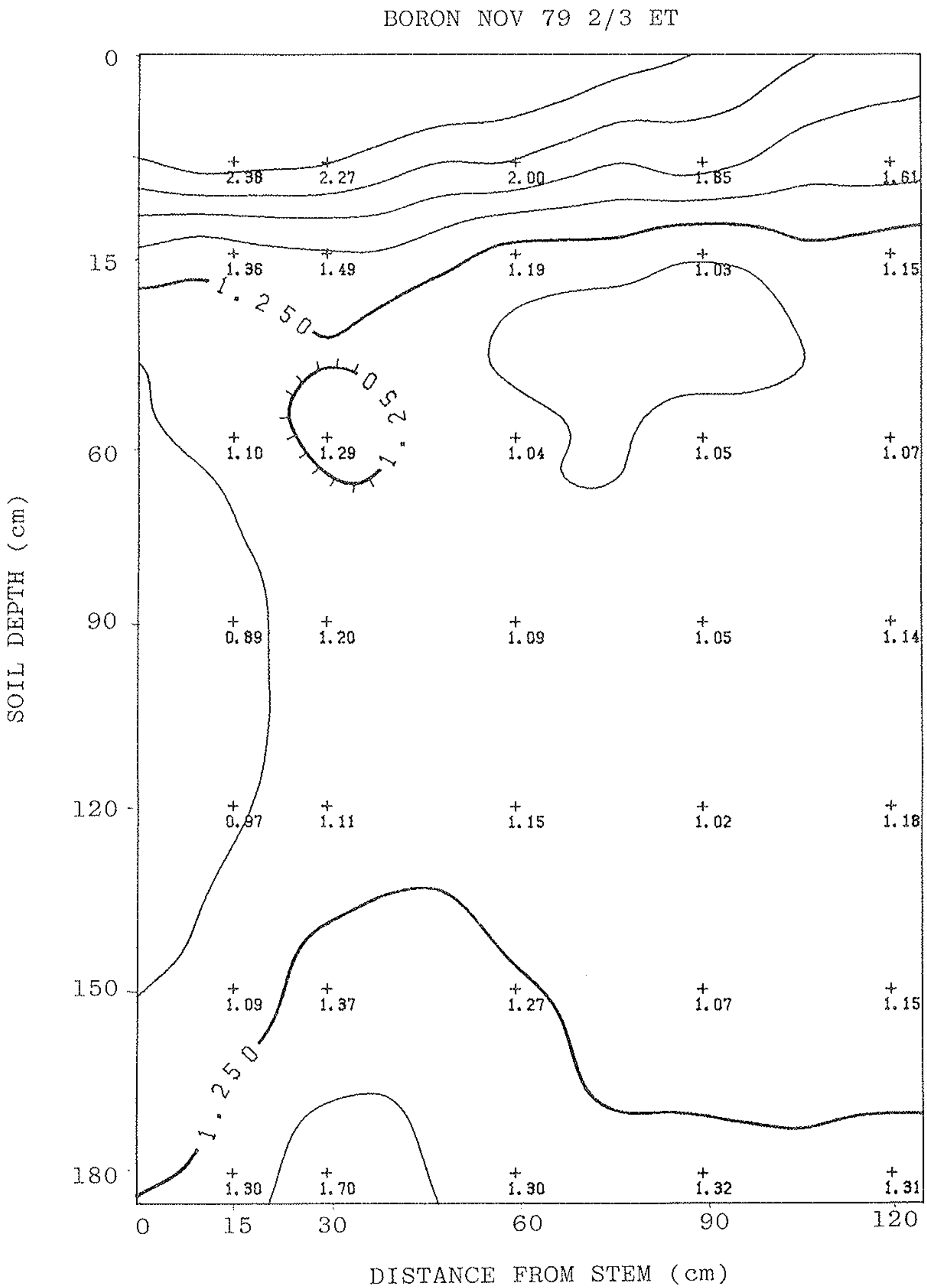

BORON NOV 79 2/3 ET
SOIL DEPTH (cm)
DISTANCE FROM STEM (cm)
0
15
60
90
120
150
180
0
15
30
60
90
120
2.38
2.27
2.00
1.85
1.61
1.36
1.49
1.19
1.03
1.15
1.250
1.10
1.29
1.04
1.05
1.07
0.89
1.20
1.09
1.05
1.14
0.97
1.11
1.15
1.02
1.18
1.09
1.37
1.27
1.07
1.15
1.30
1.70
1.30
1.32
1.31

Figure 13.

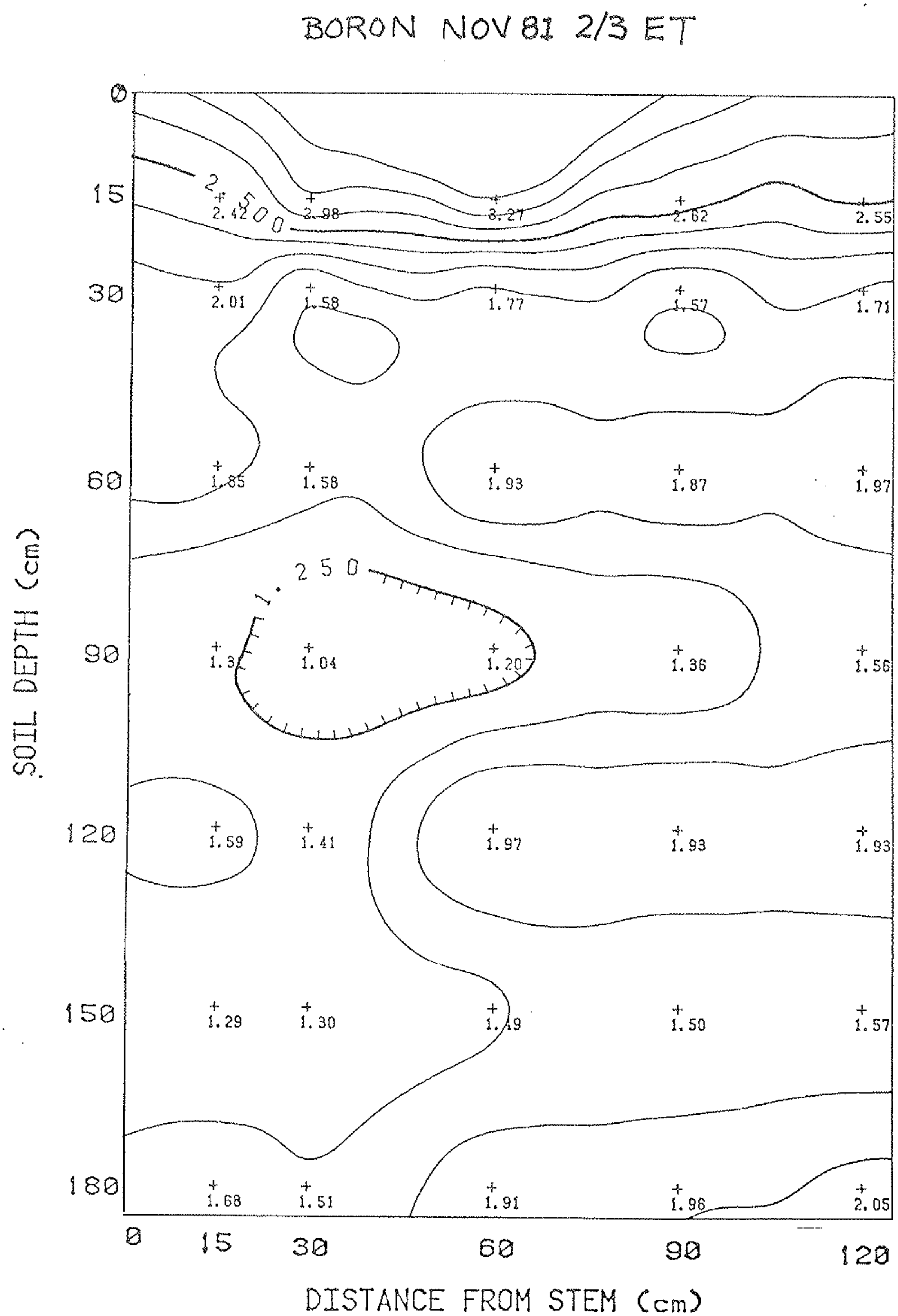

BORON NOV 81 2/3 ET
0
15
30
60
90
120
150
180
SOIL DEPTH (cm)
2.500
2.42
2.98
3.27
2.62
2.55
2.01
1.58
1.77
1.57
1.71
1.85
1.58
1.93
1.87
1.97
1.250
1.3
1.04
1.20
1.36
1.56
1.59
1.41
1.97
1.93
1.93
1.29
1.30
1.50
1.57
1.68
1.51
1.91
1.96
2.05
0
15
30
60
90
120
DISTANCE FROM STEM (cm)

Figure 14.

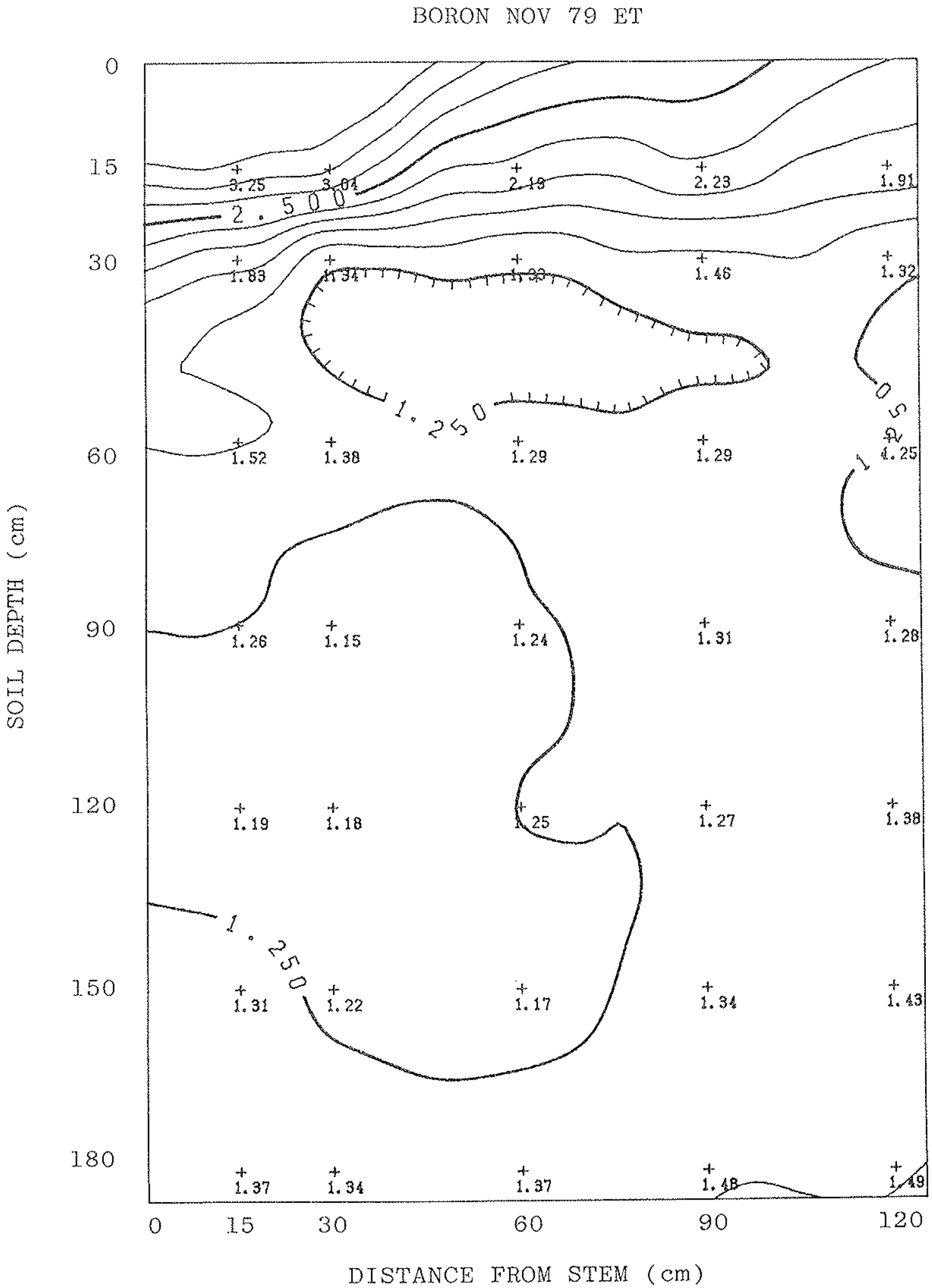
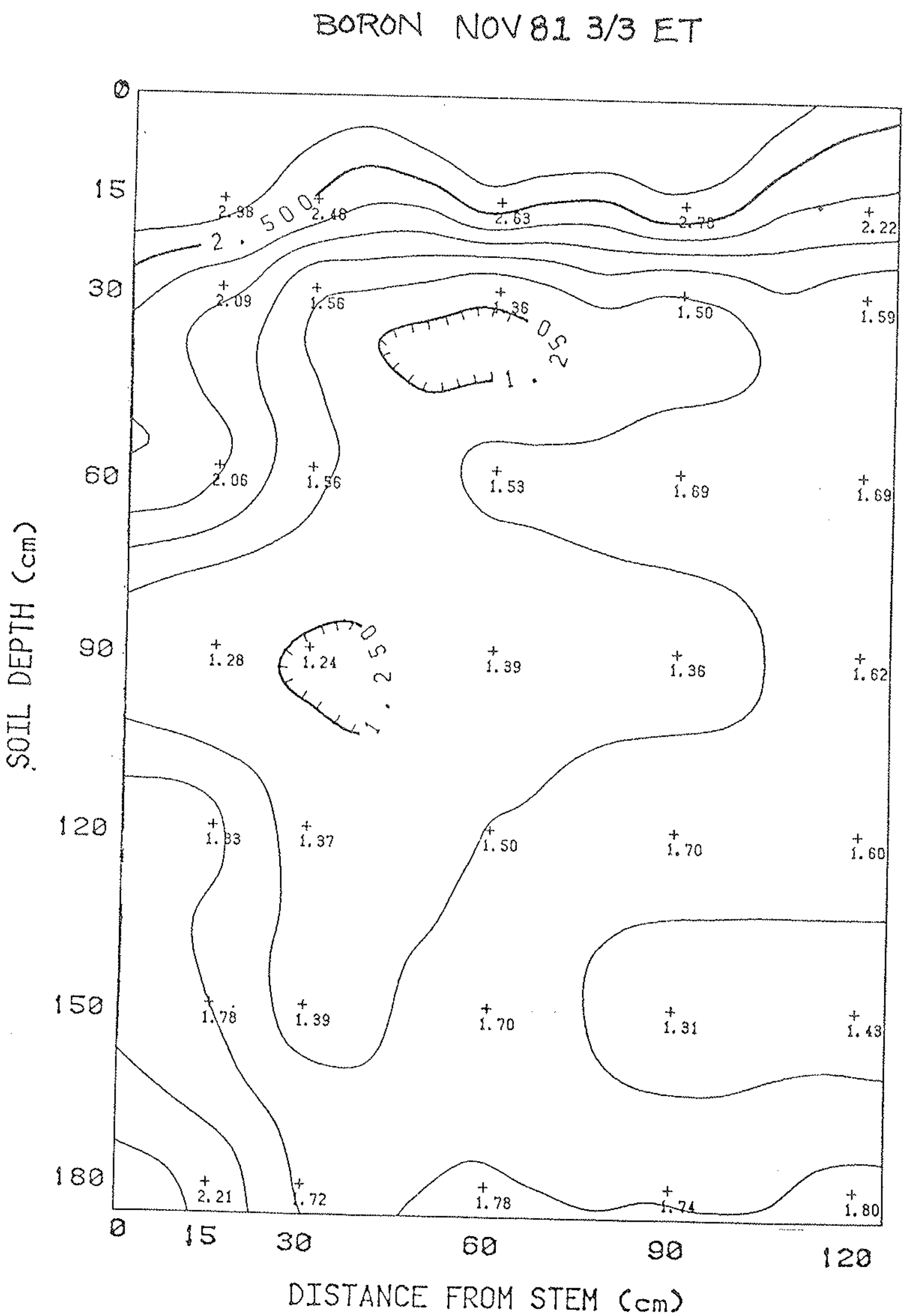

BORON NOV 79 ET
SOIL DEPTH (cm)
DISTANCE FROM STEM (cm)
0
15
30
60
90
120
150
180
0
15
30
60
90
120
2.500
1.250
1.250
3.25
3.04
2.19
2.23
1.91
1.83
1.34
1.46
1.32
1.52
1.38
1.29
1.29
1.25
1.26
1.15
1.24
1.31
1.28
1.19
1.18
1.25
1.27
1.38
1.31
1.22
1.17
1.34
1.43
1.37
1.34
1.37
1.48
1.49

Figure 15.


BORON NOV 81 3/3 ET
SOIL DEPTH (cm)
DISTANCE FROM STEM (cm)
0
15
30
60
90
120
150
180
0
15
30
60
90
120
2.500
1.250
1.250
2.38
2.48
2.63
2.78
2.22
2.09
1.56
1.36
1.50
1.59
2.06
1.56
1.53
1.69
1.69
1.28
1.24
1.39
1.36
1.62
1.83
1.37
1.50
1.70
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1.39
1.70
1.31
1.43
2.21
1.72
1.78
1.74
1.80

Figure 16.

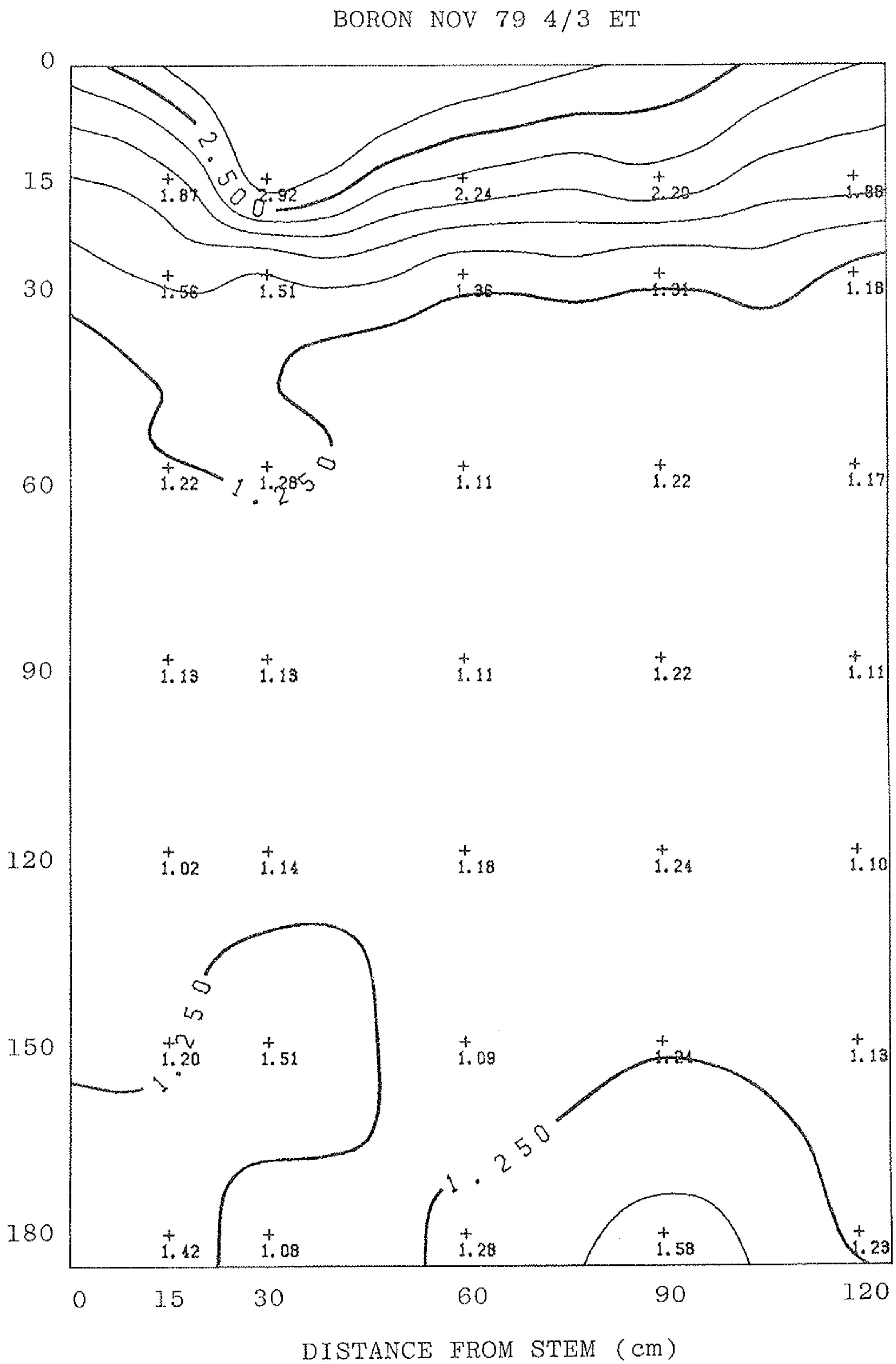
BORON NOV 79 4/3 ET
0
15
30
60
90
120
150
180
2.500
1.250
1.250
1.250
1.87
2.92
2.24
2.20
1.88
1.56
1.51
1.36
1.31
1.18
1.22
1.28
1.11
1.22
1.17
1.13
1.13
1.11
1.22
1.11
1.02
1.14
1.18
1.24
1.10
1.20
1.51
1.09
1.24
1.13
1.42
1.08
1.28
1.58
1.23
0
15
30
60
90
120
DISTANCE FROM STEM (cm)

Figure 17.

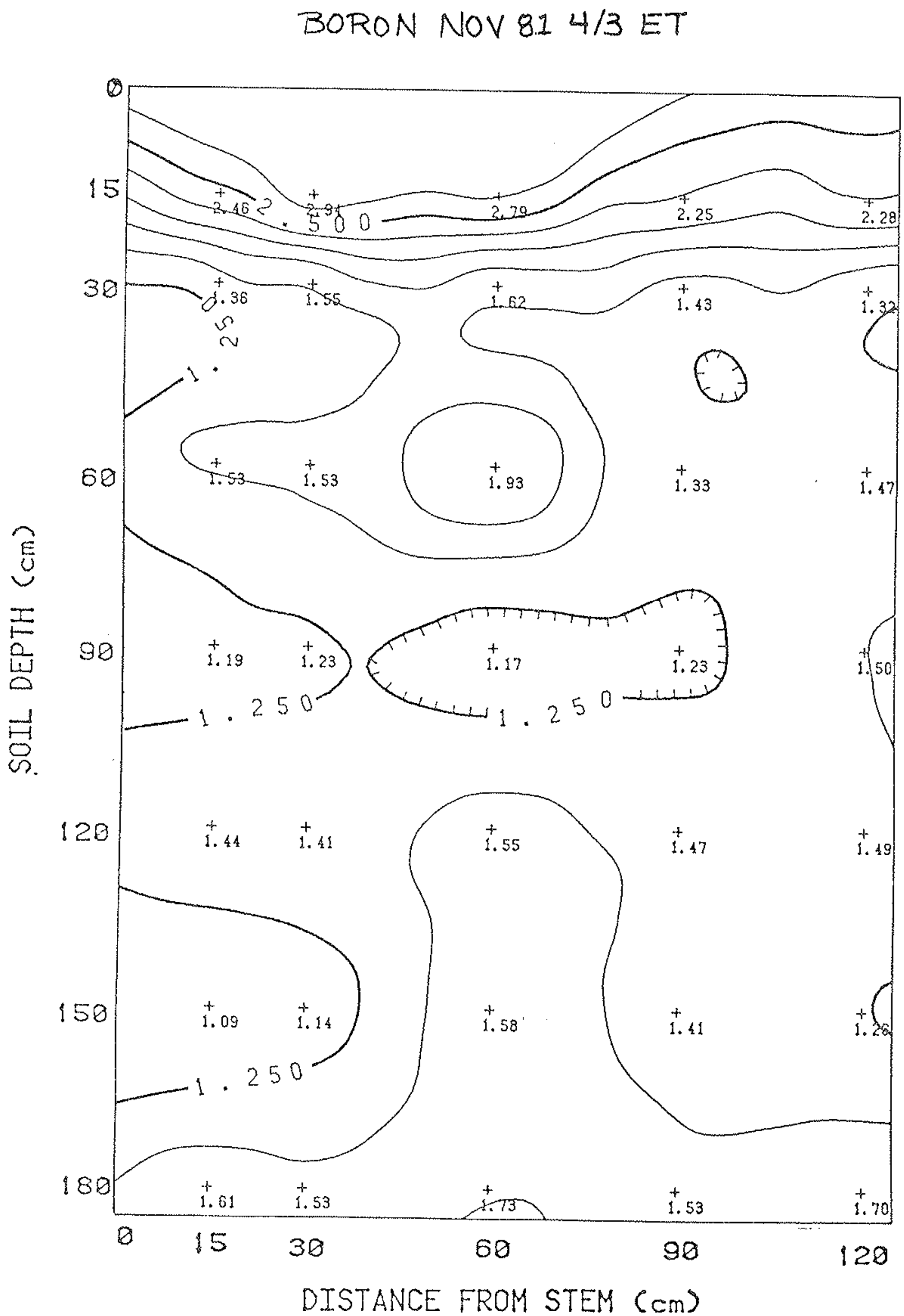
BORON NOV 81 4/3 ET
SOIL DEPTH (cm)
DISTANCE FROM STEM (cm)
0
15
30
60
90
120
150
180
0
15
30
60
90
120
2.500
1.250
1.250
1.250
1.250
2.46
2.79
2.25
2.28
1.36
1.55
1.62
1.43
1.53
1.53
1.93
1.33
1.47
1.19
1.23
1.17
1.23
1.44
1.41
1.55
1.47
1.49
1.09
1.14
1.58
1.41
1.61
1.53
1.73
1.53
1.70

Figure 18.

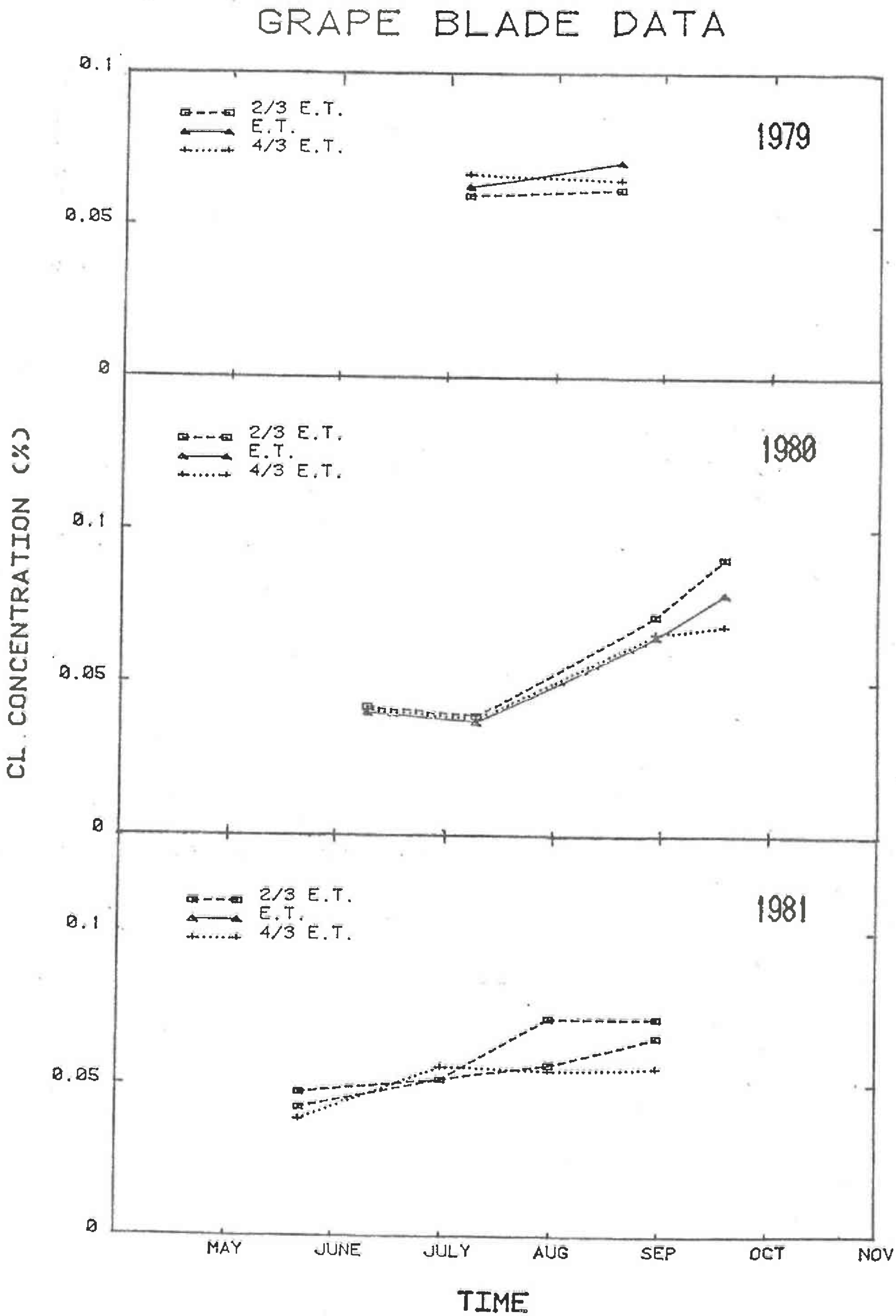
GRAPE BLADE DATA
0.1
0.05
0
2/3 E.T.
E.T.
4/3 E.T.
1979
1980
1981
CL CONCENTRATION (%)
MAY
JUNE
JULY
AUG
SEP
OCT
NOV
TIME

Figure 19.

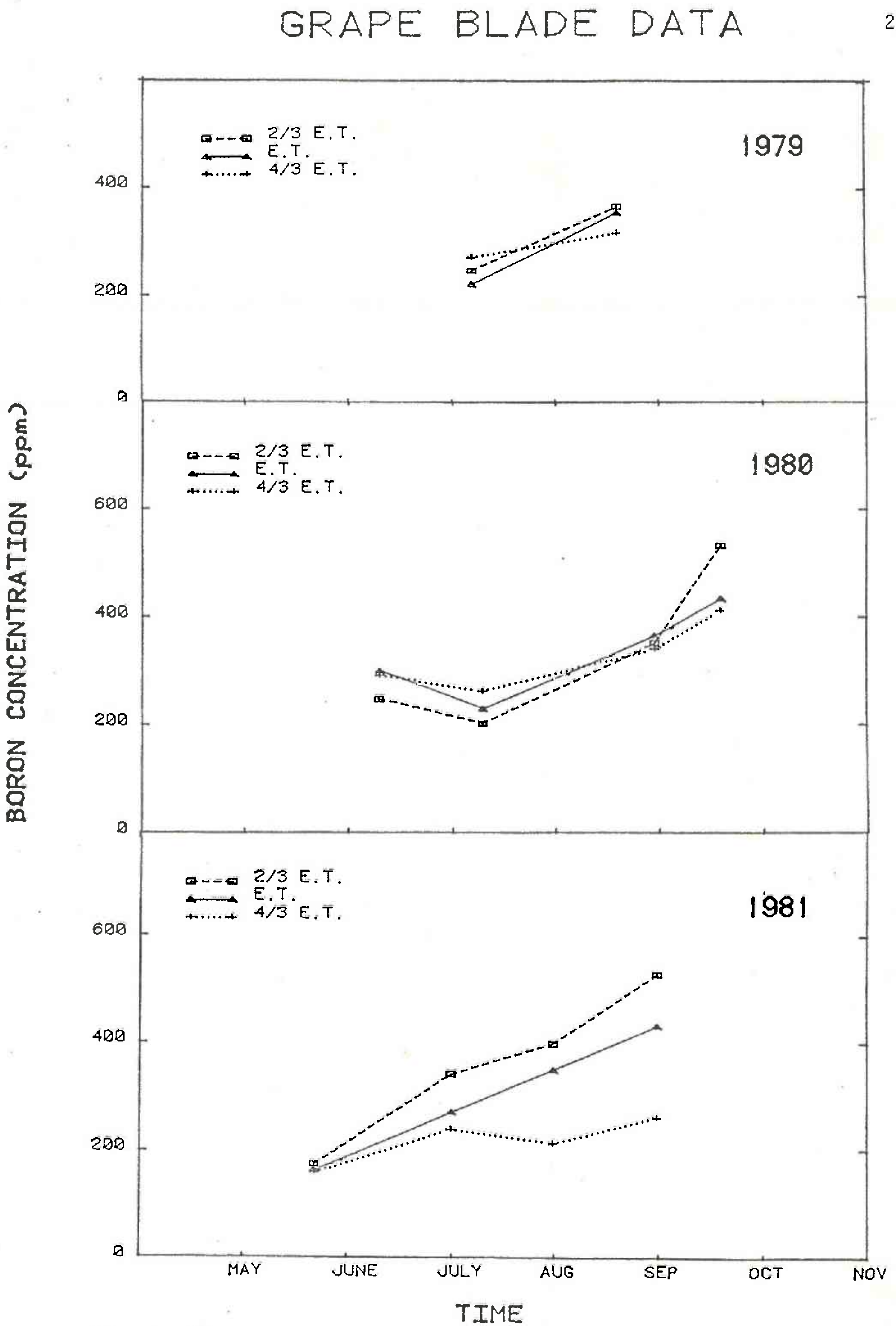
GRAPE BLADE DATA
2/3 E.T.
E.T.
4/3 E.T.
1979
400
200
0
2/3 E.T.
E.T.
4/3 E.T.
1980
600
400
200
0
2/3 E.T.
E.T.
4/3 E.T.
1981
600
400
200
0
BORON CONCENTRATION (ppm)
MAY
JUNE
JULY
AUG
SEP
OCT
NOV
TIME

Figure 20.