6-1977

Trees for Iraq from homoclimates

Mouaffaq D. Yahya

To the Graduate Council:

I am submitting herewith a thesis written by Mouaffaq D. Yahya entitled "Trees for Iraq from homoclimates." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.

Edward R. Buckner, Major Professor

We have read this thesis and recommend its acceptance:

F.W. Woods, H.A. Core

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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We have read this thesis and recommend its acceptance:

Frank W. Woods

Harold A. Core

Accepted for the Council:

L. Evans Roth

Vice Chancellor
Graduate Studies and Research

TREES FOR IRAQ FROM HOMOCLIMATES

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Mouaffaq D. Yahya

June 1977

TO MY PARENTS

For the sacrifices they made so
that I could reach this goal
can never be repaid.

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ABSTRACT

The method of Thornthwaite for classifying climate was applied to identify homoclimates for the three climatic types of Iraq, the mountain, the steppe, and the desert; all types are characterized by winter precipitation and summer drought. Data of mean monthly temperature and mean monthly precipitation were used in the identification of homoclimates. Potential evapotranspiration and moisture indices for the Iraqi stations were computed and six moisture provinces were recognized: Perhumid (A), Humid (B_1), Moist subhumid (C_2) and Dry subhumid (C_1) in the mountain areas; Semiarid (D) in the foothill areas; Arid (E) in the plains (middle and southern Iraq). Areas include parts of southern California, the Atlas mountains of Algeria and Morocco, Central Chile, West Australia, Canary Islands, part of Iraq and Turkey, parts of Greece, parts of Italy, parts of Portugal, and parts of Spain, have climates similar to those of Iraq.

Within the identified homoclimates the search for tree species more likely to be introduced to Iraw has been done. Different areas of Iraq was found to fulfill the requirement of 13 species. Those species are:

1. Abies cilicica Carr. - native to Taurus, Syria and Lebanon. For provinces A, B_1, and C_2.

2. Argania sideroxylon Roem. and Schult. - native to the arid Atlantic coastal hills south of Morocco. For provinces D and E.

3. *Alnus prientalis* Decne. - native to the eastern Mediterranean region. For provinces C_1, D, and E.

4. *Arbutus andrachne* L. - native to Greece. For province D.

5. *Callitris glauca* R. Br. - native to Australia. For provinces C_1, D, and E.

6. *Cedrus atlantica* Manetti - native to the mountains of Morocco and Algeria. For provinces A, B_1, and C_2.

7. *Cedrus brevifolia* (Hook.f.) Henry - native to Cyprus. For provinces B_1, C_2, and C_1.

8. *Pinus canariensis* C. Sm. - native to Canary Islands. For provinces C_2 and C_1.

9. *Pinus ponderosa* Laws. - native to western North America from southern British Columbia to central Mexico. For provinces A, B_1, and C_2.

10. *Peumus boldus* Molina - native to central Chile. For provinces C_1 and D.

11. *Pinus pinaster* Ait. - native to the western Mediterranean from France and Portugal to western Italy, and from Morocco to western Tunisia. For provinces A, B_1, and C_2.

12. *Quercus douglasii* Hook. and Arn. - native to California. For provinces C_1 and D.

13. *Quillaja saponaria* Molina - native to Chile. For provinces C_1 and D.

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CHAPTER I

INTRODUCTION

The numerous benefits derived from trees put them in an important position in the economy of any country. They help protect soil, our very basis of existence, and maintain its fertility. They offer shade and shelter for man and his livestock. They provide our timber. Trees serve as windbreaks and shelterbelts to make an environment for better crops. In watersheds, forests are of decided influence on the quality, quantity and regime of water and stream flow.

In Iraq, there is a growing awareness of an acute shortage of timber in areas which were naturally wooded in past times. The wholesale destruction of mountain forests was a tragic mistake which not only depleted the country's timber resources, but was followed by accelerated soil erosion, erratic stream flow and social stress. The lesson was severe, but now the country begins to turn to the modern philosophy of conservation. Territorial afforestation is being undertaken by the government, local administrations devote considerable effort to township and amenity plantations, and villages are being encouraged to establish woodlots on areas where trees have not grown before but human effort can assure their survival.

While planting of trees in areas of sustained rainfall and temperate climate is not difficult, success of afforestation measures is not easily achieved in the adverse environment of a hot climate with low rainfall. More than anywhere else, a knowledge and understanding of the arboreal vegetation is required because climate plays a dominant role in determining what tree can grow.

The native trees, Pinus brutia Ten. in the north and Tamarix aphylla (L.) Karst. in the south, may not be the most desirable species but at least they are useful and being indigenous, there is the probability that they can be successfully established in large-scale afforestation.

Exotic species have proved much more successful and useful than the indigenous species. In the mountains of Iraq, Pinus pinea L. seems to grow better than the local species and at higher elevations, Cedrus deodara (Roxb.) Loud. and Cedrus libani A. Rich. give indications that they may be useful. In the plains, Eucalyptus camaldulensis Dehn., Eucalyptus microtheca F.v.M., and Casuarina equisetifolia Frost. are showing promise.

The objective of this study is to develop a list of tree species that might be suitable for introducing in Iraq. Species included have native habitats similar to those found in Iraq. Emphasis was placed on finding "homoclimates" for those of Iraq and selecting species growing well in such areas.

CHAPTER II

REVIEW OF LITERATURE

I. IRAQ: HISTORICAL ACCOUNT OF LAND CONDITIONS

Oedekoven (1963), in discussing the forest history of the Near East, pointed out that the dawn of history found the area now called Iraq a settled and fluorishing country of village and urban communities, inheritors of many centuries of progress in the arts of community living and government, of trade and agriculture. They had no doubt developed an intricate system of irrigation. In this setting, there developed the great early civilizations in Babylon, Nineveh, Ur, and Baghdad. It is known from archaeological finds that Babylon was rich in palm trees and cypress, and the hanging gardens of Queen Semiramis were world famous, yet their ruins were discovered in treeless, desolate plains. Quintus Curtius, the Roman historian of Alexander the Great, stated that the Eulaeus (Karun River) rushed headlong for 125 miles between wooded banks.

For several centuries after the capture of Babylon by the Persian King Cyrus in 539 B.C., Iraq was to be a province belonging to other empires and the battlefield of their wars. Little was done in all this time toward restoring ruined but all important canal systems, replanting gardens, or rebuilding villages, owing to lack of leadership or wealth or security. The population was decimated by massacres and starvation steadily increased; living standards throughout the country sank extremely low. Invading tribes from the western desert occupied more and more of the country and turned plowed land into camel pasture. Short periods of safety and ease alternated with those of near anarchy and rapine; in particular, the two Mongol invasions under Haluga and Timur the Lame, with their wholesale destruction of life and property and ravishing of towns and countryside, were blows from which Iraq suffered for the ensuing centuries as a poor and forgotten country.

Most of Iraq (438,466 sq km) falls within the 100-200 mm rainfall belt, which limits the types of forest vegetation that can be expected. The original vegetative cover has been entirely destroyed over large areas and, subsequently, serious erosion has taken place. The usual effects of shifting cultivation as practiced in the Middle East, fires, excessive grazing by sheep and goats, and overcutting, combined with the unfavorable climatic conditions, account for the absence of forest cover on most of the land. Only 4 percent of the total area of Iraq supports forest cover (FAO, 1952). Table 1 shows the distribution of the remaining mountain forest area.

The remaining natural forests are situated in the northern and northeastern mountainous parts of the country and in the narrow flood plains of the great rivers. The mountain forests that still remain, begin at about 500 meters' elevation in the form of very degenerate oak coppice. Below this zone, almost all trees have been destroyed. Forests gradually improve in condition from 500 meters until their limit is reached at about 2,000 to 2,300 meters. Their survival in higher altitudes is not only the result of more rainfall but also of the

TABLE 1

THE MOUNTAIN FOREST AREAS OF IRAQ IN SQUARE KILOMETERS[1]

Kind	Nineveh (Mosul)	Arbil	Sulaimaniya	Kirkuk	Diyala	Total
Bare high lands	354	1,844	376	-	-	2,574
Oak forests of good density - unexploited	3,140	2,313	999	-	-	6,452
Oak forests of good density - exploited	1,258	976	630	18	-	2,882
Oak forests of low density	1,678	1,816	2,210	115	49	5,868
Total	6,430	6,949	4,215	133	49	17,776

Source: Directorate General of Forestry, Annual Report, Baghdad, 1970.

[1]River and pine forests are not included in the table; riverine forests occupy 201.34 sq. km scattered generally throughout the plains and pine forests cover 500 sq km in two restricted areas, Atrush, in Nineveh province, and Zawita, in Duhok province.

difficulty of access. The people of Iraq have had to make the best of a small wood supply.

Since the climate of Iraq generally is dry, irrigation has always played an important role in establishing vegetation. The destruction of the irrigation system (well documented in the historical record) is mainly responsible for the disappearance of plant cover in the plains. In addition, eradication of forests greatly accelerated the disruption of waterflow and its availability resulting in erosion and siltation. Finally, in the absence of proper drainage, much land has been ruined by salinization. All this clearly demonstrates that the rural economy is influenced by the lack of forest cover (Oedekoven, 1963). Goor (1955, 1963), in his discussion of the tree planting practices for arid zones, stated that the destruction is so great that the only remnants of some tree species are to be found in isolated pockets.

Soil erosion has resulted in the washing of deep layers of rich soil down to the plains below and to the sea leaving, in many cases, only a thin layer of soil supporting a poor, thorny vegetation. In other cases, bare rock has been exposed causing a change in the microclimate resulting in greater desiccation. Restoration to the original forest types may, therefore, have to be preceded by successional stages, using pioneer or nurse crops, often xerophilous bush species, before high forest species can be successfully planted.

It is likely, however, that some areas can be reforested immediately, provided suitable tree species for the altered sites can be located.

Botanists and foresters generally agree that the best results in re-establishing forests should be through the use of species native to the region. While indigenous trees should be tested first, exotics having native habitats similar to the altered sites may be biologically more suitable for existing conditions (Metro, 1952; Goor, 1955, 1963; Seth and Khan, 1959).

Economically, the search for suitable exotics is justified when the natural forests of a country are inadequate or the indigenous tree species appear, by reason of slow growth, lack adaptability or poor quality to be unsatisfactory for meeting the needs of the country (MacDonald et al., 1957; Champion and Brasnett, 1958). The main objectives of management in the dry zone are to hasten the pace of afforestation with protective and productive species. On such areas, however, the native species are merely the surviving elements of a relict vegetation on a continually degrading site and do not fulfill either of these functions in a satisfactory manner (Seth and Khan, 1959). Unfortunately, the native tree species of Iraq grow slowly and in all cases yield is small and returns slow, the only exception being certain species of pine which cannot be used unless there is adequate rainfall. Appropriate choice of exotic species, therefore, may provide an answer to this question. Afforestation experiments which have been conducted in several places in Iraq, sometimes with the aid of irrigation, indicate that there is no major difficulty in establishing suitable species, and there is no doubt as to the ability to produce good timber from irrigated plantations on a sound commercial basis (FAO, 1952).

II. THE ENVIRONMENT OF IRAQ

Iraq is rather complex in its topography, climate, and soils; it displays contrasting features in many respects, e.g., high mountain peaks exceeding 4,000 m and depressions almost with sea level, high plateaus and alluvial lowlands, rift valleys, sand dunes, hammadas (desert soil) and salines. The climate is also diverse, ranging from almost rainless, subtropical or tropical deserts, to extremely cold highlands. The vegetation of Iraq reflects its climate diversity, from dense mountain forests to plantless deserts.

Iraq has been divided into six districts based upon differences in topography, climate, soils, and plant life. Those are the mountain, the hill zone, the upper plains, the lower plains, the western desert, and the southern desert.

Topography

Iraq lies largely within the geosyncline that separates the Nubo-Arabian crystalline massif from the folded Zagros zone (Figure 1). The following physiographic units have been suggested by Zohary (1946, 1973).

1. The mountain region: This region extends from northwest to east and southeast and comprises the southern and western escarpments of the Zagros range. It is an extension of the Armeno-Iranian mountain complex. Elevations vary from 500 to 2,000 m, with peaks of about 4,000 m. The dominant topographic features are a series of parallel ridges interspersed here and there by fertile valleys, deep rough

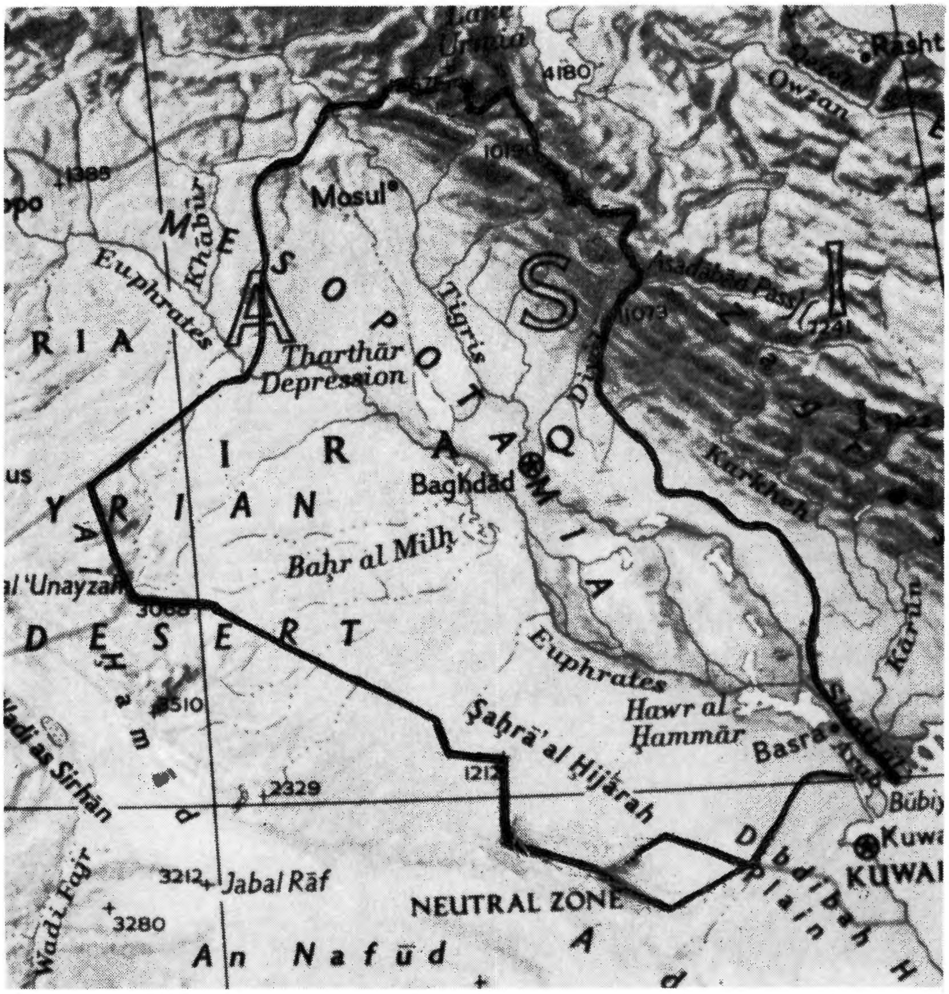

Figure 1. A physical map of Iraq.

gorges and intermountain plains and plateaus. Rainfall generally increases with elevation. The permanent rivers that cut through the mountains and the hill region are the Great and Little Zab and the Diyala, each emptying into the Tigris river.

2. The hill zone: This is an arcuate belt of low and medium foothills lying to the southwest of the mountain region. A line drawn from Khanaqin through Chemchemal, Koi Sanjaq, Khanzad (northeast of Arbil), and Aqra to Duhok roughly present this zone. It ranges in elevation from 200 to 600 m. The annual rainfall is sufficient for dry farming. The brown soils support a fairly rich steppe vegetation.

3. The upper plains, or Middle Mesopotamia: This region joins the hill zone to the south and west. It is bounded by the middle courses of the Euphrates and Tigris rivers, and includes the Iraqi part of the Jazira. Topographically, this region is an undulating plain crossed diagonally by the Jabal Hamrin (mountain) range. Soils vary from gravelly desert to calcareous brown soils, with occasional gypsum-bearing formations. Elevations range from about 50 m in the south to some 300 m northwards (near Mosul) where it is extensively dry farmed. A number of undrained basins reflect the arid conditions, the largest being Wadi Tharthar which terminates in the south with a salt late; others are Lake Habbaniya and Bahr al Milh. The Sinjar mountains (up to 1,460 m) occur as an almost isolated basaltic east-west range in the northwest.

4. The lower plains, or Lower Mesopotamia: This region extends from the Hamrin mountains in the north southward to Basrah; Baghdad is

almost centrally located in this region. This alluvial plain exceeds 50 m in altitude in the northernmost part. It is cut by the lower courses in the Euphrates and Tigris rivers which flow 1,200 km within Iraq and converge in southern Iraq to form the Shatt al Arab river which empties into the Arabian Gulf (Persian Gulf). The whole alluvial plain is considered to have once been a northern continuation of the gulf (with the Baghdad area as its northern shore), which was filled with fluviatile deposits. At present, it abounds in swamps and marshes partly caused by poor drainage and flooding of the rivers and partly by careless irrigation. Soils are clayey, or calcareous loams interspersed with sandy, swampy, or saline zones. The salty soils are of the white-alkali type. Its original desert vegetation has disappeared and it presently harbors a comparatively rich halophytic and hydrophytic flora. Date palm cultivation is the main agricultural enterprise in this region.

5. The western desert: This zone comprises the eastern part of the Syrian desert, the western portion being Syria. It consists for the most part of a rolling plateau which rises westwards. Tertiary chalks have formed here a shallow soil layer covered with desert gravel. Numerous ephemeral wadis and runnels traverse these featureless deserts. The largest of the wadis are Wadi Hawran, Wadi Amij, and Wadi Muhammadi.

6. The southern desert: This comprises the southeastern corner of the Syrian Desert, located west and south of the lower course of the Euphrates river. It is flat land with decreasing elevation toward the

southwest, and underlain with soft chalks, partly covered with compact sand. Sand dunes, mainly transported from north Arabia, extend as far north as south Jazira.

Climate

Climatic types are recognized in Iraq as: (1) the mountain type, (2) the Iraqi steppe type, and (3) the desert type. These units can be further divided into minor subdivisions.

1. The mountain type: This climatic zone dominates all of mountainous Iraq which is practically all under forest or steppe forest vegetation. Annual percipitation occurs as both snow and rain and ranges from 500 to more than 1,200 mm. Characteristic examples are Penjwin with an annual percipitation of 1,220 mm (Appendix A, Figure 2), Rawandoz with 941 mm (Appendix A, Figure 2), Amadiya with 890 mm (Appendix A, Figure 2), Sulaimaniya with 720 mm (Appendix A, Figure 2), and Rayat with 630 mm (Appendix A, Figure 2). The rainy season begins as early as September and may end in May or June; the summer is dry and hot. Generally, four or more months of the winter display mean minimum temperatures below 0°C and in seven to eight months the extreme minimum drops below 0°C. Zohary (1973) divides here the climatic year into three seasons: (a) a winter resting period in which vegetative growth ceases because of the low temperature; (b) a spring and early summer active period; and (c) a middle summer dry period. This tripartition of the climatic year characterizes not only the climate of the mountains but also that of other Irano-Turanian districts as compared to other parts of Iraq and the Middle East in general.

2. The Iraqi steppe type: This region dominates most of northern Iraq including the eastern hill country and the Jazira. The climatic patterns of Mosul (Appendix A, Figure 2) and Kirkuk (Appendix A, Figure 2) is an example of this variant. The amount of annual rainfall ranges between 300-500 mm. The rainy season lasts about six months; winter is not severe with mean minima generally above 0°C. Vegetation grows throughout the winter season while summer is the only resting period. The vegetation of this climatic area is a steppe of malaccophyllous, chamaephytes, hemicryptophytes and annuals. Agriculturally, it is the center of Iraq's extensive dry farming and permanent pasture land.

3. The desert climatic type: This xeric region dominates middle and southern Iraq, including Lower Mesopotamia, the western desert and the southern desert. Low percipitation is characteristic of the entire region, ranging from 75-200 mm. Winters are warm and summers hot; summer begins in April and is a "dead" season. Appendix A, Figure 2 gives characteristics of this type for Ramadi, Baghdad, and Basra. The vegetation in this region is that of the desert, usually patchy or possibly continuous in depressions. Dry farming cannot be maintained here without irrigation. A deviation from this type is found in the region between Basrah and Salman where the influence of the Arbian Gulf creates conditions which resemble a tropical desert. Evidence of this is the sporadic occurrence of tropical desert species, such as <u>Ziziphus nummularia</u> (Burm.) Walk. and the recently discovered stand of <u>Acacia gerrardii</u> Rech.

III. THE FLORA OF IRAQ

The available information on the flora of Iraq was first summerized by Zohary in 1946. Subsequently Blakelock (1948 et seq.) published the Rustam Herbarium of Iraq plants, and Rechlinger (1964) the flora of lowland Iraq. At present, a flora of Iraq is in preparation by members of the Kew Herbarium. Three volumes of this work are currently available.

The features that are characteristic of Iraq's flora may be summarized as follows:

1. For geographical reasons, the flora of most of Iraq did not develop traits of its own but is a transitional assemblage between the floras of southern Turkey and the Syrian Desert.

2. The arboreal flora of the mountain forests and steppe-forest presents a marked contrast to the flora of the adjacent steppes and deserts. The genera *Quercus*, *Pistacia*, *Celtis*, *Cercis*, *Juniperus*, *Crataegus*, *Pyrus*, *Cerasus*, *Prunus*, *Rhamnus*, *Amelanchier*, *Sorbus*, *Acer*, and *Cornus* are represented. Although only a few of them play an important part in the forest vegetation, they constitute the richest arboreal flora of the Kurdo-Zagrosian system in Iraq. This is because the Iraqi mountains are climatically the most favorable for tree growth; the number of tree species decreases both towards the east and the south.

3. The Saharo-Arabian and tropical influence of the Persian Gulf region on Iraqi flora is indicated by the appearance of some Sudanian or Sub-Sudanian species in the southern desert.

4. Considerable areas of tragacanthic vegetation (plants that produce gum) are in the higher mountain zones. It is this zone that has supplied the bulk of Iraq's endemics.

5. There occurs in certain localities of the mountains a relic forest consisting of Pinus brutia Ten. and some other Mediterranean species such as Juniperus oxycedrus L. Iraq is also specially noted for the presence, mostly in fields or other secondary habitats, of scores of Mediterranean weedy annuals such as species of Medicago, Trigonella, Trifolium, Galium, many members of Gramineae, Cruciferae, Compositae and others.

Information about the vegetation of Iraq is given in Appendix B.

IV. SELECTION OF SPECIES

Naturalists first began to introduce new tree species in the eighteenth century largely for botanical collections or to enrich parks and gardens. During the nineteenth century, introduction of trees to fulfill the needs of forestry was first attempted. According to Morandini (1964), there were four basic reasons for introducing species: (1) to enrich the local flora; (2) to obtain resistance to disease and other unfavorable environmental factors; (3) to exploit superior growth rate; and (4) to obtain wood quality.

In 1963, Wright pointed out that species introduction has already proved its value in Australia, New Zealand, South Africa, the United Kingdom, and other countries. In parts of these countries, exotic plantations provide most of their wood. In some instances, exotic trees produce four times as much as the native species. Exotics usually furnish valuable softwood lumber, whereas the native trees are hardwoods.

Programs for introducing exotic trees have been suggested by both Wright (1963) and Morandini (1964). The programs emphasize genetics and tree improvement. Wright's plan suggests the following eight steps.

1. Study the climates of the world and select regions with climates similar to the study region. The climatic matches need not be exact because some factors compensate for small deficiencies in others.

2. Study the intrinsic growth and wood properties of the tree species in those regions, and plan to introduce and test all those with desirable properties.

3. Study the monotypic genera because of their probable freedom from pests and the north European species because of their probable adaptability to a variety of site conditions.

4. Include close relatives of the most promising species to prepare for future hybridization.

5. Study the site preferences of the species to be introduced and plan tests accordingly.

6. Introduce from three (small-range species) to 20 (large-range species) provenances of each species. Follow up with larger provenance tests of promising species. Test only material of known origin.

7. Test the new species under three or four different conditions.

8. Progress from small-plot plantings which test possibilities of single trees to large-plot plantings which test stand performance.

The program of Morandini (1964) is based on the following needs:

1. Studies of climatic similarities between the various regions of the world.

2. Biological and economic analyses of the forest flora of similar climatic regions, and the choice of quick-growing species, the wood of which is readily utilizable in large-scale industries such as paper manufacture.

3. Ecological studies to distinguish the most suitable races and provenances.

4. Tests to screen out, by planting small groups in arborata, a large number of species and test plantations (on sufficiently large areas to insure the statistical value of the results) of those species which have good prospects of success.

Both authors agreed that such a program will take a long time and require sizable investment. However, it could be accomplished in a reasonable length of time if well planned and if new developments in experimental design were used.

V. CLASSIFICATION OF PLANTING SITES FOR SPECIES SELECTION

In 1952, the Word Meteorological Organization was asked to develop a standard scheme of climatic classification "based on the relationships between climate and vegetation. Such a classification would be extremely useful to forestry agencies as a guide for the choice of exotic species for trial plantings." The importance of this problem in forestry is indicated by the fact that southern hemisphere countries (Australia, Chile, Kenya, New Zealand, South Africa) invested 6,427,000 acres of their land resource in exotic conifer plantations (FAO, 1955). To this must also be added great areas of *Eucalyptus* spp. and *Acacia* spp. (indigenous to Australia).

Comparative study of climates and search for source-regions which are, as nearly as possible, homoclimes of the areas proposed for exotic afforestation are comparable with the technique of agro-climatic analogy used in agriculture (Nuttonson, 1947; Hanson, 1949; Richards, 1950). However, forest crops require a much greater time interval even for provisional results. Considering the large scale and greater expense of initial plantation trials, the forecast of performance provided by this type of study is thus even more desirable in forestry than in forms of annual crop husbandry (Jackson, 1962).

Several methods have been developed for classifying climatic zones of the world: (a) those which deal with the study of the influence of single climatic factors on the development of the plant, e.g., Koppen (1884) and Supan (1879); (b) those in which values for the two main climatic elements, temperature and precipitation, are used in simple formulae to give a climatic index, e.g., Emberger (1955), Gaussen (1955), Walter (1955), and Swain (1938); and (c) those based on the concept of energy and water balance, estimated from generally complex formulae in which factors such as temperature, day length, humidity and solar radiation are included, e.g., Thornthwaite (1948).

Koppen (1884) and Supan (1879) both adjusted the five astronomical zones on the basis of temperature, the latter choosing the mean annual isotherm of 20°C (68°F) as the limit of his "hot belt" and the isotherms of 10°C (50°F) for the warmest month as the limits of his "cold caps," with "temperate belts" in between. These temperature limits were chosen because they fixed approximately the limits for the growth of palms and the limits of cereals and forst trees, respectively; and they demonstrate the principle of the use of such figures as the basis of many climatological classification. As a result of this procedure, these belts were widened over continents and narrowed over the oceans, where the mobility of water causes a more even distribution of temperature. Koppen's primary breakdown was by mean temperature of the coldest month (MTCM) and of the hottest months (MTHM), corresponding with deCandolle's "megathermal" (MTCM 18°C) and "mesothermal" (MTCM 3° to 18°C), plant physiological classes. Secondary breakdown was in terms of season and amount of precipitation. As early as 1920, Lauri Slvessalo presented Cajander's adaptation of Koppen's classification specifically for the purpose of introducing exotic species to Finland.

A classification of climate for forestry purposes was devised by Swain (1938). His objectives were to compare forest environments, and to determine homoclimes for exotic introductions. He drew up a climatic index designed for global use which he based on:

1. occurrence and extent of a period of inadequate rainfall during the year, that is, the seasonal drought period;

2. the mean temperature of the coldest month (MTCM);

3. The temperature range as expressed by the mean temperature of the hottest month (MTHM) in relation to MTCM; and

4. the mean annual rainfall as a subordinate factor.

On the basis of the first of these factors, he divided the land surface of the globe into four broad regions according to the number of months of seasonal droughts; and he defined a drought month as one with a mean rainfall of less than 50 mm (2 in.). This is a higher limit than that set by some other workers who have adopted defninitions varying from 20 to 50 mm (0.8 to 2 in.). He divided each of these regions into two zones according to the season of the year in which the main drought occurred. This division is probably not of much significance for tropical and equatorial regions, particularly highlands, where seasonal differences in temperature are small and diurnal variations high, and where winter and summer have little meaning. It might be necessary to create one or two special zones for these regions (Table 2).

Swain then allocated localities in each zone to ten subzones (1.0 to 1.9, 2.0 to 2.9, etc.) on arbitrarily selected scales of the relationships between the mean temperature of the coldest month (MTCM) and the mean temperature of the hottest month (MTHM) for each locality (Table 3).

Finally, he used an arbitrary scale of mean annual rainfall (MAR) to indicate by a letter following the decimal of the subzone the relative character of that rainfall (for example, 1.0a, 1.0b, etc.) (Table 4).

TABLE 2

SWAIN'S CLIMATIC INDEX-ZONES[1]

Climate	Number of Drought Months	Season of Drought	Zone
Moist	0-1	Winter and/or spring	1
	0-1	Summer and/or autum	2
Medium Moist	2-4	Winter and/or spring	3
	2-4	Summer and/or autumn	4
Dry	5-7	Winter and/or spring	5
	5-7	Summer and/or spring	6
Arid	8-12	Winter and/or spring	7
	8-12	Summer and/or autumn	8

[1]After Champion and Brasnett (1958). Choice of Tree Species, FAO Forestry Development Paper 13.

TABLE 3

SWAIN'S CLIMATIC INDEX-SUBZONES[1]

Mean Temperature of the Coldest Month of All Zones (°F)	Mean Temperature of the Hottest Month		Corresponding Subzones
	For Zones 1 to 6 (°F)	For Zones 7 and 8 (°F)	
Below 34°	Below 55°	Below 60°	0.0
	55° - 68°	60° - 70°	0.1
	Over 68°	Over 72°	0.2
34° - 46°	Below 68°	Below 72°	0.3
	Over 68°	Over 72°	0.4
46° - 55°	Below 72°	Below 75°	0.5
	Over 72°	Over 75°	0.6
65° - 67°	Below 75°	Below 80°	0.7
	Over 75°	Over 80°	0.8
Over 67°			0.9

[1]After Champion and Brasnett (1958). Choice of Tree Species, FAO Forestry Development Paper 13.

TABLE 4

SWAIN'S CLIMATIC INDEX-MEAN ANNUAL RAINFALL[1]

Subzones	Mean Annual Rainfall (cm)	Indicating Letter
1.0-1.8	Below 102	a
and	102-152	b
2.0-2.8	152-254	c
	Over 254	d
1.9 and 2.9	Below 152	a
	152-254	b
	Over 254	c
3.0-3.8	Below 89	a
and	89-127	b
4.0-4.8	127-216	c
	Over 216	d
3.9 and 4.9	Below 127	a
	127-216	b
	Over 216	c
5.0-5.8	Below 64	a
and	64-102	b
6.0-6.8	102-152	c
	Over 152	d
5.0 and 6.9	Below 76	a
	76-152	b
	Over 152	c
7.0-7.8	Below 20	a
and	20-38	b
8.0-8.8	38-64	c
	Over 64	d
7.9 and 8.9	Below 20	a
	20-38	b
	38-76	c
	Over 76	d

[1]After Champion and Brasnett (1958). Choice of Tree Species, FAO Forestry Development Paper 13.

In this way all similar climates of the world can be grouped together into subzones from 1.0a to 8.9d and climatological maps can be drawn on which the accuracy of the boundaries of the subzones will depend on the destiny of the recording stations in the regions concerned. This results in a total of 286 subzones. The system is dependent on the arbitrary selection of limits of the various factors and the limits may not be universally suitable. More important, little account is directly taken of precipitation-effectiveness and the consequences of evaporation (Jackson, 1962).

Emberger (1932) formulated the bio-climatic value "Q" for application in arid zones. He considered that, in a practical sense, the precipitation and temperature together characterize the bio-climate of a region. He defined it as a percentage, $100 \times 2p/M^2 - m^2$, in which "P" is the annual precipitation (mms.), "M" is the average maximum temperature of the hottest month, and "m" is the average minimum temperature of the coldest month (°C). "Q" will decrease with increasing aridity and continentiality of climate and increase as precipitation and maritime influence increase. According to this formula, Emberger (1955) has classified the Mediterranean region, Sahara desert and part of equatorial Africa into bio-climatic regions. The result for the Mediterranean regions is shown in Table 5. This formula has been used by Seth and Khan (1959) in classifying the dry zones of India for the purpose of exotic introduction.

Gaussen (1955) proposed a simple means of determining a moisture index by merely comparing the monthly precipitation (in mm) with the

TABLE 5

EMBERGER BIO-CLIMATIC REGIONS OF THE MEDITERRANEAN[1]

Climate	Country	Climatic Index of Each Site
Semi-arid	Morocco	48
	Cyprus	51
	Italy	54
	Portugal	63
	Turkey	70
Sub-humid	Italy	77
	Italy	80
	Algeria	83
	Turkey	91
	Greece	111
Humid	Turkey	118
	Tunisia	142

[1]After Emberger (1955). Afrique du Nord-Quest. Arid Zone Res., Plant Ecol. UNESCO.

value of the mean monthly temperature (in °C) doubled. If the value of temperature doubled represents the potential evaporation of water with the available monthly energy, then the ratio again becomes the simple P/PE index of earlier investigators. This moisture index was adapted by Bagnouls and Gaussen (1957) as the basis for a more formalized climatic classification. Walter and Lieth (1965) used it in modified form to produce climatic diagrams of the world, which serve as a part of a climatic classification. Meher-Homji (1963) used the same basic index in a bio-climatic classification. Since the index involves monthly data and classifies the moisture condition of each month, it presents a significant break from the older approaches more concerned with annual data.

The number of dry months is used as the primary variable in a climatic classification by Bagnouls and Gaussen (1957). Twelve major climatic provinces are identified on the basis of (1) the number of dry months, and (2) three types of thermal regimes: (a) no temperatures below freezing, (b) temperatures above and below freezing, and (c) no temperature above freezing.

Carter (Carter and Mather, 1966) has pointed out serious deficiencies in the Bagnouls-Gaussen scheme: (1) the lack of validity of the estimate of potential evapo-transpiration; (2) the failure to consider how stored soil moisture might modify the dryness of a month; and (3) the lack of functional and rational criteria by which to define climatic types.

Walter (1955) modified Gaussen's scheme by plotting the temperature curve during warm months at three times the precipitation curve. This attempt to rectify Gaussen's underestimation of evapo-transpiration provides for a monthly water loss of only 90 mm when air temperature is 30°C (or an annual evapo-transpiration of 1,100 mm), well below the expected value on the basis of observation. Walter and Lieth (1964), using this modification, identified 10 major climatic types.

The method of classification most commonly used is that of Thornthwaite (1948) who proposed what he claimed was an entirely new classification of climates. He wrote (1955): "the climate of a locality, considered statistically, is often regarded simply as 'average weather,' which is essentially a meteorologist's view. Climate considered in the light of physical processes is better thought of as the complex reaction of vegetation and atmosphere at the earth's surface, especially as expressed in the exchange of energy, moisture and momentum between the surface and the atmosphere. We believe that a soundly based classification, of real value in the study of vegetation, ought to seek its parameters in these complex exchanges, and not in the raw observational data of the meteorologist."

The principal parameter, or determining factor, of Thornthwaite's classification is a climatic potential derived from the thermal regime which he called Potential Evapo-transpiration (PE) and defined as the combined evaporation and transpiration which would occur from a vegetation-covered surface if soil moisture conditions were adequate for unrestricted transpiration.

He pointed out that natural evaporation, including evaporation from open water, from intercepted rainfall on the surface of plants, from the surface of the soil, and transpiration from green plant tissues, can only take place when the vapor pressure of the surrounding air is less than the vapor pressure at the evaporating surface and when there is an external source of energy. Thornthwaite considered that ". . . evapo-transpiration clearly depends on the:

(a) external supply of energy to the evaporating surface, principally by solar radiation;

(b) capacity of the air to remove the vapor, that is, on wind speeds, turbulent structure and the decrease of vapor concentration (pressure) with height (elevation above sea level);

(c) nature of the vegetation, especially as regards its capacity to reflect incident radiation, the extent to which it fully occupies the soil, and the depth of its root system; and

(d) nature of the soil, especially the amount of available water in the root zone."

In an endeavor to establish a valid, practical, empirical relationship between climate and potential evapo-transpiration, Thornthwaite studied monthly and seasonal data from irrigation and drainage projects and daily observations from carefully operated evapo-transpiration tanks. He found that when adjustments are made for variations in day length, there is a close relationship between mean temperature and potential evapo-transpiration. He evolved an empirical formula for the computation of potential evapo-transpiration (PE) for any place whose latitude is known and for which monthly temperature records are available. It is a complicated formula and in the computation of PE, three steps are involved for each of which a monogram and table are required.

When PE is compared with the precipitation and allowance made for the storage of water in the ground and its subsequent use, periods of moisture deficiency and excess are clearly revealed. In some places where precipitation is always greater than evapo-transpiration, soil moisture remains near field capacity and there is a water surplus (S). In other places there are dry seasons in which precipitation is less than potential evapo-transpiration and differences are made up in part from the stored moisture in the soil but as this is used up a water deficit (d) occurs, and actual evapo-transpiration falls below the potential evapo-transpiration by this amount. "Using the new procedure, it is possible to work out a water balance sheet from climatological data alone, showing at all times the soil moisture conditions and providing values of moisture surplus and deficiency" (Thornthwaite and Hare, 1955). The data required are monthly precipitation, monthly PE (computed from the monthly temperature and precipitation records and from latitude), soil moisture storage change (obtained from a table designed according to the water holding capacity of the soil), and soil moisture storage (a standard figure of 30 cm or 11.8 in., when there is a water surplus, reduced by the monthly negative values and increased again when it falls below 30, by positive values of the moisture storage change). As long as monthly precipitation is greater than monthly PE, actual evapo-transpiration is assumed to be the same as the potential.

According to Thornthwaite (1948), a surplus of 15.2 cm (6 in.) of rainfall in one season will counteract a deficiency of 25.4 cm (10 in.) in another because evapo-transpiration is slowed down when only stored soil water is available for use. He did not amplify this statement nor explain why the ratio should remain the same for all soils. From the relationship of the annual values of water surplus (s) and water deficit (d), the weighting of the ratio stated and the water need which is the potential evapo-transpiration, he derived a formula for a Moisture Index, Im, which is Im = (100s - 60d)/PE. In the classification, as slightly revised in (1955) potential evapo-transpiration (PE) and precipitation (P), are the bases of four climatic criteria: moisture adequacy, thermal efficiency, seasonal distribution of moisture adequacy, and summer concentration of thermal efficiency. Each is represented by an index value and boundaries are set quantitatively. When adjustments are made for the storage of water in the soil, the difference between mean monthly amounts of (P) and (PE) is the monthly surplus (S) or deficit (D). Moisture adequacy may then be expressed by the monthly moisture index (Im) in the formula:

$$Im = 100 \frac{(S - D)}{PE}$$

If soil moisture is assumed to be constant, the question is simply:

$$Im = 100 \left(\frac{P}{PE} - 1\right)$$

The sum of the 12 monthly values of Im gives the annual moisture index. He uses this index as a basis for the division of the world into nine moisture regions which are given in Table 6.

Thornthwaite stated that potential evapo-transpiration is an index of thermal efficiency for it is an expression of temperature effects with due allowance for effect of variation in day length. He defined climatic regions based on thermal efficiency which he called Thermal Provinces. These are analogous to those derived from the moisture index and are designated by similar symbols. Microthermal (C) and mesothermal (B) climates are subdivided like the sub-humid (C) and humid (B) climates as shown in Table 7.

Use of these methods enables a quantitative value to be put on the climatic regions. At the same time, a comparison can be made between the climatic zones of a particular country.

Practical application of these indices in species selection for afforestation is the identification of homoclimates. When introducing species to a country, the logical starting point is to obtain seed from a locality with a relatively similar climate.

Goor (1955, 1963) stated that once the climate and soil have been carefully studied, the choice of species for the particular area should be considered not only with regard to their suitability for growth, but also as to whether they fit the purpose for which they are planted. The species suitable for timber production in an area like Iraq are very limited. In some cases, "pioneer species" are planted, trees that can grow well on poor soils for soil improvement.

TABLE 6

THE MOISTURE REGIONS, 1948 AND 1955 THORNTHWAITE CLASSIFICATIONS[1]

Climatic Type	Moisture Index 1948	Moisture Index 1955
A Perhumid	100 and above	100 and above
B_4 Humid	80 to 100	80 to 100
B_3 Humid	60 to 80	60 to 80
B_2 Humid	40 to 60	40 to 60
B_1 Humid	20 to 40	20 to 40
C_2 Moist Subhumid	0 to 20	0 to 20
C_1 Dry Subhumid	-20 to 0	-33.3 to 0
D Semiarid	-40 to -20	-66.7 to -33.3
E Arid	-60 to -40	-100 to -66.7

[1]After Mather (Carter and Mather, 1966). Climatic Classification for Environmental Biology, Pub. in Climatology, Vol. 19, No. 4.

TABLE 7

THORNTHWAITE'S THERMAL PROVINCES[1]

Symbol	Thermal Province	PE (Annual)
A	Megathermal	Greater than 114.0 cm
B_4	Mesothermal	99.7 - 114.0 cm
B_3		85.5 - 99.7 cm
B_2		71.2 - 85.5 cm
B_1		57.0 - 71.2 cm
C_1	Microthermal	42.7 - 57.0 cm
C_2		28.5 - 42.7 cm
D	Tundra	14.2 - 28.5 cm
E	Frost	Below 14.2 cm

[1]After Critchfield (1974). General Climatology. Prentice Hall, Inc., New Jersey.

The suitability of a species for growth on a given site depends in part on its adaptability to the soil and whether it will withstand the salinity so common in arid regions. The plant must be drought-resistant. It should have a highly developed root system extending horizontally to take advantage of light rains or the underground water supply present in deeper soil layers. Most plants are capable of developing layers of dense roots corresponding to soil zones of available moisture.

The presence of mycorrhizae-forming fungi on the roots of introduced trees may be of utmost importance to the success of afforestation efforts. Numerous failures of plant establishment have been attributed to the absence of suitable fungi. The existence of mycorrhizae in natural stands of *Pinus halepensis* Mill., their effect on vigor or healty in *Pinus pinea* L. plantations, as well as the correlation between health and vigor and mycorrhizae development in seedlings of pine and oak (*Quercus calliprinos* Webb. and *Quercus aegilops* L.), point to their importance in tree planting in arid zones. Variations in mycorrhizae development in the past may be due to differences in residual root material from earlier plantations or from natural forests.

Arid regions are generally hot but some deserts also have frosts, freezing weather or at least low temperatures. It is necessary, therefore, when introducing species to such regions, even when the soil is good and water is available, to consider temperature ranges in the planting area. Many attempts to introduce tropical xerophytic plants failed because of the low temperature of the desert (Goor, 1955, 1963).

Even though a large number of exotic species may meet the theoretical requirements of the planting area, no judgements are possible until successful plantings have been demonstrated. Furthermore, final evaluation must be delayed until the species has survived for a considerable time, generally through a complete rotation.

Much care should be given to the selection of suitable exotic species for introduction to new territories. Such caution should not, however, preclude the testing of a wide variety of possibilities since some species have done well in areas where they were not expected to thrive. Such species may be found to fluorish in areas with soils or climatic conditions quite different from those of their native habitat. In general, some species growing naturally in colder and more humit areas may be introduced to warmer and drier climates. Pinus brutia Ten. has been successfully planted in regions much further south than its native habitat. Eucalyptus camaldulensis Dehn. has grown well in areas with less than 300 mm of rain a year and with no floods (Metro, 1955). In its native habitat in Australis, it grows in areas with over 450 mm of rainfall a year plus regular annual floods lasting for more than six weeks at a time. Past experience has revealed some rather surprising "acclimatizations" (Champion and Brasnett, 1958). Some species from zones or summer rainfall and of uniform rainfall, such as Eucalyptus saligna Sm. and Eucalyptus paniculata E.v.M., have grown quite well despite marked summer drought-conditions. Other species originating in tropical zones have been successful under Mediterranean-type conditions, but the reverse process has not been pronouncing.

Success is most likely where species having the desired growth-form are selected from similar homoclimates. Once homoclimates have been identified, published information about the species will generally permit reasonable judgements as to their suitability for the stated objectives where available, experienced gained in other countries should be used to guide species selection.

CHAPTER III

HOMOCLIMATES FOR THE THREE CLIMATIC TYPES OF IRAQ

The successful introduction of a species depends essentially on the degree of similarity of climate and soils in the natural site to that of the proposed sites. The most widely used method for determining this similarity is based on Thornthwaite's climatic classification (1948, 1955) in which the deficit of precipitation (P), in relation to potential evapo-transpiration (PE), is the important factor. The data needed are as follows:

1. Mean monthly or daily air temperatures.
2. Mean monthly or daily precipitation
3. Information on the water holding capacity of the soil.

Air temperatures and precipitation are measured daily at a large number of stations over the world. According to Thornthwaite and Mather (1957), it is more difficult to obtain information on the water hold capacity of the soil. In their "Instructions and Tables for Computing Potential Evapo-transpiration and the Water Balance," they included essentially all of the needed tables and computational aids for determining the potential evapo-transpiration. Accordingly, available data of mean monthly temperature and mean monthly precipitation for 26 stations in Iraq were used to compute potential evapo-transporation. The annual (PE) ranges between 228 and 1456. Moisture adequacy was then expressed by the moisture index (Im) according to the formula:

$$Im = 100 \left(\frac{P}{PE} - 1\right)$$

Based upon this formula, six moisture provinces have been recognized in Iraq (Table 8).

The climate of Iraq is characterized by winter precipitation and summer drought. In the search for climates similar to those of Iraq, 271 stations over the world have been identified as having similar precipitation patterns. The patterns of the potential evapotranspdration, precipitation, and temperature of the Iraqi stations are shown in Appendix A, Figure 2. The comparison between selected stations and those of Iraq resulted in finding stations with approximate values of (PE), (P), and (Im). The moisture index of the stations was classified according to Thornthwaite moisture provinces and compared with those of the Iraqi stations. Table 9 represents the moisture provinces of Iraq and those of other countries around the world. Although stations were selected according to similar moisture indices, (PE) values were also similar.

The representatives of (A) moisture provice are three stations, two of them in Iraq, Rayat and Penjwin, and Ain Draham in Tunisia. The highest range of (PE) in this province is (787) at Ain Draham which compares that of Penjwin in Iraq (600). Considering that the mean annual precipitation of the two stations is 1,220 mm for Penjwin and 1,607 for Ain Draham, it is evident that both have a water surplus. The most significant difference between those stations is the mean monthly temperature of coldest and hottest months. In Penjwin, the mean monthly temperature of the coldest month (MTC) is below 0°C, while in Ain Draham it is above 10°C.

TABLE 8

MOISTURE PROVINCES OF IRAQ

Moisture Province	Station	Im
Perhumid A	Rayat	175.88
	Penjwin	103.33
Humid B_1	Amadiya	23.58
Moisture Subhumid C_2	Rawanduz	17.90
	Sulaimaniya	8.93
Dry Subhumid C_1	Duhok	-27.87
	Zakho	-28.27
Semiarid D	Arbil	-57.23
	Sinjar	-60.68
	Mosul	-65.38
Arid E	Baghdad	-88.26
	Baiji	-85.85
	Basrah	-87.79
	Diwaniya	-90.89
	Habaniya	-90.75
	Haditha	-90.07
	Kut (Hai)	-89.78
	Hindiya	-90.41
	Khanaqin	-72.73
	Kirkuk	-68.21
	Najaf	-90.84
	Nasiriya	-90.57
	Ramadi	-90.89
	Rutba	-89.10
	Al-salman	-93.28
	Shaibah	-90.31

TABLE 9

CLIMATES OF SELECTED STATIONS

Country	Station	Im	T[1]	PE	P
		A Perhumid			
Iraq	Rayat	175.88	03	228	629
	Penjwin	103.33	02	600	1,220
Tunisia	Ain Draham	104.19	23	787	1,607
		B_1 Humid			
Iraq	Amadia	23.58	03	704	870
Algeria	Fort National	30.19	13	795	1,035
U.S.A.	Yosemite (Cal.)	27.31	03	659	839
	Ukiah (Cal.)	22.10	13	742	906
W. Australia	Collie	25.88	13	796	1,002
	Donnybrook	31.80	23	802	1,057
		C_2 Moist Subhumid			
Iraq	Rawanduz	17.90	03	799	942
	Sulaimaniya	8.93	03	661	720
Algeria	Miliana	14.73	13	828	950
	Hafir	1.63	13	736	748
Morocco	Azrou	12.37	13	784	881
	Daiet Achlef	3.85	13	650	675
U.S.A.	Sonora (Cal.)	3.59	13	808	837
Spain	Gilbraltar	4.33	13	854	891
Chile	San Fernando	12.38	13	719	808
W. Australia	Bridgetown	16.80	13	762	890
		C_1 Dry Subhumid			
Iraq	Duhok	-27.87	13	854	616
	Zakho	-28.27	14	1,139	817
Iran	Khurramabad	-7.84	13	893	823
Palistine	Mt. Kena'an	-11.80	13	839	740
Lebanon	Ksara	-22.87	13	822	634
	Riyaq	-25.52	13	776	578

TABLE 9 (Continued)

Country	Station	Im	T	PE	P
		C_1 Dry Subhumid			
Turkey	Gaziantep	-25.58	13	825	614
	Islahiye	-0.97	13	926	917
	Mardin	-24.87	13	941	707
Algeria	Berrouaghia	-23.39	13	774	593
	Tiaret	-22.64	13	804	628
	Teniet-El-Had	-16.38	13	751	622
Libya	Shahhat	-25.50	13	800	596
Morocco	Azilal	-28.82	13	819	583
U.S.A.	Oroville (Cal.)	-21.30	13	878	691
	Palomar Mt. (Cal.)	-10.39	13	722	647
Greece	Mesolongion	-22.58	13	952	737
	Patrai	-25.03	13	947	710
Italy	Ragusa (Sicily)	-12.54	13	997	872
	Rossano	-2.38	13	965	942
Portugal	Beja	-31.59	13	785	537
	Elvas	-31.75	13	819	559
	Mertola	-16.69	13	833	694
	Santarem	-17.39	13	805	665
Spain	Caceres	-32.94	13	838	562
	Cordoba	-31.93	13	927	631
	Cuenca	-21.94	13	670	523
	Jae'n	-29.60	13	892	628
Chile	Cauquenes	-3.17	13	757	733
	Talca	-6.07	13	758	712
		D Semiarid			
Iraq	Arbil	-57.23	14	1,155	494
	Sinjar	-60.68	14	1,185	466
	Mosul	-65.38	14	1,115	386
Palestine	Jerusalem	-33.76	13	865	573
Jordan	Amman	-65.47	13	889	307
Syria	Aleppo	-62.25	13	967	365
	Homs	-52.07	13	847	406
	Idlib	-64.21	13	975	349
	Kittinah	-42.04	13	861	499
	Selemiya	-61.66	13	879	337
Algeria	Aflou	-53.09	13	729	342
	Ain-El-Gotia	-50.41	13	732	363
	Aumale	-34.05	13	790	521

TABLE 9 (Continued)

Country	Station	Im	T	PE	P
		D. Semiarid			
Algeria	Les Attafs	-57.99	13	1,007	423
	Maillot	-38.87	13	934	571
	Mascara	-42.39	13	887	511
Libya	Gharyan	-66.21	13	953	322
Morocco	Fes	-38.60	13	912	560
	Marchand	-49.09	13	882	449
U.S.A.	Lemon Cove (Cal.)	-60.48	13	921	364
	Orland (Cal.)	-53.26	13	952	445
	Paso Robles (Cal.)	-46.90	13	757	402
	Sacramento (Cal.)	-43.80	13	815	458
	Willows (Cal.)	-52.11	13	902	432
Greece	Athin	-58.16	13	913	382
	Khalkis	-54.33	13	935	427
Italy	Brindisi	-34.99	13	843	548
Portugal	Campo Maior	-34.54	13	831	544
Spain	Badajoz	-37.51	13	861	538
	Ciudad Real	-51.10	13	771	377
	Madrid	-43.70	13	746	420
	Toledo	-56.03	13	812	357
Chile	Los Andes	-57.03	13	782	336
	Rancagua	-37.93	13	733	455
		E Arid			
Iraq	Baghdad	-88.26	14	1,269	149
	Baiji	-85.85	24	1,456	206
	Basrah	-87.79	24	1,384	169
	Diwaniya	-90.89	24	1,295	118
	Habaniya	-90.75	14	1,286	119
	Haditha	-90.07	14	1,350	134
	Kut (Hai)	-89.78	24	1,311	134
	Hindiya	-90.41	14	1,304	125
	Khanaqin	-72.73	14	1,232	336
	Kirkuk	-68.21	14	1,211	385
	Najaf	-90.84	24	1,343	123
	Nasiriya	-90.57	24	1,315	124
	Ramadi	-90.89	14	1,273	116

TABLE 9 (Continued)

Country	Station	Im	T	PE	P
		E Arid			
Iraq	Rutbah	-89.10	14	1,110	121
	Al-Salman	-93.28	24	1,280	86
	Shaibah	-90.31	24	1,383	134
Afghanistan	Farrah	-90.05	14	1,116	116
	Herat	-80.56	13	936	182
Iran	Abadan	-88.77	24	1,407	158
	Ahwaz	-86.16	24	1,373	190
	Dizful	-73.32	14	1,098	293
	Isfahan	-79.90	13	826	166
	Khorramshahr	-89.22	24	1,327	143
Palestine	Beersheba	-77.28	23	999	227
Pakistan	Chaman	-81.84	14	1,079	196
Syria	Damuscus	-78.72	13	954	203
	Deir Ezzor	-84.80	14	1,138	173
Algeria	Ain-Sefra	-78.38	13	888	192
	Biskra	-86.86	24	1,187	156
Libya	Ajedabya	-87.92	23	1,076	130
	Bardia	-85.87	23	991	140
	Benghazi	-80.66	23	998	193
	Bu Ghelian	-79.88	24	1,138	229
	Derna	-69.83	23	938	283
	El Azizia	-80.72	23	1,115	215
	El Gusbat	-67.41	23	991	323
	Er-Regima	-67.37	23	953	311
	Marawa	-69.64	13	873	265
	Misurata Citta	-75.44	23	1,014	249
	Sirte	-83.32	23	1,031	172
	Suluq	-81.83	23	1,018	185
	Tarhuna	-74.05	23	998	259
	Tobruk	-84.99	23	966	145
	Zuara	-76.50	23	949	223
Morocco	Elkelaa Des Srarhna	-72.34	23	987	273
S. Africa	Clanwilliam	-75.72	23	906	220
Tunisia	Ben Gardane	-82.07	23	1,015	182
	Foum Tatahouine	-87.36	23	1,068	135
	Gabes	-82.56	23	992	173
	Sfax	-79.22	23	972	202

TABLE 9 (Continued)

Country	Station	Im	T	PE	P
		E Arid			
U.S.A.	Fresno (Cal.)	-74.44	13	943	241
	Los Banos (Cal.)	-77.34	13	909	206
	Madera (Cal.)	-71.34	13	827	237
	Merced (Cal.)	-68.47	13	885	279
	Middlewater (Cal.)	-86.74	13	973	129
	San Diego (Cal.)	-68.03	23	782	250
Chile	Jahuel	-69.45	23	802	245

[1]For the temperature symbol used in the table, e.g., 24, the first digit represents the coldest month and the second digit the hottest month based on mean monthly temperatures as follows:

0 = below 0°C.
1 = 0° - 10°C.
2 = 10° - 20°C.
3 = 20° - 30°C.
4 = above 30°C.

The stations of the (B_1) moisture province have (PE) values which range from 659 to 802. The smallese (PE) value is for Yosemite station in California, U.S.A. It is close to that of Amadiya in Iraq, (Table 9). The highest value of (PE) is represented by Donnybrook station of West Australia, but here the major difference between this station and that of Iraq is in the (MTC). There is freezing weather during the winter at the Iraqi station but not at the Australian station. Generally, the (MTC) is not below freezing except for two stations, Amadiya in Iraq and Yosemite in the U.S.A.

Iraq has two stations in the (C_2) province, Rawanduz and Sulaimaniya. Fourteen similar stations were selected from six countries, Algeria, Morocco, California (U.S.A.), Spain, Chile, and West Australia. The (PE) values range from 650 to 893. The difference again between the stations of Iraq and those of other countries within this province is in the temperature; while the (MTC) of Rawanduz and Suliamaniya is below 0°C, those of the stations of other countries are above 0°C. For all stations the mean monthly temperature of the warmest month (MTW) is in the same temperature class as the two Iraqi stations (20° - 30°C).

In Iraq, two stations were identified in the moisture province (C_1), Duhok and Zakho. Although both have nearly identical (Im), they differ widely in (PE) and T values (Table 9). No suitable homoclimes were found for Zakho. Similar stations for Duhok were identified in Iran, Palestine, Jordan, Lebanon, Turkey, Algeria, Libya, Morocco, U.S.A., and Greece, for a total of 46 stations. In this province, the range of potential evapo-transpiration is between 512 and 997. The

(MTC) and (MTW) in the stations of the province are the same, above 0°C for the coldest month and more than 20°C for the warmest month.

Three stations in Iraq (Arbil, Sinjar, and Mosul) fall into the (D) moisture province. Thirty-one homoclimes were selected from several countries in the world (Table 9). The potential evapo-transpiration values of the three Iraqi stations are 1,155, 1,185, and 1,115, respectively. No station in other countries of this province reaches the lowest value of (PE) for those three stations. The highest (PE) of selected stations was for Les Attafa in Algeria with a potential evapo-transpiration of 1,007. Other stations are in the range of 645 and 975. All the stations of the (D) province have (MTC) above 0°C. The (MTW) for the Iraqi stations is above 30°C, while that of the station of other countries is below 30°C.

Iraq has 16 stations in the moisture province (E), and 41 stations in 12 different countries were selected as suitable homoclimates. Potential evapo-transpiration values of the 16 Iraqi stations range from 1,110 at Rutbah as a lowest value and 1,456 at Baiji as a highest value. Of the 41 homoclimates, one station has a potential evapo-transpiration of 1,407 (Abadan, Iran), the rest are within the range 782 to 1,373. The (MTC) of the Iraqi stations is either above 0°C (Baghdad, Khanaqin and Rutbah) or above 10°C (Baiji, Najaf, and Basrah). The (MTW) for all the Iraqi stations is above 30°C. The (MTC) of the homoclimates are similar to those of Iraq. However, the (MTW) is commonly lower than those of Iraq.

From the previous discussion, it is apparent that although several countries have similar moisture provinces to those of Iraq, there are no exact climatic matches for the climates of Iraq. There is, however, approximate similarity between the climatic regions of Iraq and those in some other countries having similar patterns of precipitation. Wright (1963) in his program for introducing exotics stated that "the climatic matches need not be exact because some factors compensate for small deficiencies in others." In addition, Golfari (1963) has the opinion that it may be enough to examine three fundamental, closely related factors, namely: rainfall distribution, mean annual precipitation and temperature pattern. From these comments, it would appear that the homoclimates selected here will provide realistic guides for selecting trees to be tested in Iraq.

CHAPTER IV

POTENTIAL TREES FOR IRAQ BASED ON HOMOCLIMATES

In Iraq trees are grown both with and without irrigation. Only in the mountains rainfall is sufficient to assure plantation survival without irrigation. The native species Pinus brutia is a suitable choice for the mountainous forest as it can be grown without irrigation. Other species which have been planted in the past include Cupressus simpervirens L., Cupressus arizonica Greene, Pinus nigra Arnold, Pinus halepensis Mill., Pinus pinea L. and at nearly 2,000 m altitude, Cedrus deodora (Roxb.) Loud. and Cedrus libani A. Rich. (Chapman, 1948; Raeder-Raitzsch 1969; and Kaul, 1970). Hardwood species were introduced but so far, no particular promise has been shown in the mountains except species grown under irrigation such as planes, walnut, and poplar.

Kaul (1970) has suggested the introduction of species from similar climatic regions to those of northern Iraq, i.e., regions with winter rainfall, cold winters and hot very dry summers. Such climates are found in parts of southern California, the Atlas mountains (in Algeria and Morocco), and parts of Turkey and Iran. He recommended some species for trial include Abies cilicica Carr., Cedrus atlantica Manetti, and species of Callitris. In addition, Alnus orientalis Decne. and Pinus canariensis C.Sm. were suggested by Chapman (1948).

Irrigated plantations in the plains have already been established in a number of localities in Iraq. In particular, the irrigated cultivation of poplars is likely to be of great importance in the future of forestry in Iraq and much research effort has been spent on the study of methods to improve poplar cultivation (Kaul, 1970). A list of tree species that have been already tried in Iraq other than eucalypts is shown in Appendix D. Another list of the introduced species of eucalypts which were tried in Iraq is shown in Appendix E.

The species more likely to succeed in Iraq are as follows:

Argania sideroxylon Roem. and Schult. A small to medium-sized spreading tree, up to 10 m tall, native to the arid Atlantic coastal hills of south Morocco and southward to the edge of the Sahara. It grows on poor soil and between rocks but it is not found on sands. It forms open stands where the annual rainfall is between 100 and 200 mm and summers are nearly rainless. The tree grows up to 1,500 m in elevation. It cannot withstand cold but does resist extreme heat and drought. This species could be cultivated in areas of Provinces D and/or E in Iraq.

Callitris glauca R. Br. An evergreen conifer, normally 20 m tall, but in the dry plains may be no more than 6 m. A native of Australia, principally of New South Wales and Queensland, it also occurs in the other states on the continent. Usually found on good, sandy loam, it also grows on poor, sandy soils. Climate of its habitat is warm-temperature to subtropical with 150 to 650 mm rainfall, and temperatures generally range between 10° and 30°C, but it can withstand light frost. The species might be suitably cultivated in Provinces C_1, D, and/or E.

Cedrus altantica Manetti. An evergreen conifer, up to 40 m in height. Its natural habitat is the mountains of Morocco and Algeria, where it grows between 1,000 and 2,500 m altitude. The species occurs on deep, moist, permeable, sandy or stony soils and often on limestone or sandstone formations. Its habitat is in semiarid zones with 600 to 1,600 mm rainfall, but it does well in areas with 700 mm and grows in areas with only 500 mm rainfall and with eight dry months. It can withstand temperatures to -15°C. The species can be planted in Provinces A, B_1, and C_2.

Cedrus brevifolia (Hook.f.) Henry. Shrubby, everngreen conifer, up to 12 m in height, native to Cyprus. It grows at altitudes of 900 to 1,400 m. In its natural habitat, it receives about 900 mm rainfall with nine dry months annually. It often grows on poor soil. It is frost and drought resistant, and is used in semiarid afforestation. This species seems to be suitable for Provinces B_1, C_2, and C_1.

Pinus canariensis C. Sm. A large, confierous evergreen tree, up to 30 m high. Its natural range is limited to the Canary Islands where it grows on volcanic soils and deep, well-drained sand or clayey loam soils over sandstone and granit. It requires a subtropical to warm-temperatre climate with annual rainfall of 400 to 650 mm falling mostly during winter and seven to eight dry months. The lowest temperature in its habitat is -8°C. It is a fast-growing tree; in favorable sites it gains up to 1.5 meters in height per year. The species may be suitable for Provinces C_2 and C_1.

Pinus ponderosa Laws. A large evergreen tree up to 60 m high but usually under 30 m in dry regions. Indigenous to western North American from southern British Columbia to central Mexico, it is found in the United States in all states west of the Great Plains. In the north, it occurs about 400 m asl, and in the south up to 2,700 m. It grows on a variety of soils from sandy soils, in Nebraska, to clay loam, and it tolerates a wide range of pH in soil solution, from pH 4.9 to 9.1, depending on locality and depth below the surface. It requires rainfall of 250 to 1,500 mm but it is resistant to drought and frost, even to -40°C in some places. The wood is used for construction, carpentry, posts, and mine props. This is probably the most successful species in shelterbelt plantings on sand hills and dunes in the Great Plains of western United States. If planted in favorable sites and under intensive cultivation, it will produce as much as 15 m^3/ha/year. Ponderosa pine has been planted in South America with success, but plantations in Europe and the Mediterranean Basin have not been encouraging and the poor results have, at times, been attributed to lack of proper mycorrhizae. Ponderosa pine could be suited for Provinces A, B_1, and C_2.

Alnus orientalis Decne. A medium-sized decidious tree, native to the eastern Mediterranean region. It grows in wet areas and along rivers at low to medium altitudes. This species is a useful one for planting on the banks of rivers and water channels.

The wood is used for furniture, paneling, and floor blocks. The species could be planted in areas of Provinces C_1, D and/or E.

Arbutus andrachne L. A quite common evergreen shrub or small tree from 3 to 9 m tall. It is found in Greece and the eastern Mediterranean maquis on a variety of soils, but grows best on well-drained soils and generally requires shade. It is not frost-hardy, bears attractive red fruit. The wood is used for furniture and the tree is valuable to beekeepers. It could be cultivated in Province D.

Peumus boldus Molina. A small straight-stemmed, evergreen tree, up to 8 m high. It grows in central Chile in a Mediterranean climate and coppices vigorously. The wood is extremely hard and is used for making many kinds of implements and tool handles. The charcoal is prized by smiths. Bark extracts are used for tanning and dyeing leather. Bark fiber is used for making ropes. Tea from the leaves is said to aid digestion. It is planted as an ornamental. The species may be planted in Provinces C_1 and D.

Pinus pinaster Ait. An evergreen tree, up to 30 m high, native to the western Mediterranean from France and Portugal to western Italy and from Morocco to western Tunisia. It grows on a wide range of soils but its best growth is on well-drained sandy soils. It occurs from sea level to over 1,000 m in Italy and is found up to 2,000 m in Morocco. There are several different races adapted to different soils and climates. For fast growth, this pine needs permeable, loose, well-aerated soil. Some races avoid lime but others grow on limey soil. Some races are adapted to hot summers and others are hardy to frost. It grows in a mild temperate climate with percipitation of 400 to 1,200 mm a year with dry summers. This pine is tapped for resin and its wood is used for carpentry, poles, and sleepers. Under intensive cultivation and on short rotation, it is used for production of pulp. It is planted in most semiarid regions. The species could be planted in Provinces A, B_1, and C_2.

Quercus douglasii Hook. and Arn. A deciduous tree, usually from 15 to 18 m high; rarely to 30 m. Its natural range is restricted to California where it is found on dry loams and gravels of the inner coastal ranges and the foothills of the Sierra Nevada. It occurs mixed with other oaks and *Pinus sabiniana*, and grows in a Mediterranean climate with about 250 to 600 mm of precipitation annually and temperatures ranging from 45° to -15°C. Its wood is used for fuel. Natural stands are extremely important for watershed protection and soil establization. The species may be planted in Provinces C_1 and D.

Quillaja saponaria Molina. A glabrous, evergreen tree, 10 to 12 m high, found in the semiarid zone of Chile where the annual rainfall is about 350 mm and the summers are dry. It grows at both low and high altitudes and can withstand some frost. The bark contains the alkaloid saponin from which a soap is prepared for washing wool and silk; it is also used as a shampoo. The species may be suitable for Provinces C_1 and D.

Abies cilicica Carr. Tree up to 30 m high, native of the Taurus, Syria and Lebanon. Generally grows with other conifers on very rocky limestone soils of the terra rossa type at altitudes from 800 to 2,000 m above sea level where there is plenty of snow in the winter and not more than two rainless summer months. Often grows in association with the cedar of Lebanon. The wood is used for general construction purposes. The species may be tried in Provinces A, B_1, and C_2.

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APPENDICES

APPENDIX A

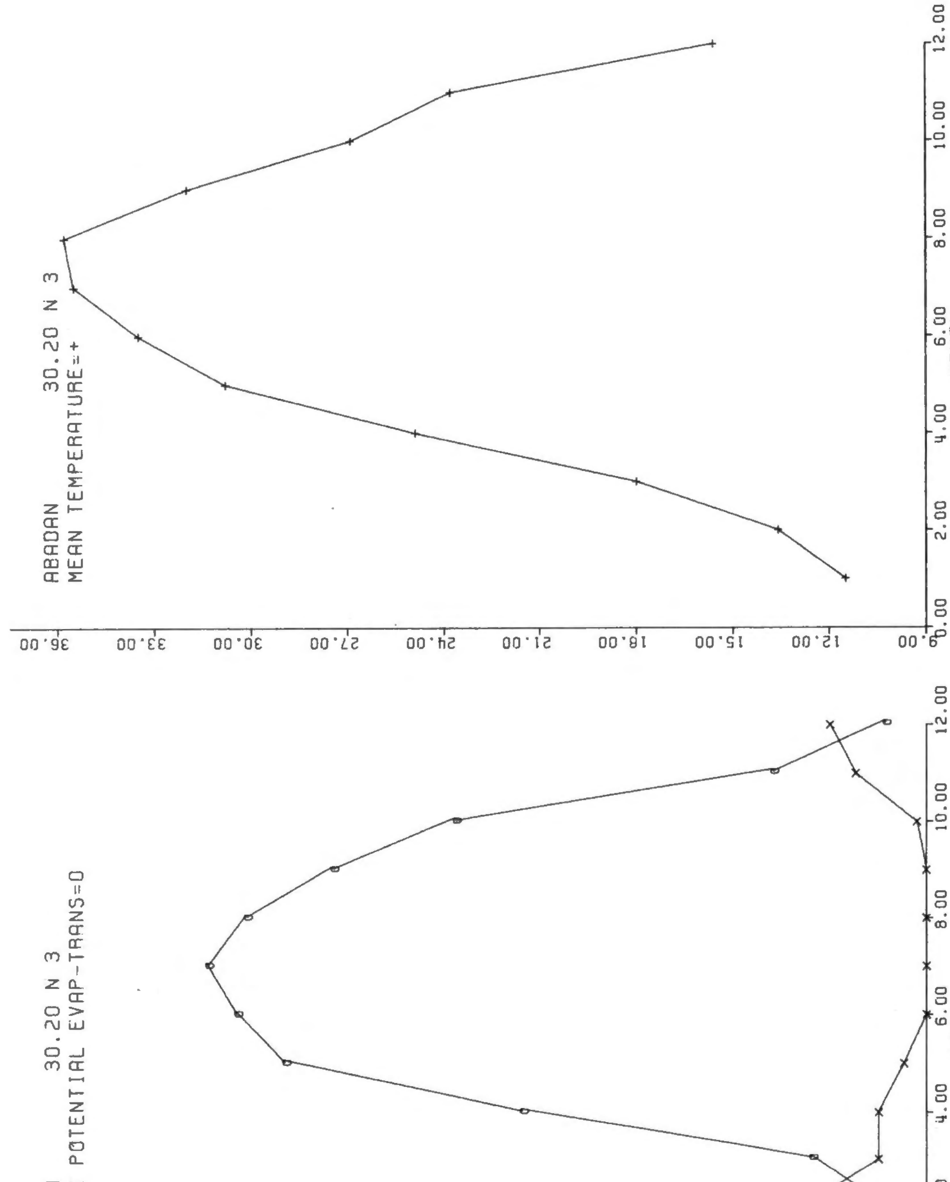
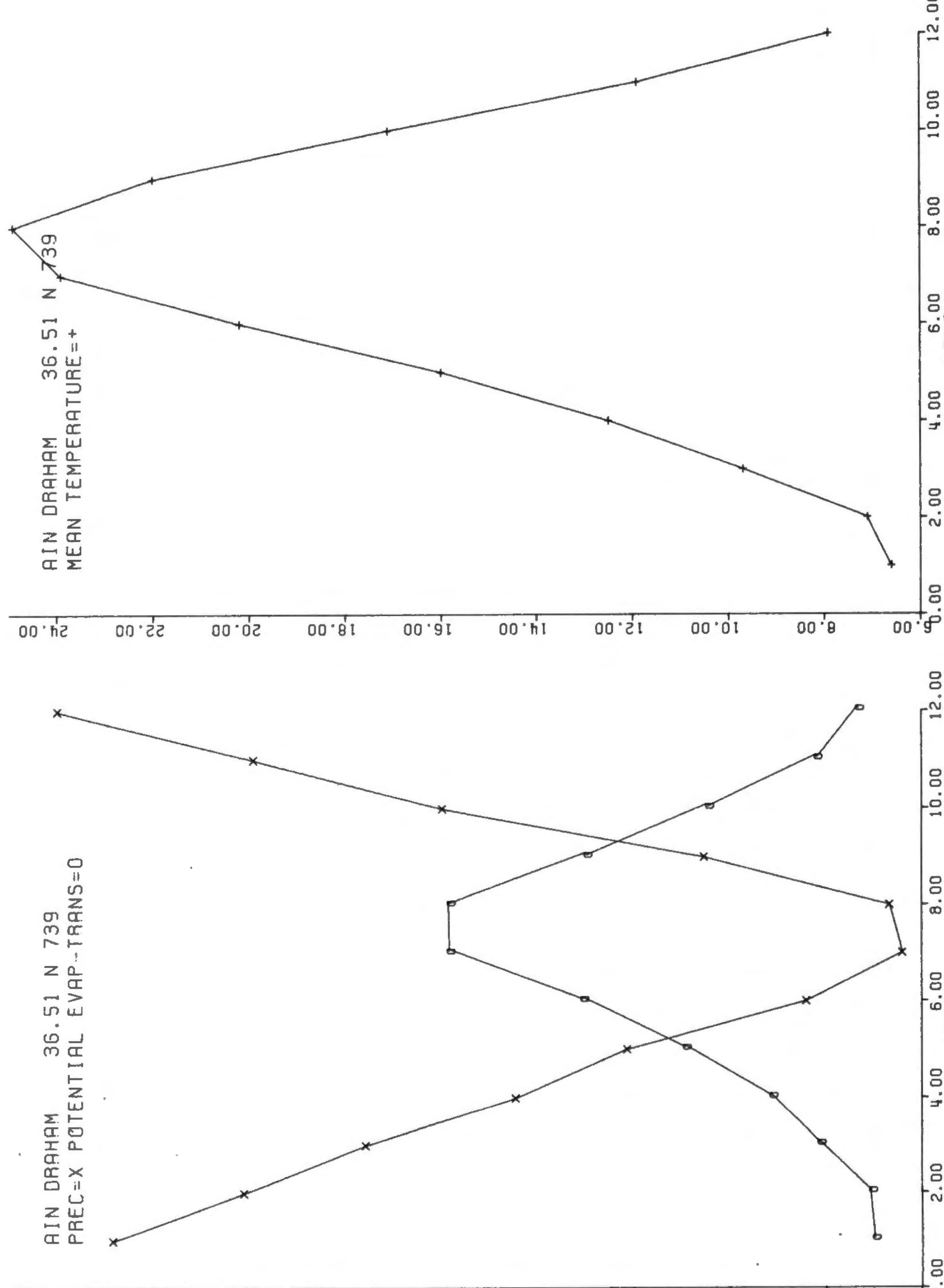


Figure 2. Climatic diagrams for Iraqi stations and their homoclimes.



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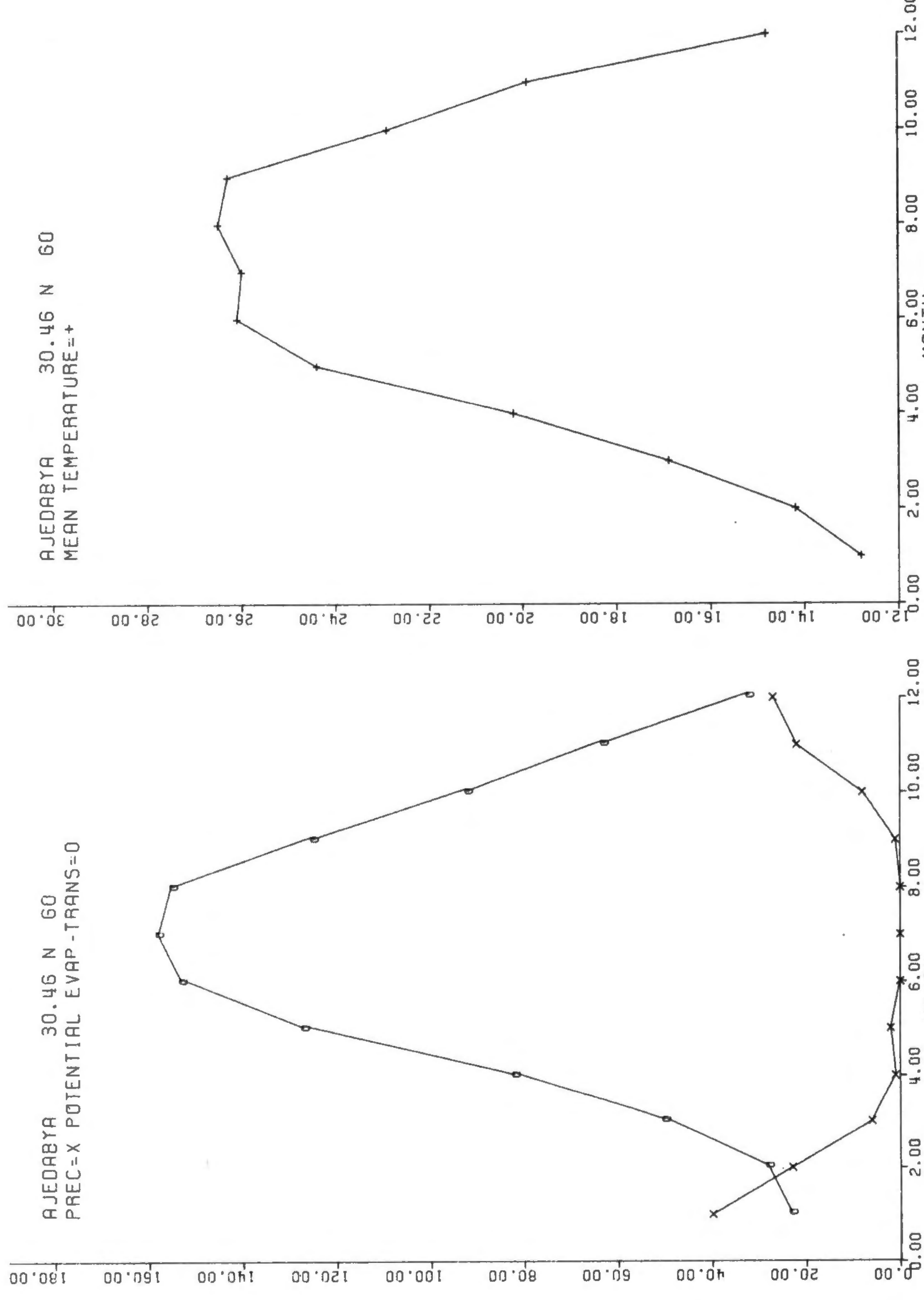

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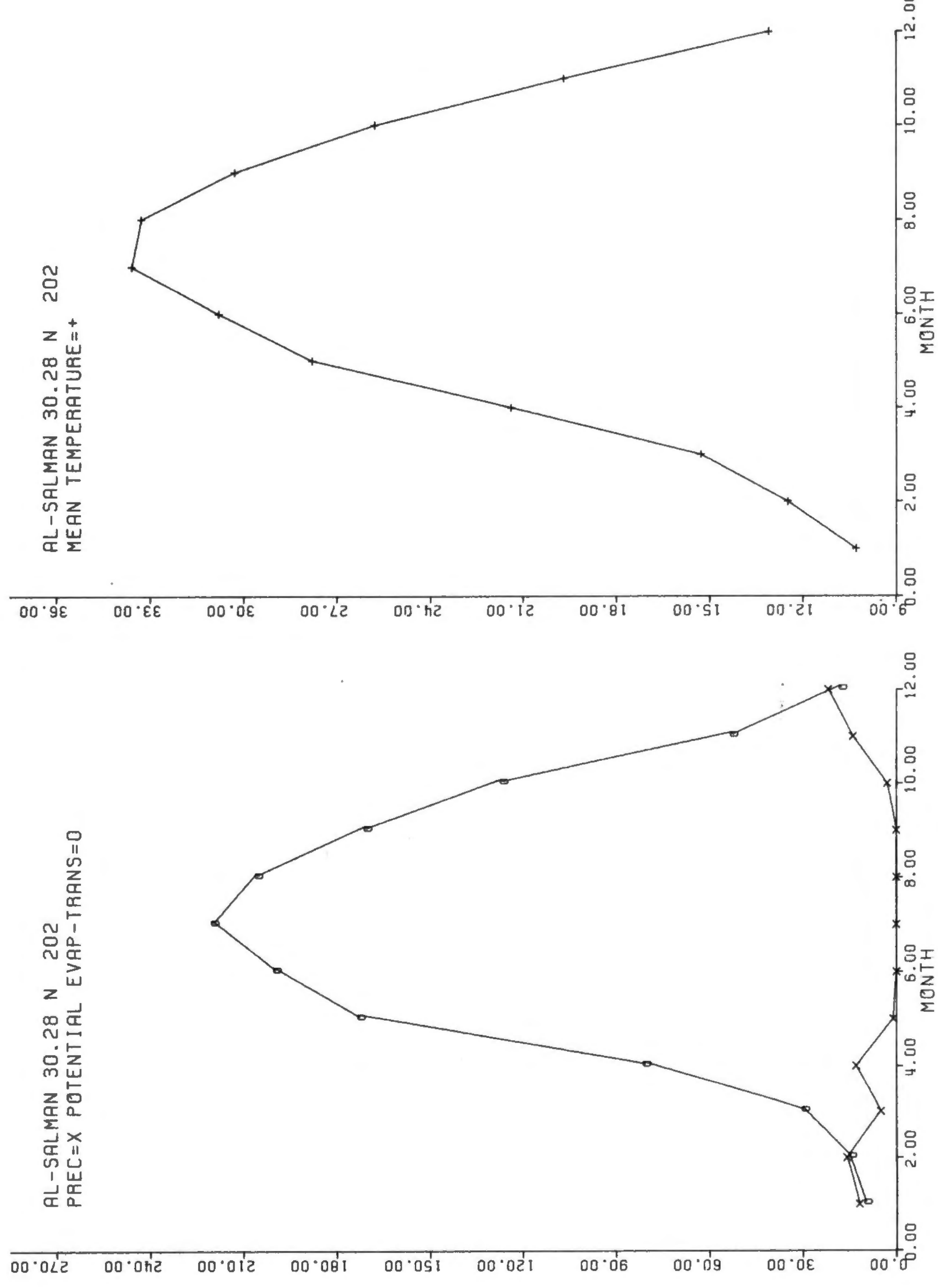

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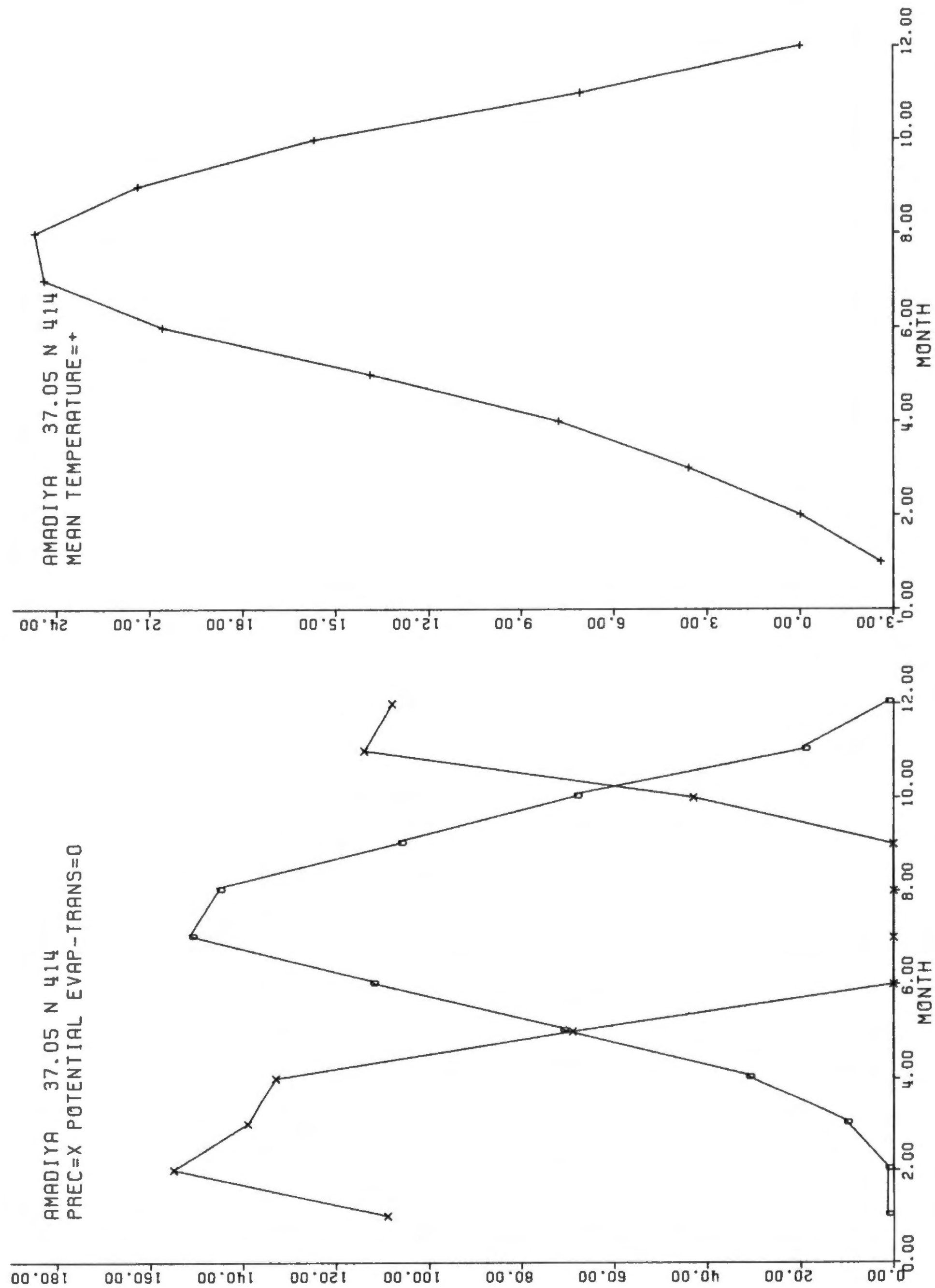

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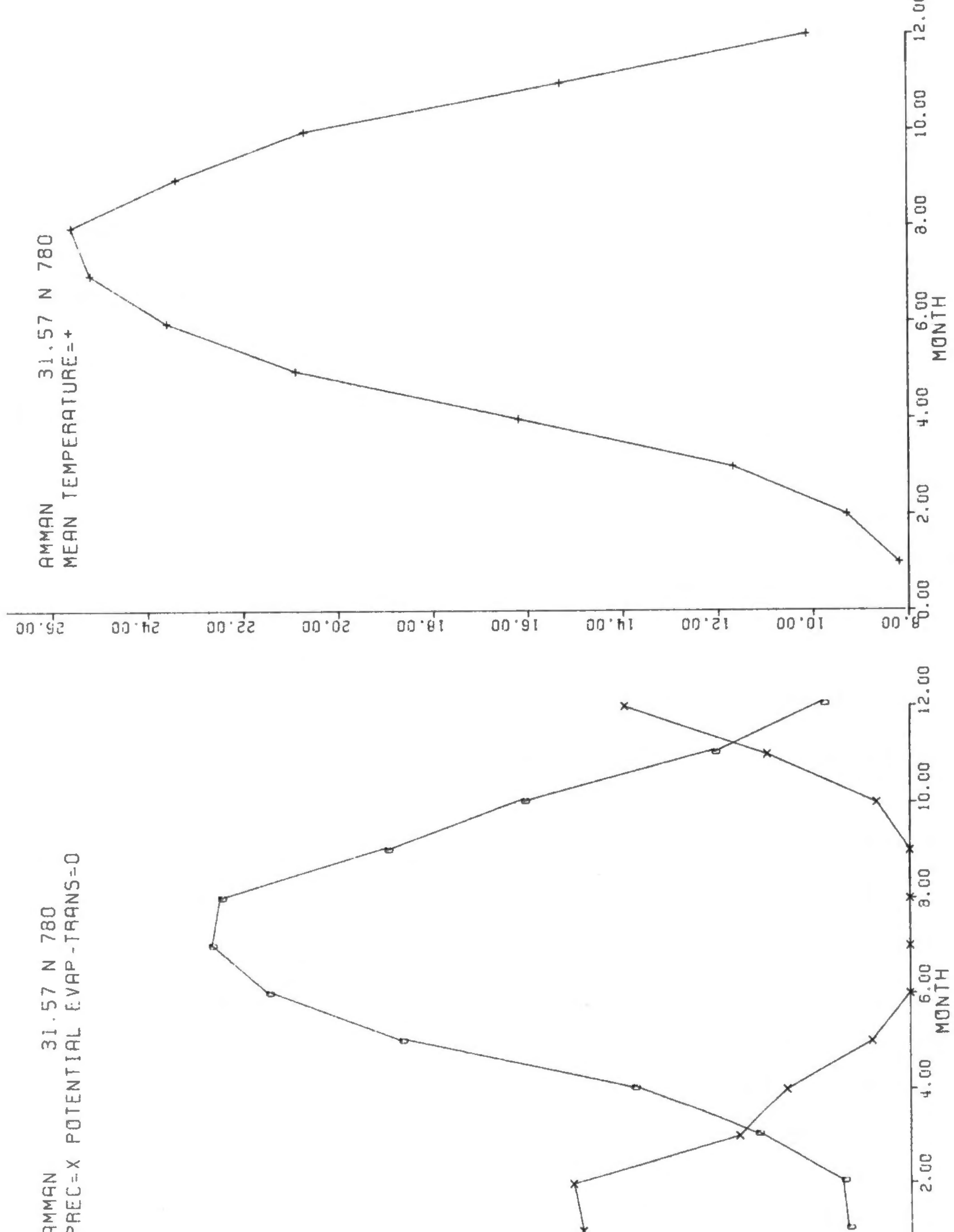

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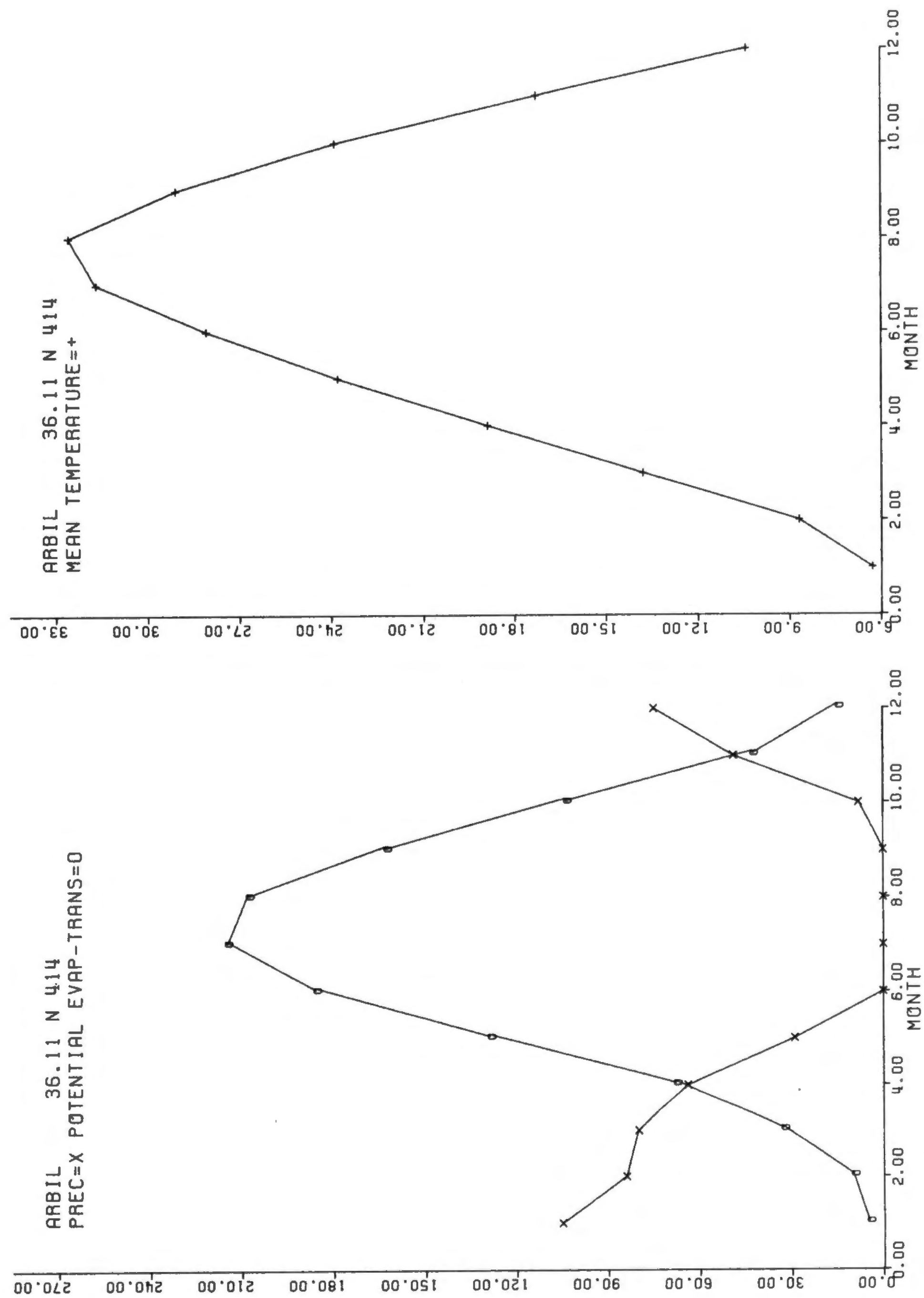

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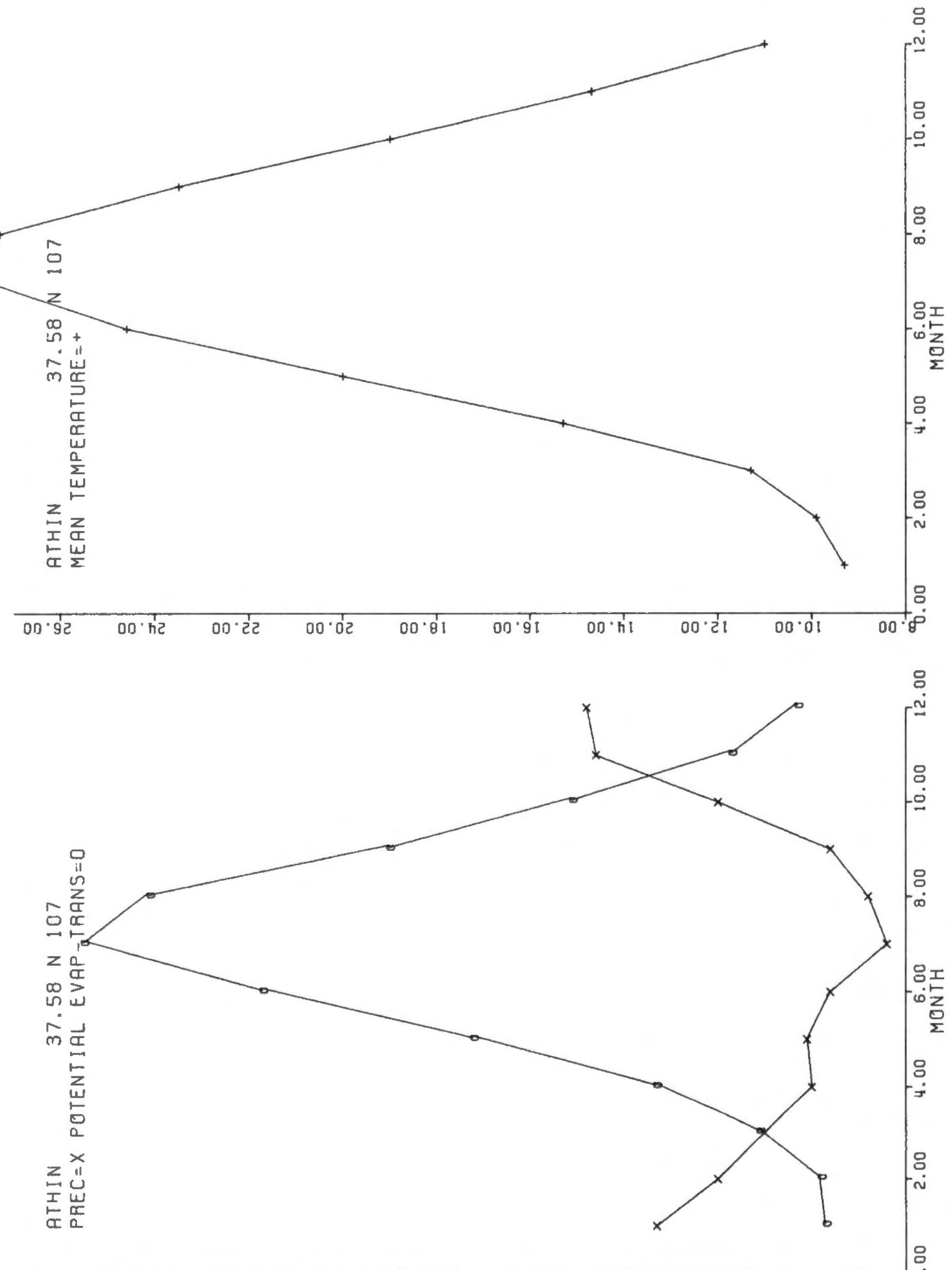

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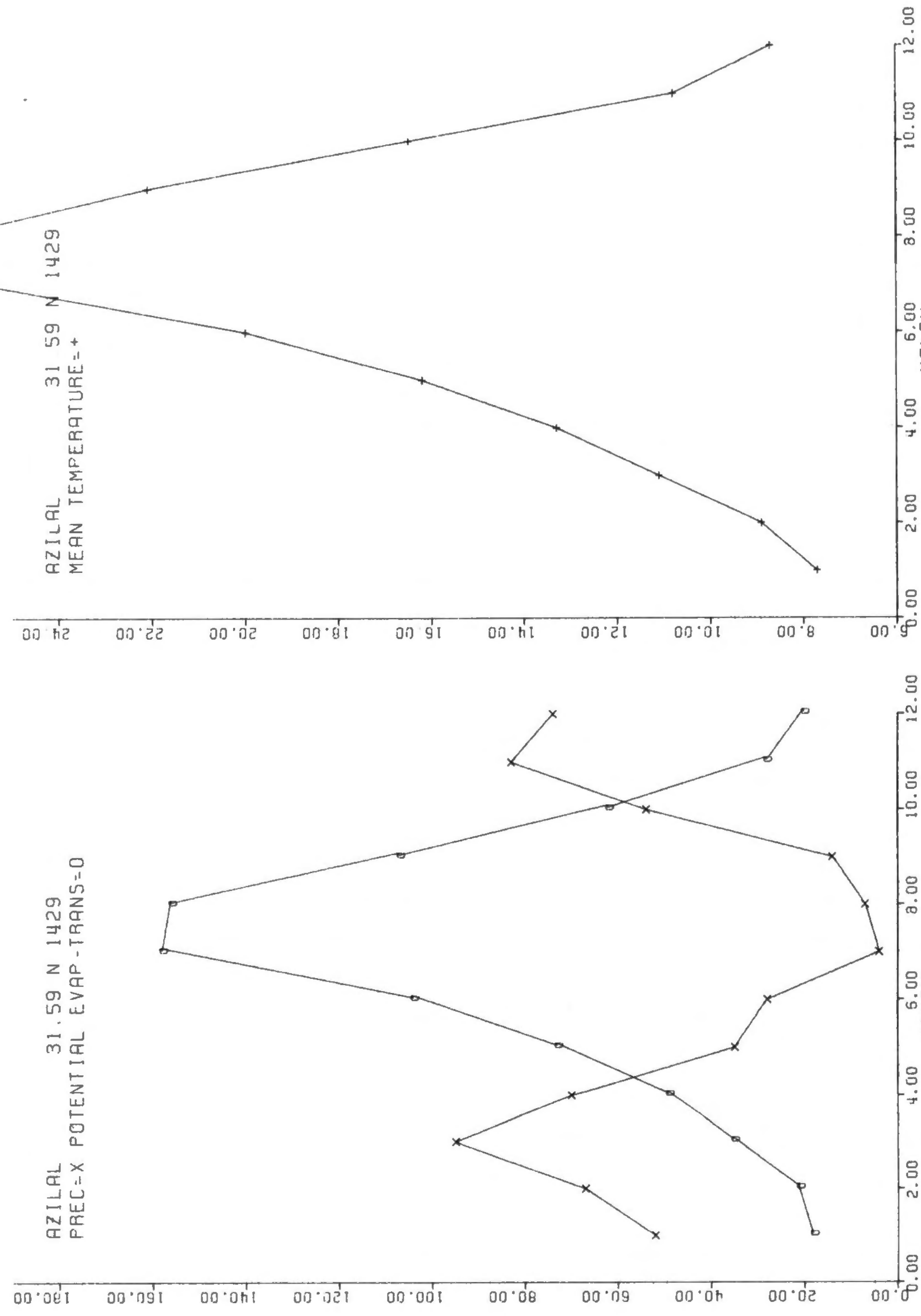

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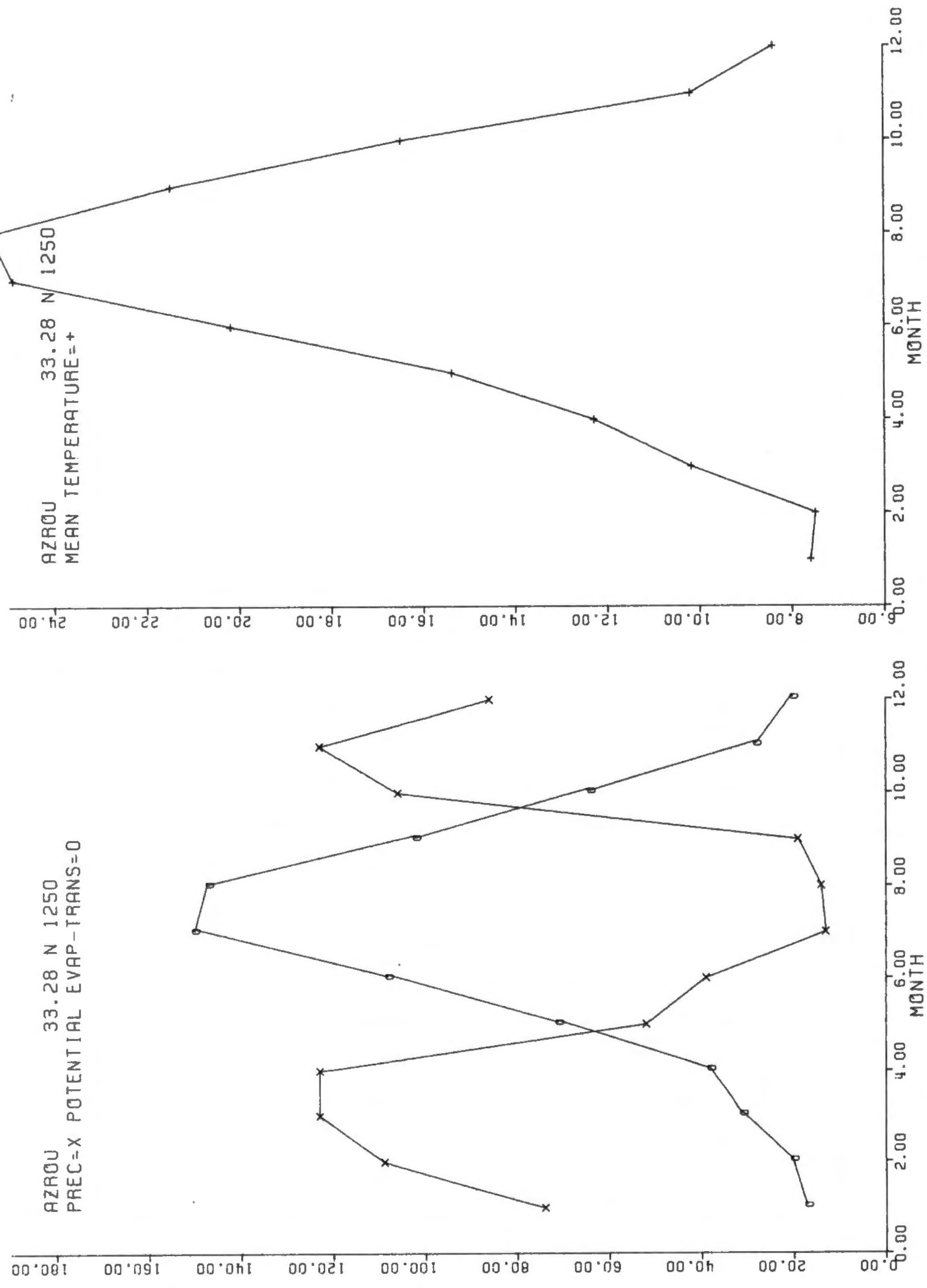

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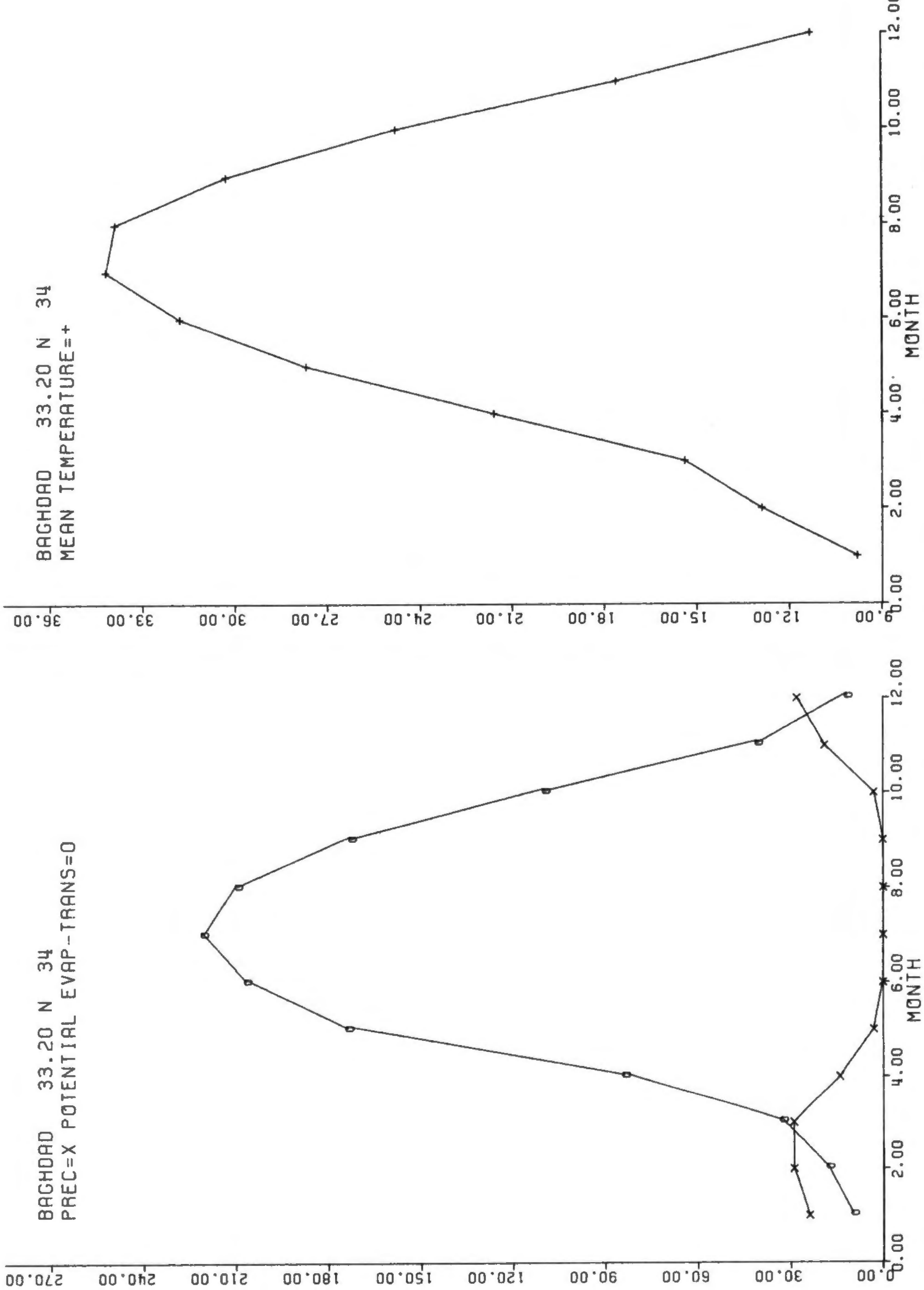

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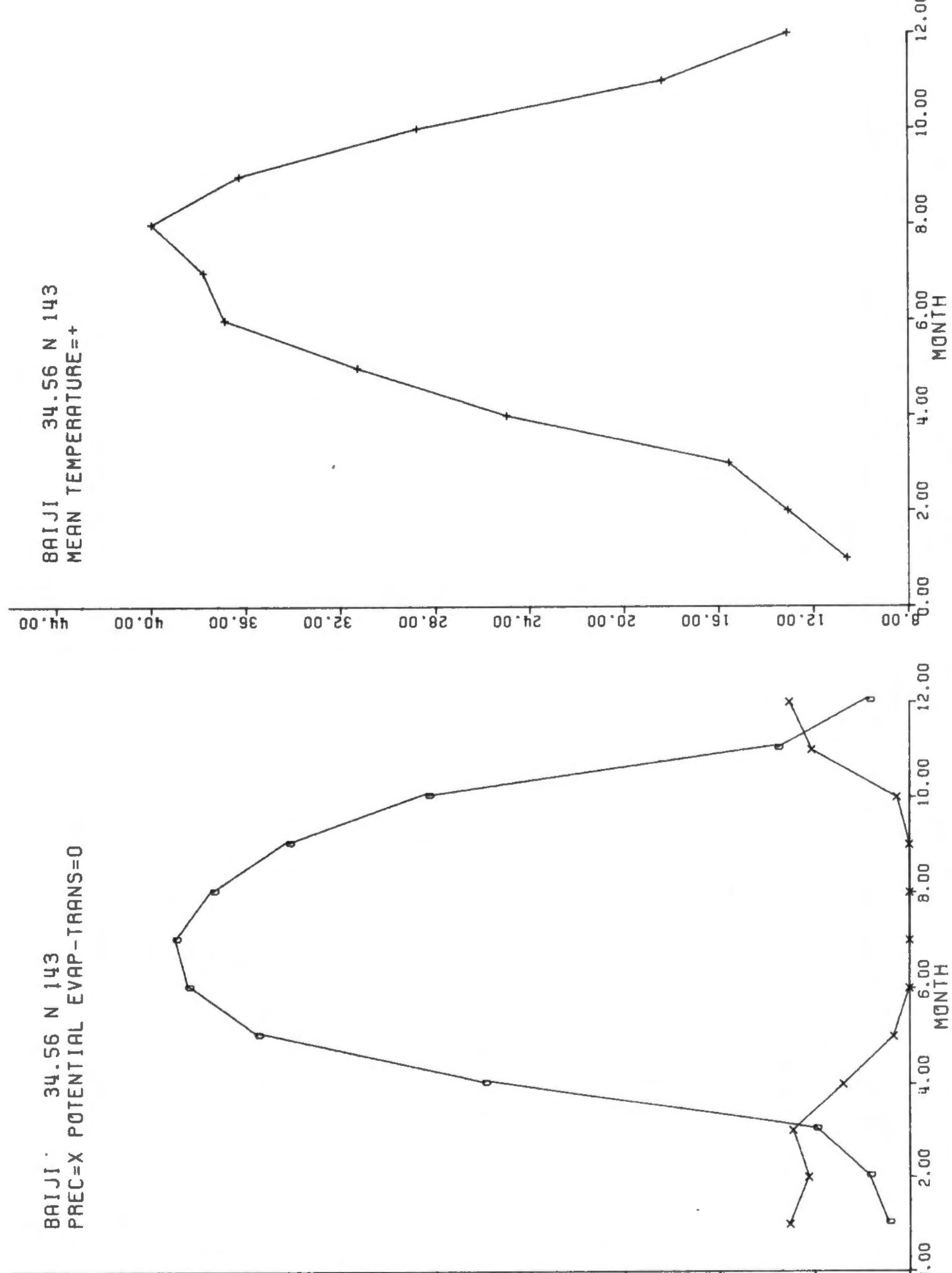

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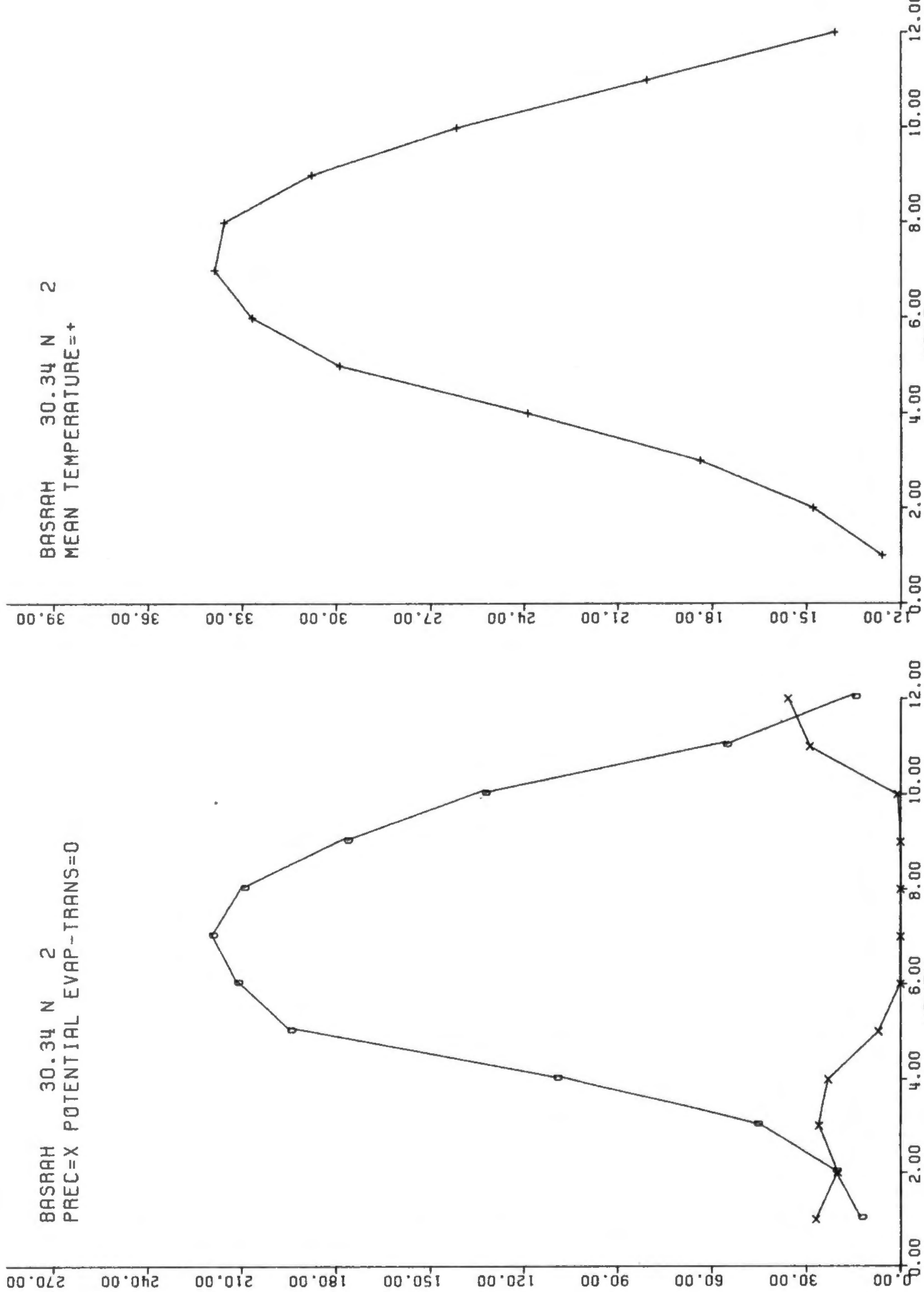

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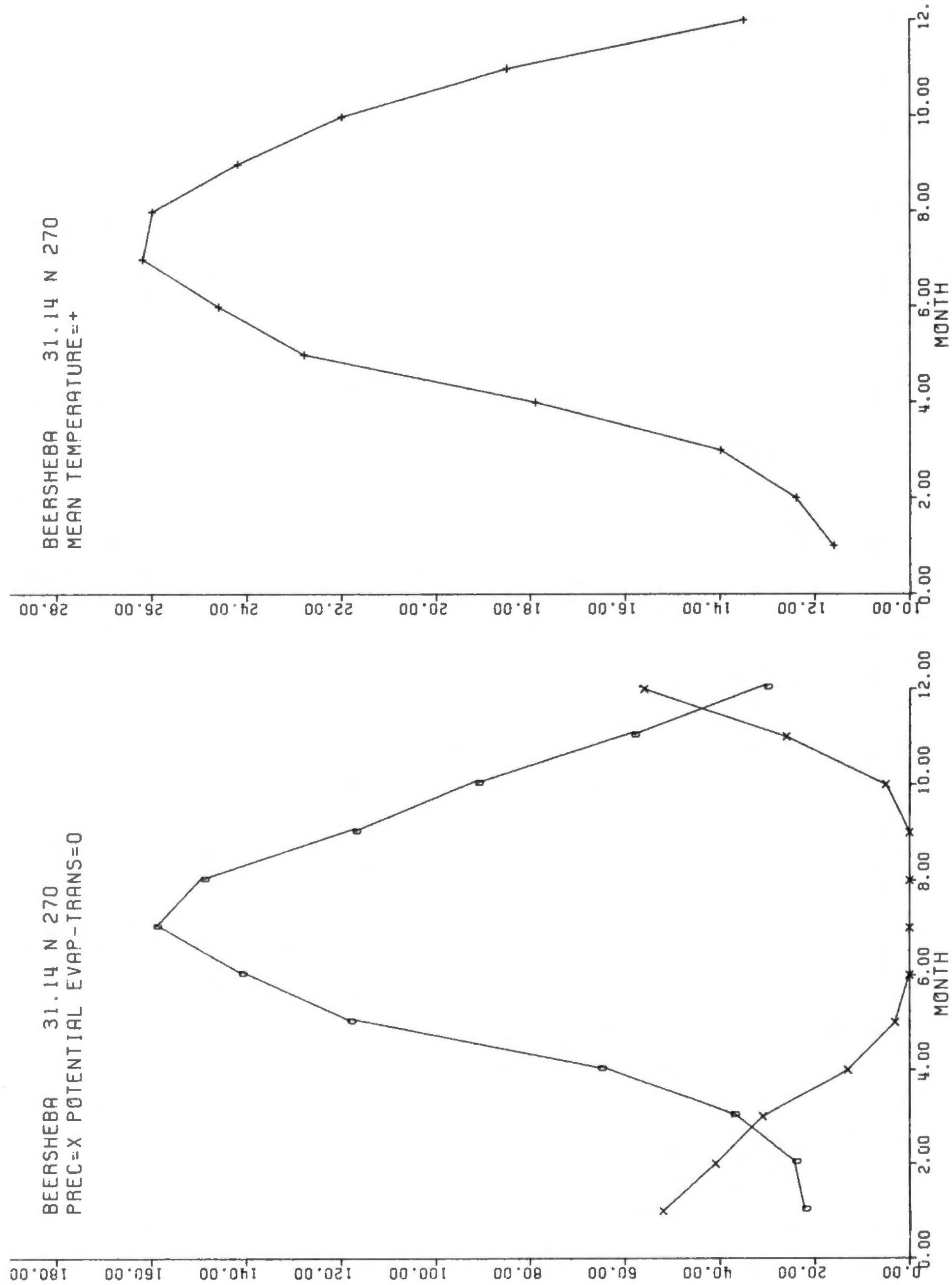

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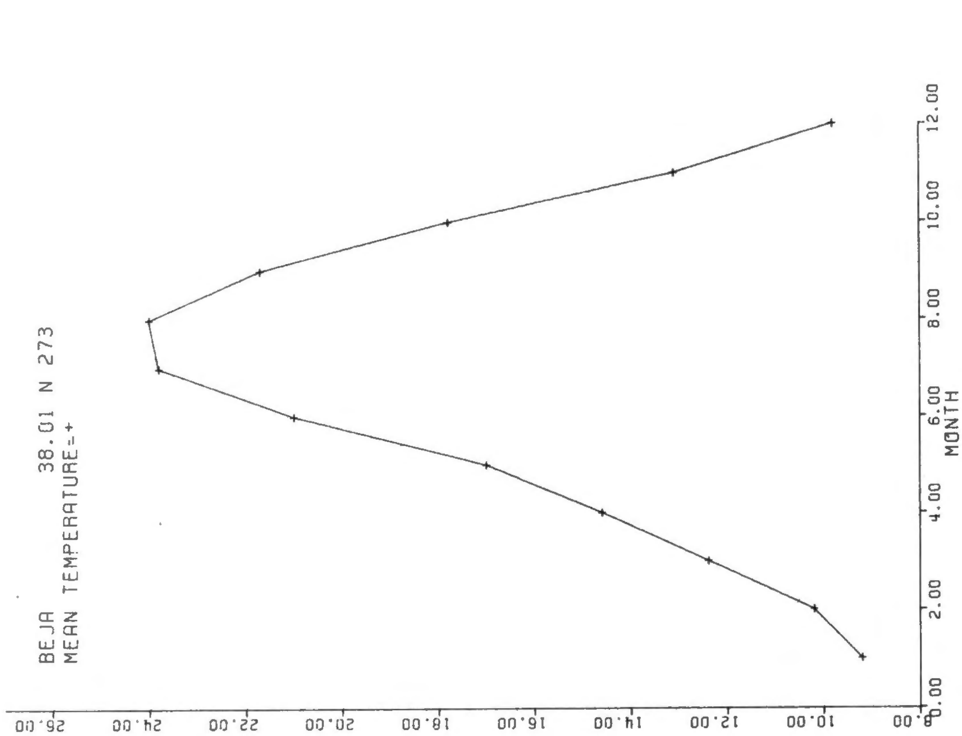

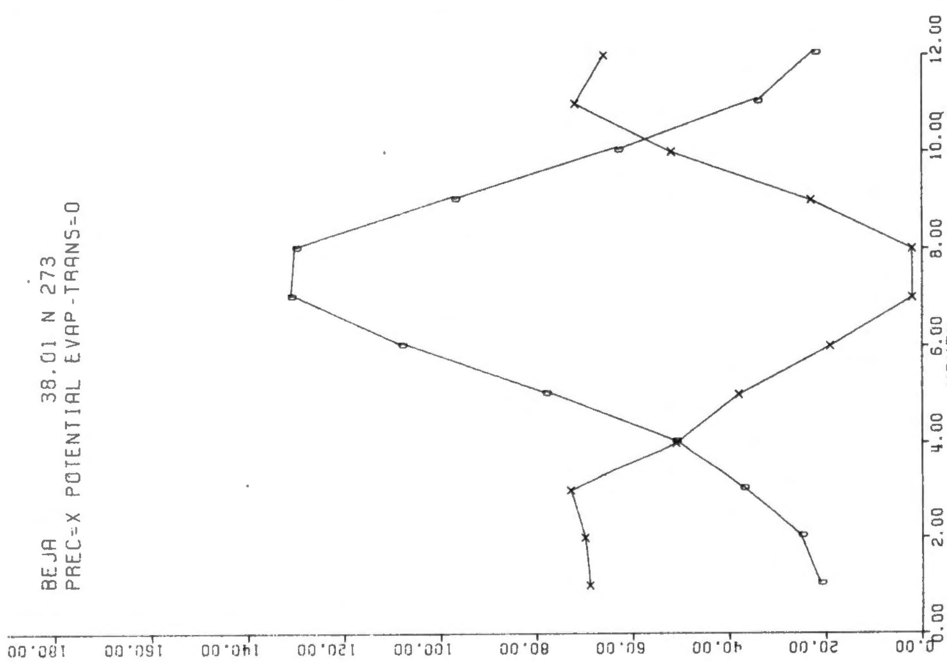

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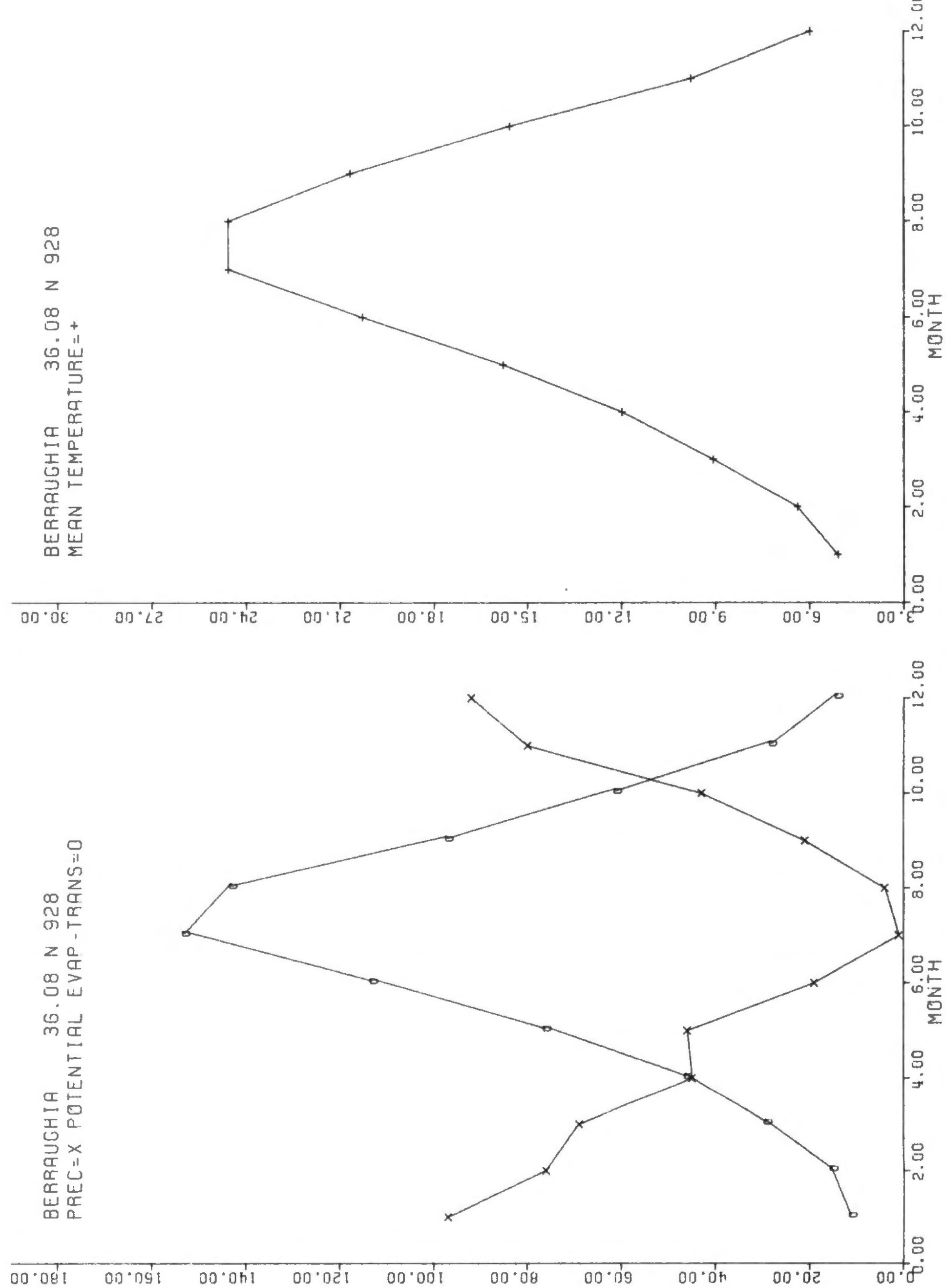

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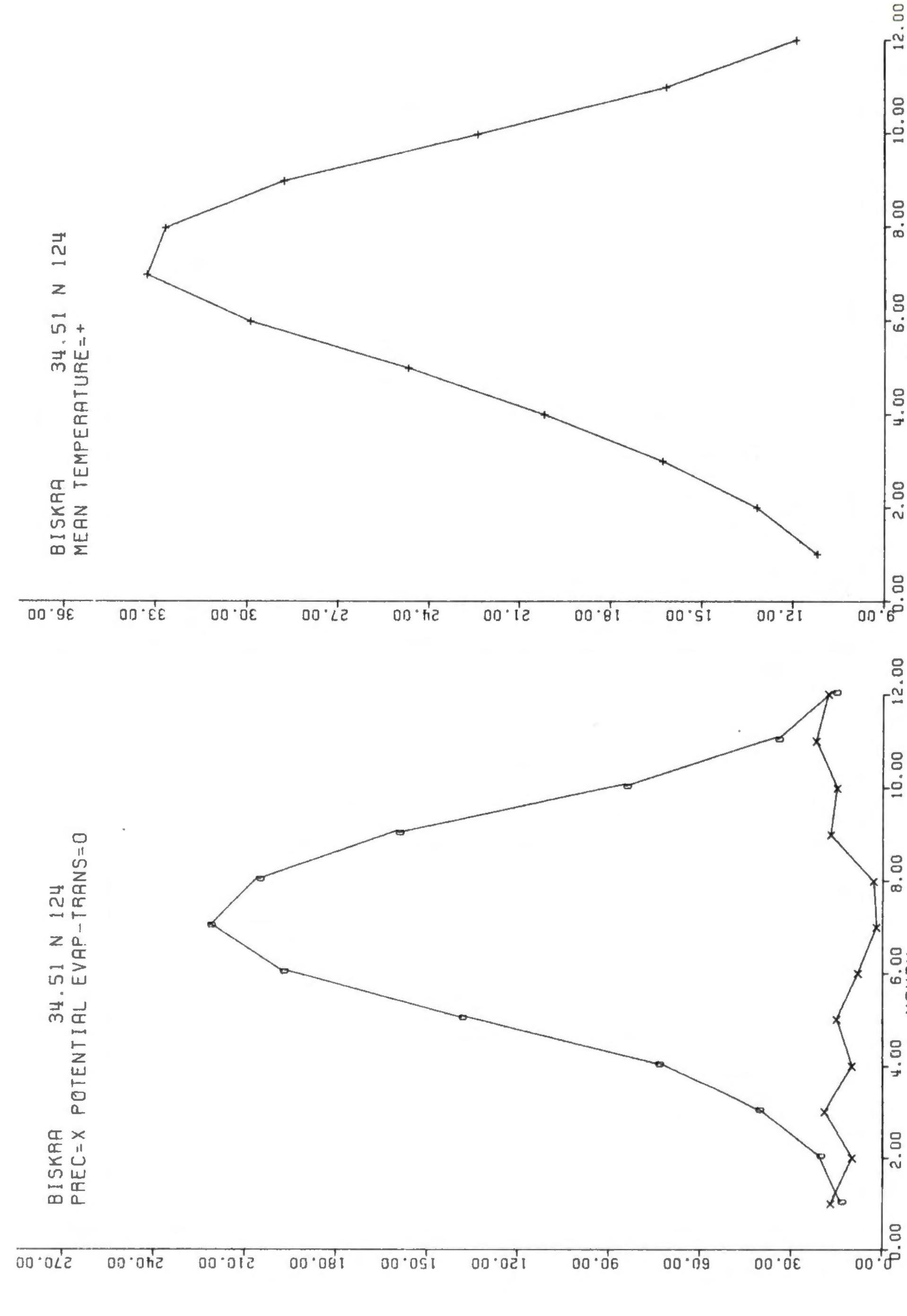

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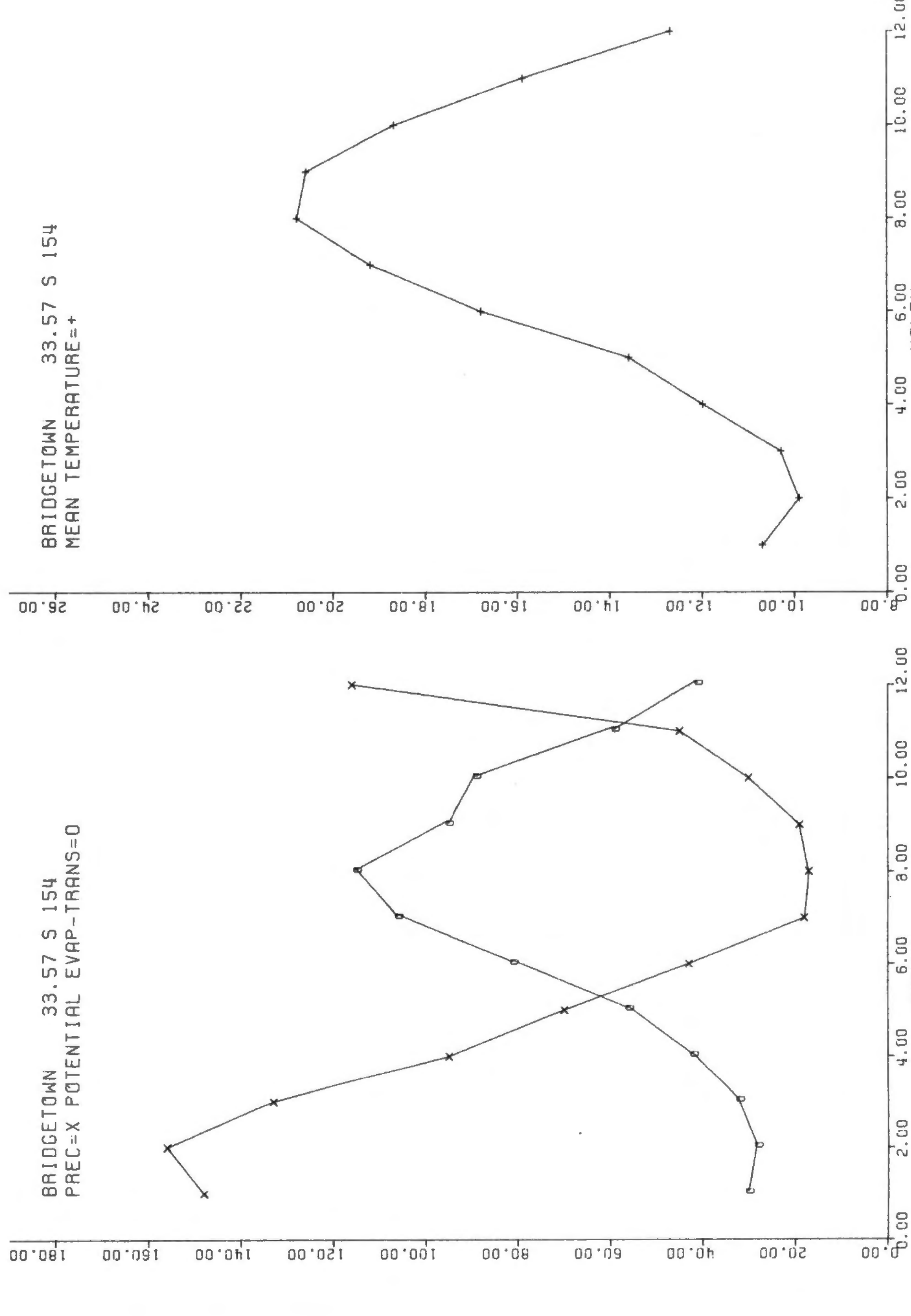

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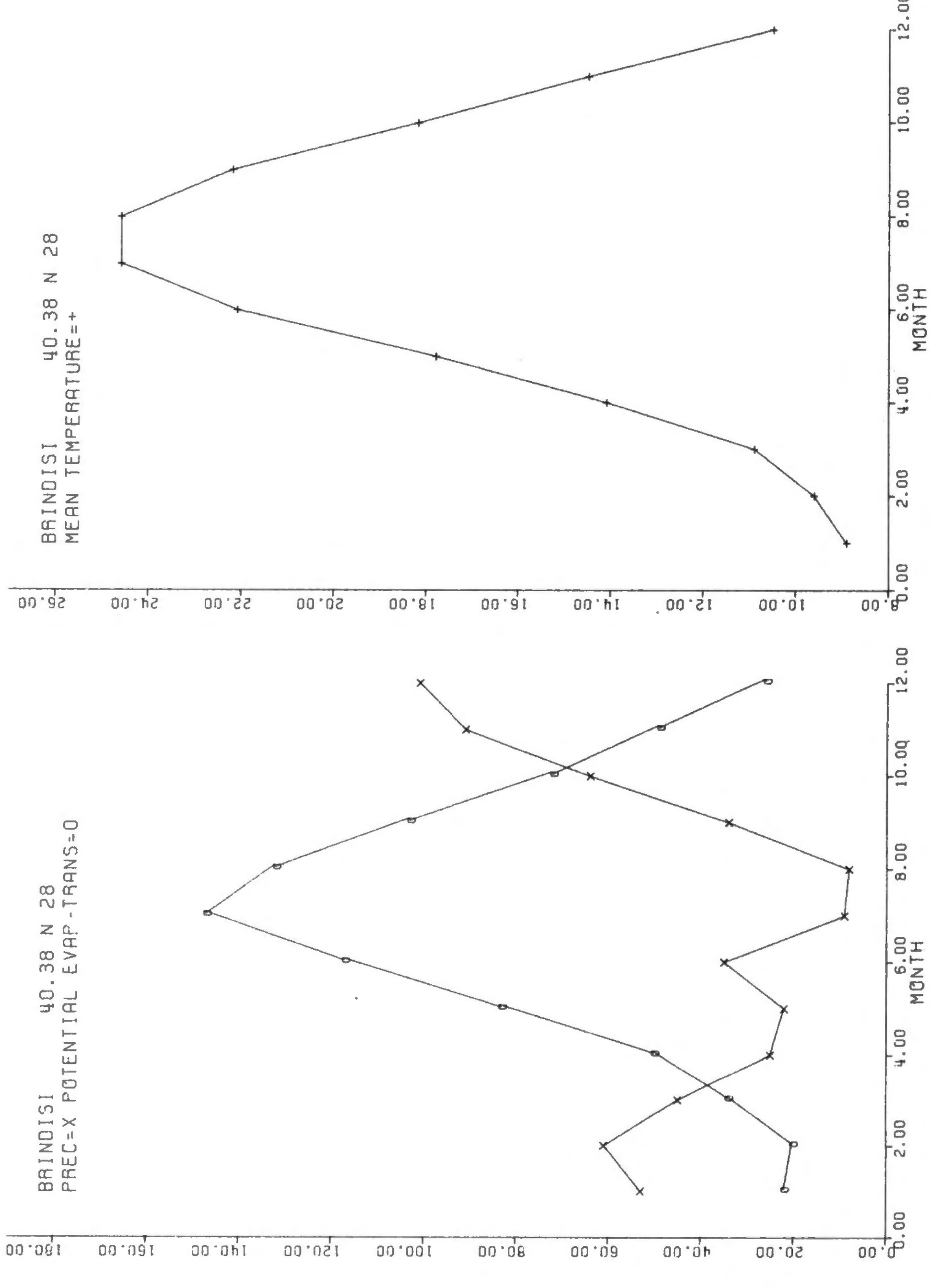

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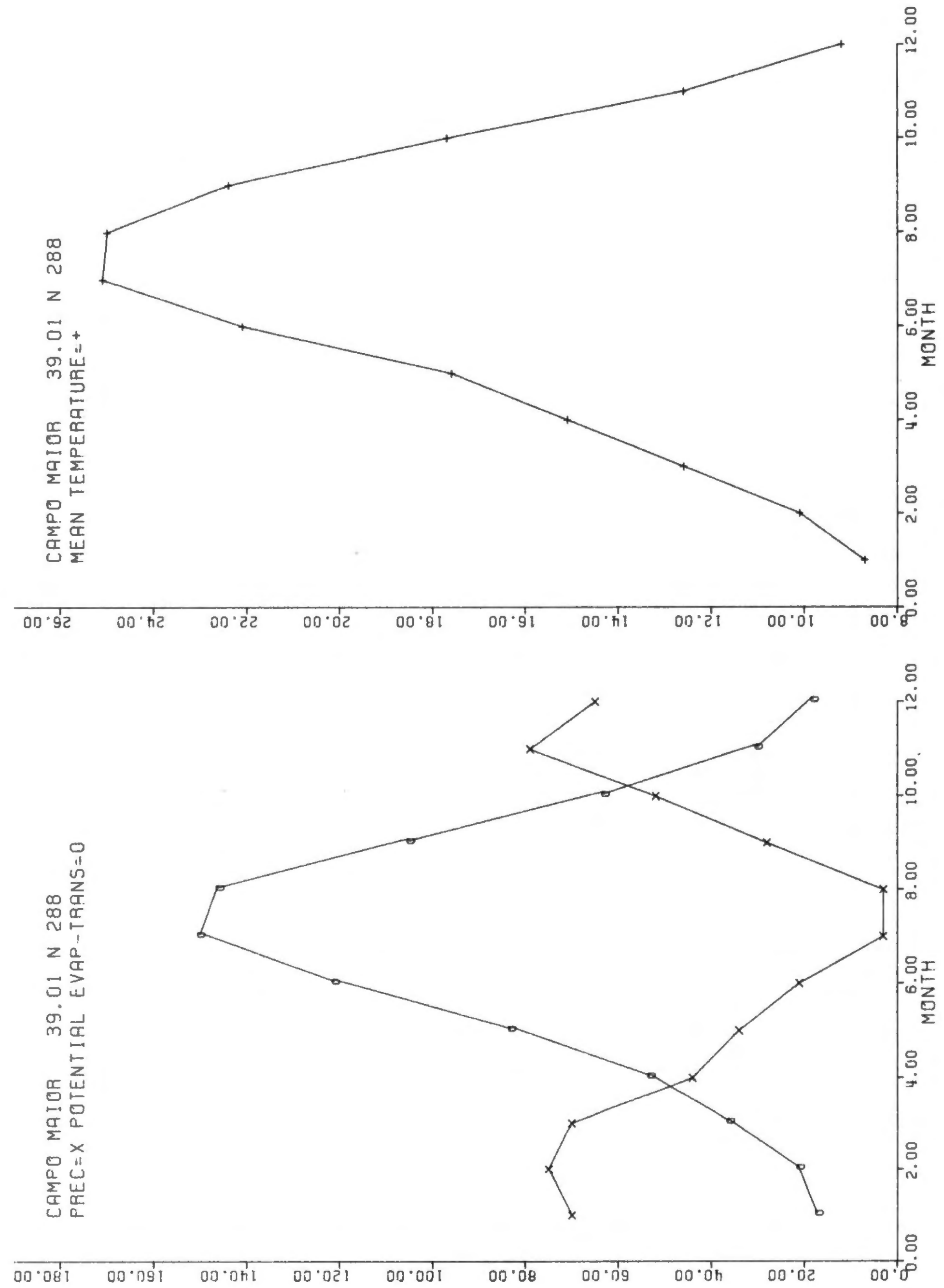

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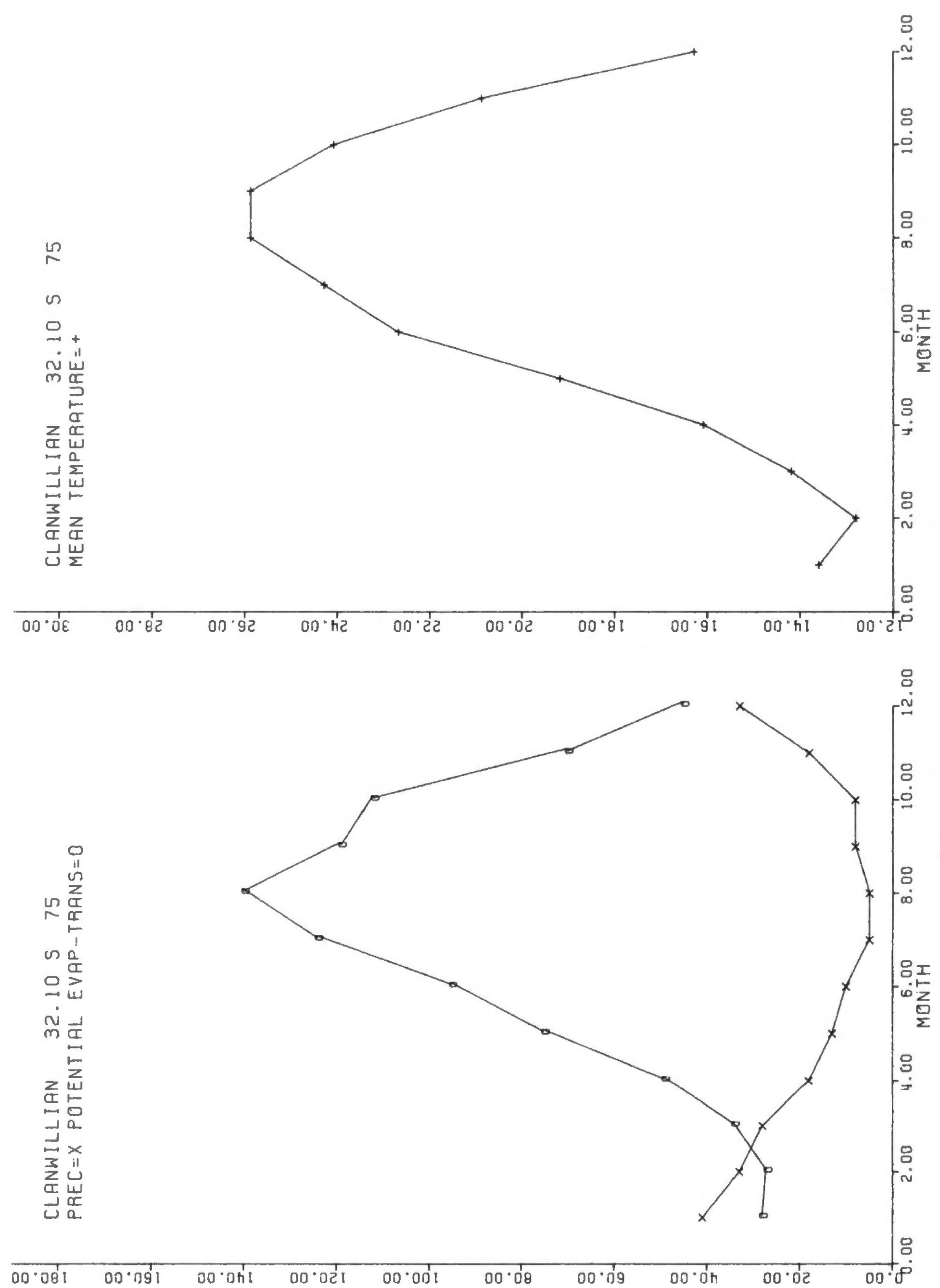

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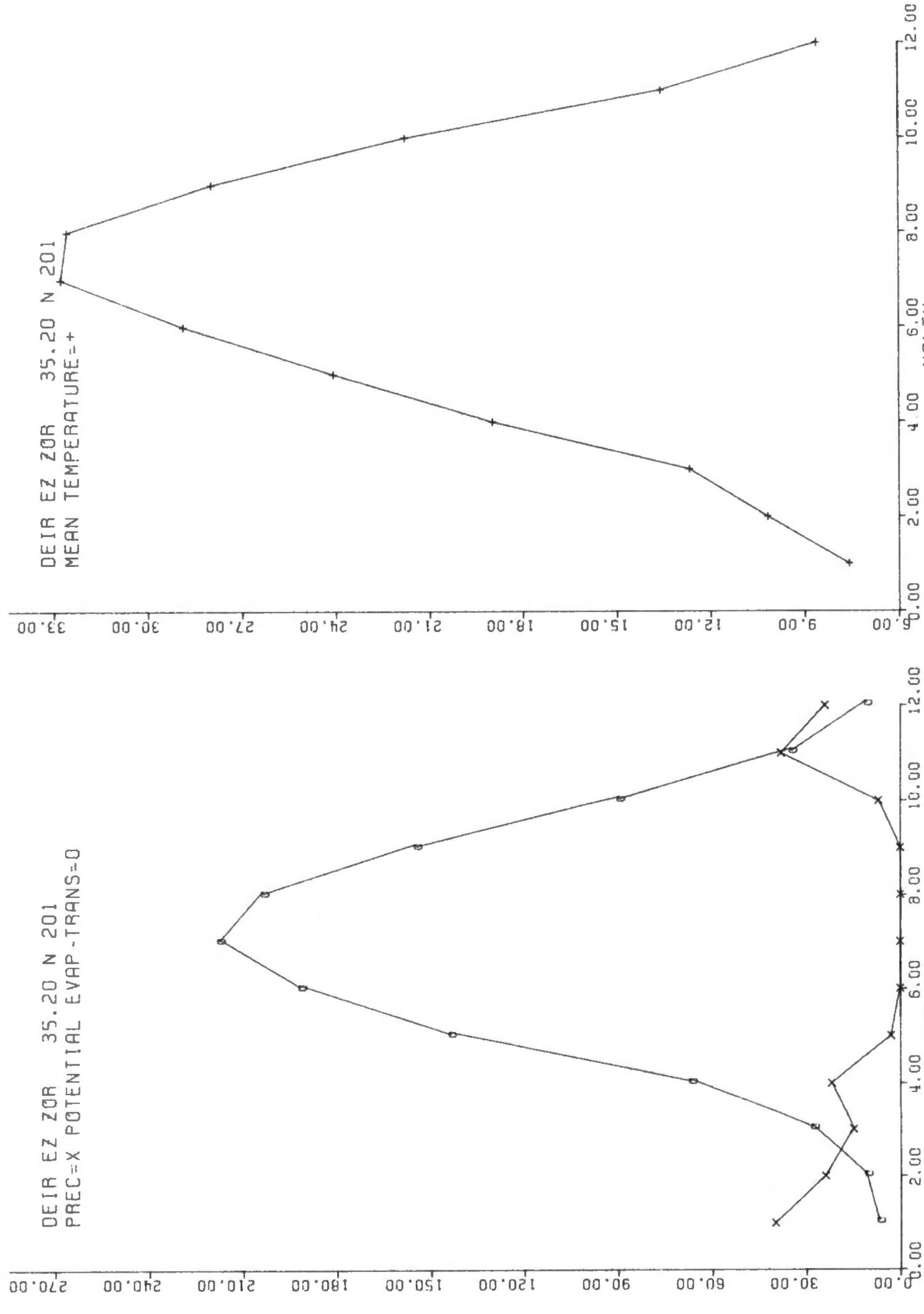

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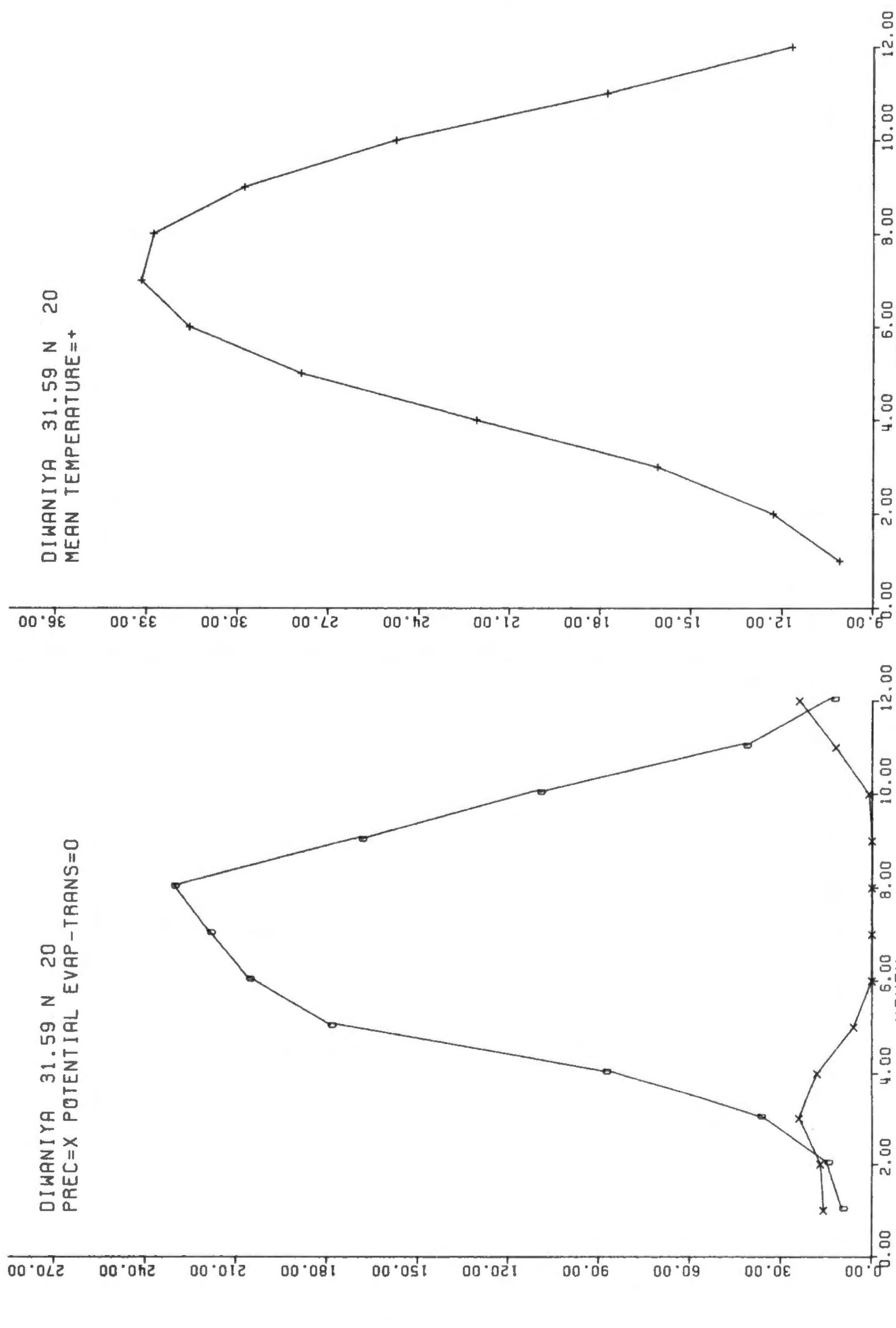

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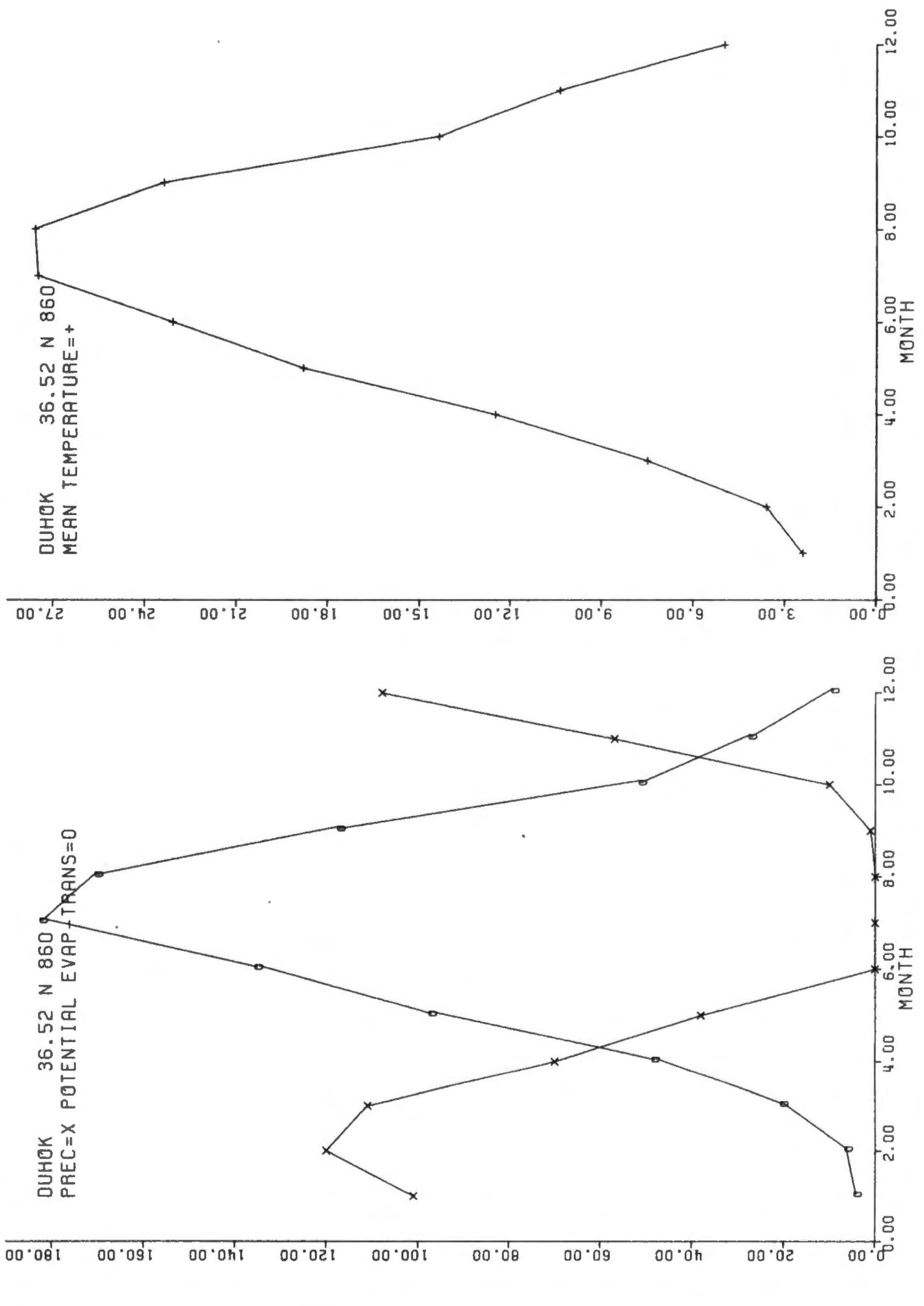

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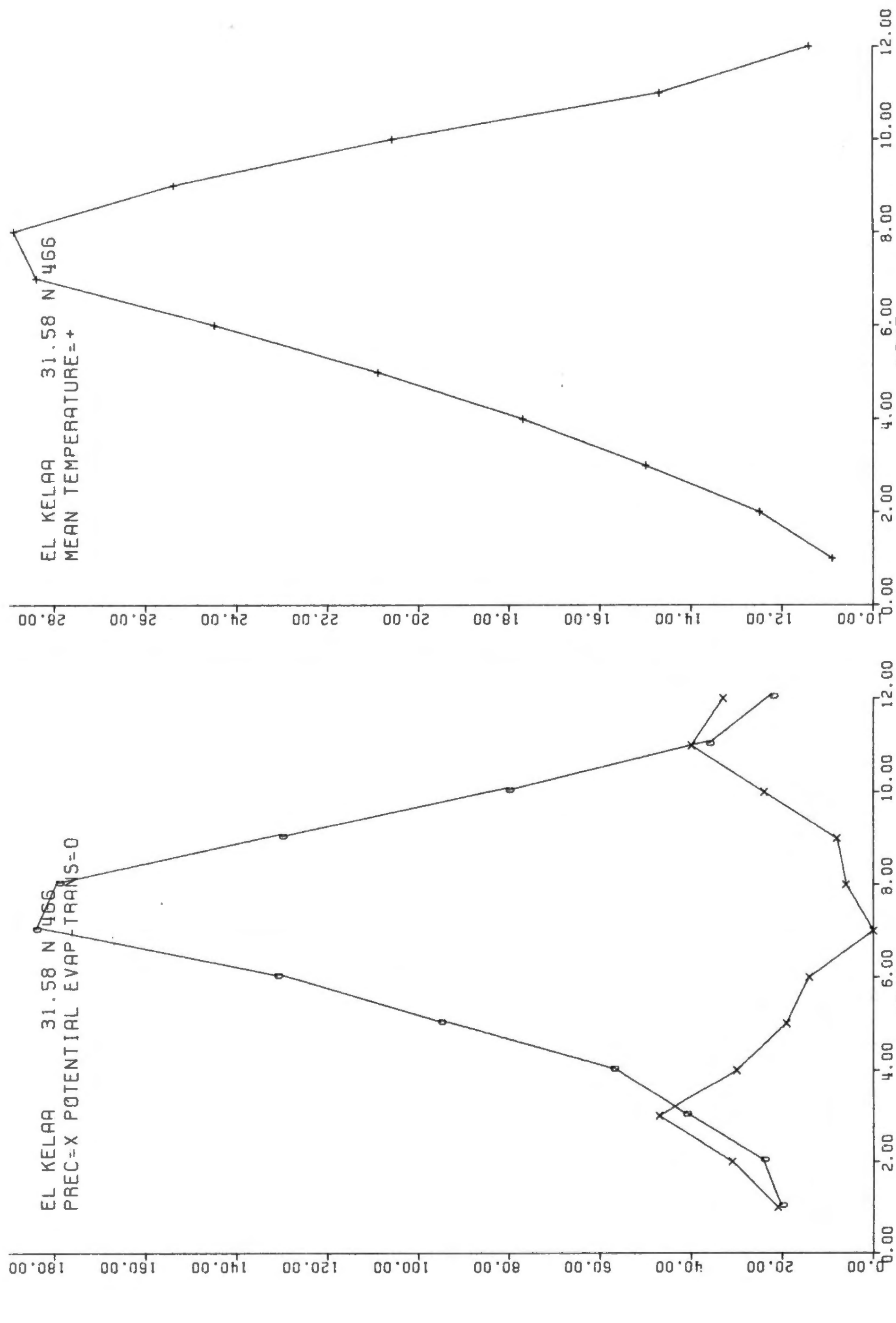

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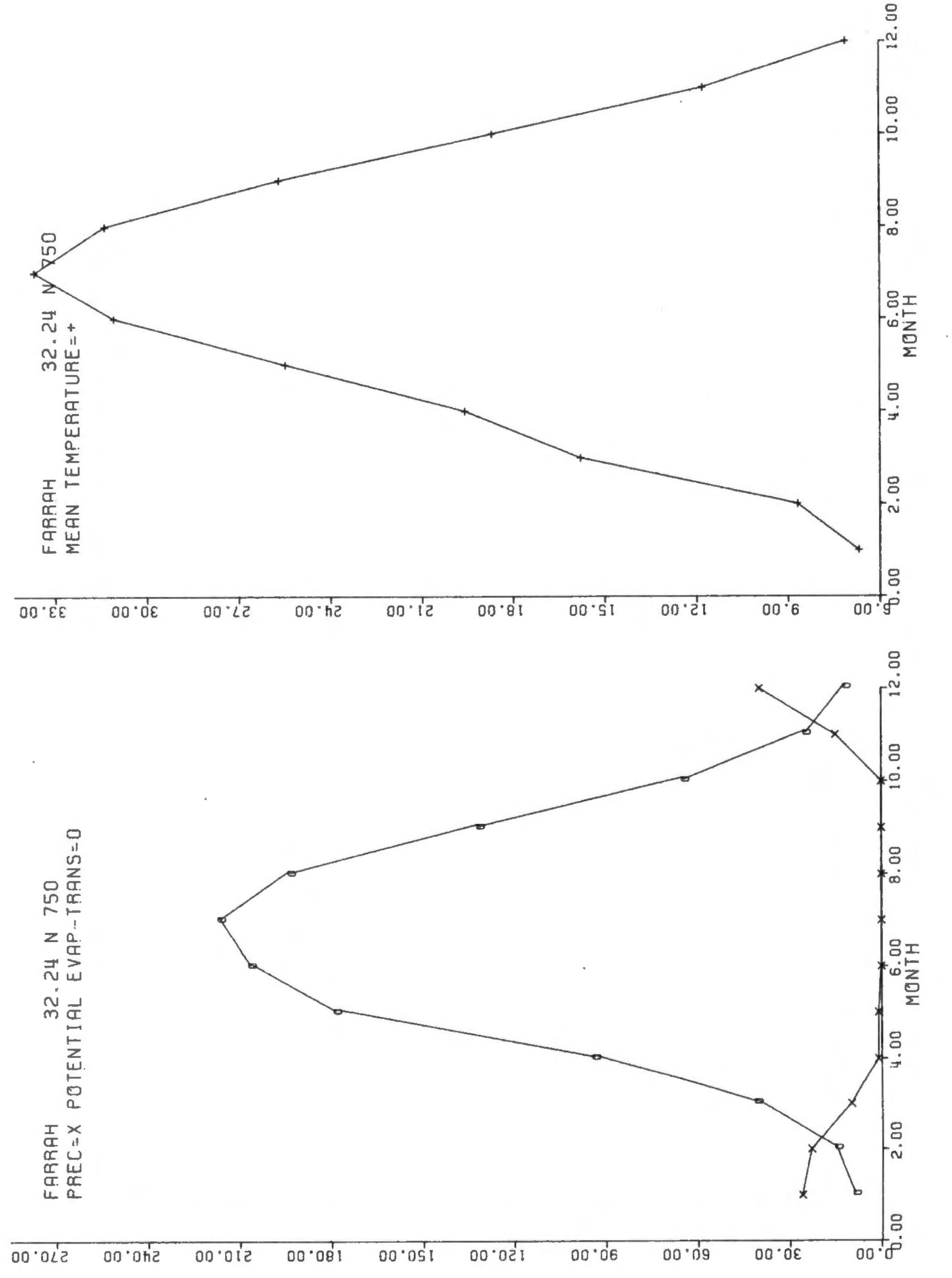

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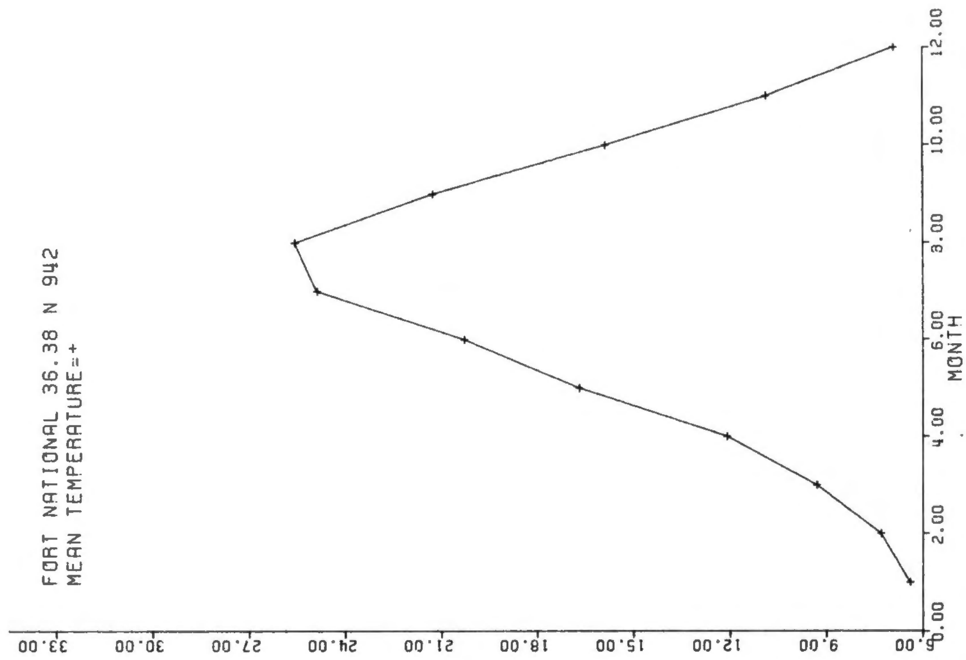

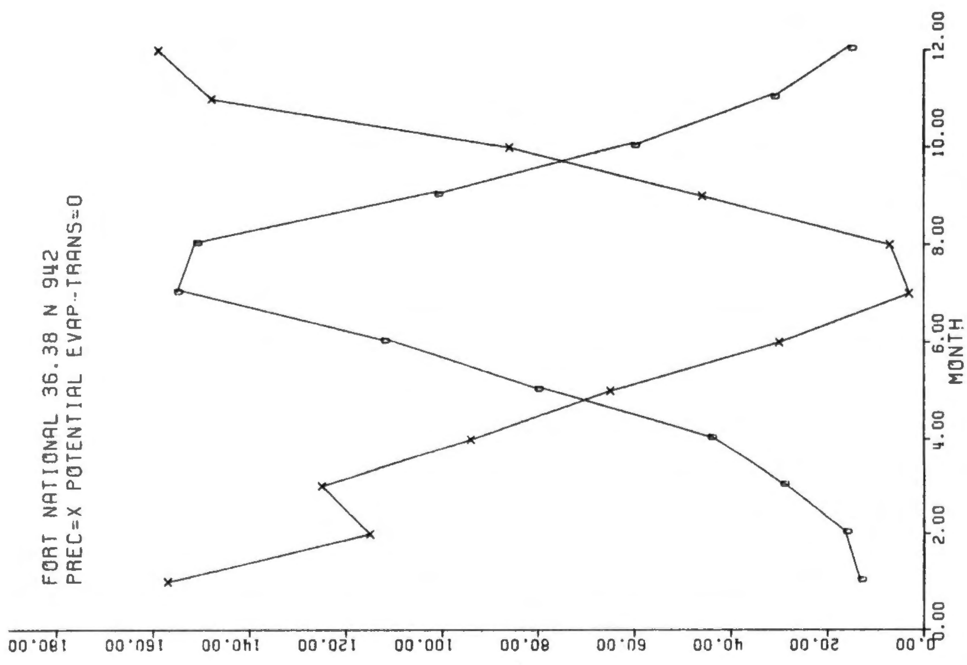

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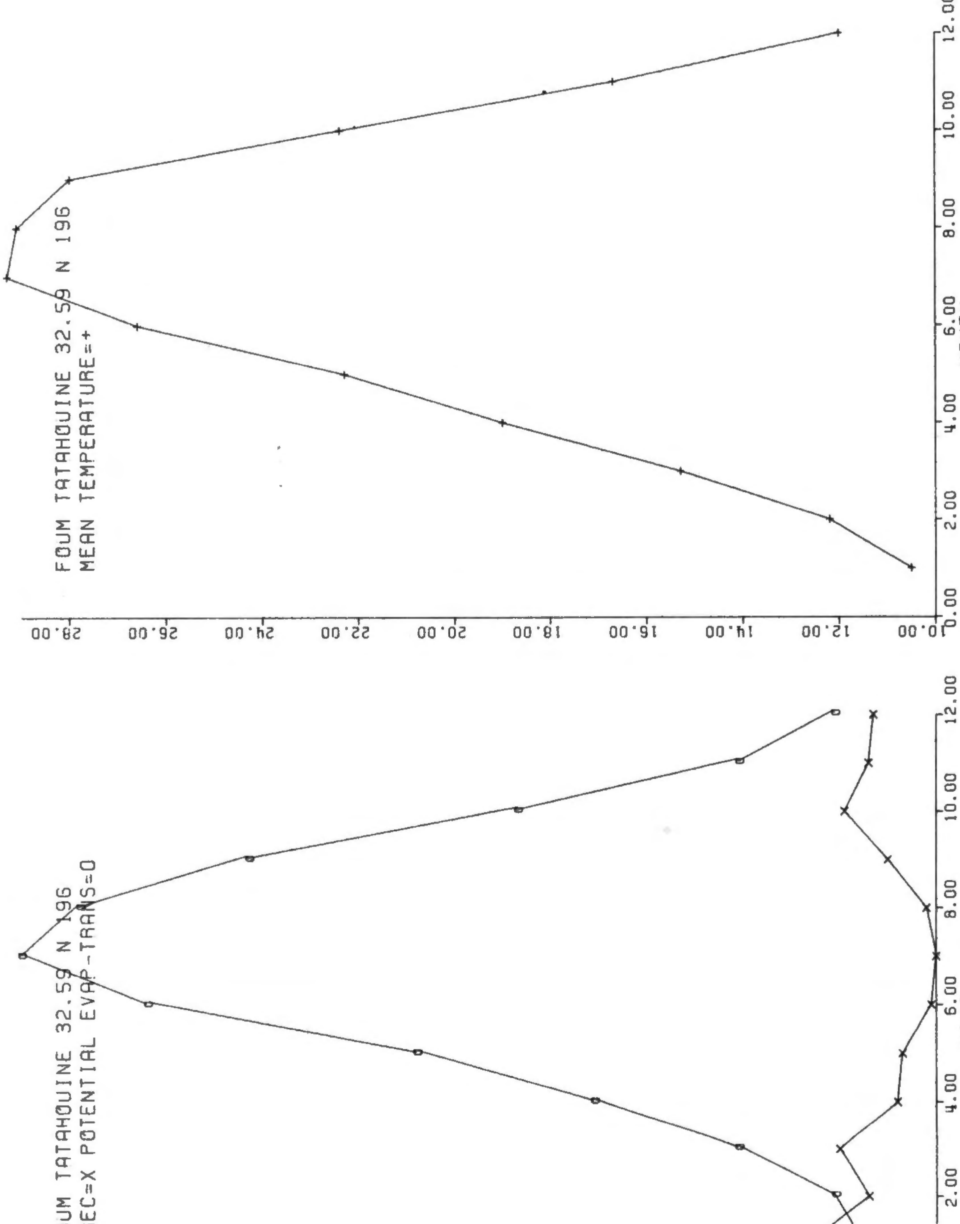

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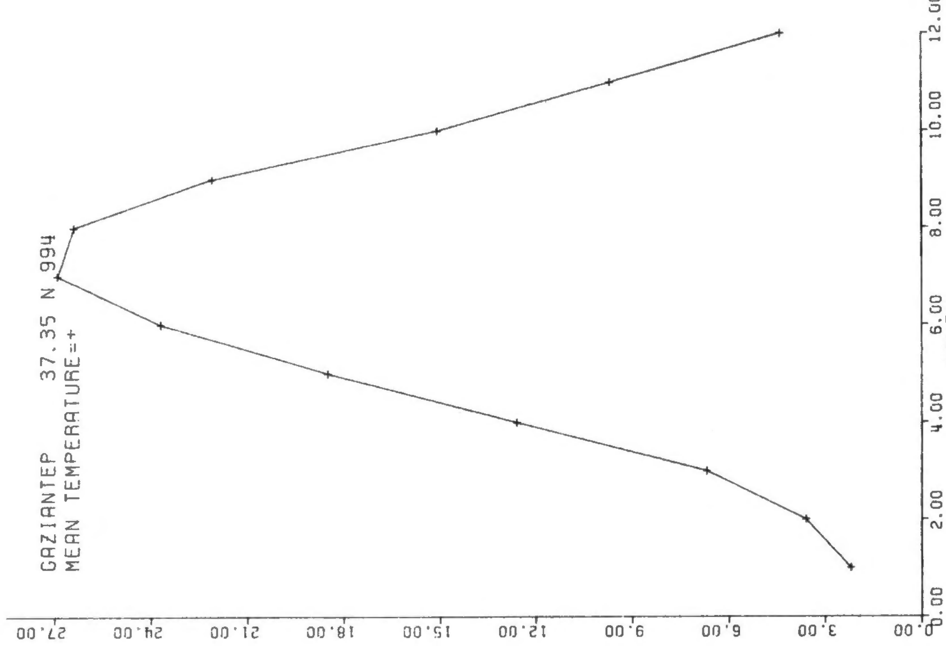

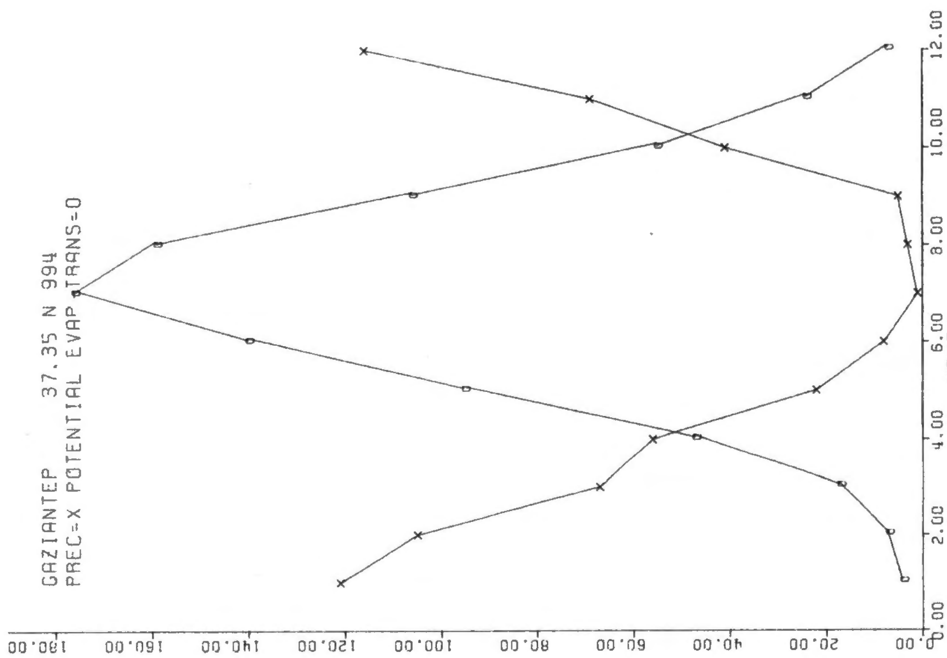

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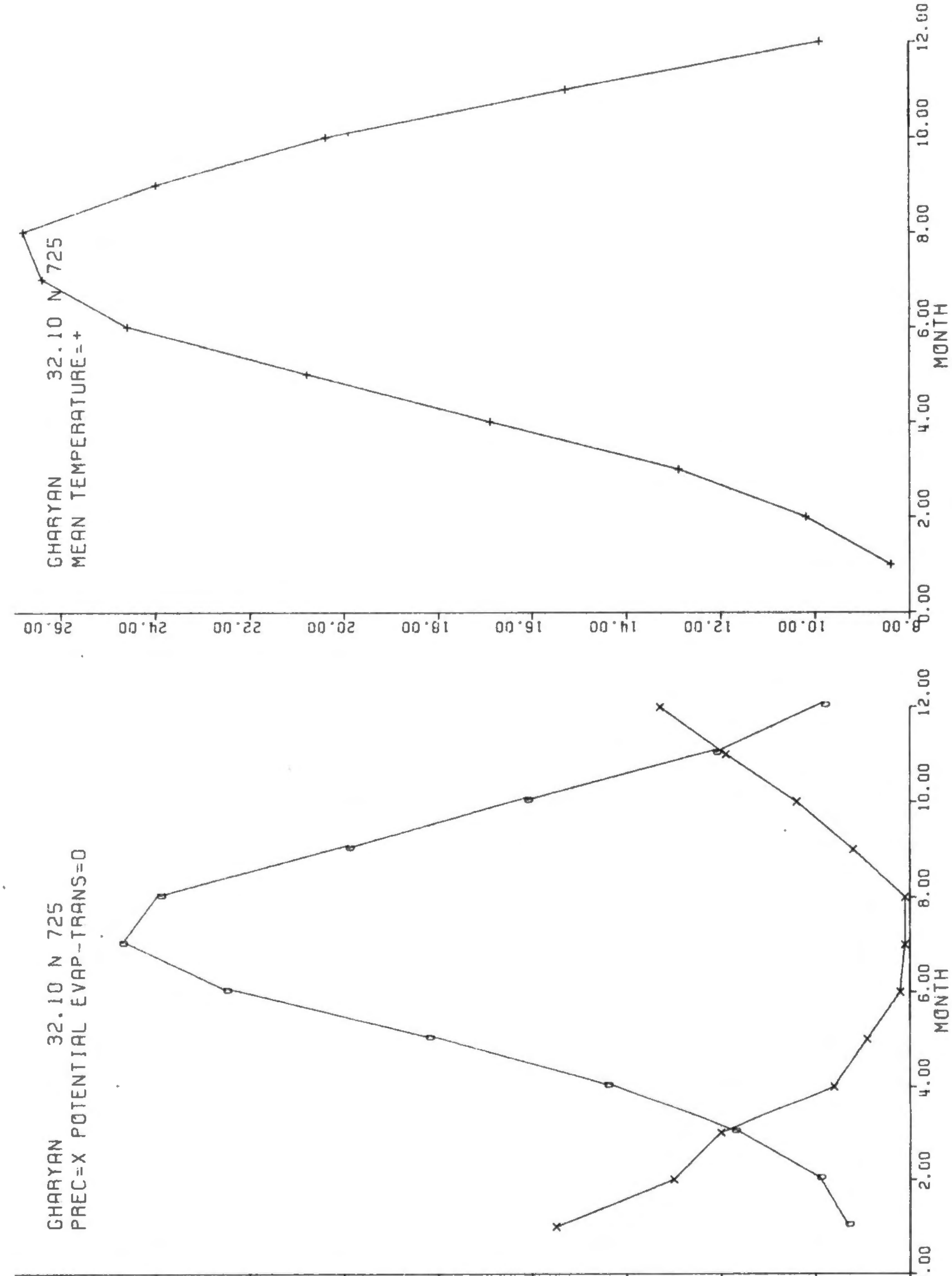

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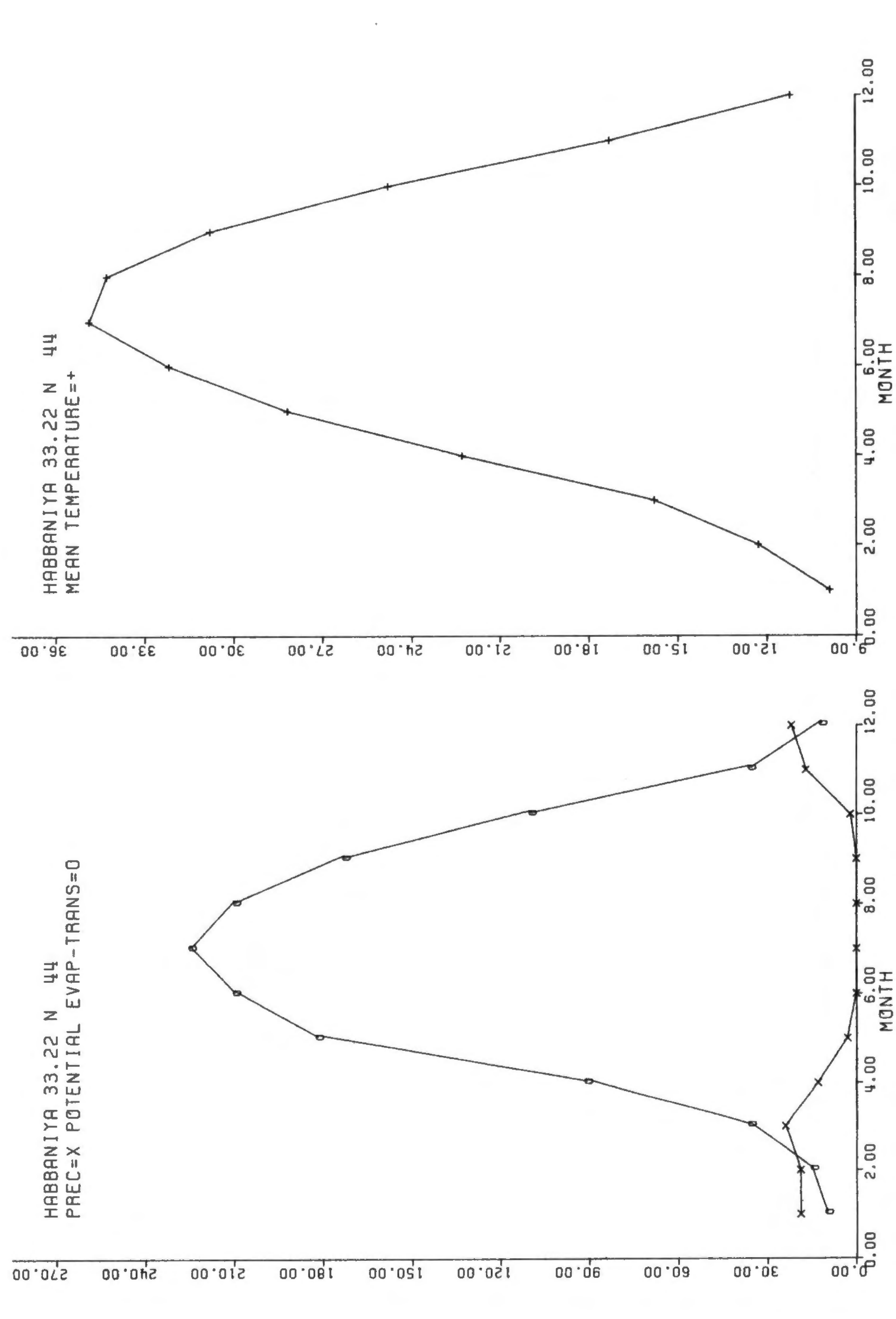

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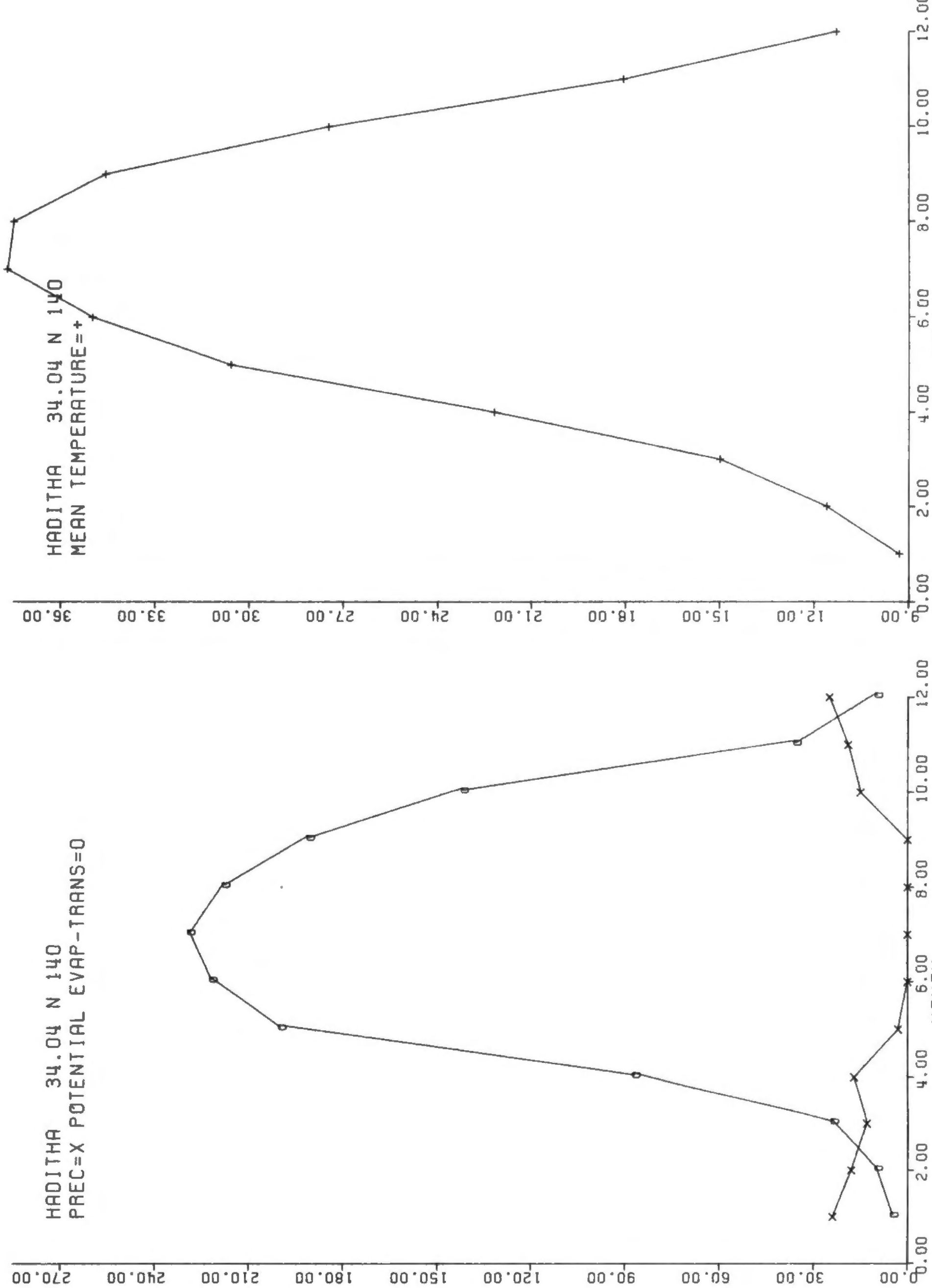

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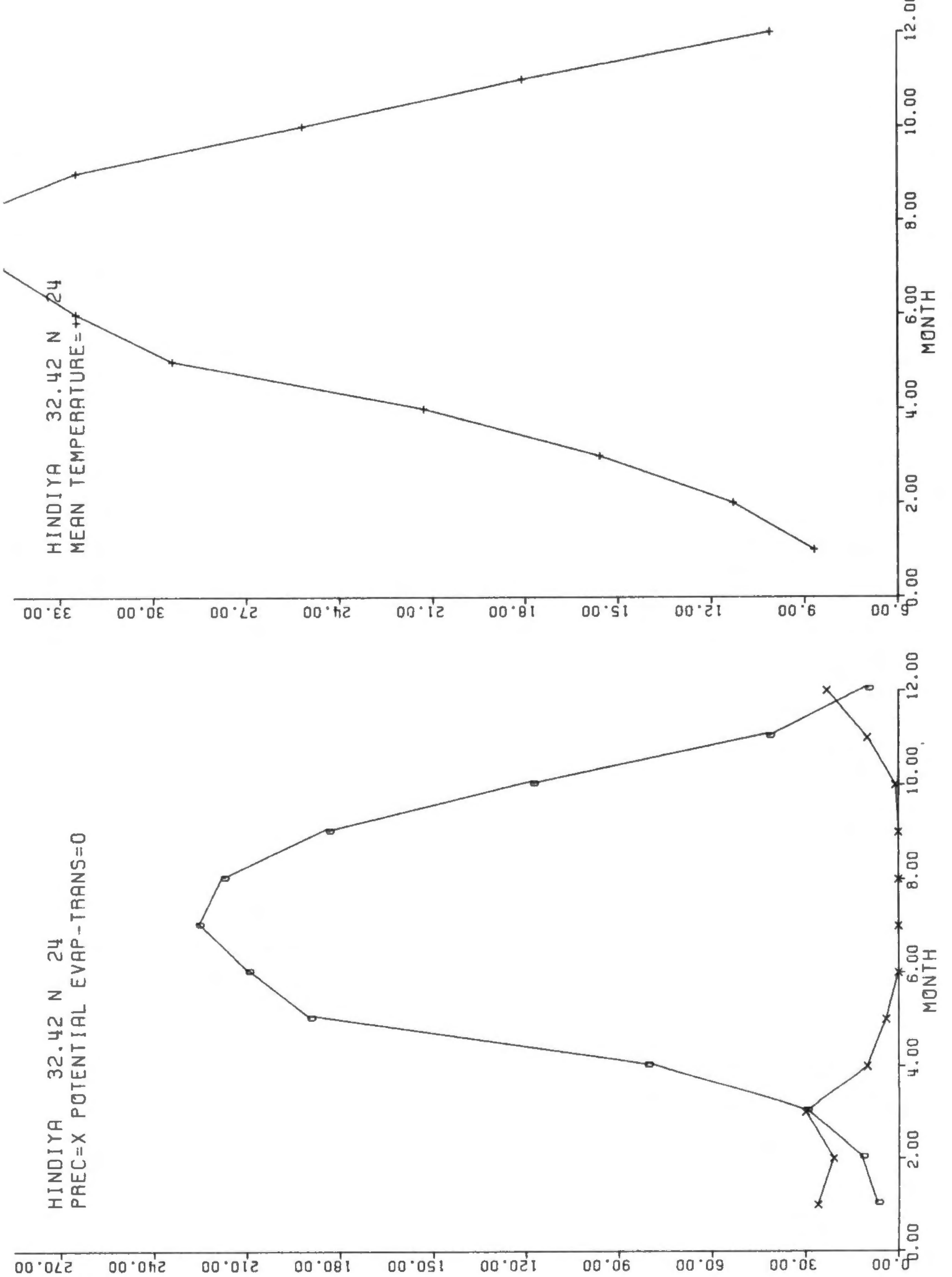

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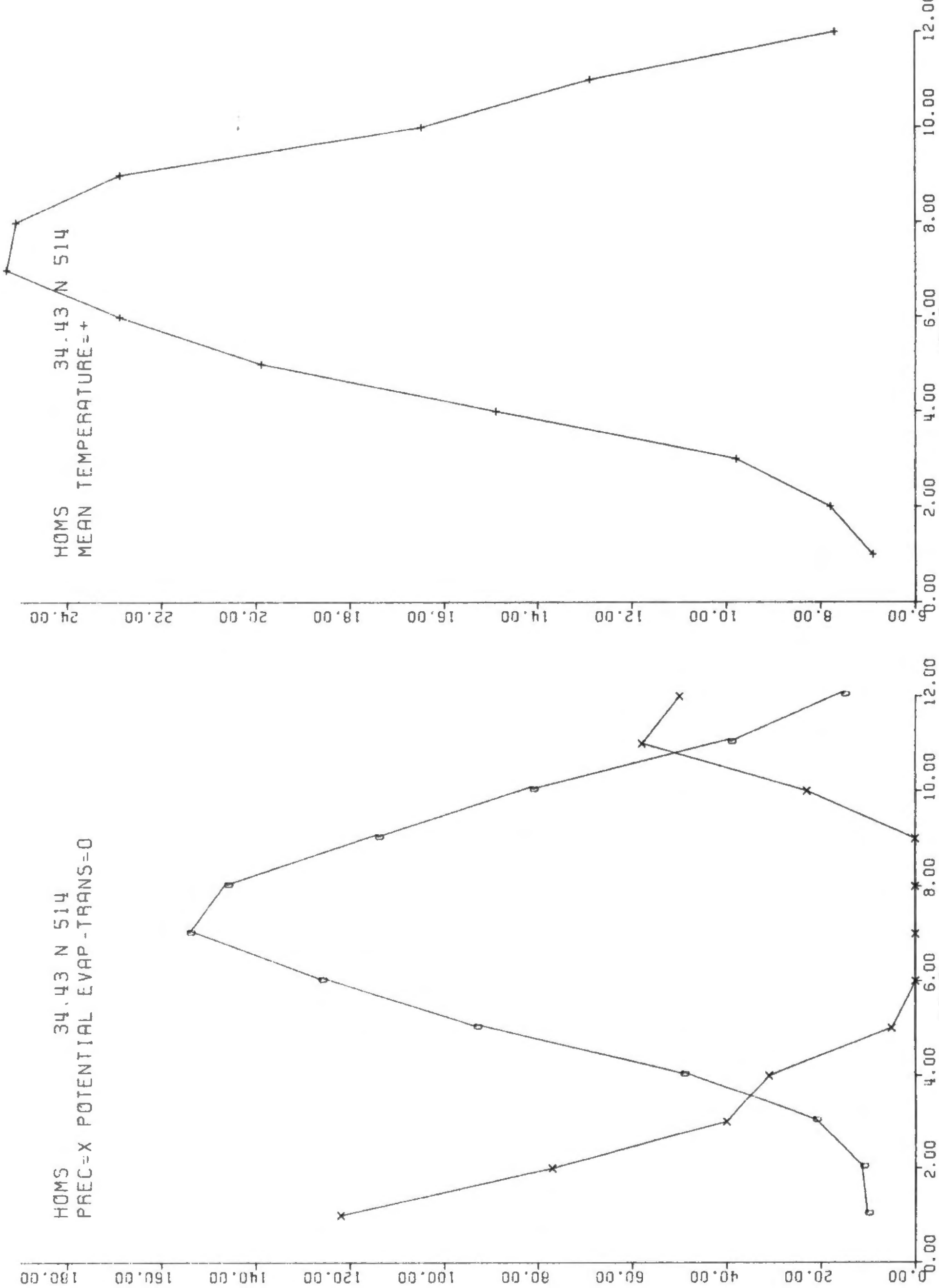

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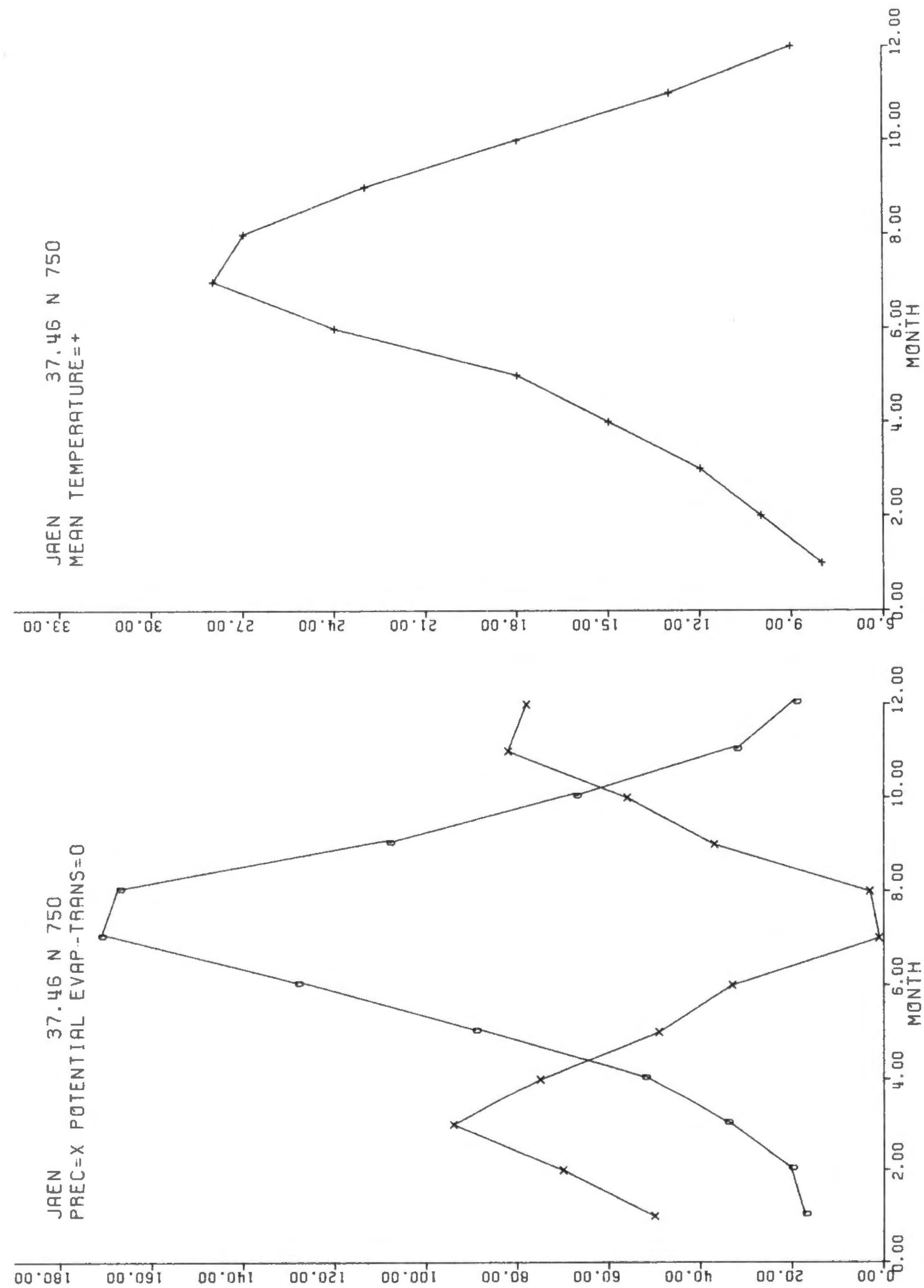

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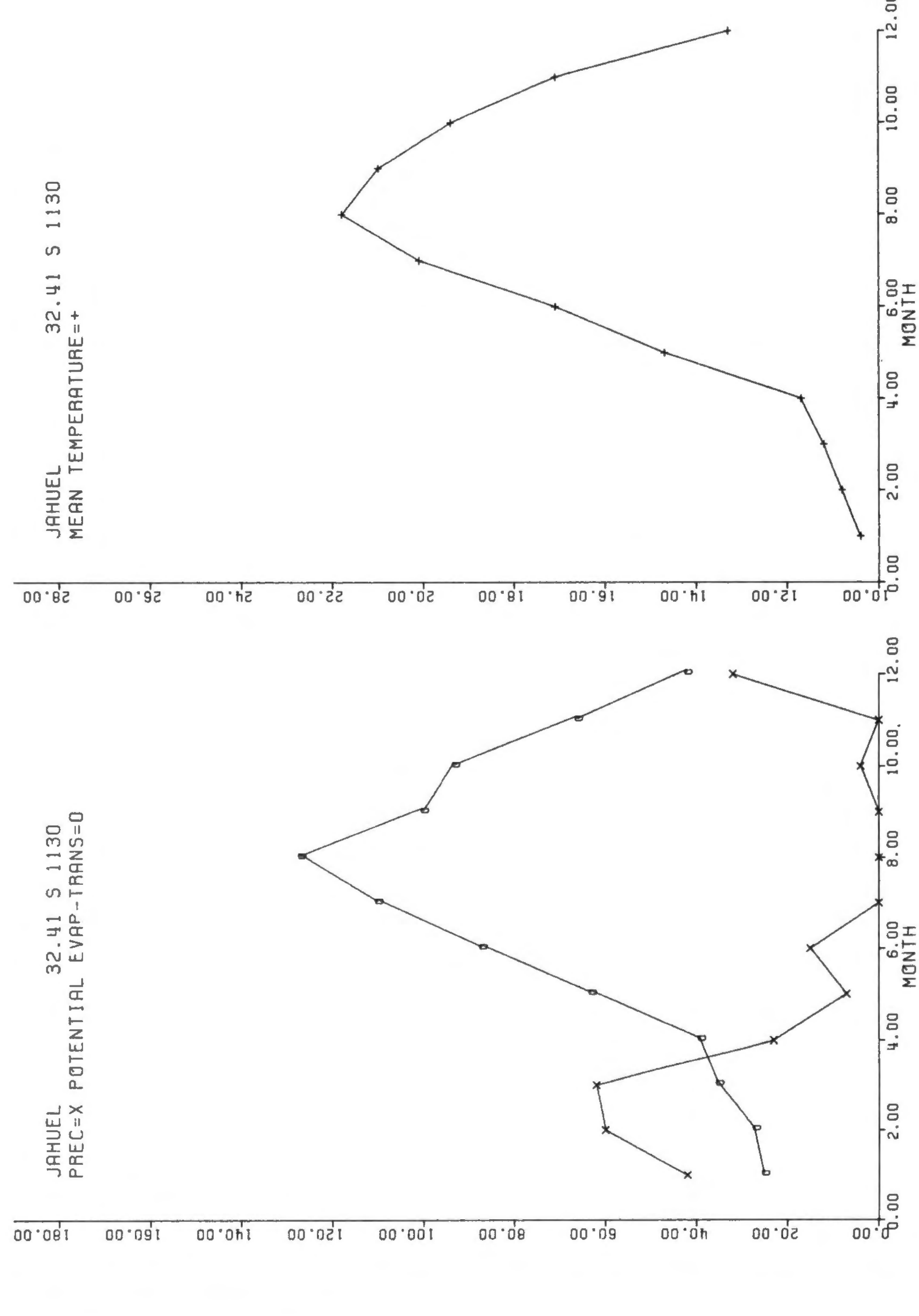

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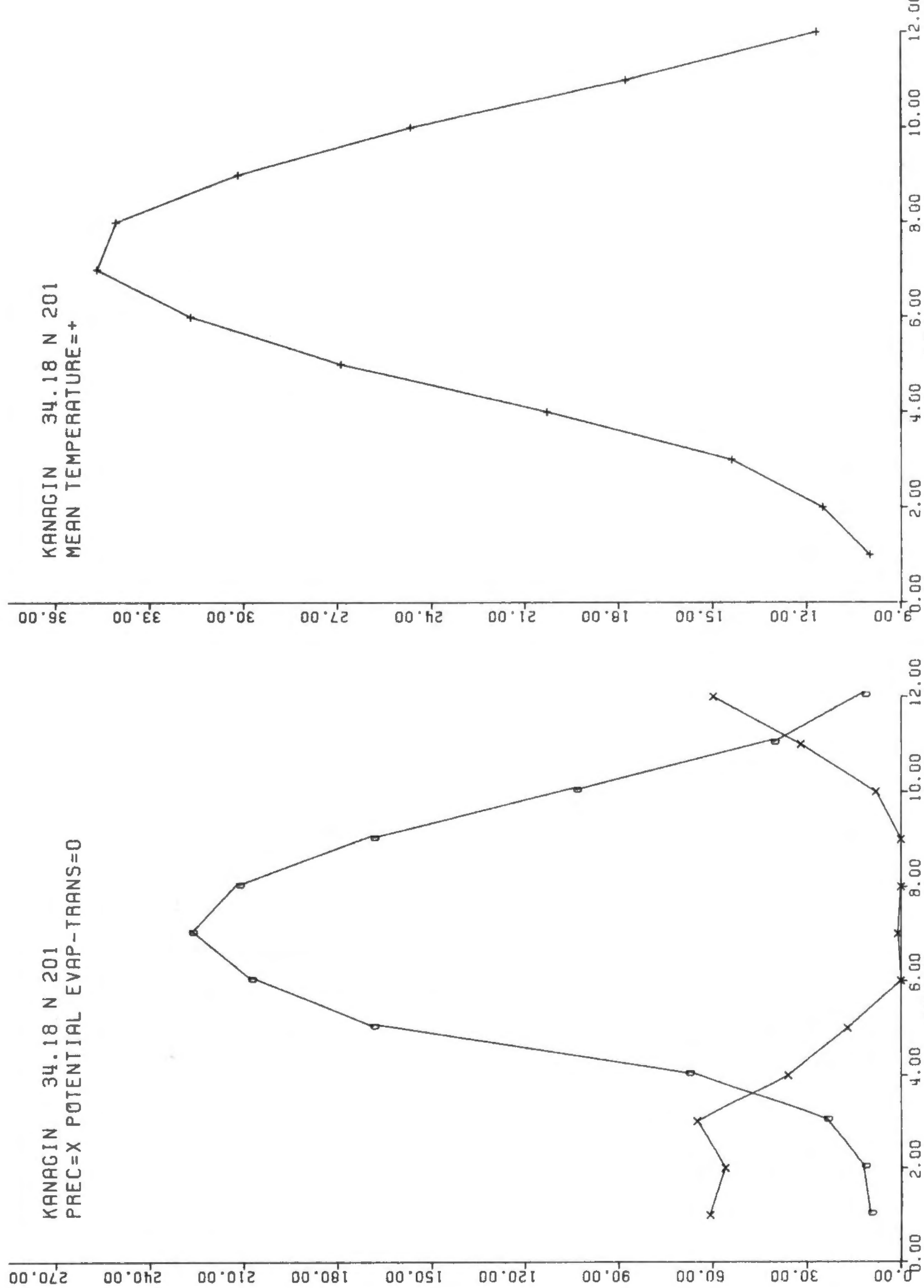

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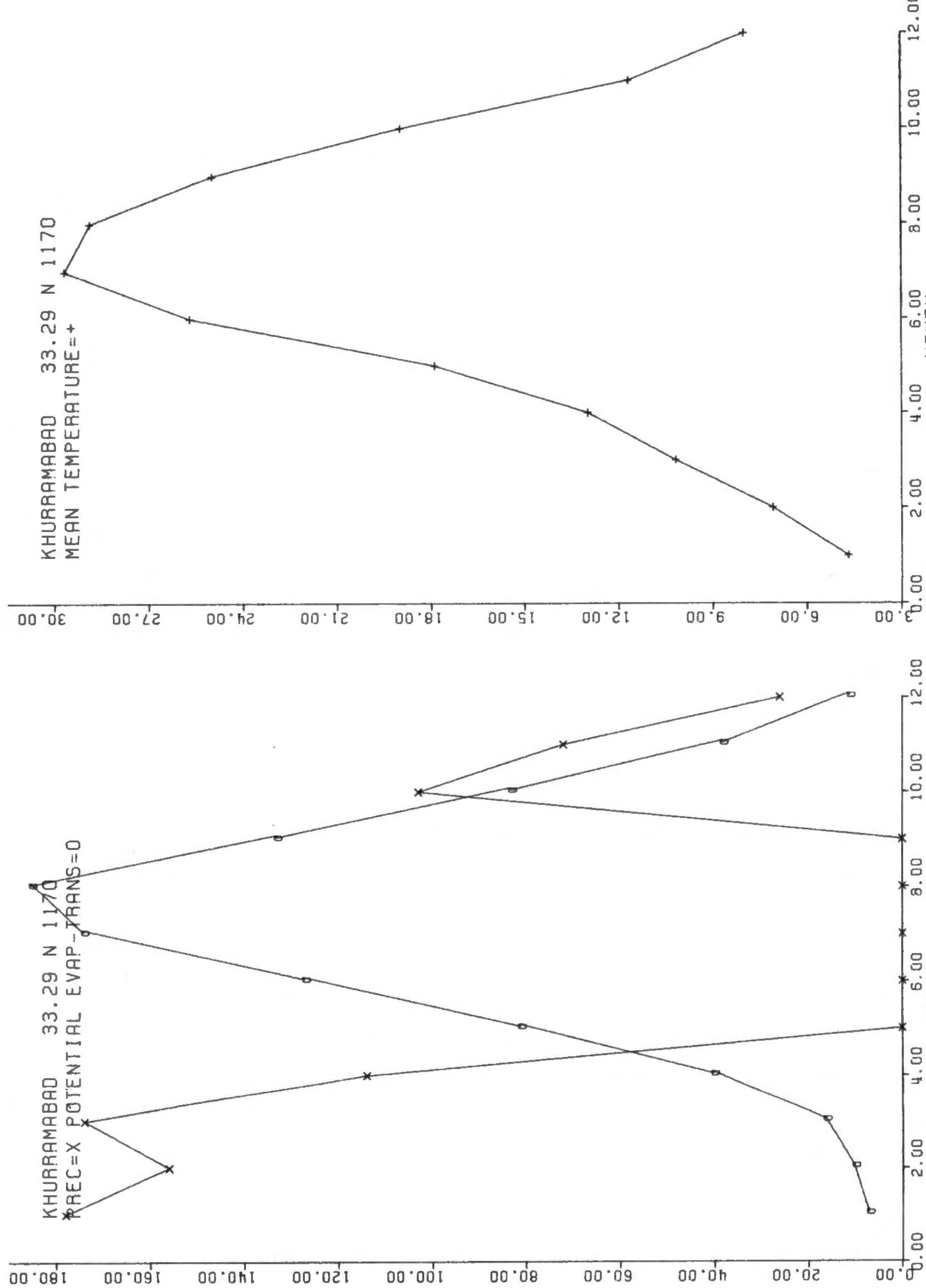

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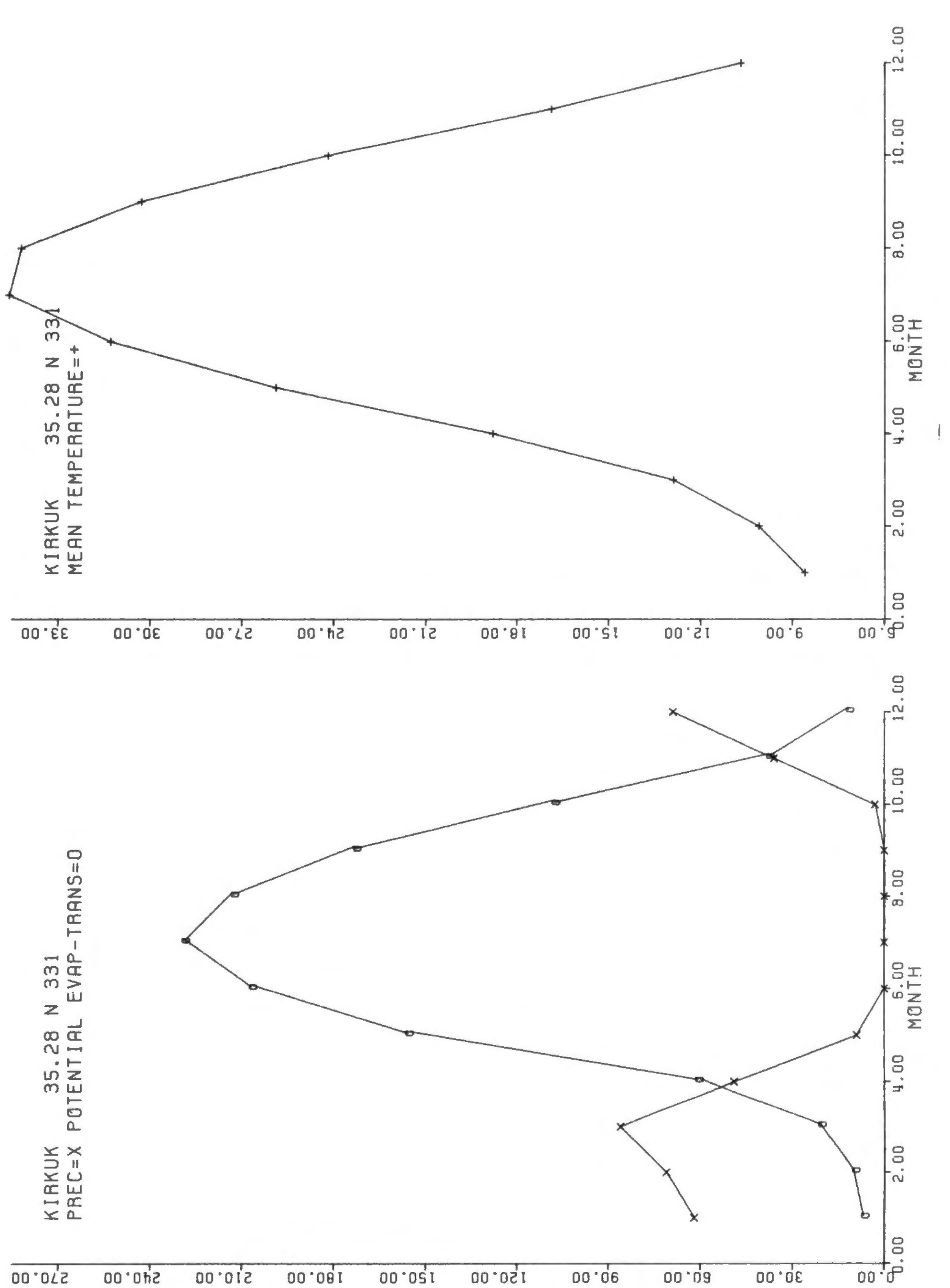

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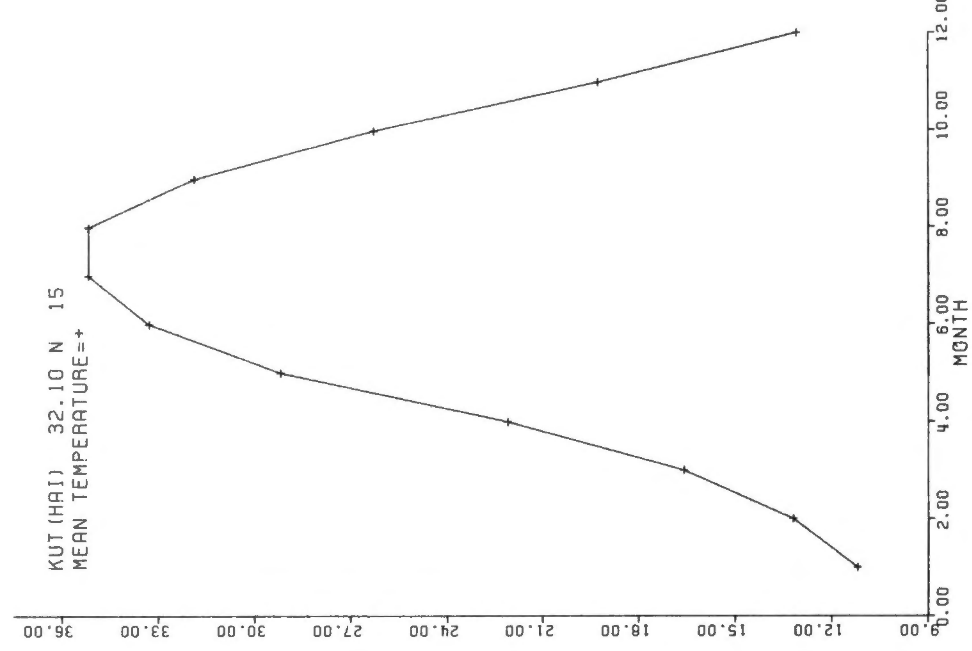

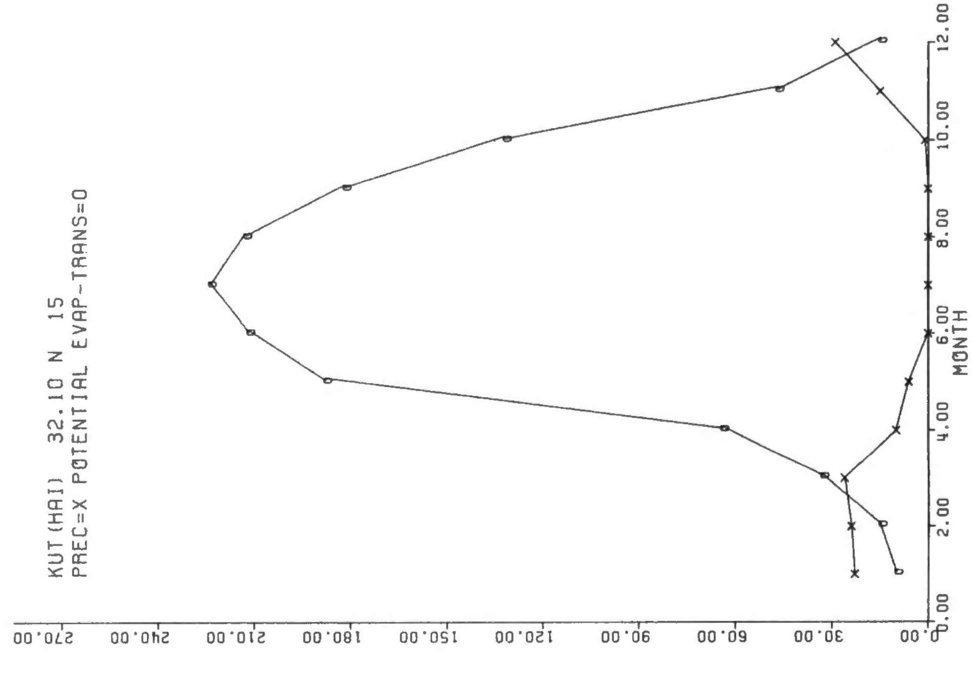

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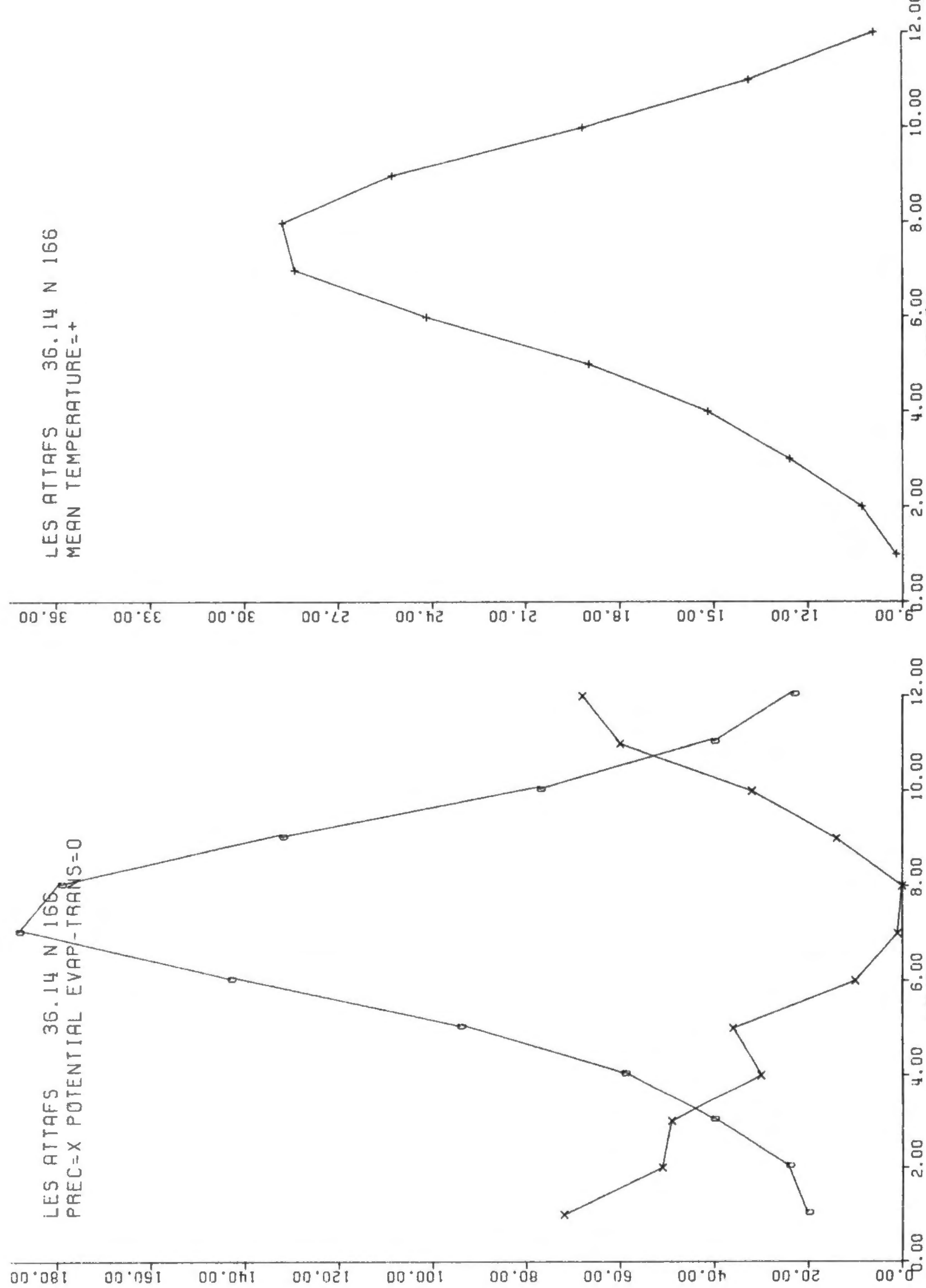

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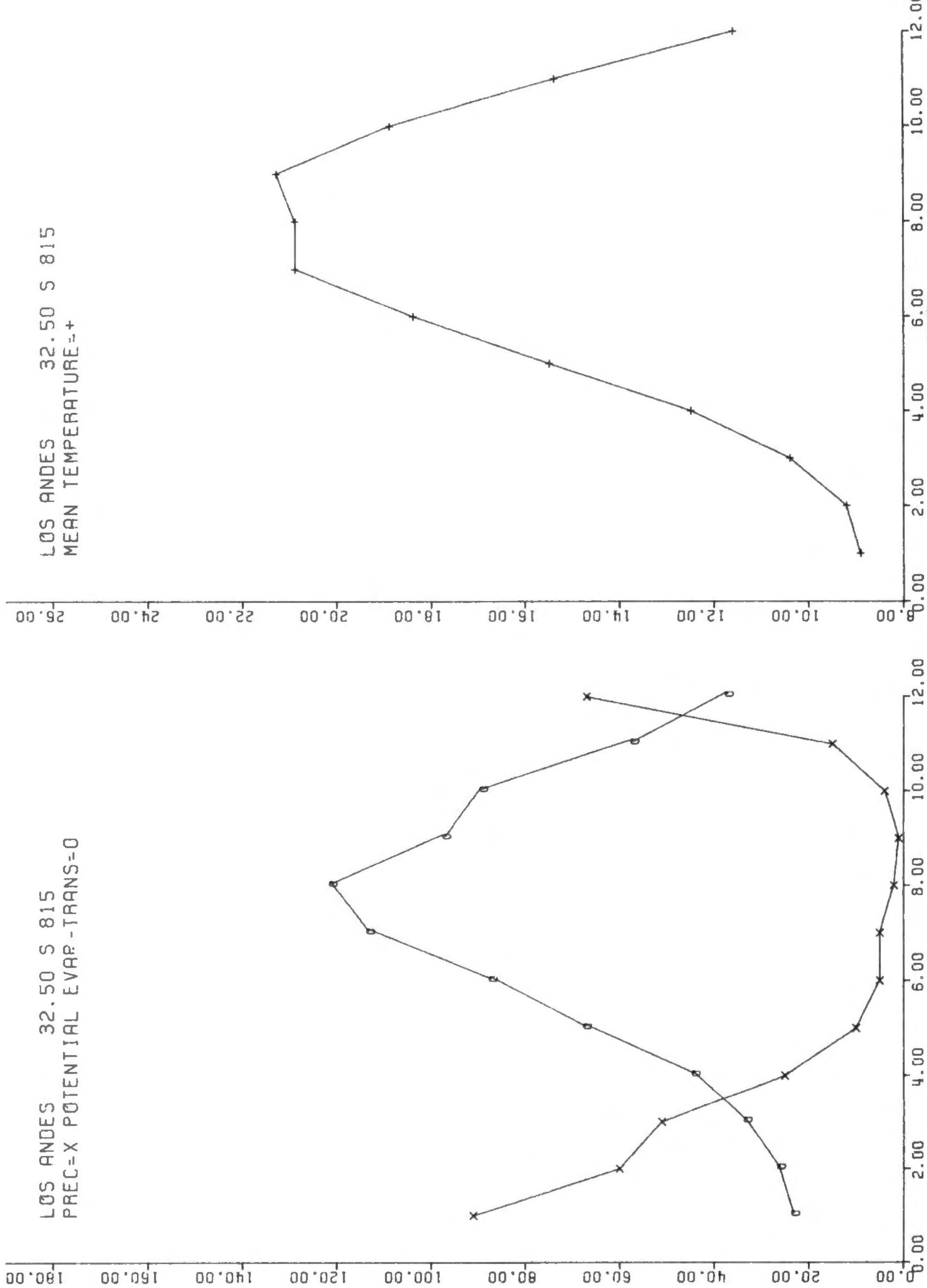

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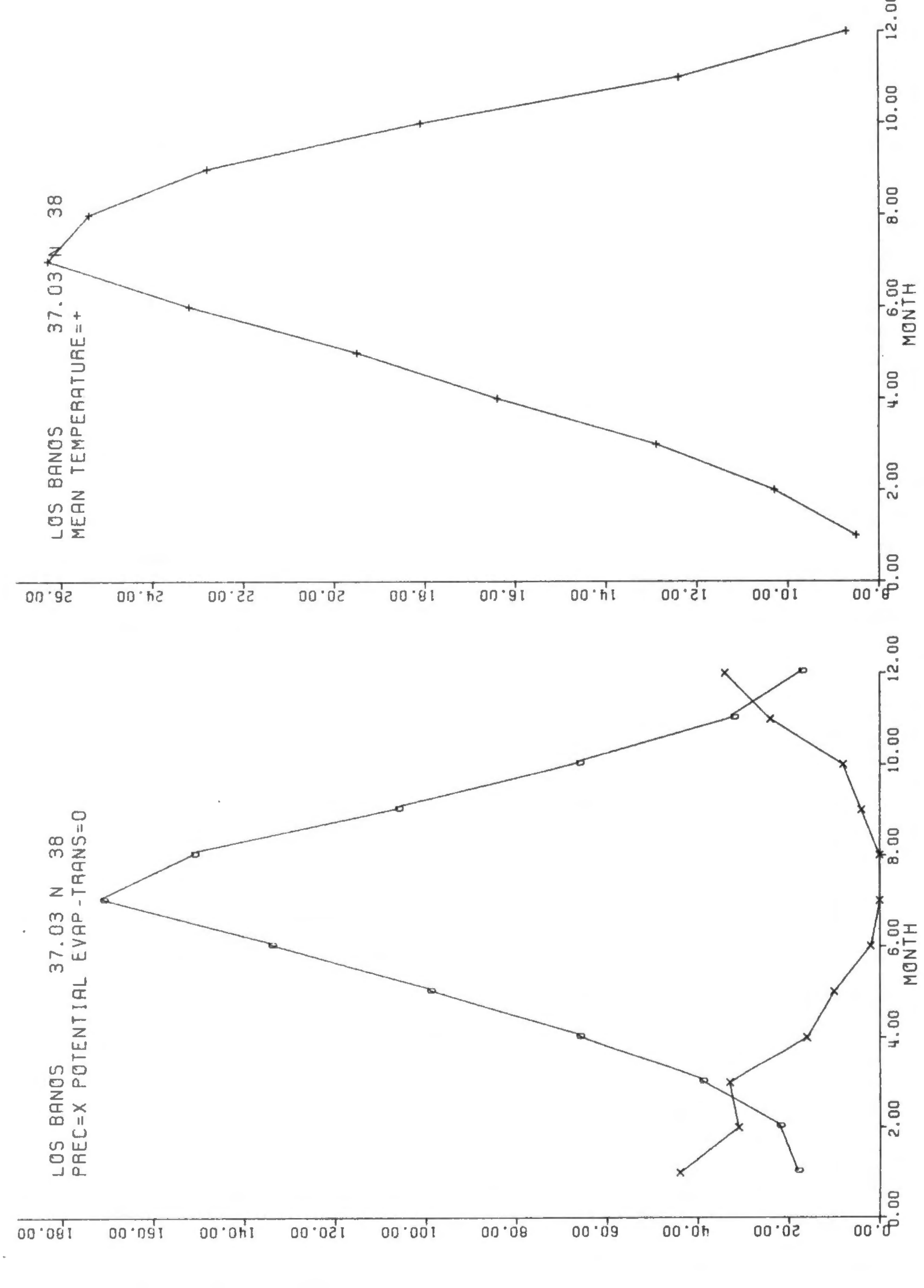

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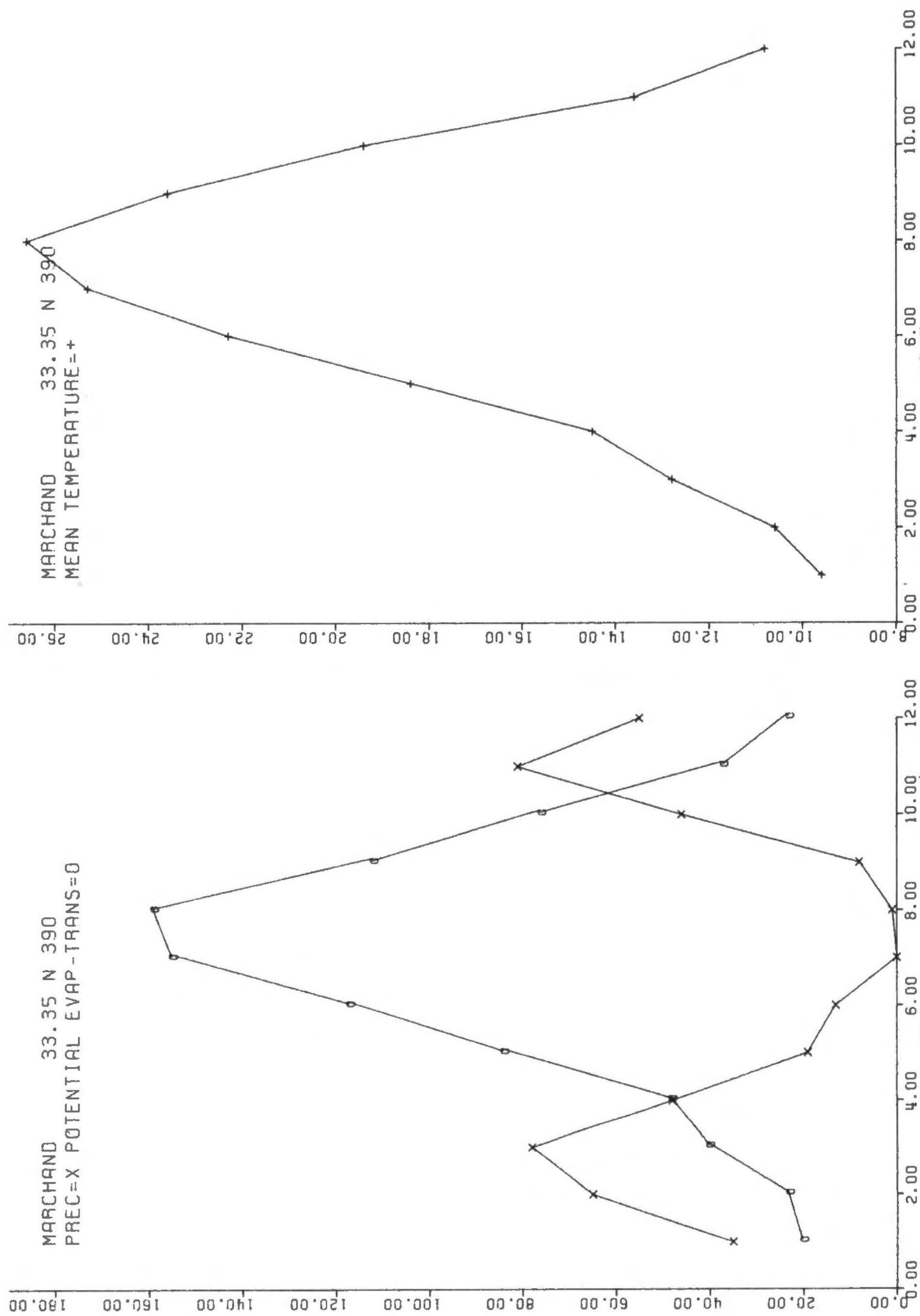

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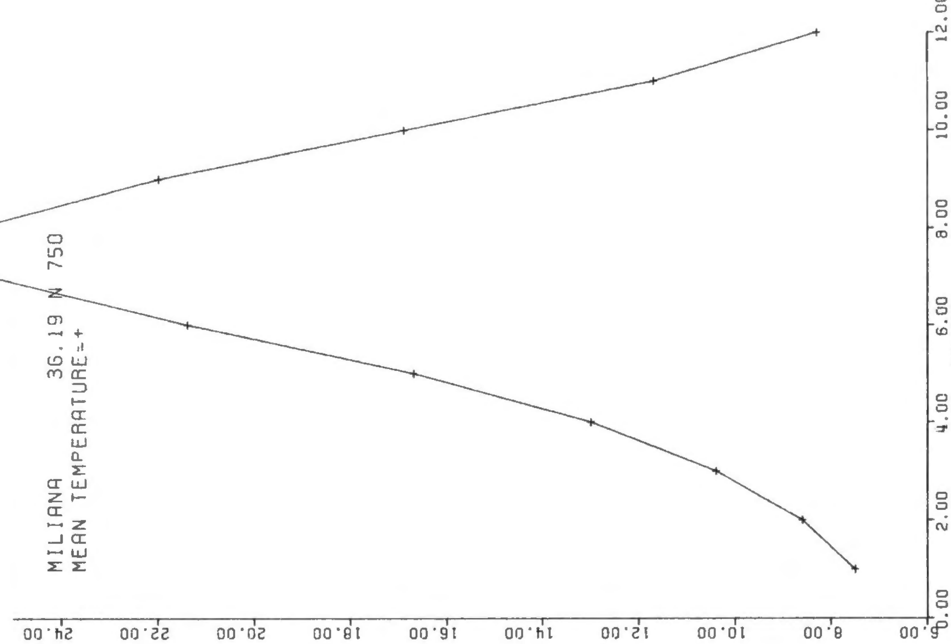

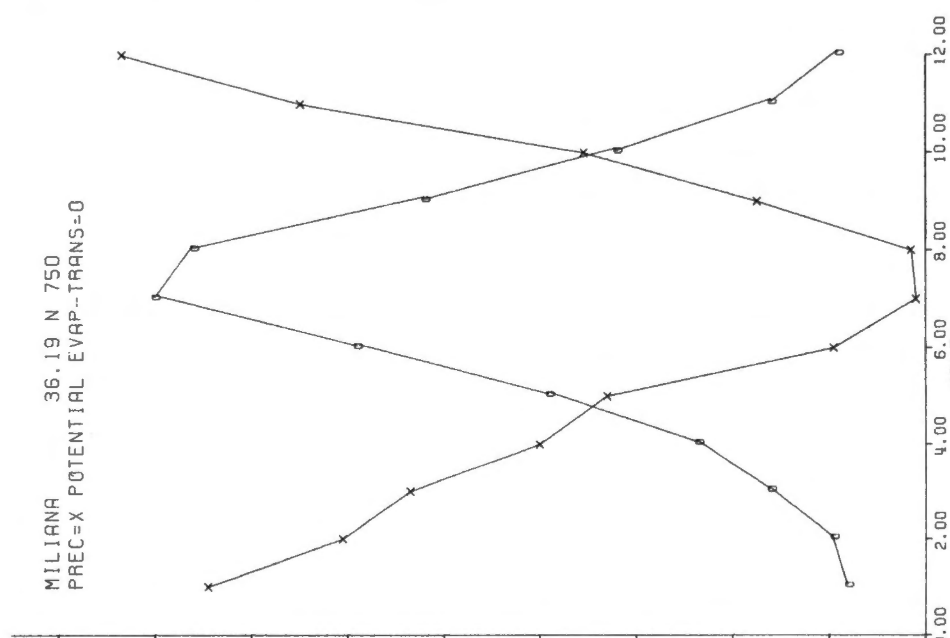

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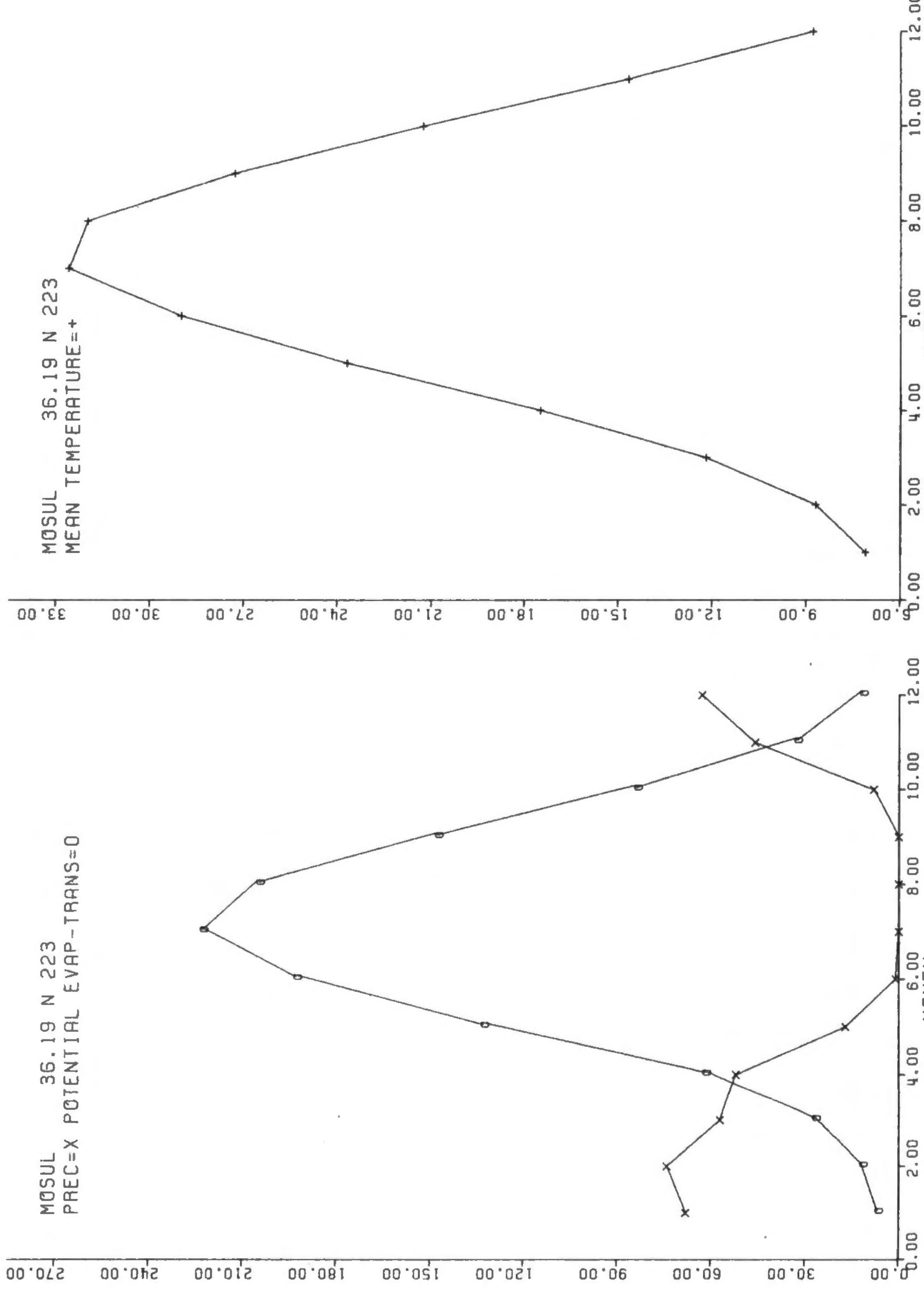

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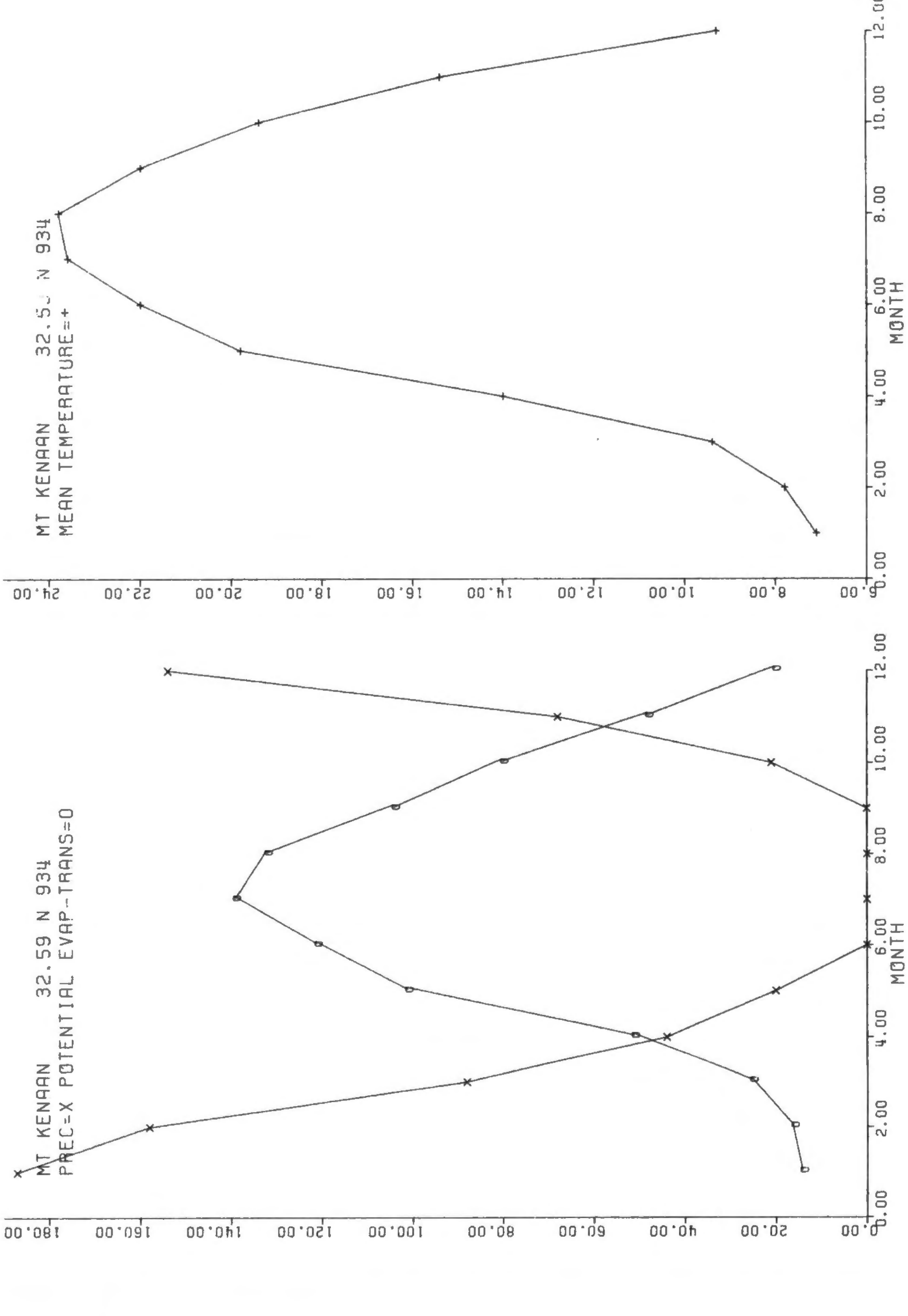

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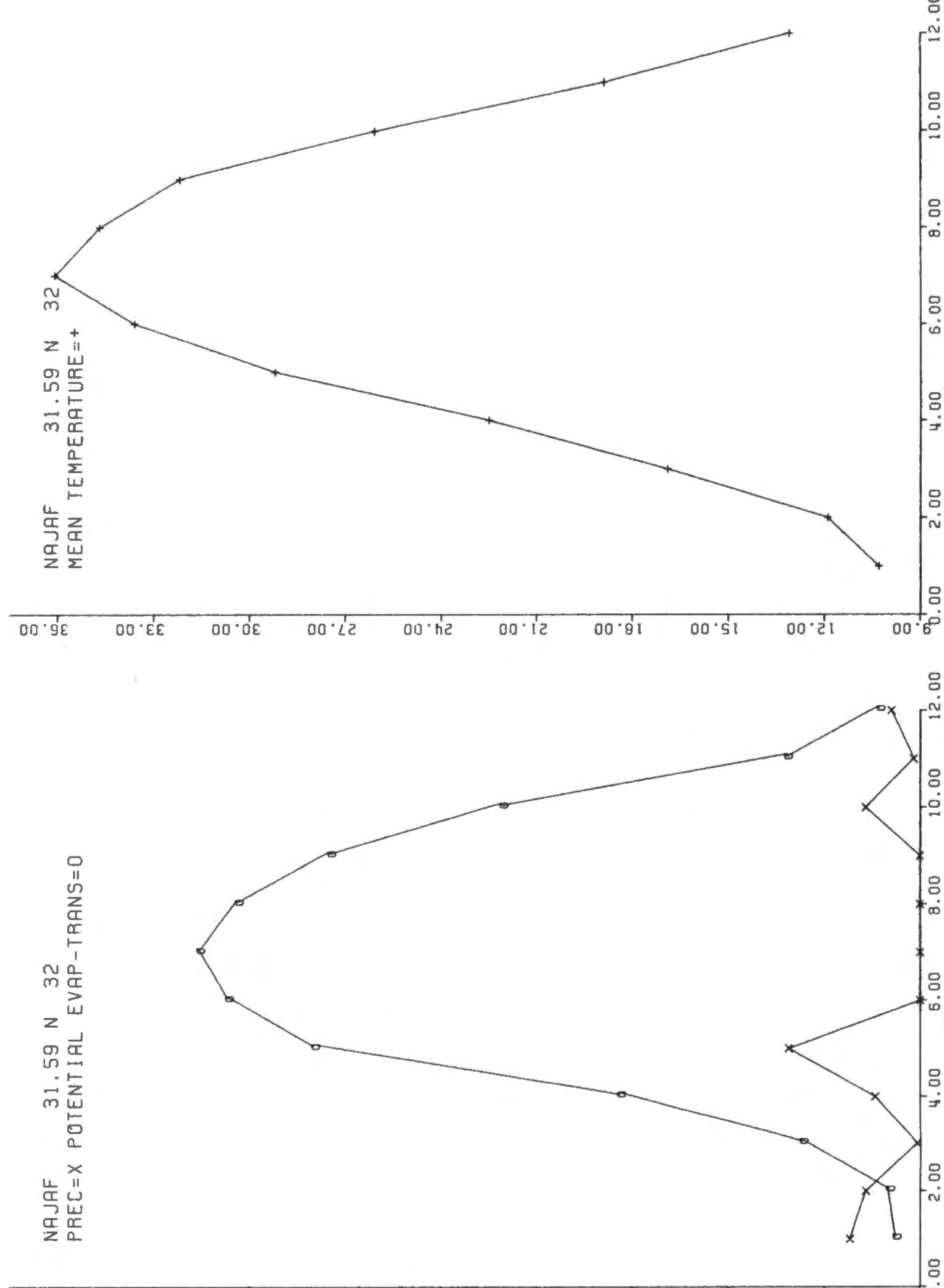

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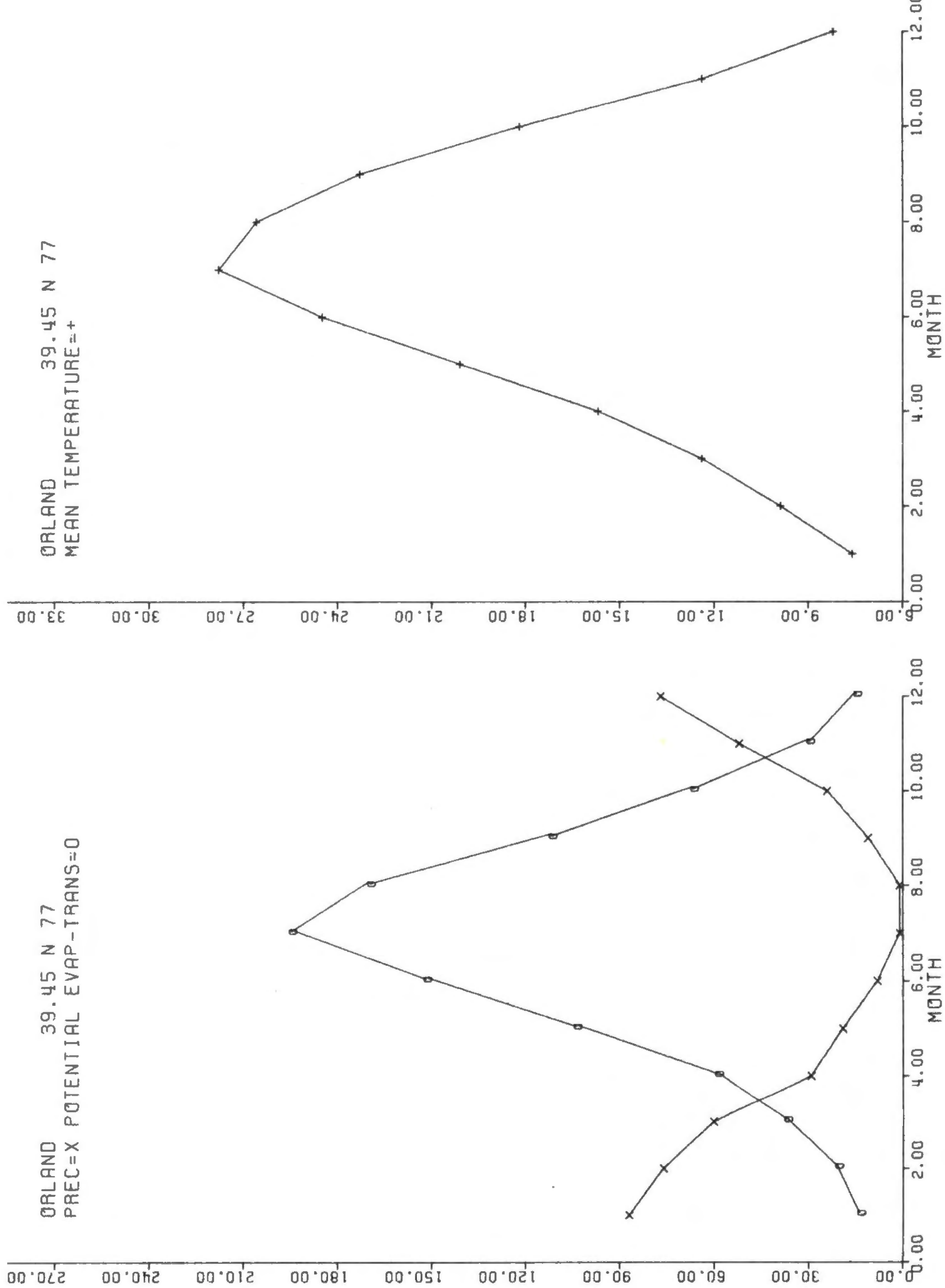

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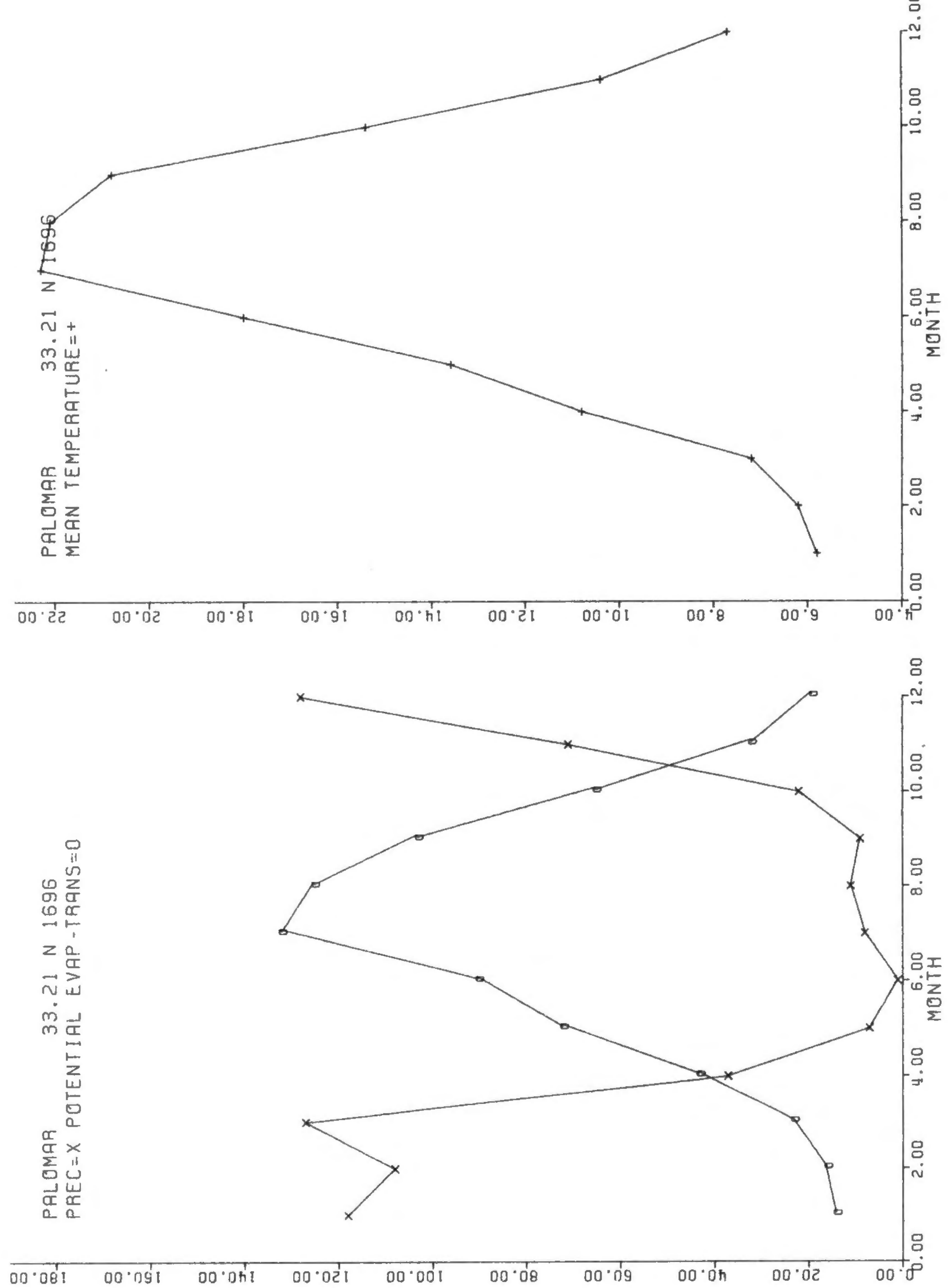

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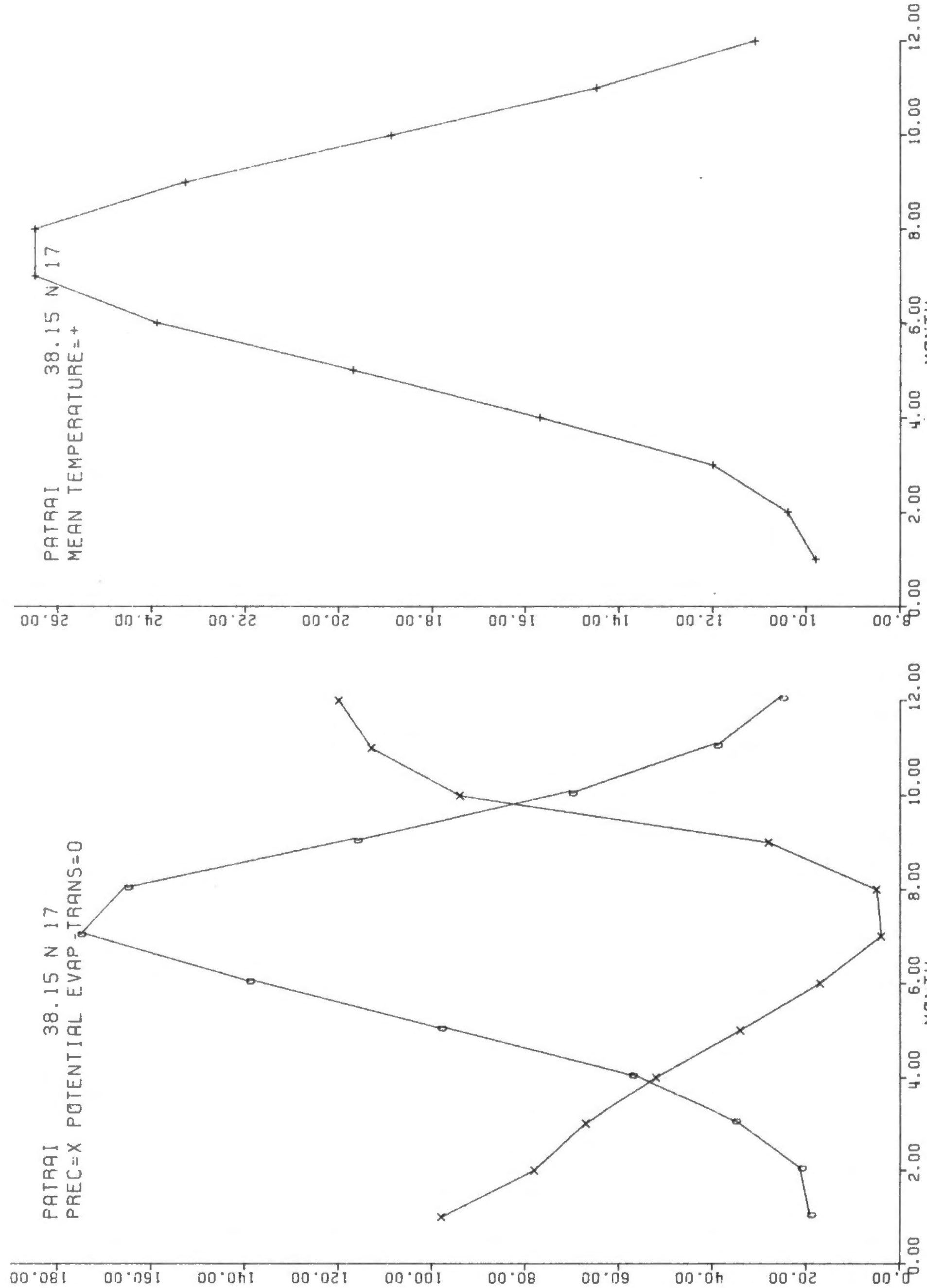

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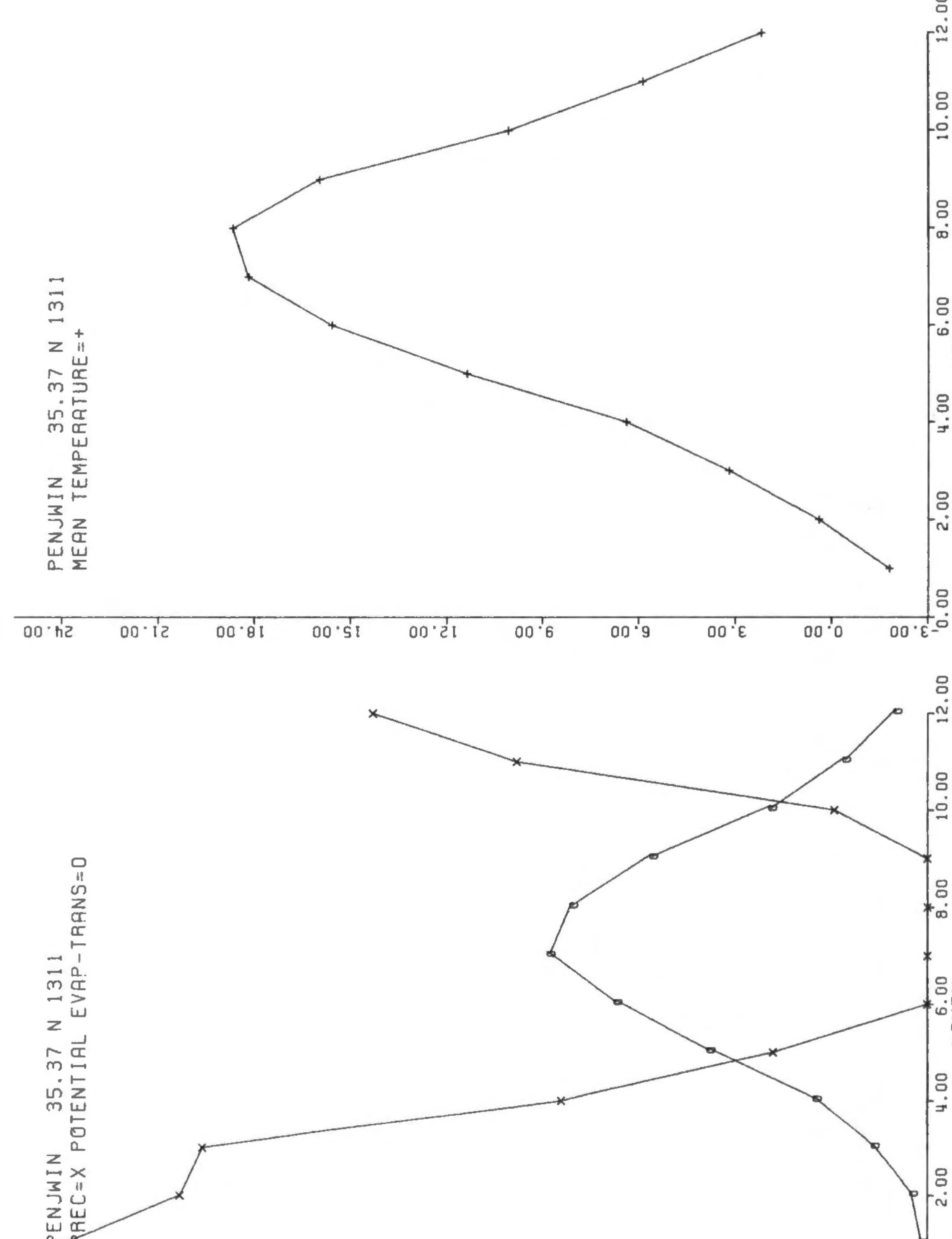

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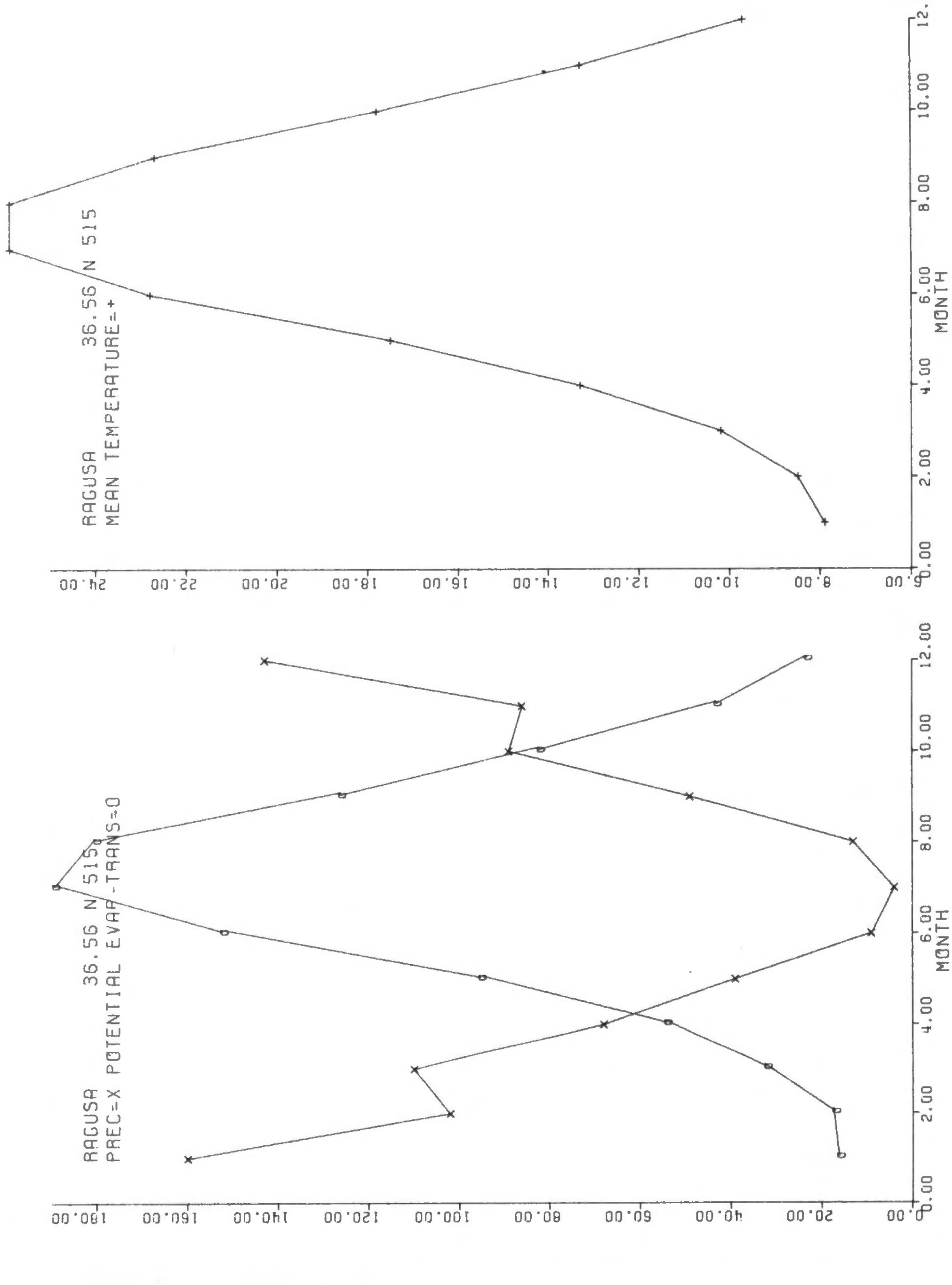

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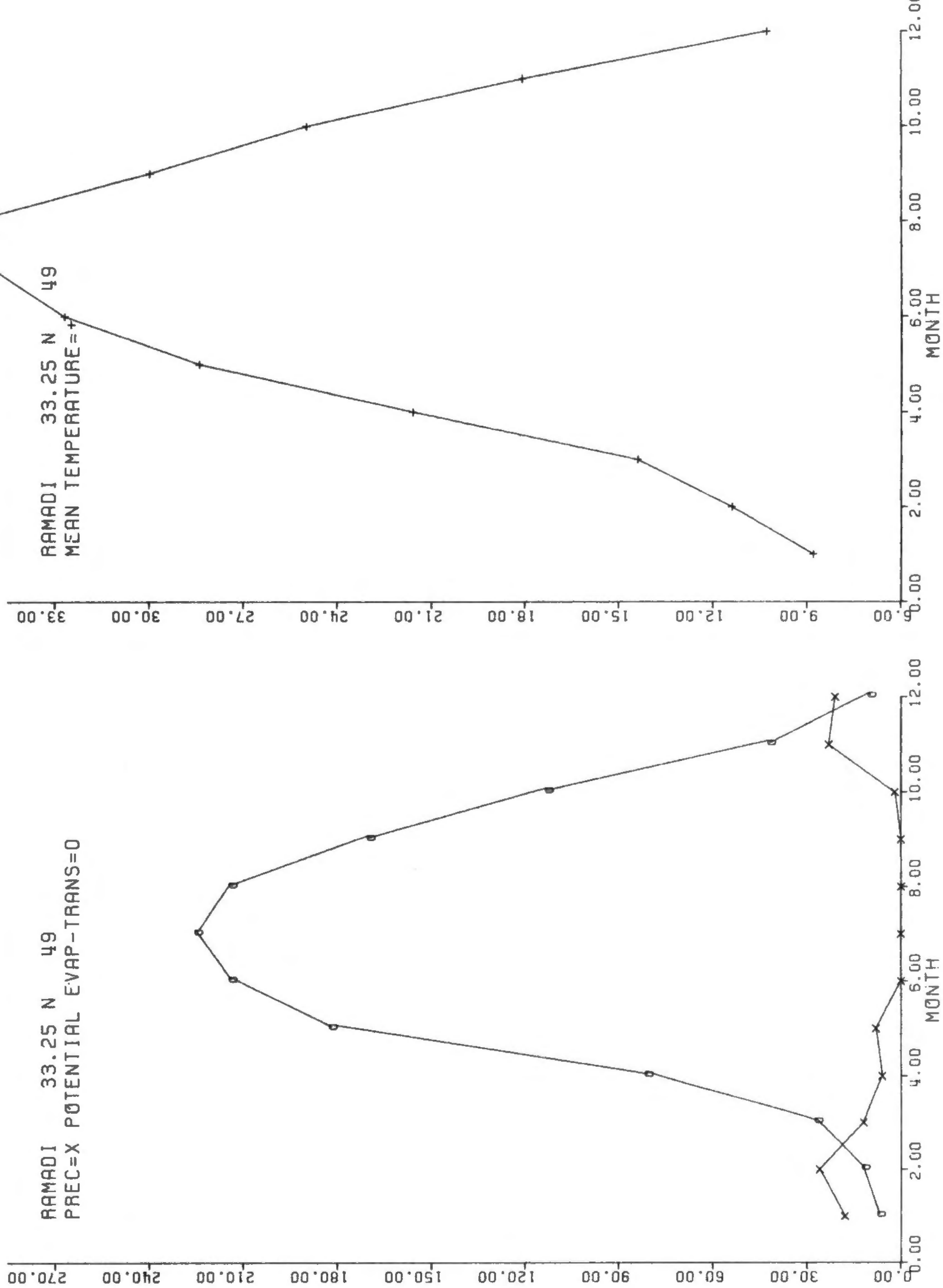

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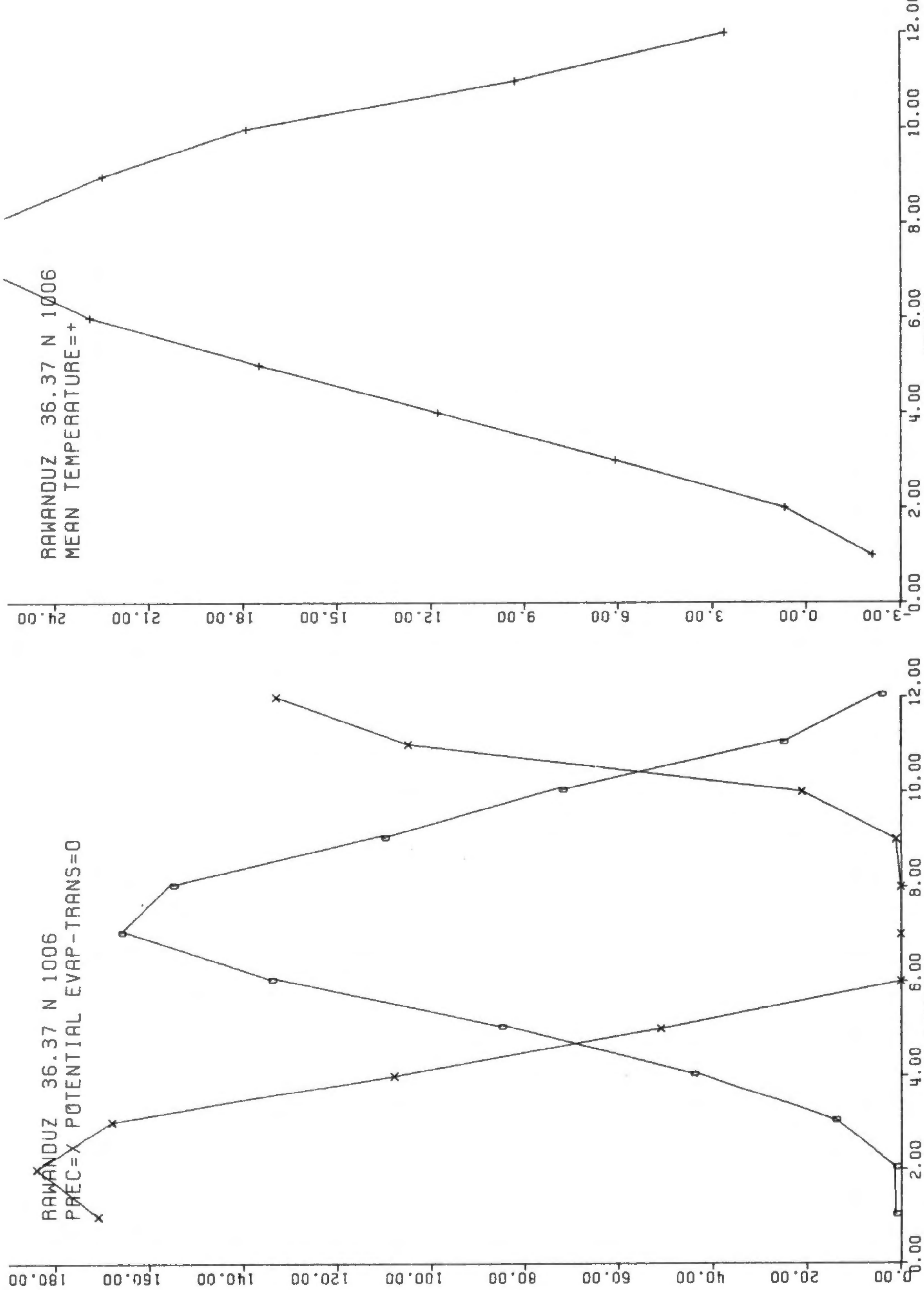

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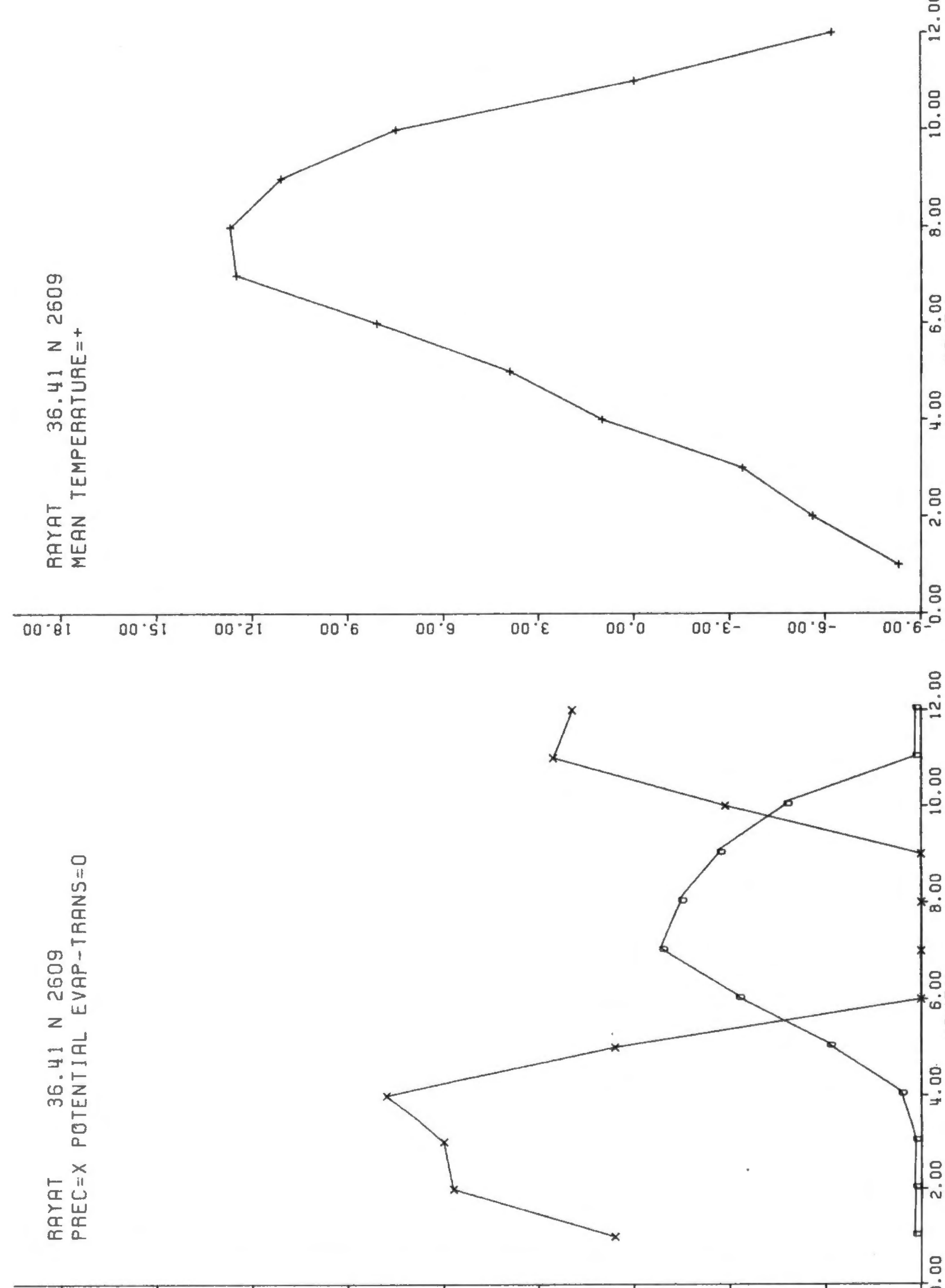

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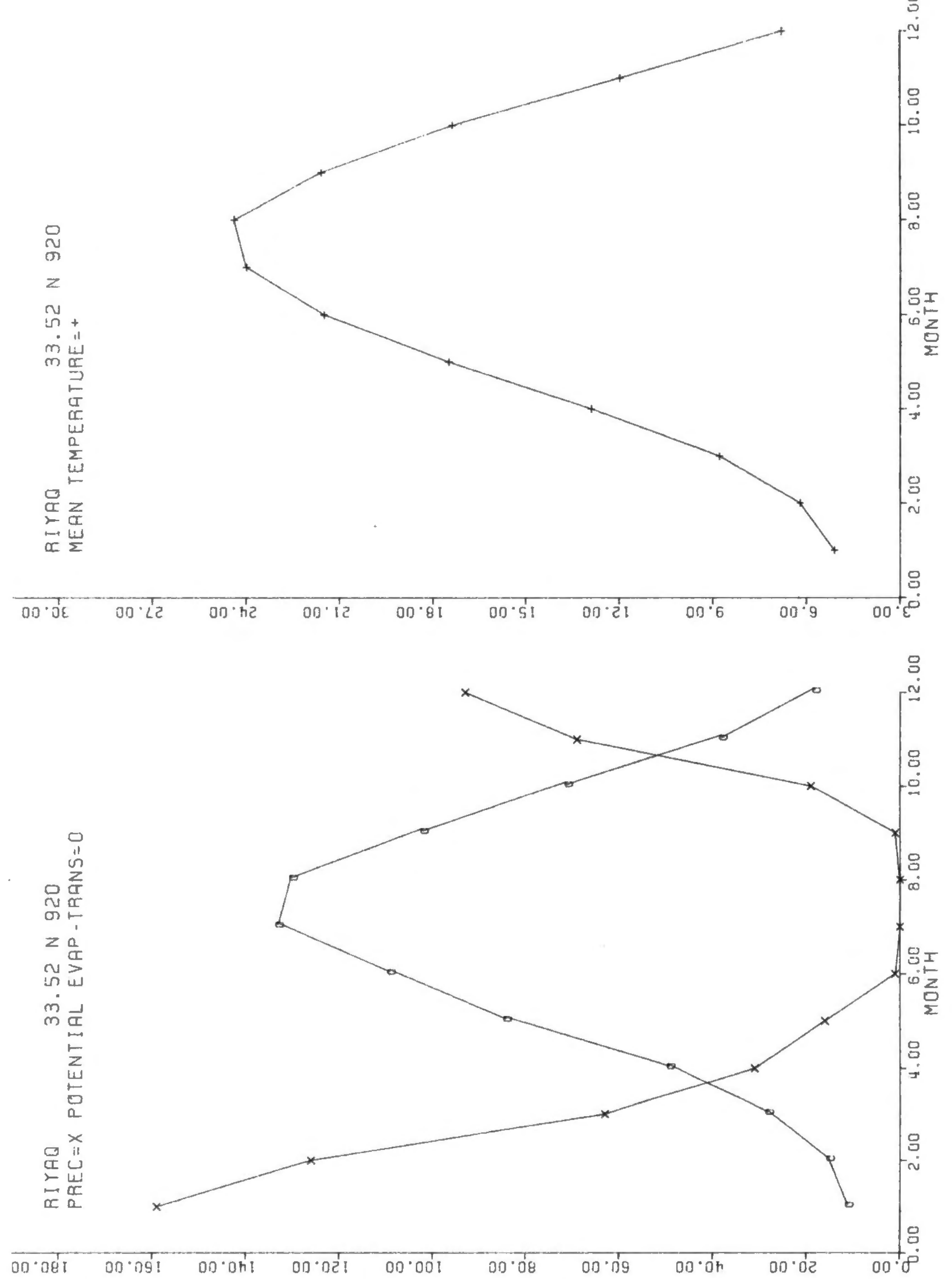

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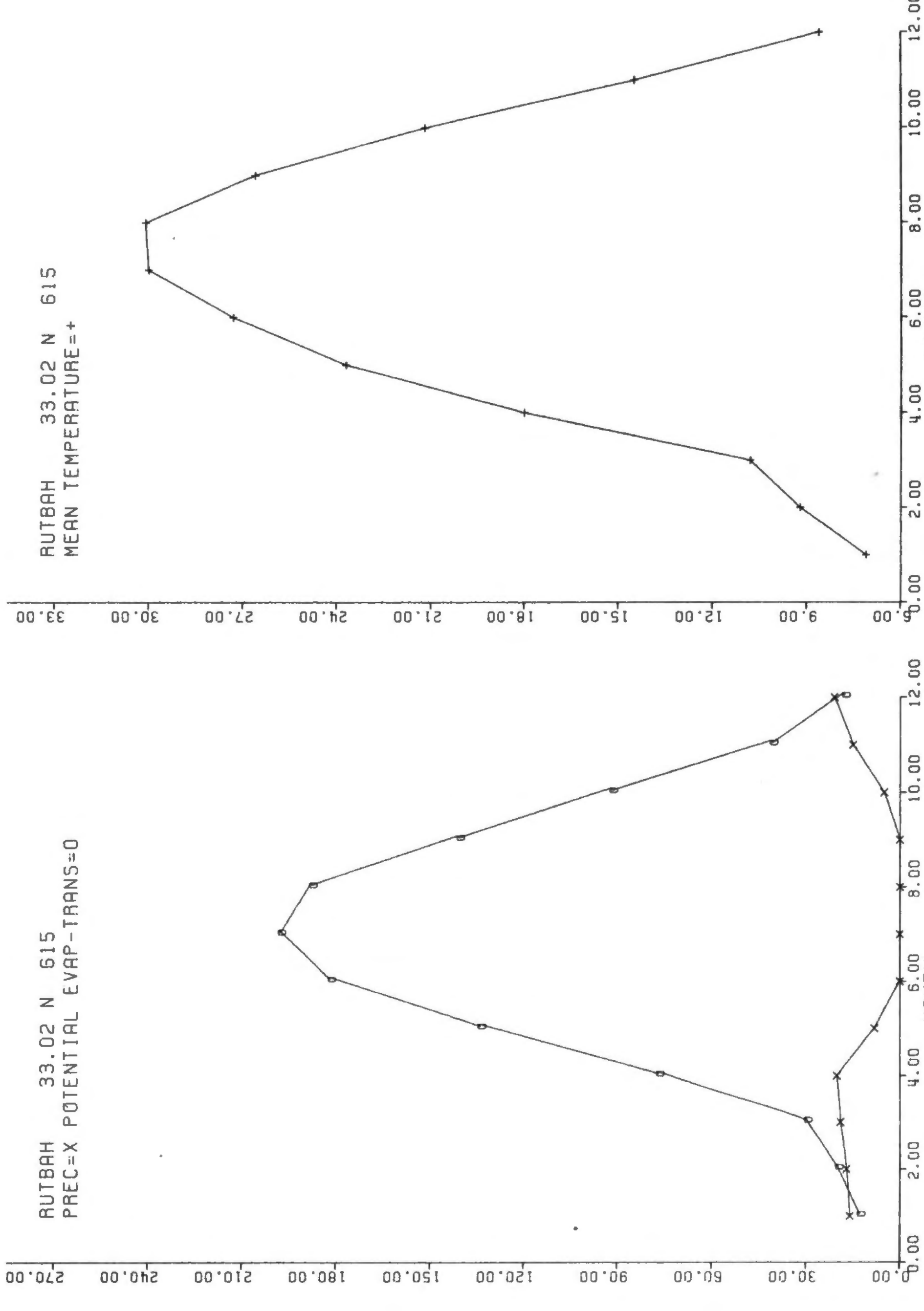

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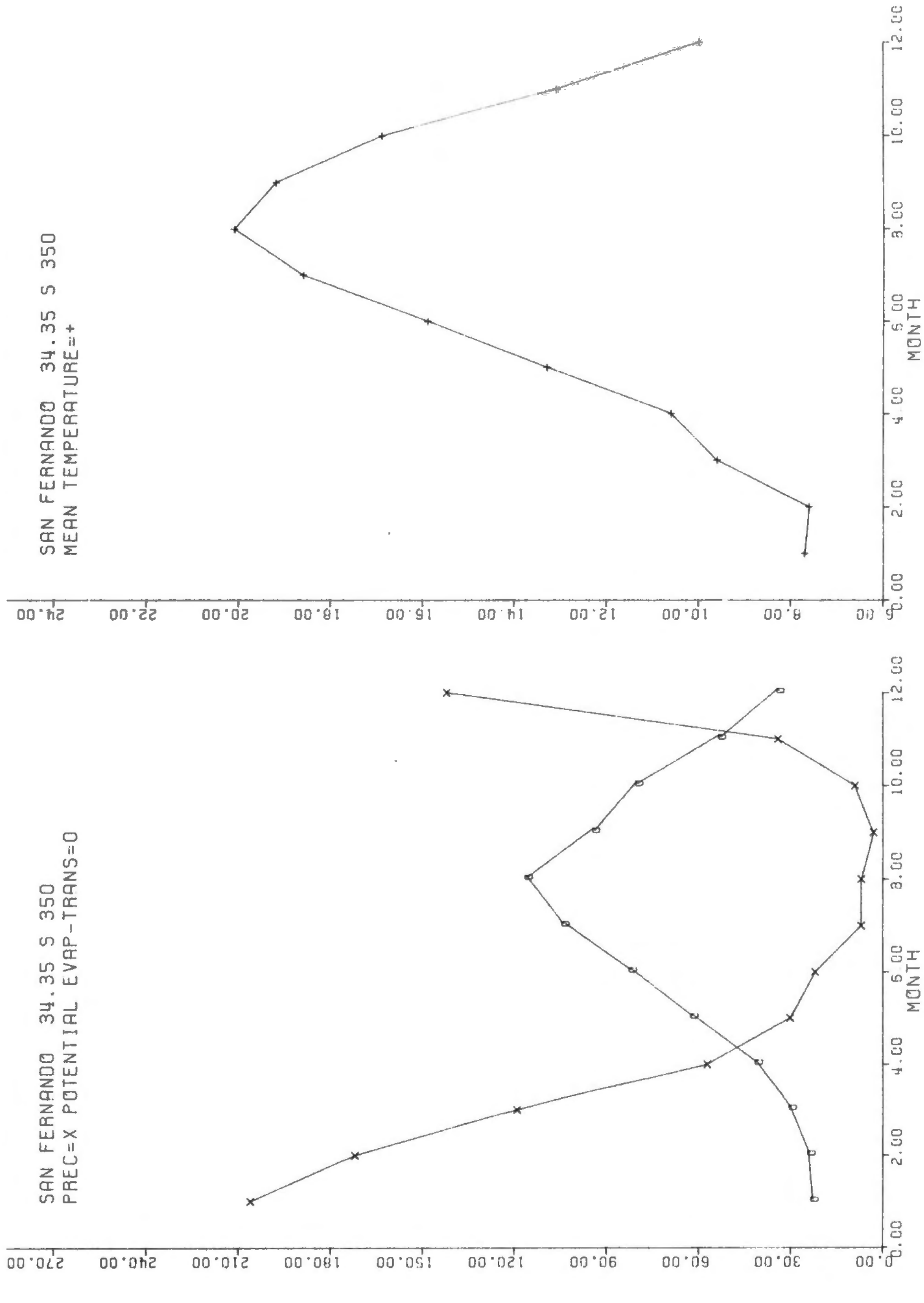

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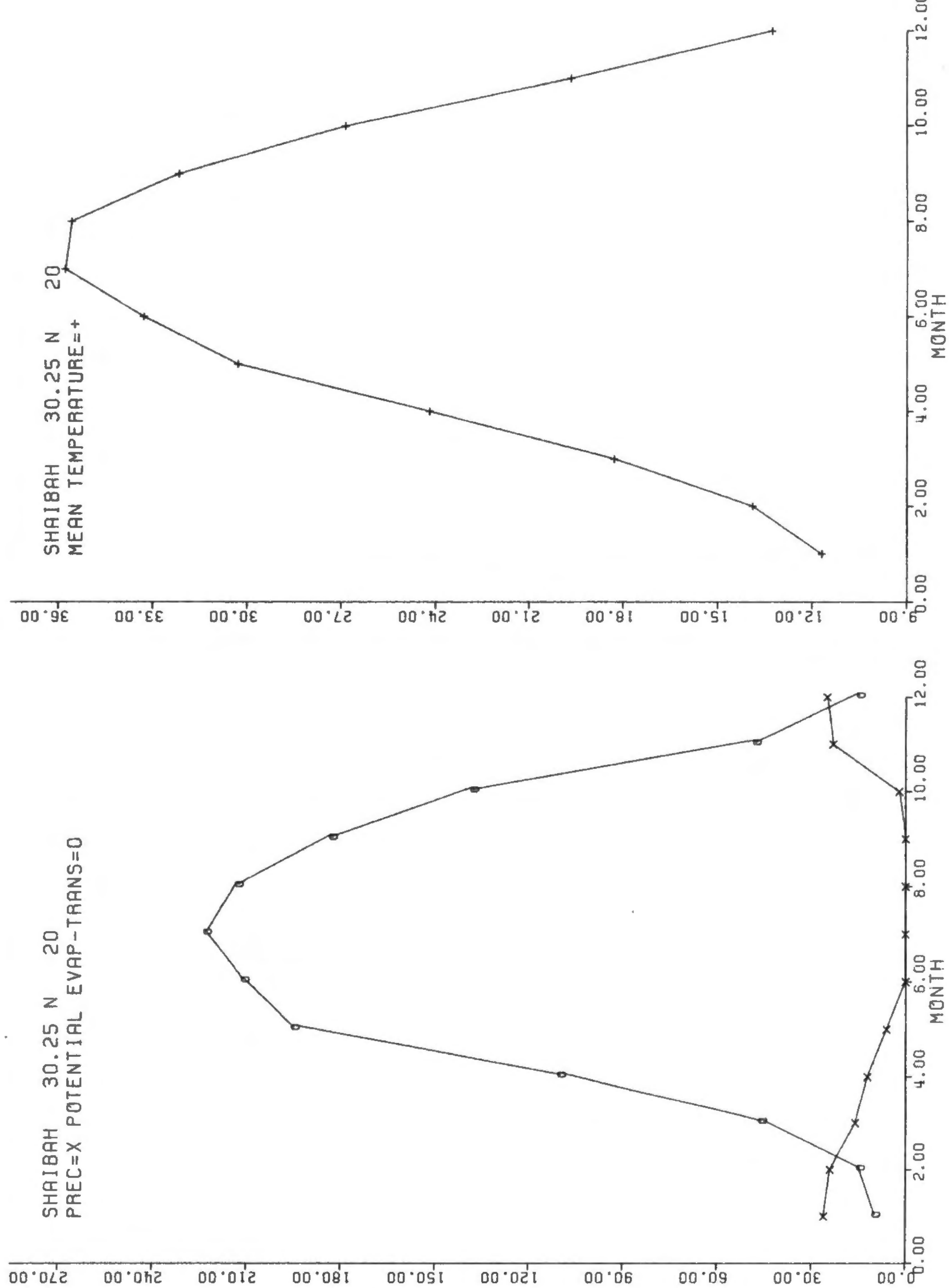

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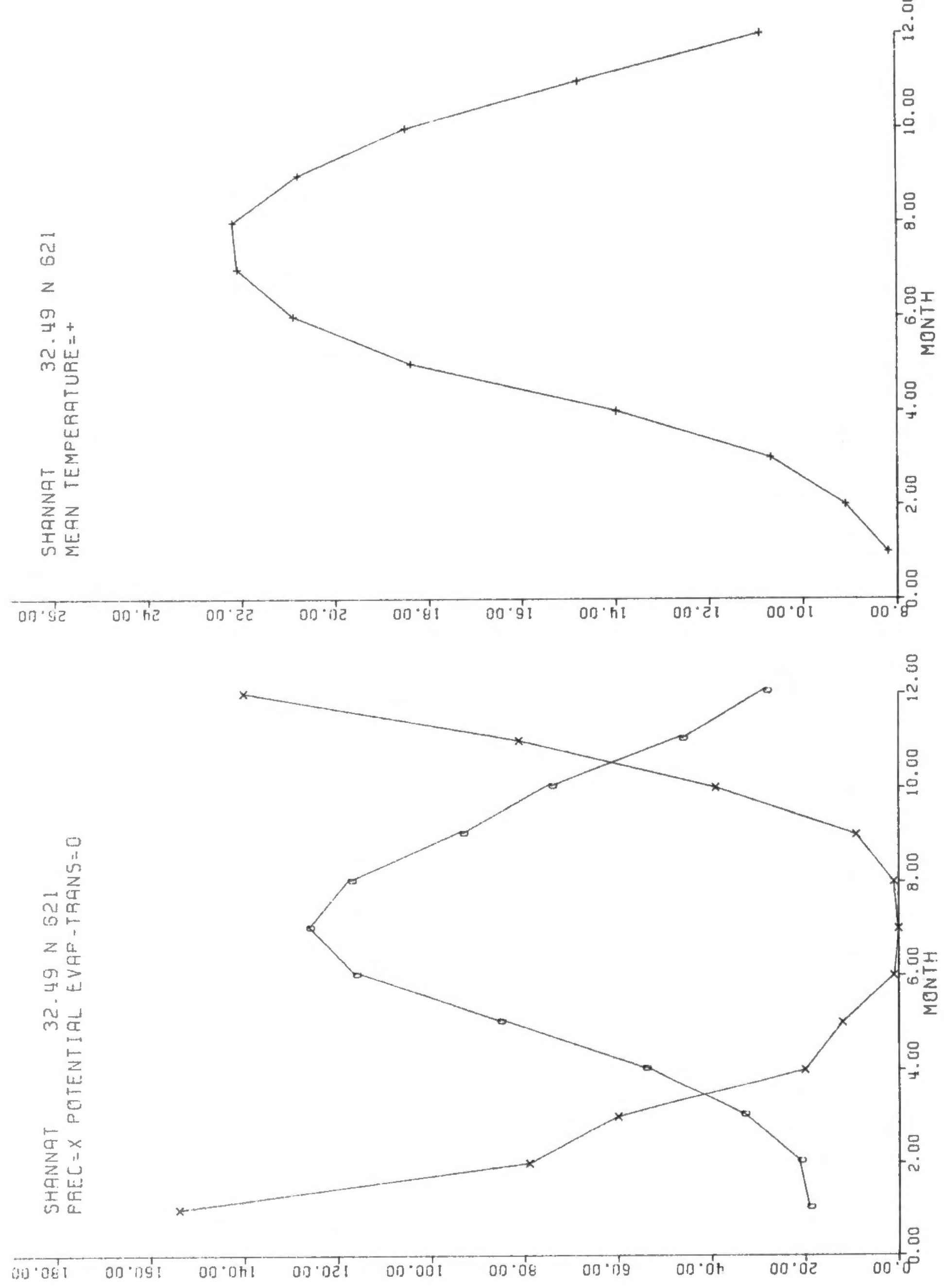

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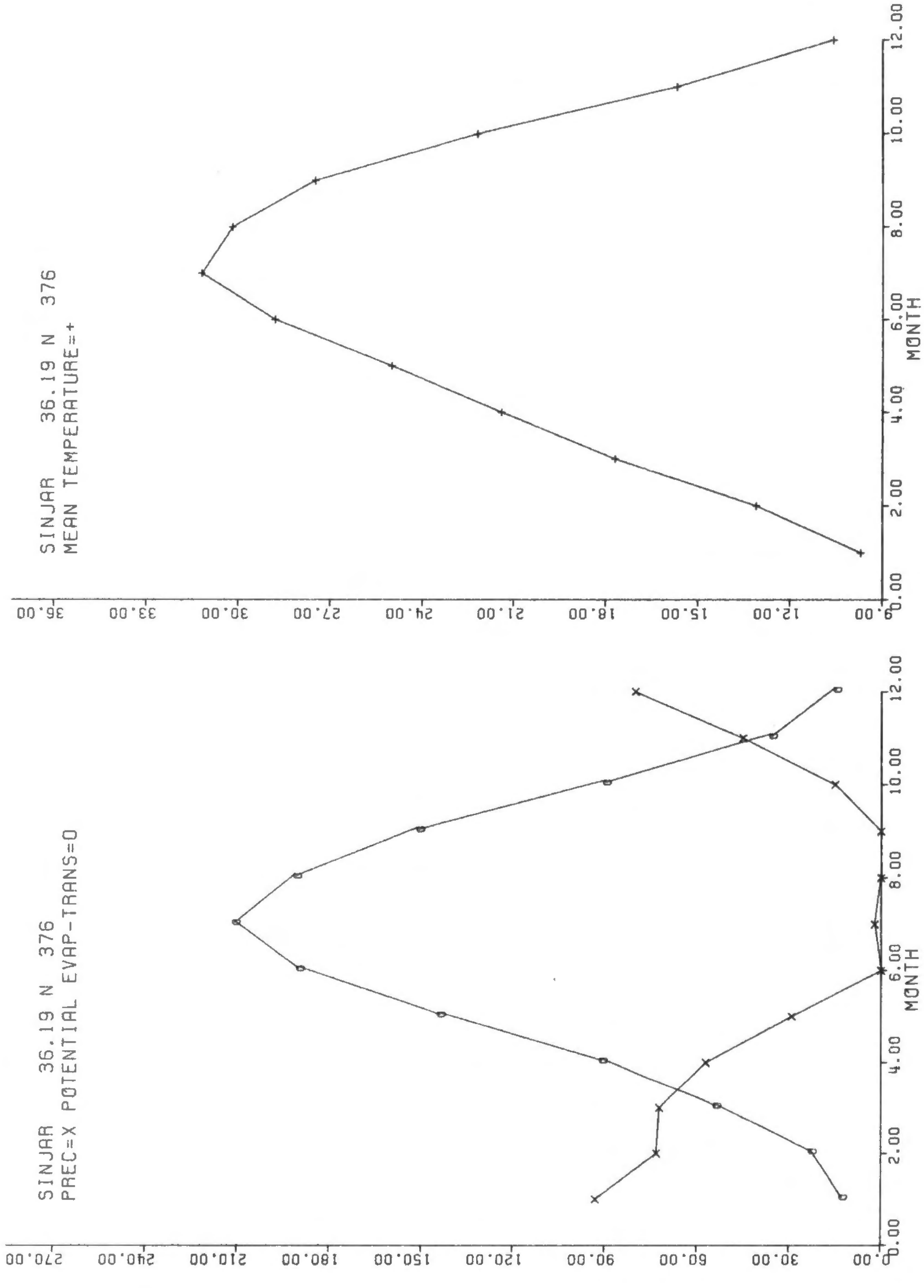

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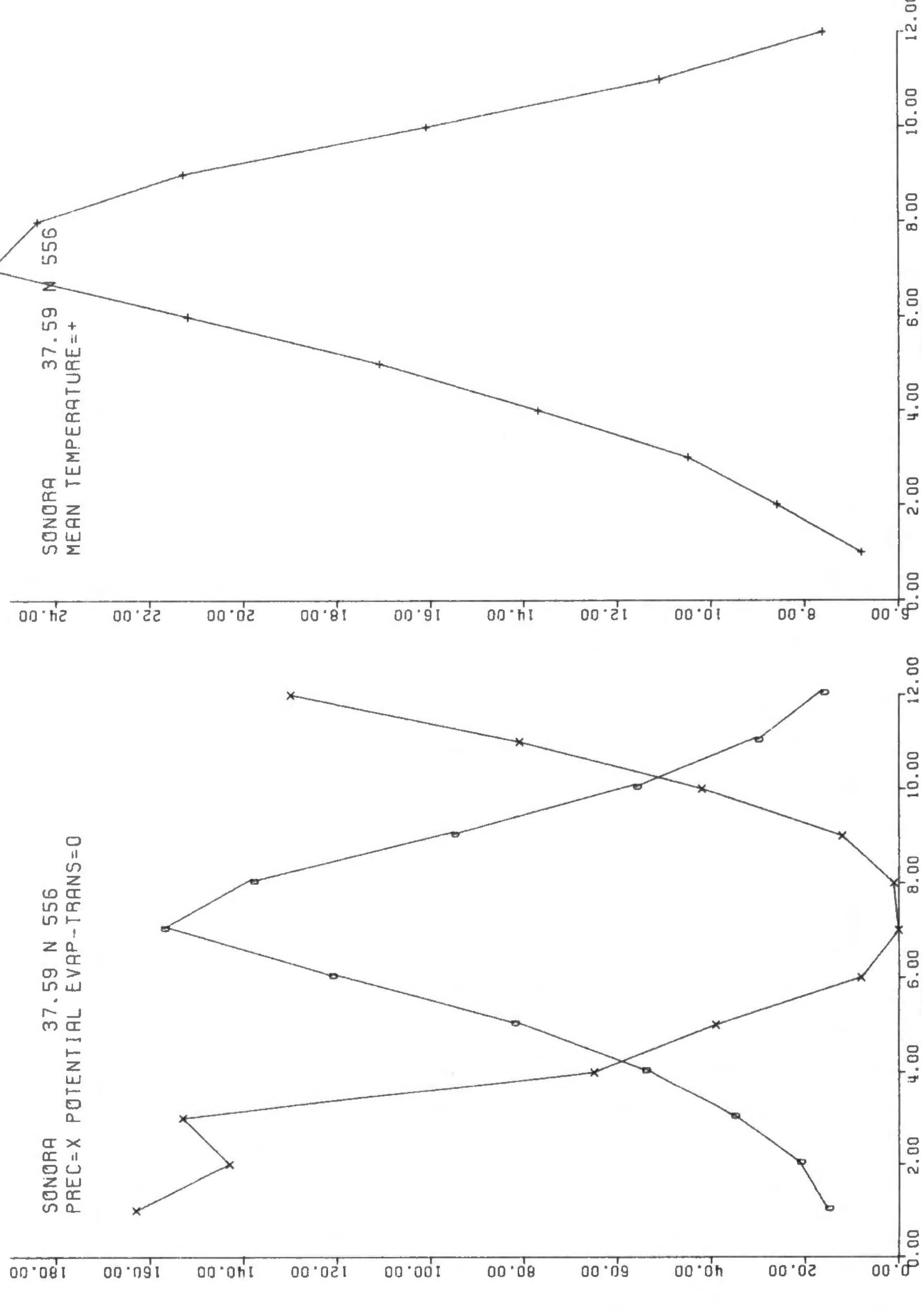

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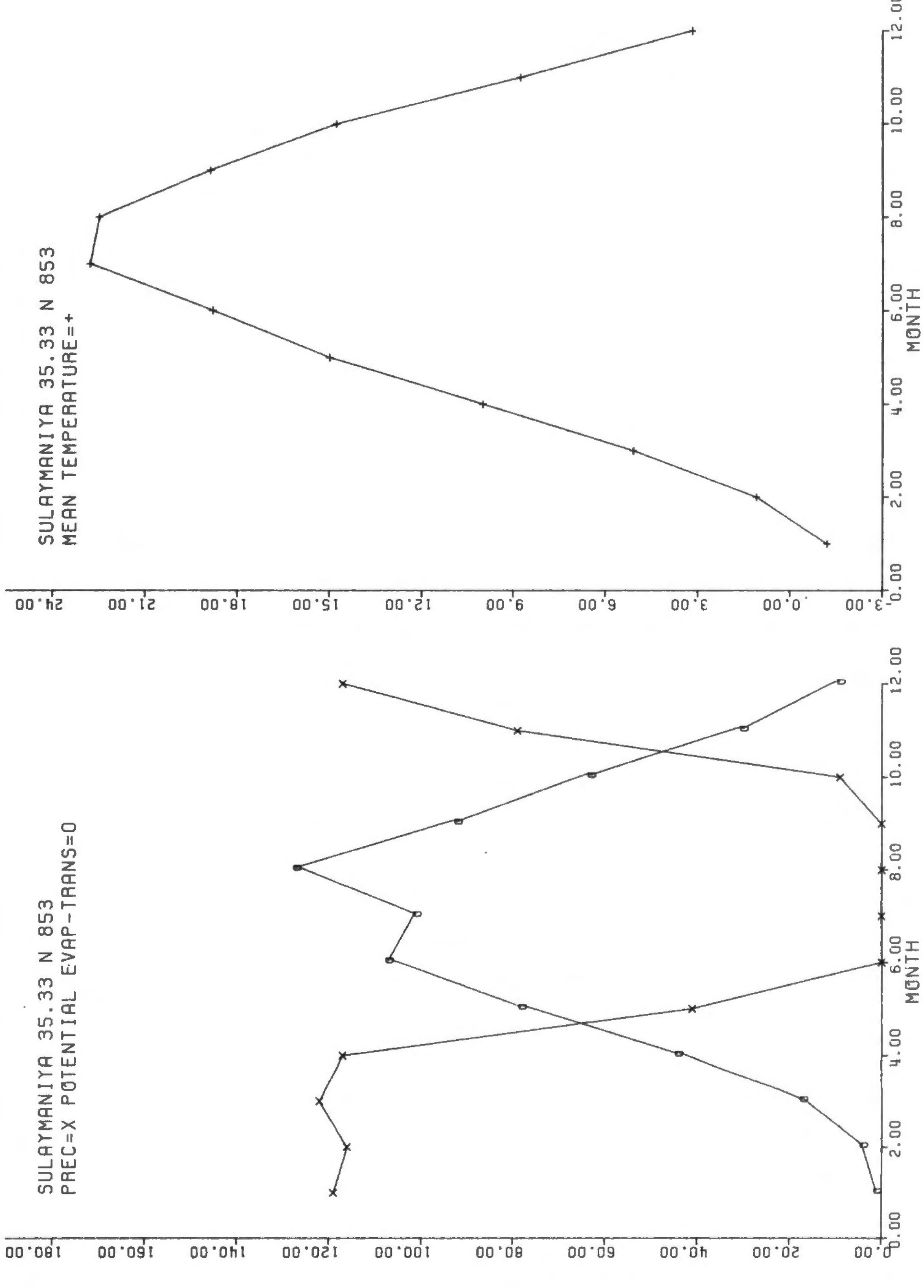

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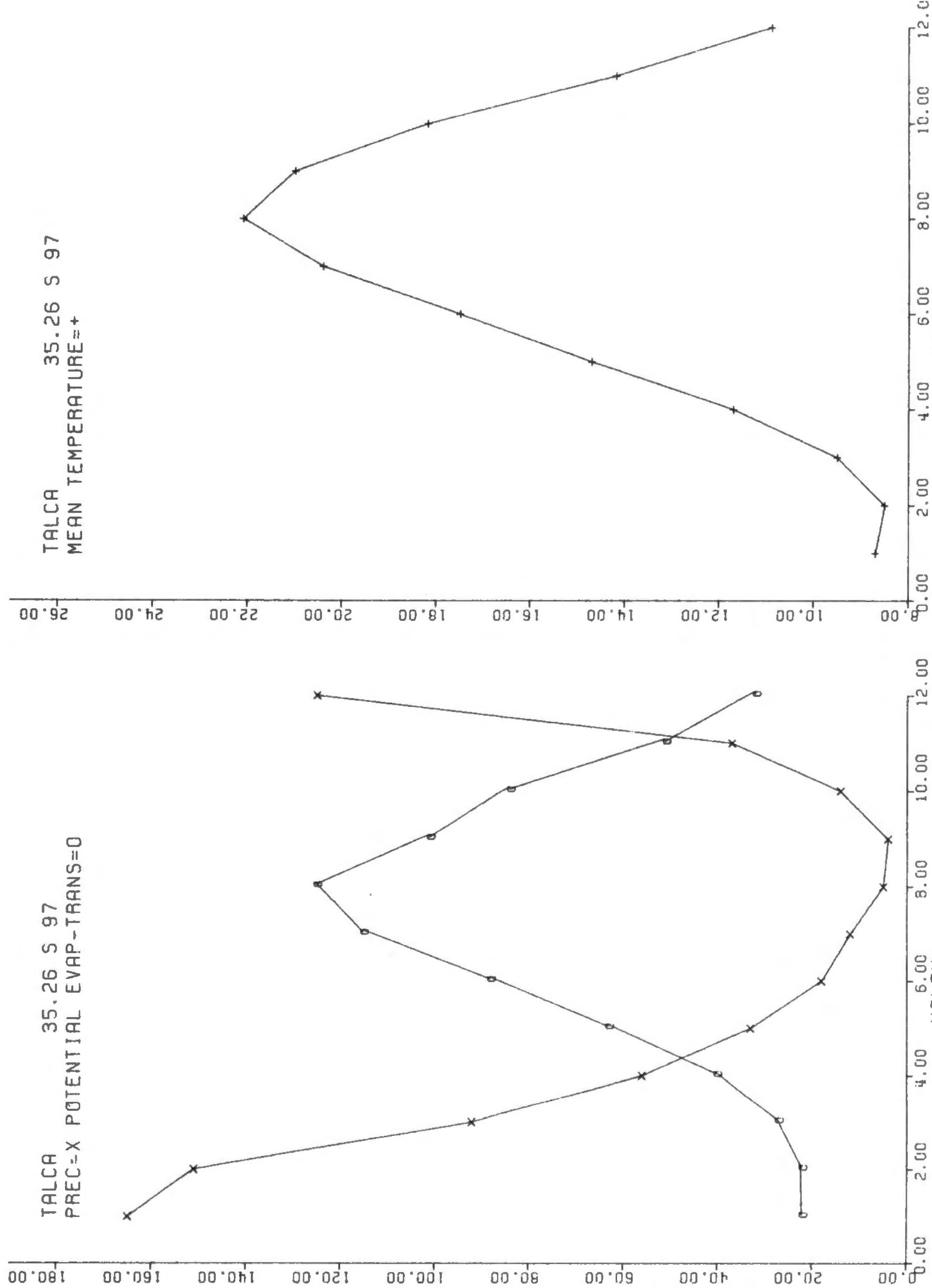

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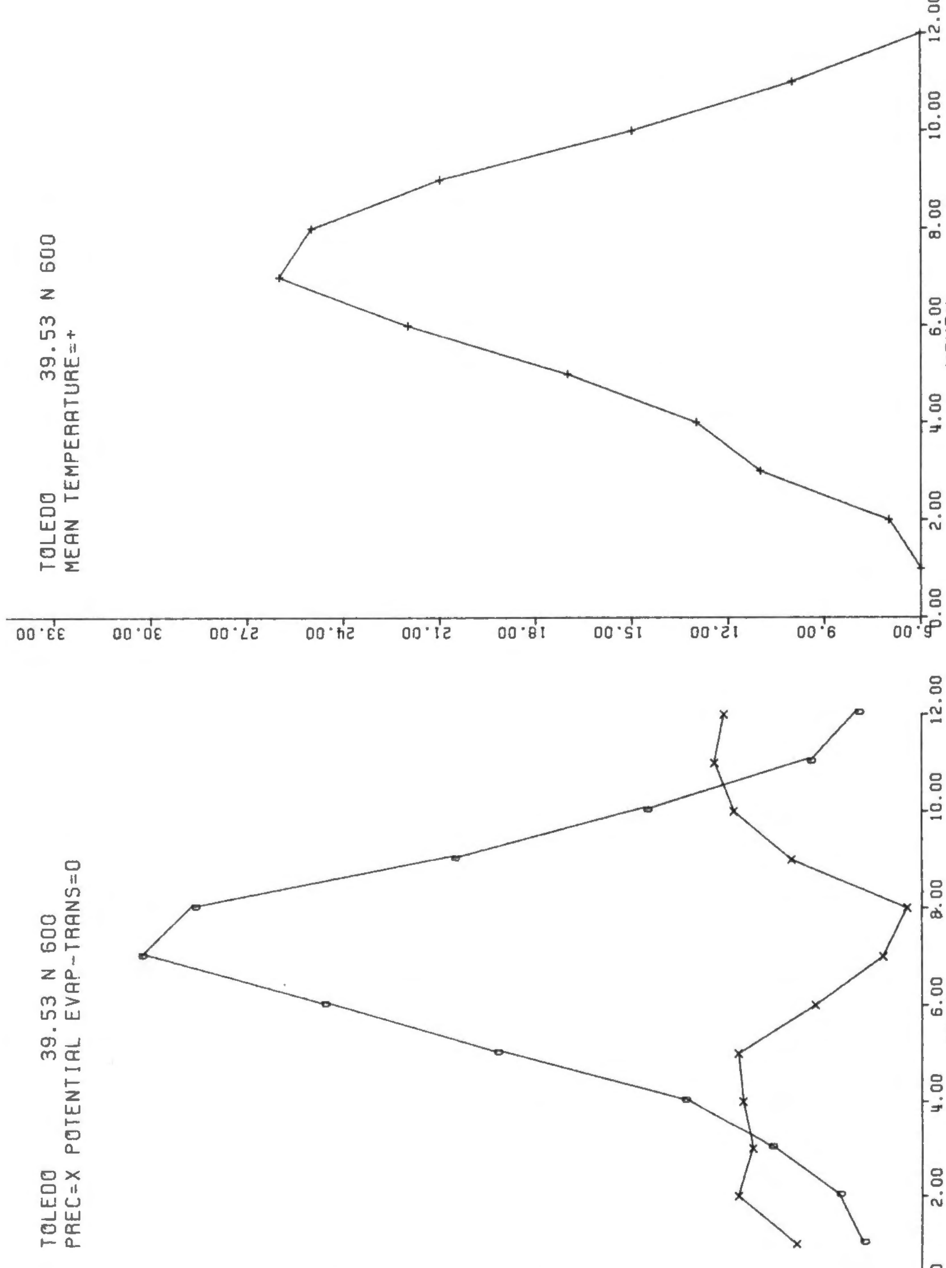

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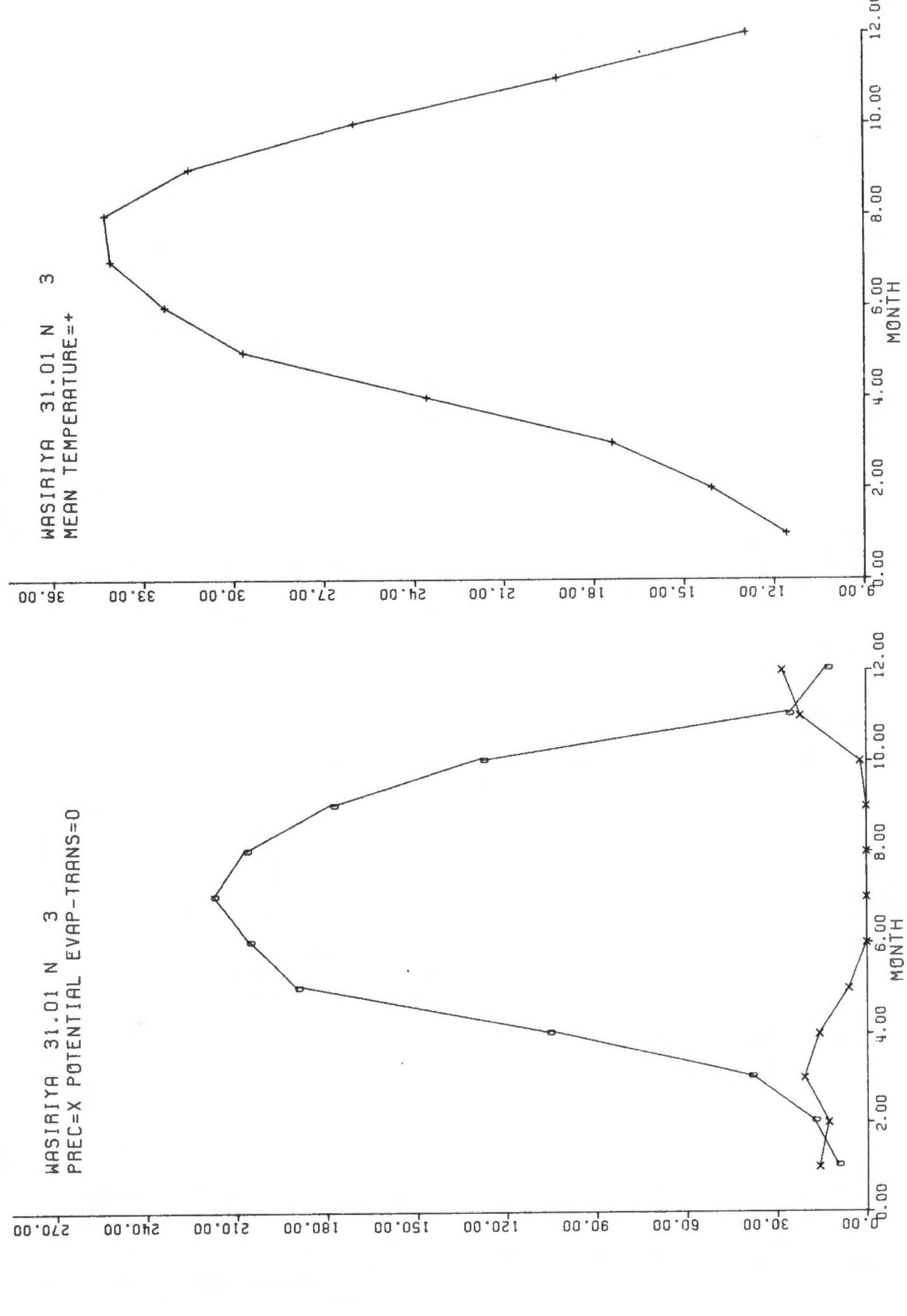

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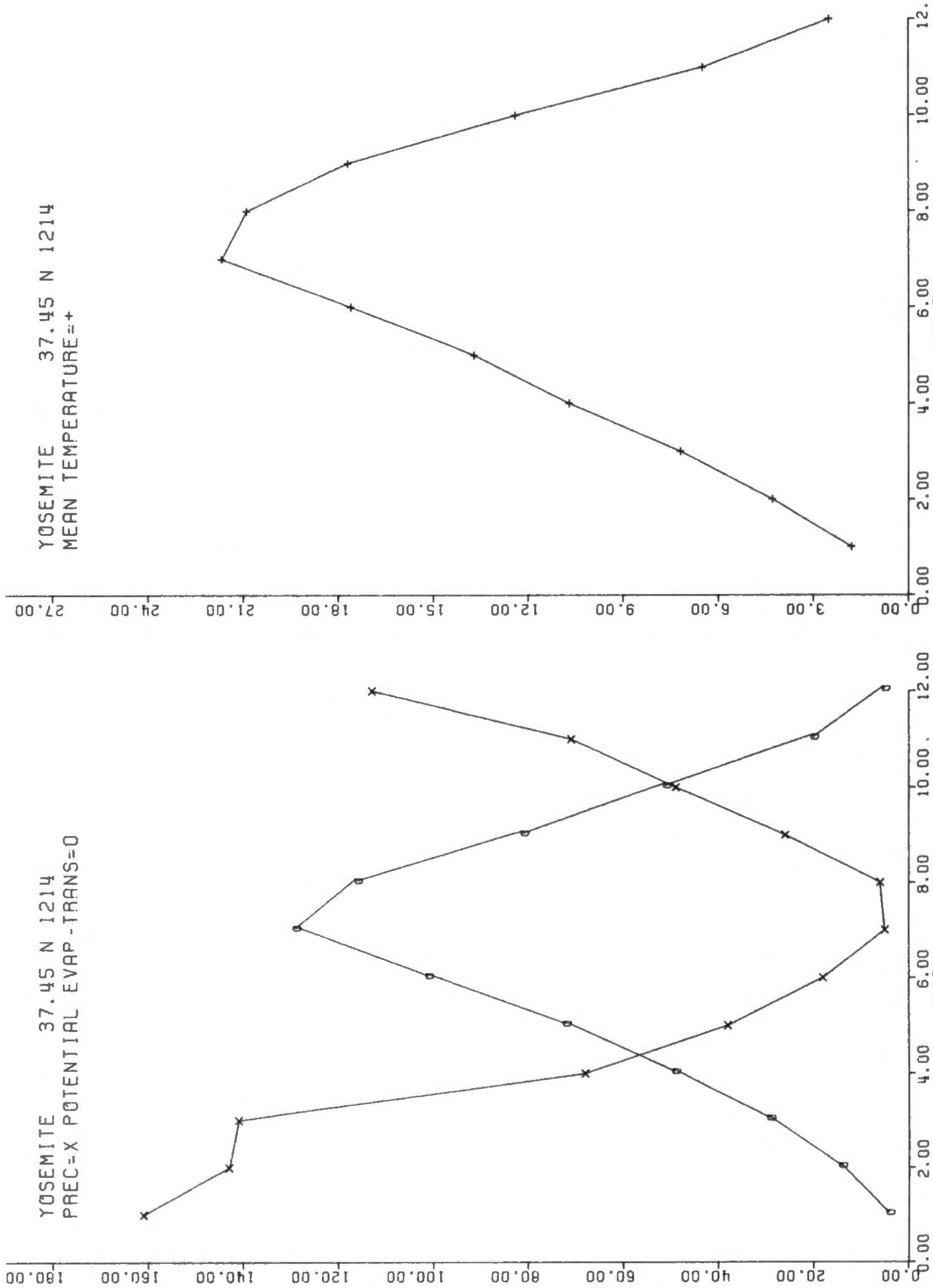

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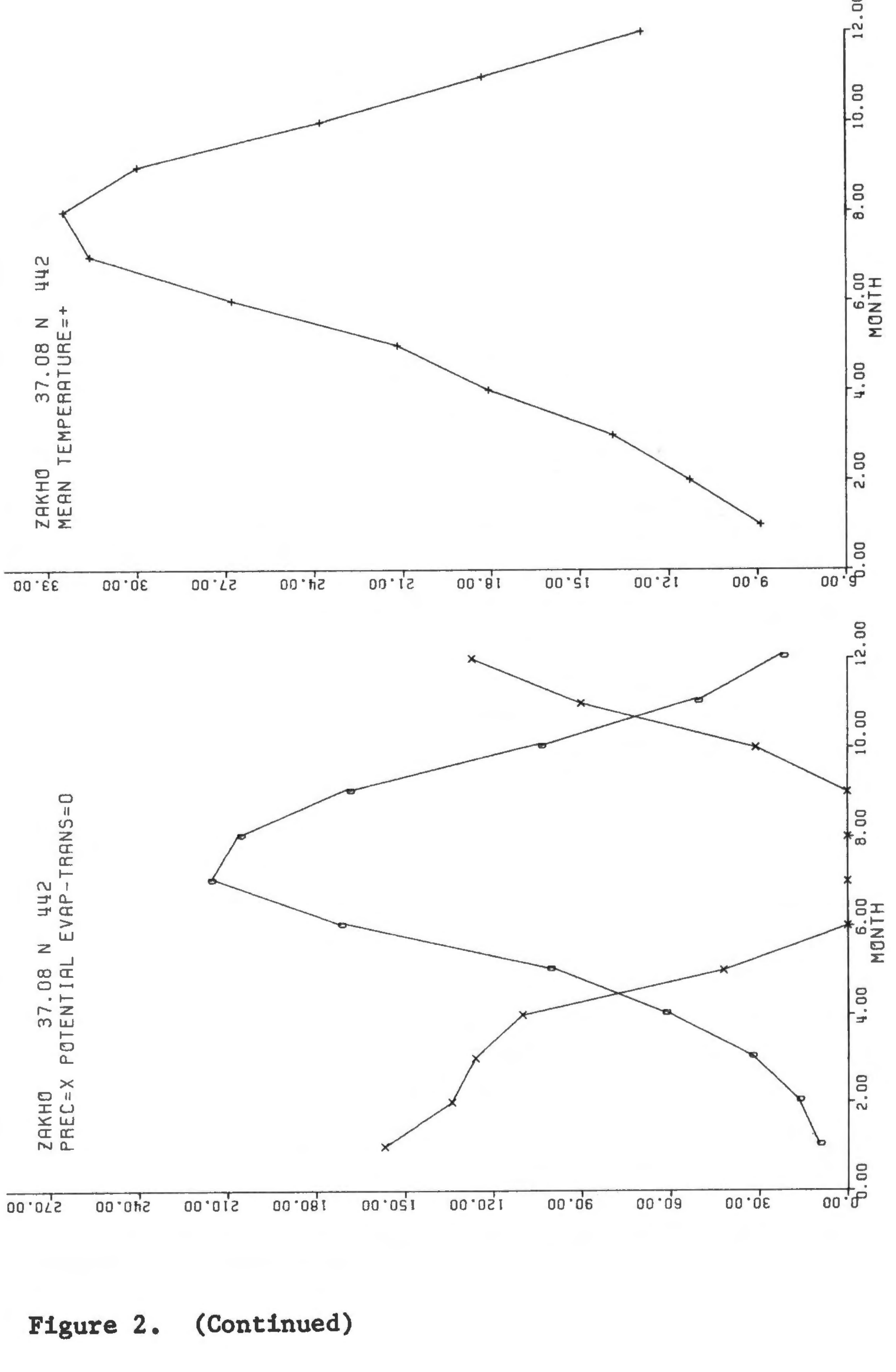

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APPENDIX B

THE VEGETATION OF IRAQ

The following survey of the vegetation of Iraq is an attempt to use present vegetation cover as an indicator of site conditions for the selection of suitable taxa to be tested in the various climatic regions of Iraq.

The vegetation of Iraq is generally derived from four territorial groupings: (A) Mediterranean element, (B) Irano-Toranian, (C) Saharo-Arabian, and (D) Sudanian (Zohary, 1973).

A. THE MEDITERRANEAN ELEMENT

Iraq's vegetation includes a high percentage of Mediterranean plants (16%). This is rather puzzling in view of the fact that there are no Mediterranean habitats in Iraq, nor climatogenic vegetation characterized by Mediterranean plants. The reasons for this occurrence seem, in the opinion of Zohary (1973), to be the following: (1) The Jazira of Iraq is widely open to Turkish Mesopotamia, which in its turn is Mediterranean in its western part and harbors a wealth of Mediterranean plants (especially annual segetals of northwestern Iraq). (2) The western slopes of the mountains in Iraq are open in part to the climatic influence of the Mediterranean. There is a gap between the Lebanon ranges and the Ansariye ranges (Syria) exposing the mountains of north Iraq to moisture-bearing winds coming from the

Mediterranean which do supply Iraqi mountains with a significant amount of rain so that some trees and shrubs are shared by West Iraqi mountains and the Eastern Mediterranean mountains.

In southern Iraq, Mediterranean segetals (plants growing in grain fields) are less common, merely because of the extreme climate conditions unsuitable for dry farming.

An examination of the Mediterranean element in Iraq shows that most of them are xero-segetals and ruderals (plants growing in waste places), some are hydro-segetals, and others are members of the hydrophytic and halophytic vegetation, as shown by Zohary (1946).

Accordingly, the Mediterranean element of Iraq may be divided into the following groups:

1. Trees and shrubs of the mountain forest district. This group of Mediterranean species is rather small in number. Some of them are: Quercus aegilops L., Quercus libani Oliv., Crataegus azarolus L., Cercis siliquastrum L., Pinus brutia Ten., Juniperus oxycedrus L., Fraxinus rotundifolia Mill., and Platanus orientalis L. They may be considered either as the easternmost isolated vanguards of the Mediterranean vegetation which once inhabited the borders of the ancient Tethys. This fits Pinus brutia Ten. in particular which is confined to the northern part of the country where it is a characterizing plant of the Pinetum brutiae accommodated here as a historical relic in the midst of Irano-Turanian territory.

2. Subalpine plants. Above the timber line of the mountain forests there occur a series of plants also shared by the subalpine and

alpine vegetation of some East Mediterranean ranges. These bi-regionals should, according to their distribution pattern, be considered Mediterrano-Irano-Turanian taxa (Zohary, 1973). This distribution pattern is due to similar climates in the subalpine-alpine zones.

3. Segetal and ruderal plants. These plants constitute the great majority of the Mediterranean element in Iraq. A large number of Mediterranean weeds of different families, notably of Graminae, Cruciferae, Caryophyllaceae, Leguminosae and Compositae, occur in Iraq, mainly in winter crops, side by side with weeds of Irano-Turanian origin. Another series of plants are ruderal. These plants, limited to favorable habitats, are only slightly affected by the general conditions of the country.

B. THE IRANO-TURANIAN TERRITORY

Except for Lower Mesopotamia, the southeastern and parts of the northwestern desert, the whole of Iraq is an Irano-Turanian territory which can be divided into two districts: the Mesopotamian and the Kurdo-Zagrosian (Zohary, 1973).

The Mesopotamian Sector

The Mesopotamian sector consists of two parts; the northeastern part of the Syrian Desert (including the Iraqi Jazira) and the foothill area between the latter and the mountains.

The main traits of the vegetation in each part are summarized in the following:

There are four main habitat regions characteristic of the Iraqi Jazira: (1) the western area of brown steppe soils, reminiscent of loess soil (e.g., between Mosul and Tall Afar); (2) the gypseous soils northwest and northeast of Wadi Tharthar (Figure 3); (3) the sandy soils in the south of the Jazira; (4) the saline lands, especially those of the Tharthar depression (Figure 1, page 9 and Figure 3).

The foothill area is not sharply delimited from the Jazira. It consists of an arched strip with a hilly configuration; the soils are brown to grey; the rainfall is fairly high and sufficient for dry farming but still insufficient to support any arboreal vegetation. The vegetation here shows more primary traits than that of the Jazira, owing to the presence of rocky outcrops and broken non-arable lands.

Both the Jazira and the foothill regions are strongly influenced by the Saharo-Arabian territory in the south. This is because of the gradual climatical and topographical transitions between the respective phytogeographical territories and because both have large areas of sandy soil. The following is a description of the vegetation of Irano-Turanian Iraq which has been little studied to date.

1. Segment Diyala-Arbil (foothill area): The southern part of this segment is a transition area between the Saharo-Arabian and the Irano-Turanian territories. In a trip between Diyala and Arbil (about 300 km; elevations 200 - 300 m), made in 1933 by M. Zohary, E. R. Guest, and A. Eig, they found the following plant communities: on alluvial, often somewhat saline soils the Stipa Capensis-Leontodon hispidulum association which includes some associate plants showing Saharo-Arabian

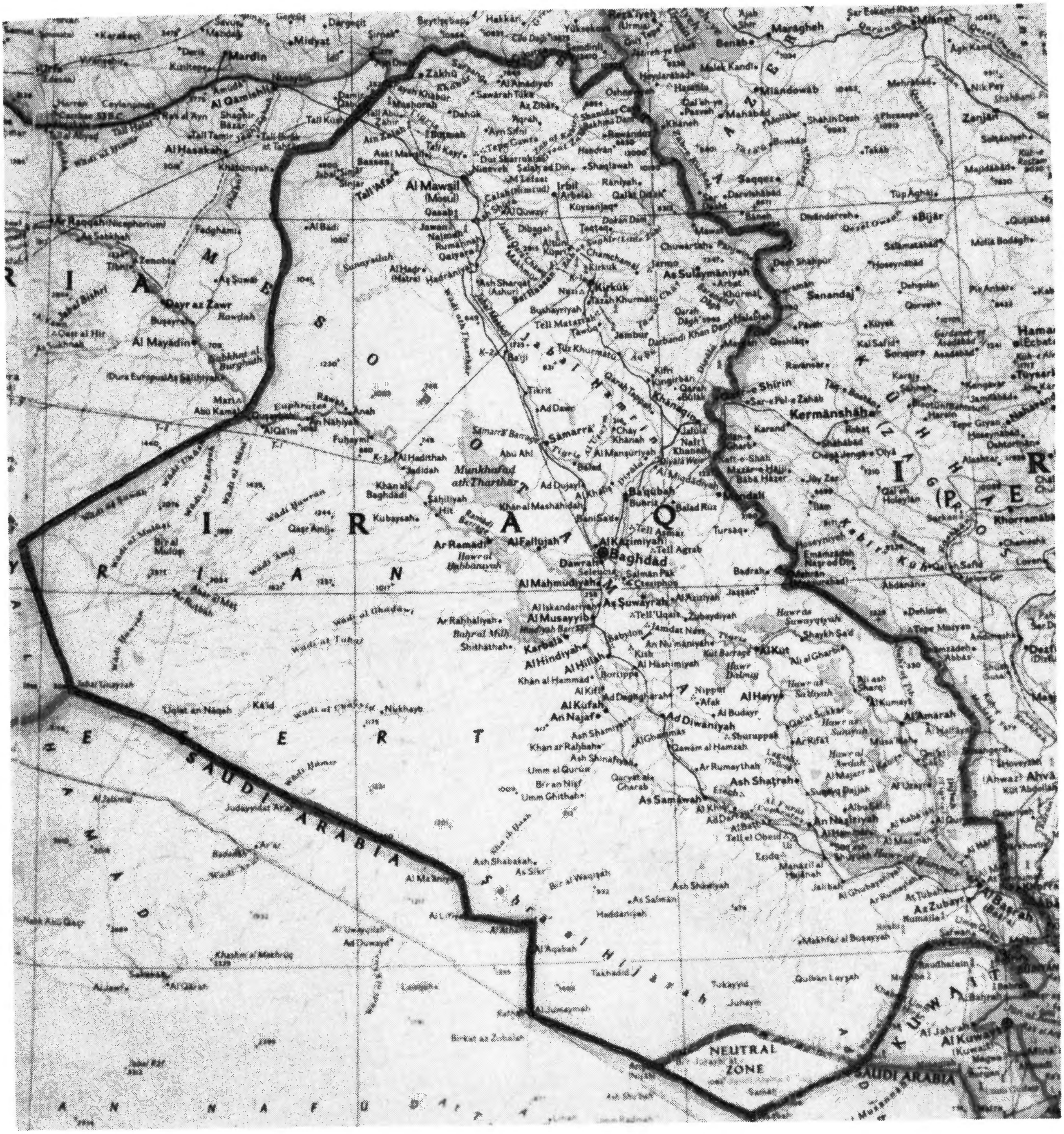

Figure 3. General map of Iraq.

affinities, e.g., Limonium spicatum (saline), and Aizoon hispanicum. Further north, up to 50 km north of Diyala, there are large stretches of non-irrigated fields, characterized by a segetal plant community in which Centaurea myriocephala and others were dominant, all characteristic of the Irano-Turanian territory; however, the dominance of Stipa-Leontodon, with or without Poa bulbosa in non-cultivated areas still indicates transitional conditions. True Irano-Turanian conditions begin about 60 km north of Diyala. Characteristic of this region is the very common association of Poa bulbosa-Ranunculus asiaticus which is common in the Arbil-Mosul area. The Jabal Hamrin (mountain complex) which extends across this region has several distinctive floral elements. It consists of a long ridge of hills built up of a friable sandstone producing sandy soil. Although containing some Saharo-Arabian plants, these do little to affect the general Irano-Turanian character of the area.

At an elevation of 50 - 200 m, a particular variety of Artemisietum herbae-albae and Phlomidetum kurdicae dominate the gypsiferous grey soil despite the desertic influence of the sandy rock which supports an association of Astragalus russelii and Onobrychis lanata. Extending into this area is a Sub-Sudanian association of Convolvulus oxyphyllus and Teucrium oliverianum characteristic of the compact sands along the Iraqi-Saudi Arabian border.

Northward from Jabal Hamrin there again occurs typical brownish steppe soil with a characteristic Irano-Turanian herbaceous cover. The following association site complexes characterize the region:

Teurium polium-Gundelia tournefortii on overgrazed hills, the Artemisietum herbae-albae in fallow fields and on hill sides, Prosopidetum farctae in non-irrigated fields with deep soils, and the association of Phlomis kurdica-Gundelia tournefortii on stony hills.

From an altitude of 200 m in Jabal Hamrin upwards to 450 m at Kirkuk, Artemisietum dominates all the hills and abandoned fields; it often includes Poa bulbosa. Prosopidetum farctae, so characteristic of the fields here, indicates a fairly large amount of moisture in the deeper layers. Characteristic segetal plants on brown steppe soil and loess are Achillea santolina and Hyoscyamus reticulatus.

Further north (between Kirkuk and Arbil), Phlomis burguieri or Phlomis kurdica or a hybrid form between them (Phlomis proetervisa Rech.) becomes abundant. It is often associated with Cousinia stenocephala, Achillea conferta, Gandelia tournefortii, or Poa bulbosa which also occur as co-dominants. On the outskirts of the city of Arbil, Artemisia herba-alba together with the above named perennials and dozens of annuals dominate the vegetal landscape.

2. Segment Arbil-Jabal Singar (via Mosul) - Tall Afar - Haseke (Syria), the northern Jazira; a route distance of about 300 km, altitude 400 m (Figure 3, page 141).

This area is more or less uniform in topography, soil, and vegetation. It is dominated by wheat and barley fields which leave comparatively little space for natural vegetation.

But wherever there is a hill free of cultivation, Artemisia herba-alba-Poa bulbosa association or Poetum bulbosae, which is evidently an anthropogenic derivation of the former is dominant.

Between Mosul and Tall Afar (Figure 3, page 141), the brown steppe soils predominate and they are mostly cultivated. On non-arable land, the Phlomis bruguieri-Gandelia tournefortii association is common, often found together with Cousinia stenocephala. On less stony ground, it is replaced by Artemisietum herbae-albae. Large areas are occupied by Centaurea behen accompanied by Phlomis.

The segetal associations are still very rich in species. From repeated observations, it becomes clear that the Phlomis-Gandelia association is a post-segetal community, i.e., the first stage of revegetation of fields fallowed for a long period.

Between Tall Afar and Sinjar, cultivation is less frequent due to Jabal Sinjar (mountain) range. Its vegetation presents an isolated outpost of the Zagros system. It is built of calcareous rocks and rises up to 1,400 m. Although the vegetation is largely destroyed, it still exhibits remnants of a poor Quercetum aegilops.

The arboreal components of this steppe forest are: Quercus aegilops L., Pistacia khinjuk Stocks, Acer cinerascens Boiss., Prunus arabica (Oliv.) Meikle, Rhamnus kurdicus Boiss. et Hoh. It appears as a sparse shrubbery with scattered trees. The interspaces between woody plants as well as the denuded parts of the mountains support typical steppe herbaceous communities. The annual flora is exceedingly rich. This mountain ridge vegetation is clearly of Irano-Turanian character.

Further west to the Iraqi-Syrian border, the Mesopotamian nature of the vegetation becomes apparent. Common herbaceous plant communities in non-cultivated areas and abandoned fields allowed to revegetate are Artemisietum herbae-albae and Phlomidetum bruguieri.

The salient feature along the highway to Sinjar and further west are the huge tracts of wheat and barley with a wealth of interesting segetals.

Another feature characteristic of the northwestern Jazira is the gypsophilous vegetation. When the brown steppe soil layer, usually occupied by the Artemisia herbae-alba-Poa bulbosa association, is removed a calcareous gypsiferous stratum appears on the surface. Characteristic plants include Achillea aleppica and Teucrium pruinosum.

The most prominent vegetative feature in the southern part of Jazira is the occurrence of Hammada salicornica dominating both raised dunes and sandy flats between Wadi Tharthar and the Euphrates River (Agnew, 1961a)

Psammophytes (sand plants) found here are such as: Cutandia memphitica, Schimpera arabica and Arnebia decumbens. Five non-psammophilous plants occur here of which Ephedra faliata is the most common suggests that those constitute an indication center of some Saharo-Arabian and Sub-Sudanian plants similar to those found in the southern desert near the Iraqi-Saudi Arabian boundary.

Among the halophytic flora of the Jazira are Irano-Turanian and Saharo-Arabian elements represented by 10-12 dominant species such as Cornulaca ancheri. There are considerable stretches of saline vegetation in this district, especially at the southern edge of the Tharthar depression which is dominated by Arthrocnemum macrostachyum.

The Kurdo-Zagrosian Steppe-Forest Section

The Iraqi mountains are the only part of this district included within the boundaries of Iraq (Figure 3, page 141). These mountains have an annual rainfall ranging from 600 to 1,350 mm. Vegetation varies from fairly dense forests to steppe-forest, depending on altitude, aspect, and soil. The lower timber line is about 500 to 700 m, while the upper line reaches 1,800 to 2,000 m or more, depending on latitude and exposure.

The forests consist mainly of deciduous, broadleaved trees or shrubs with a low coverage and a dense ground cover of herbaceous steppe vegetation. Density and number of arboreal species decrease markedly towards the south. A list of the trees and shrubs occurring in the Iraqi mountains is given in Appendix C.

Only the oaks, pistacias, and to some extent Crataegus and Pyrus are dominant in the vegatation; others are rare to very rare.

Examples of trees of the Kurdo-Zagrosian mountains that recur in the East Mediterranean mountains are: *Pinus brutia* Ten., *Juniperus oxycedrus* L., and *Quercus libani* Oliv.

Characteristic plants on uncultivated foothills, 400 to 500 m above sea level, are *Astragalus russelii*, *Phlomis bruguieri*, *Salvia multicaulis*, and *Cousinia stenocephata*. At about 700 m, scattered and stunted *Cratageus azarolus* L. appear. In other localities (e.g., in the Duhok district), *Pistacia khinjuk* Stocks, and *Pistacia atlantica* Desf. may also occur at the same altitude. Above 800 m, forests or forest remnants of *Quercus aegilops* L. and/or *Quercus infectoria* Oliv.

extend to an altitude of 1,700 m. In the Amadiya district, about 8 km north of Zawita and about 1,200 m above sea level, the following species were noted: Quercus infectoria Oliv., Quercus aegilops L., Quercus libani Oliv. (the latter on northern and western exposures only), Juniperus oxycedrus L., Crataegus monogyna Jacq., and Pistacia khinjuk Stocks. One of the most common understory shrubs in the forest is Prunus microcarpa C.A.M. Sorbus umbellata (Desf.) Fritsch ex kerner commonly accompanies the mesic Quercus libani Oliv. Pyrus syriaca Boiss. and Prunus amygdalus Batsch occur on open land or in glades. Sumac (Rhus coriaria L.) is dominant on degraded forest lands. The first of the oaks to regenerate is Quercus aegilops L.

Further south, in the district of Sulaimaniya, the forest is greatly impoverished: Quercus libani Oliv. and Juniperus oxycedrus L. have disappeared, Quercus infectoria Oliv. has become rare, while Pyrus syriaca Boiss., Crataegus heterophylla Fluegge, Crataegus azarolus L., Prunus microcarpa C.A.M., Acer cinerascens Boiss. and Pistacia khinjuk Stocks are the common associates of the dominant Quercus aegilops L.

A pine forest in which Pinus brutia Ten. is found in the Duhok district (environs of Zawita and Atruch) is worth mentioning. Common associates are: Crataegus azarolus L., Quercus aegilops L. Quercus infectoria Oliv., Pistacia atlantica Desf., Juniperus oxycedrus L., Astragalus gossypinus, Astragalus questii, and Argyrolobium crotalariodes.

In the Duhok district, the composition of the oak forst is strongly conditioned by exposure and soil structure. In the highest zone observed (1,260 m) Quercus aegilops is dominant. The trees are widely spaced and are accompanied by Paliurus spina-christi Mill., Juniperus oxycedrus L., and Crataegus azarolus L. On the western slopes Quercus infectoria Oliv. dominates and Quercus aegilops L. becomes poor and stunted. On the nothern and northwestern slopes considerable stretches of the forest are dominated by Quercus infectoria Oliv. and Quercus libani Oliv., while on the southern and eastern slopes forests are exclusively Quercus aegilops L. Acer cinerascens Boiss. occurs at around 1,200 m. Pistacia khinjuk Stocks is an associated of the Quercetum aegilops, but Pistacia atlantica Desf. var. kurdica Zoh. (which is the characteristic form here), is usually restricted to slopes of wadis. Prunus microcarpa C.A.M. occurs in all oak communities here, while Juniperus oxycedrus L. is mainly confined to Quercetum infectoria community. Sorbus umbellata (Desf.) Fritsch ex Kerner is very rare; it was encountered only under the canopy of Quercus libani Oliv. Pyrus and Prunus never gain high coverage here.

On the whole, the mountain forest of Iraq (and elsewhere) is steppe-forest in which the trees are fairly distant from one another leaving room for a steppe vegetation in the interspaces.

In addition to the oak and pine forest, there are in Iraqi mountains a number of other plant communities confined to river banks, ditches, irrigated and non-irrigated fields. The following are records for three such habitats:

1. Platanetum orientalis: Rawandoz gorge, near water, 600 to 700 m, with Platanus orientalis L., Salix alba L., Acer cinerascens Boiss., etc.

2. Association of Mentha longifolia on the Jafaran mountains (east of Sulaimaniya) with Mentha longifolia, Epilobium hirsutum, etc.

3. A segetal community in the Jafaran district at Kanitakht, 1,180 m, with Convolvulus arvensis, Euphorbia chamaesyce, etc.

Above the upper timber line (between 1,900 to 2,000 m), there is a fairly wide zone of subalpine vegetation. Guest (1966) records from the Halgurd Dag and Chiya-Mandali (northeast of Rawandoz main ridge about 3,000 m, peak 3,600 m): Daphne acuminata and tragacenthic plants.

In a recent study by Hadac and Agnew (1963) of the subalpine and alpine zones of the same mountains (Halgurd Mts., 2,200 m), a few communities are recorded of tragacanthic, which named Prangeto-Astragaletum tragacanthae, Aethionemeto-Astragaletum tragacanthae, by the above authors.

The following is a summary of the flora and vegetation of the western Kurdo-Zagrosian mountains, as found in Iraqi mountains.

The inclusion of the Zagros mountains within the Irano-Turanian region, despite the presence of some trees and shrubs that occur also in come of the East Mediterranean mountains, has been reasoned by Zohary (1973) as follows:

1. There are many species in this deciduous forest which bear no relation whatever to the Mediterranean flora. Examples are Pistacia

khinjuk stocks, Pistacia atlantica Desf. var. latifolia DC. and var. kurdica Zoh., a series of species of Prunus and Acer.

2 . The arboreal species shared by the Kurdo-Zagrosian and East Mediterranean floras, provide evidence that the Zagros was the original home of these plants from whence they migrated westwards. An instructive example in this point are the two representatives of the genus Quercus, which the Zagros shares with the mountains of southern Turkey and the Lebanon. These are Quercus libani Oliv. and Quercus aegilops L. Both are very common and are richly differentiated taxonomically in Turkish, Iraqi, and Iranian Kurdistan mountains but are poorly represented in the Mediterranean area. In addition, these species and some of their Mediterranean relatives avoid true Mediterranean conditions wherever they occur in the Mediterranean territory. From the above Zohary concluded that this young group of deciduous oaks has originated in the Kurdo-Zagrosian district, whence it has reached the East Mediterranean via the low ranges of the "Fertile Crescent."

3. The Irano-Turanian nature of the Kurdo-Zagrosian vegetation is also marked by the representatives of the genus Pistacia. Iran should be considered as part of the main evolutionary center of the section Eu-Terelinthus (Zohary, 1952b) of which Pistacia vera L. and Pistacia khinjuk Stocks are not only the most primitive members, but probably also the original stock that has given rise to the Mediterranean Pistacia terbinthus and Pistacia palaestina. The other most characteristic species of the Iranian steppe-forest and the Zagros

forest area is *Pistacia atlantica* Desf. in its various forms. *Pistacia atlantica* Desf. var. *kurdica* Zoh. with its larger fruits and large, ovate and few-paired (occasionally also simple) leaves, closely resembles certain forms of *Pistacia vera* L. and may be derivative of the latter. It is, therefore, probable that the typical *Pistacia atlantica* Desf. is a derivative of the above variety.

The double timber line (lower and upper) is here, as in inner Anatolia, most characteristic of the steppe-forest, but the complete lack of *Quercus cerria*, *Quercus pubescens* Willd. and *Pinus nigra* Arnold in Kurdistan shows how different these forests are from the Xero-Euxinian. The northwestern border between the Kurdo-Zagrosian and Euxinian forests runs in the vicinity of the Elazig Mus line.

C. THE SAHARO-ARABIAN TERRITORY

In 1946, Zohary referred to 118 species of Iraq's flora to the Saharo-Arabian element. It has since become quite evident that a considerable part of this group should be considered as Sub-Sudanian (Nubo-Sindian). For further information on the Iraqi flora, refer to Rechinger (1964), Zohary (1940-41, 1946), Agnew (1961, 1962), Agnew and Haines (1960), Guest (1966), Townsend et al. (1966-1968).

Most of the species typical of the bulk of the Saharo-Arabian vegetation are here altogether lacking or extremely rare.

There are three areas in Iraq which at first glance could be considered as Saharo-Arabian, and where one would expect to find Saharo-Arabian vegetation. These are Lower Mesopotamia, i.e., the area between the two rivers, located approximately between Ba'qubah and Basra (Figure 3, page 141); the second area is the Southern (southeastern) Desert, i.e., south of the Ur-Samawa railway line; the third is the Western Desert, i.e., that part of the Syrian Desert located south of the Rutba-Habbaniya route, approximately between the 40th and 44th meridian. A more critical insight into the vegetation and flora of these territories discloses the following features:

Lower Mesopotamia is a center of hydrophytic, hydrosegetal and halophytic vegetation in Iraq and offers little space for zonal vegetation. It need not be stressed here that the first two types of vegetation, though comparatively rich in species, are of little significance. A few species occuring in this vegetation suggest a tropical origin, e.g., Marsilia capensis, and Nymphoides incidum.

The halophytic vegetation in this area is most remarkable. It is in the main Saharo-Arabian but shows some Irano-Turanian traits. In Lower Mesopotamia, Prosopis farcta occupies large areas on the inundated and saline banks of the Euphrates, Tigris and the Shatt al Arab. It is in this habitat that this widespread halosegetal plant appears to have its primary home. Here it forms natural plant associations, mostly along with Alhagi sp. and other components (e.g., in the extensive Amara-Samawa marshes). Generally, these associations are Saharo-Arabian in their floristic composition. The Irano-Turanian influence on this region is manifested by the presence of Bassia hyssopifolia, Halocharis brachyura, etc. Nevertheless, Lower Mesopotamia should be considered as Saharo-Arabian territory.

The Southern Desert, roughly limited on the north and west by the 31st parallel and by the 44th meridian, is to some extent climatically influenced by the Arabian Gulf (Persian Gulf). It has higher temperatures and also in some places a higher amount of rainfall than the adjacent parts of the Western Desert (e.g., about 140 mm in Al Zubair). Though its flora is predominantly Saharo-Arabian, its vegetation shows definite Sudanian (Nubo-Sindian) traits. This is manifested by the fact that the leading species of the prevailing local communities such as Hammada salicornica and others are confined to hot deserts in Arabia and the adjacent countries.

The third area, the Western Desert, presents in its southern portion a mere continuation of northwestern Arabia. It is a stony, gravelly desert exceedingly poor, in and sometimes almost devoid of vegetation as is evident from the descriptions by Guest (1966) and others. The information on this area is very scant. According to Guest (l.c.) and other floristical and climatical data, it is not a true Saharo-Arabian desert. Artemisia herba-alba may occur abundantly here where above normal annual rain occurred for a few consecutive years, but it soon dies off after a single dry winter.

The Saharo-Arabian Retametea in Iraq can be characterized by the Haloxyletum persici occupying some areas of sand soils, both in the Southern Desert and the southern Jazira (Guest, l.c.). In addition to Haloxylon persicum, it often includes a few other dominant species. Strictly speaking, the above species are Turanian derivatives rather than Saharo-Arabian by origin. Of the Anabasetea class, there are no associations recorded, but a series of species collected by Zohary and others point to the existence of some associations in the Western Desert that could be assigned to this class.

However, Zohary (1973) came to the conclusion that the typical Saharo-Arabian territory of the Middle East reaches its northern limit not far beyond the northern border of Arabia. Iraq, itself, does not display many of the zonal and typical representatives of the Saharo-Arabian vegetation. Iraq's vegetation is predominantly Irano-Turanian (Mesopotamian and Kurdo-Zogrosian) and to much lesser degree Sub-Sudanian (Nubo-Sindian), though the number of Saharo-Arabian species and the extent of the Saharo-Arabian territory are quire considerable here.

D. THE SUDANIAN TERRITORY IN IRAQ

Although of limited extent, there is, however, an area where Sudanian or Sub-Sudanian plants are quite concentrated and form associations together with Saharo-Arabian plants. This area lies in the southeastern corner of Iraq. So far, only one stand of about 30 trees of Acacia gerrardii has been found in the south not far from Shabicha (Guest, 1966). All the other associations are included within the class of Hammadetea salicornicae. In the latter, the following associations have been observed by Zohary (1940, 1941).

1. The Hammadetum salicornicae south and west of Basra. Here Hammada salicornica is accompanied by numerous annuals such as Astragalus tribuloides.

2. The *Hammada salicornica-Convolvulus oxyphyllus* association, 18 km south of Al-Zubair, on compact sandy soils. The above characterized by Hammada and Convolvulus is accompanied here by *Polycarpaea repens*, and many others.

3. The *Hammada salicornica-Ammothamnus gibbosus* association is recorded by Agnew (1961a), Agnew and Haines (1960) from Al Jazira on semi-stable dunes.

4. *Rhanterietum epapposi*. This is the northernmost outpost of the huge area covered by this plant community in Arabia. It occupies here a vast area of sandy soil southwest of Basra. It shows a high coverage and is often accompanied by *Scrophularia deserti* and many annuals.

5. *Cymbopogonetum parakeri* is another important community. It is most typical of consolidated sandy soil and displays a high coverage of annuals among which Cymbopogon is regularly interspersed.

Here in the sandy soils southwest of Basra as well as in Al Jazira and in the whole area between them, the numerous scattered shrubs of *Ziziphus nummularia*, found also in northern Arabia, southern Iran, are most indicative of a Nubo Sindian vegetation climax.

The fact that *Hammada salicornica* and other Nubo-Sindian or Sub-Nubo-Sindian leading perennials are accompanied here by annuals, mostly Saharo-Arabian, shows that in Iraq there is not true Sudanian territory but a penetration area only.

APPENDIX C

TABLE 10

TREES AND SHRUBS OF THE IRAQI MOUNTAINS

Trees	Shrubs
Pinus brutia Ten.	Cotoneaster racemiflora (Desf.) K. Koch
Juniperus oxycedrus L.	Prunus kotschyi (Boiss. et Hoh.) Meikle
J. polycarpos C. Koch	P. carduchorum (Bornm.) Meikle
Juglans regia L.	P. argentea (Lam.)Rehd.
Betula pendula Roth.	P. arabica (Olive.)Meikle
Quercus aegilops L.	P. webbii (Spach) Vierh.
Q. libani Oliv.	P. mahaleb L.
Q. infectoria Oliv.	P. microcarpa C.A.M.
Q. macranthera Fisch. et Mey. (very rare)	P. brachypetala (Boiss.) Walp.
Ulmus carpinifolia Gled.	Rhus coriaria L.
Celtis caucasica Willd.	Rhamnus kurdica Boiss. et Hoh.
Ficus carica L.	R. cornifolia Boiss. et Hoh.
Pyrus syriaca Boiss.	Paliurus spina-christi Mill.
Prunus amygdalus Batsch	Ziziphus nummularia (Burm.) Walk.
Sorbus umbellata (Desf.) Fritsch ex Kerner	
Crataegus azarolus L.	
C. pentagyna Waldst. et Kit	
C. meyeri Pojark. (rare)	
C. monogyna Jacq.	
C. heterophylla Fluegge	
Cercis siliquastrum L.	
Pestacia khinjuk Stocks	
P. atlantica Desf. var. kurdica Zöh.	
P. vera L.	
Acer monspressulanum L.	
A. cinerascens Boiss.	
Ziziphus spina-christi (L.) Willd.	
Elaeagnus angustifolia L.	
Fraxinus rotundifolia Mill.	

APPENDIX D

TABLE 11

A LIST OF TREE SPECIES THAT HAVE BEEN ALREADY TRIED IN IRAQ OTHER THAN EUCALYPTS

Species	Country of Native Habitat
Acacia nilotica Del.	Northern Nigeria, Lake-Chad area and Sudan
Acaia farnesiana (L.) Willd.	Tropical America
Acacia cyanophylla Lindl.	Australia
Ailanthus altissima (Mill.) Swingle	Northern China
Albizzia lebbek (L.) Benth.	Tropical Asia and North Australia
Bombax malacabrium BC.	India and Burma
Cassia siamea Lamk.	India
Casuarina cunninghamiana Mig.	Australia
Casuarina equisetifolia Forst.	Australia
Casuarina stricta Ait.	Australia
Cedrela toona Roxb.	Burma and India
Cedrus deodara (Roxb.) Loud.	Western Himalayas (Afghanistan to Garheval)
Cedrus libani A. Rich.	Lebanon and Turkey
Celtis australis L.	Mediterranean region with a northern limit in Switzerland
Cupressus sempervirens L.	Italy, Greece, Jordan, Cyreniaca and Morocco
Delonix regia (Bojer) Raf.	Madagascar
Ficus carica L.	Iran, Armenia, and Anatolia
Gleditsia triacanthos L.	North America
Juglans nigra L.	North America
Juglans regia L.	Northern Iran, Northern India and China
Melia azedarach L.	Northern China
Olea europaea L.	Mediterranean Basin
Parkinsonia aculeata L.	Tropical America
Pinus halepensis Mill.	Syria, Spain, Morocco, Greece, Libya, and Jordan

TABLE 11 (Continued)

Species	Country of Native Habitat
Pinus nigra Arnold	In southern Europe from Spain to Austria, Turkey, Caucasus, Crimea, Morocco, and Algeria
Pinus pinea L.	Northern Mediterranean region from Portugal to eastern Turkey
Platanus occidentalis L.	Mixico to Canada
Populus nigra L.	Iran and Afghanistan
Robinia pseudoacacia L.	North America
Salix babylonica L.	China and Japan
Schinus molle L.	Peru
Sophora japonica L.	China and Korea
Swietenia mahoganii Jacq.	West Indies
Thuja orientalis L.	China and Japan
Ulmus carpinifolia Gled.	From the warmer parts of Europe to the eastern Mediterranean region
Ziziphus officinarum Medic.	India and China

APPENDIX E

TABLE 12

A LIST OF EUCALYPTS THAT HAVE BEEN TRIED IN IRAQ

Species	Performance
Eucalyptus camaldulensis Dehn.	Very good over wide areas
Eucalyptus microtheca F.v.M.	Very good over wide areas
Eucalyptus largiflorens F. Muell.	Good
Eucalyptus hemiphloia F.v.M.	Fair
Eucalyptus racemosa Cav.	Fair
Eucalyptus algeriensis Trabut	Good
Eucalyptus sideroxylon A. Cunn. ex Benth.	Good
Eucalyptus melliodora A. Cunn. ex Schau.	Good
Eucalpytus polyanthemos Schauer.	Fair
Eucalpytus occidentalis Endl.	Fair
Eucalpytus paniculata Sm.	Fair
Eucalpytus rudis Endl.	Fair
Eucalpytus bridgesiana R. T. Baker	Poor
Eucalyptus umbellata (Gaertn.)Domin.	Good
Eucalyptus alba Reinw. ex Blume	Fair
Eucalyptus cladocalyx F.v.M.	Good
Eucalyptus gomphocephala A.DC.	Good

VITA

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In March, 1975, he was awarded a full scholarship from the Ministry of Higher Education and Scientific Research in Iraq to complete his graduate study in the United States. In June, 1975, he entered the graduate school at the University of Tennessee, Knoxville, to study for the degree of Master of Science in Forestry. He received the Master of Science degree with a major in Forestry in June, 1977.