Project Report: Deficit Irrigation Management During Hull-Split

Project leader: Ken Shackel, Dept. of Pomology, UC Davis

Sub-Project Leaders: Rick Buchner, Joe Connell, Roger Duncan, John Edstrom, Allan Fulton, Brent Holtz, Bruce Lampinen, Bill Krueger, Wilbur Reil, Larry Schwankl, Mario Viveros

Objective: The objective of this project is to test the practicality and benefits of a plant-based deficit irrigation strategy during hull split. The expected short term benefits are: 1) water savings, 2) reduced incidence of hull rot, 3) improved harvestability, and 4) an overall reduction in the level of tree water stress during and after harvest. The potential long term benefits include increased return bloom and improved overall tree health, but such benefits may not become apparent during the course of the project.

Background: Irrigation management is a key element in almond production, and as water becomes more expensive and more politically competitive in the state, the need for reliable and cost-effective methods to manage irrigation, especially deficit irrigation, in a high acreage crop like almonds becomes more important. Previous almond board funded research by B. Teviotdale and D. Goldhamer has shown that hull rot and sticktights can both be reduced by deficit irrigation during hull split, but the best way to manage this deficit has not been determined. Deficit water management during this period is particularly difficult, because by the end of hull split, irrigation must be suspended for harvest, and hence the grower runs the risk of causing excessive late season tree water stress, which has also been shown to be detrimental to return bloom and ultimately to almond production. A plant-based approach to deficit irrigation (midday stem water potential, "SWP") has been very successful in prunes, allowing a substantial savings in seasonal water use (typically 40%), while at the same time maintaining yields and in some cases improving fruit quality. Since the growth of the kernel (seed) is generally thought to be less sensitive to water stress than the growth of the fruit flesh in many species, it is reasonable to assume that similar or greater savings in water use can be accomplished in almond orchards without a negative impact on production. A one year study on almonds in the Bakersfield area in 1999 showed that, as expected, there were a number of potentially beneficial responses to stress during hull split, and combining this approach with a full irrigation just prior to harvest also resulted in overall less postharvest tree water stress. The full irrigation just prior to harvest did not increase barking injury, and hence it appears that moderate water stress can be imposed during hull split without having to balance the dangers of excessive stress with the dangers of excessive barking injury.

Procedures: This project was performed on grower demonstration plots in the main almond growing regions of the state (Table1). In each plot the growers normal irrigation practice was compared to a Regulated Deficit Irrigation (RDI) practice, which was based on achieving a "target" level of midday stem water potential (SWP). Midday SWP was measured with a pressure chamber on at least 10 trees per treatment in each plot. The target level of SWP prior to hull split was from -7 to -9 bars, which is the value that is expected for fully irrigated almonds under typical midday weather conditions. During hull split, the target SWP was from-14 to -18

Table1. Sites and site information for the 2001 almond RDI trials.

County	Location	Soil type	Orchard age (yr)	Irrigation system type	Approximate dates of hull split
Tehama	Corning (A)	Silt-Loam	9	Microsprinkler	13 July - 13 August
Tehama	Corning (B)	Gravel-Loam	9	Microsprinkler	13 July - 13 August
Butte	Chico	Vina-Loam	7	Solid-set Sprinkler	6 July - 6 August
Glenn	Orland	Silt & Gravel Loam	22	Solid-set Sprinkler	6 July - 6 August
Colusa	Arbuckle	Gravel-Loam (Class 2)	11	Single line drip	5 July - 23 July
Yolo	Esparto	Yolo-Loam	7	Microsprinkler	6 July - 20 July
Stanislaus	Salida	Hanford FSL	15	Flood	6 July - 20 July
Madera	Madera (A)	Hanford FSL	13	Microsprinkler	13 July - 30 July
Madera	Madera (B)	Hanford FSL	16	Microsprinkler	13 July - 30 July
Madera	Madera (C)	Dinuba FSL	8	Microsprinkler	13 July - 30 July
Kern	Delano	McFarland Loam	6	Microsprinkler	2 July - 24 July

bars (mild to moderate stress), and following hull split the target was returned to the baseline value (from -7 to -9 bars). The progression of hull split was monitored, as well as yield, nut size, harvestability and the occurrence of hull rot strikes. Observations were also made regarding any differences between the treatments in barking injury or other important production characteristics.

Results and discussion: For most cooperators, this was the first year of using the pressure chamber to manage irrigation, and at each site it was necessary to gain the experience of seeing how SWP responded to irrigation management over this first season. The details of two contrasting sites are shown in Figs. 1A (Butte Co.) and 1B (Yolo Co.), but the data from all sites are given at the end of this report. In the Butte County site (Fig. 1A), trees in the Grower control

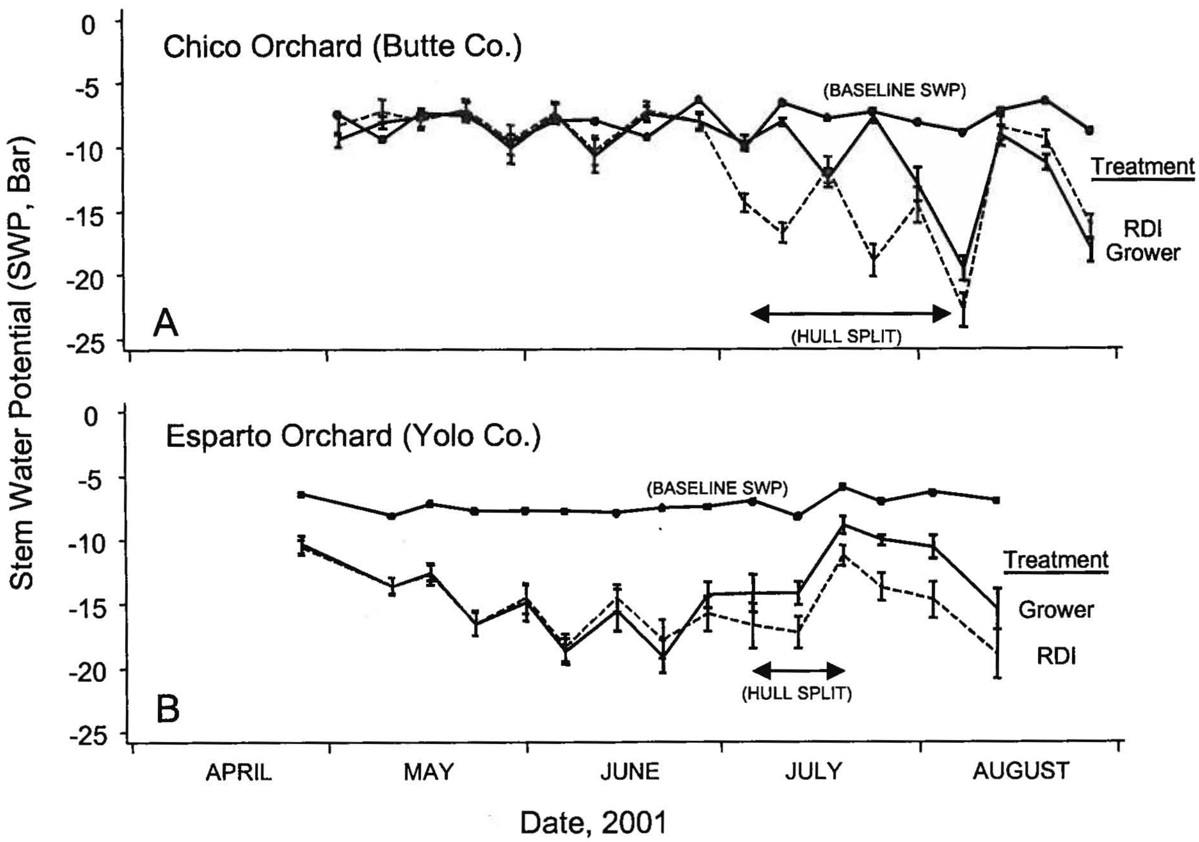


Figure 1. Seasonal pattern of midday stem water potential (SWP) in two of the orchard locations used in this study: (A) the Chico orchard in Butte Co. and (B) the Esparto orchard in Yolo Co. In both locations, the baseline value expected for a fully irrigated almond tree is shown for each date of measurement, as well as the mean (± 2SE) for the Grower and RDI treatments. The approximate beginning and ending dates of hullsplit in the two locations are also shown.

exhibited values of SWP that were very close to baseline until mid July, followed by cycles of mild to moderate stress and recovery that were associated with irrigation cycles during July and August, and progressive stress to moderate levels (-20 bars) when water was withheld prior to harvest. The normal irrigation practice of this grower is to follow crop Evapotranspiration (ET) and a fairly regular irrigation schedule, with soil moisture monitoring by Veihmeyer tube and the feel method to confirm expectations. Water was withheld from trees in the RDI treatment in early July, and irrigations were adjusted to attempt to keep the trees in the target range of -14 to -18 bars through the hull split period, although by early August the RDI trees were experiencing more than moderate water stress by the end of each cycle (Fig. 1A). At this site, it appears that the normal grower practice already involved imposing cycles of stress during the hull split period, particularly toward the end of hull split, followed by an early to mid-August heavy irrigation to carry the trees through the harvest period. On average, there was more water stress in the RDI trees than in the grower control trees during the hull split period, but because the grower trees also experienced some water stress at this time, large differences in hull rot or hull splitting between these treatments was not expected.

The seasonal pattern of SWP observed in the Yolo Co. site was quite contrasting to that seen in the Butte Co. site. By mid-May in the Yolo Co. site, trees in both treatments were already exhibiting mild to moderate stress, and from mid-May to mid-July, trees in both treatments were in the -15 to -20 bar range (Fig. 1B). The normal irrigation practice of this grower is to apply approximately 12 hours of irrigation every 3 days, but for the first half of the 2001 season, less than this was applied because of a broken irrigation pump. It is also normal for this grower to impose water stress during hull split to reduce hull rot, so for the purposes of our experiment an attempt was made to increase the irrigation in the non-RDI treatment by increasing the size of the microsprinkler heads. This did result in an increase in SWP around the time of hull split in the non-RDI treatment (Fig. 1B), but because all trees experienced some water stress at this time, large differences in hull rot or hull splitting between these treatments was not expected.

The data for all of the individual sites are shown in the series of figures at the end of this report. In each case the symbols used are the same as those used for figure 1, with the fully irrigated baseline shown as dots, the grower treatment as a solid line and the RDI treatment as a dashed line. In all cases the error bars represent ±2 SE, which, for our sample size is about a 95% confidence interval. At the Chico site, two varieties were monitored (Non-pareil and Price), and both showed very similar patterns in all treatments. This is consistent with previous findings that, under the same soil and environmental conditions, midday SWP is not variety specific in almonds.

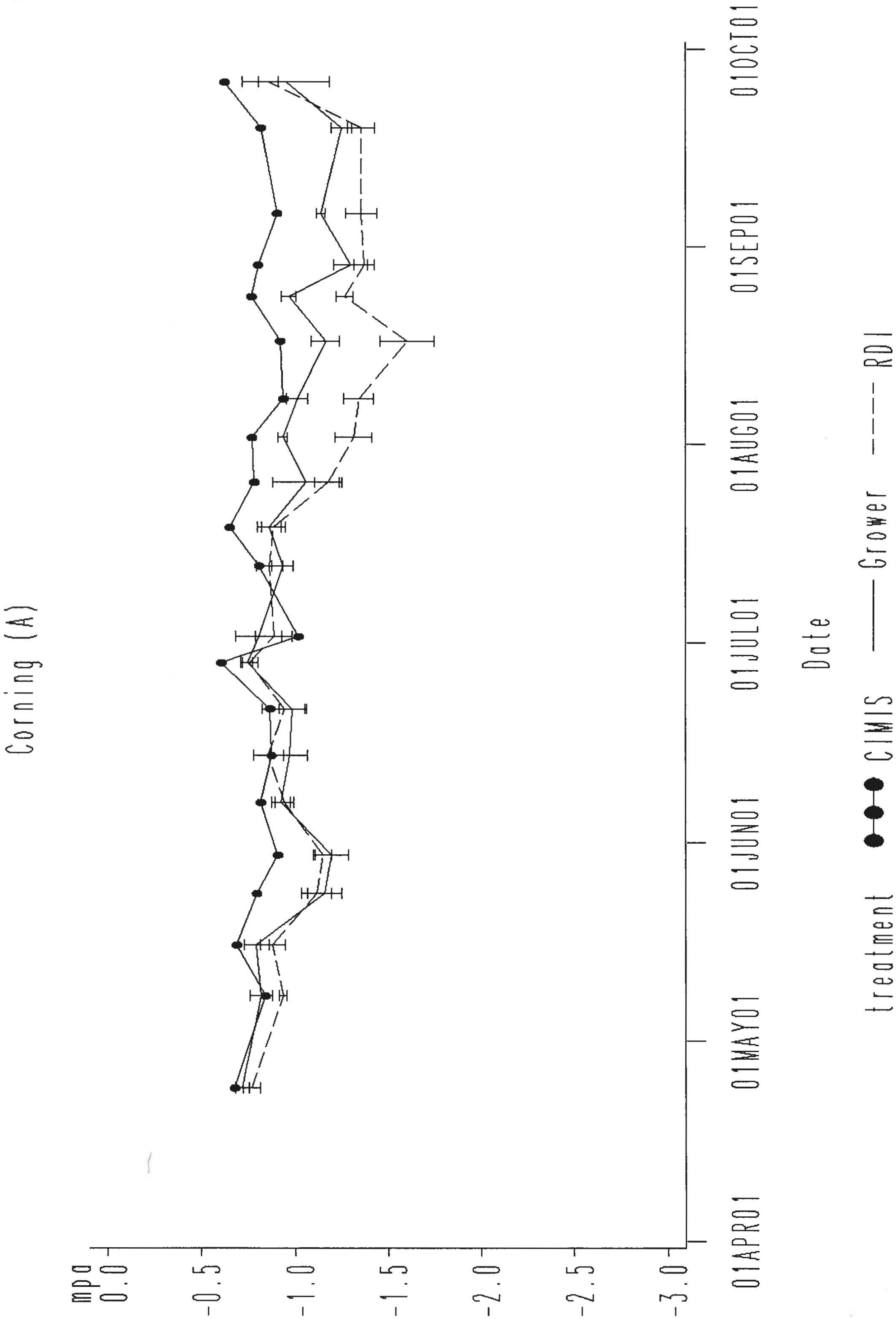
For each site, the average SWP before, during, and after hull split was calculated, and are summarized, together with measurements or observations of treatment effects on hull splitting, hull rot, and yield, in Table 2. Prior to hull split, most orchards in this study were already experiencing mild to moderate levels of stress, some with SWP values of almost -18 bar. At only two of the sites (Corning and Chico) were the trees within the RDI target of -7 to -9 bar. During hull split, many of the orchards were within the RDI target of -14 to -18 bar, but in most cases, some stress was also experienced by trees in the grower control treatment during this time. Of all the locations, the Chico and the Orland sites were the closest approximations to a non-stressed grower treatment compared to a moderately stressed RDI treatment during hull split. All of the orchards (both RDI and grower control treatments) were below the RDI target after hull split. Under these conditions, it was not surprising that most orchards showed no treatment effect on the rate of hull splitting (Table 2). In only one case (Orland) was any measurable difference reported, but this was small. Hull rot was only observed in one-half of the orchards of this study, but in all cases where there was a large enough difference to be meaningful (Chico, Orland and Madera[B]), the RDI treatment was associated with a reduction in hull rot (Table 2). Since treatments were not imposed until early to mid-July, the lack of any treatment effect on yield (Table 2) was not surprising.

Conclusions: This was the first year of this project, and even though the only clear effects that were observed were the expected beneficial effects of a reduction in hull rot strikes, firm conclusions about the potential benefits of hull split RDI will not be possible without further study. However, one observation that was consistent across most sites this year is that many almond growers are already managing irrigation at a deficit level, at least as measured by SWP. This is a similar result to that found in a 1993 survey of California prune orchards, and it suggests that some form of RDI management has already been found by growers to be an effective tool in almond orchard management. With further research we should be able to identify the appropriate target levels of SWP to control hull rot and improve the economic and horticultural performance of almond orchards, and also to recommend the irrigation strategies that will accomplish these targets.

Table 2. Summary of the observed and target SWP values for all locations in the 2001 almond RDI trials, as well as the treatment effects on hull splitting, hull rot and yield (where data were available).

Location	Average SWP prior to hull split (Bar) RDI target: -7 to -9		Average SWP during hull split (Bar) RDI target: -14 to -18		Average SWP after hull split (Bar) RDI target: -7 to -9		Effects on Hull splitting		Hull rot (strikes per tree)		Yield (lbs nutmeats per acre)	
	Grower	RDI	Grower	RDI	Grower	RDI	Grower	RDI	Grower	RDI	Grower	RDI
Corning (A)	-8.9	-9.1	-9.6	-11.1	11.2	-13.0	(No difference)		0	0	(No difference)	
Corning (B)	-9.3	-9.3	-9.8	-11.7	-14.7	-16.5	(No difference)		0	0	(No difference)	
Chico	-8.6	-8.7	-10.3	-15.5	-15.7	-15.4	(No difference)		4.0	1.9	1,890	1,820
Orland	-12.5	-12.0	-9.9	-13.8	-22.1	-19.0	80% on 7/27	71% on 7/27	4.6	0.5	2,910	3,030
Arbuckle	-11.0	-11.3	-8.0	-9.0	-12.0	-14.0	(No difference)		0	0	(No difference)	
Esparto	-15.1	-14.9	-12.4	-15.1	-12.0	-15.8	(No difference)		2.1	1.9	2,160	1,970
Salida	-11.8	-12.3	-10.8	-20.0	-12.7	-11.5	(Not Determined)		44.1	27.2	(1.34 g/nut)	(1.43 g/nut)
Madera (A)	-17.7	-17.8	-18.9	-18.1			(No difference)		0	0	(No difference)	
Madera (B)	-15.3	-16.4	-18.0	-18.1			(No difference)		15.1	7.8	(No difference)	
Madera (C)	-12.2	-14.1	-16.0	-18.1			(No difference)		0	0	(No difference)	
Kern	-10.5	-10.5	-13.3	-17.8	-12.5	-12.6	(No difference)		8.7	9.1	(No difference)	

Additional figures: The following 12 figures represent the SWP data collected at all sites.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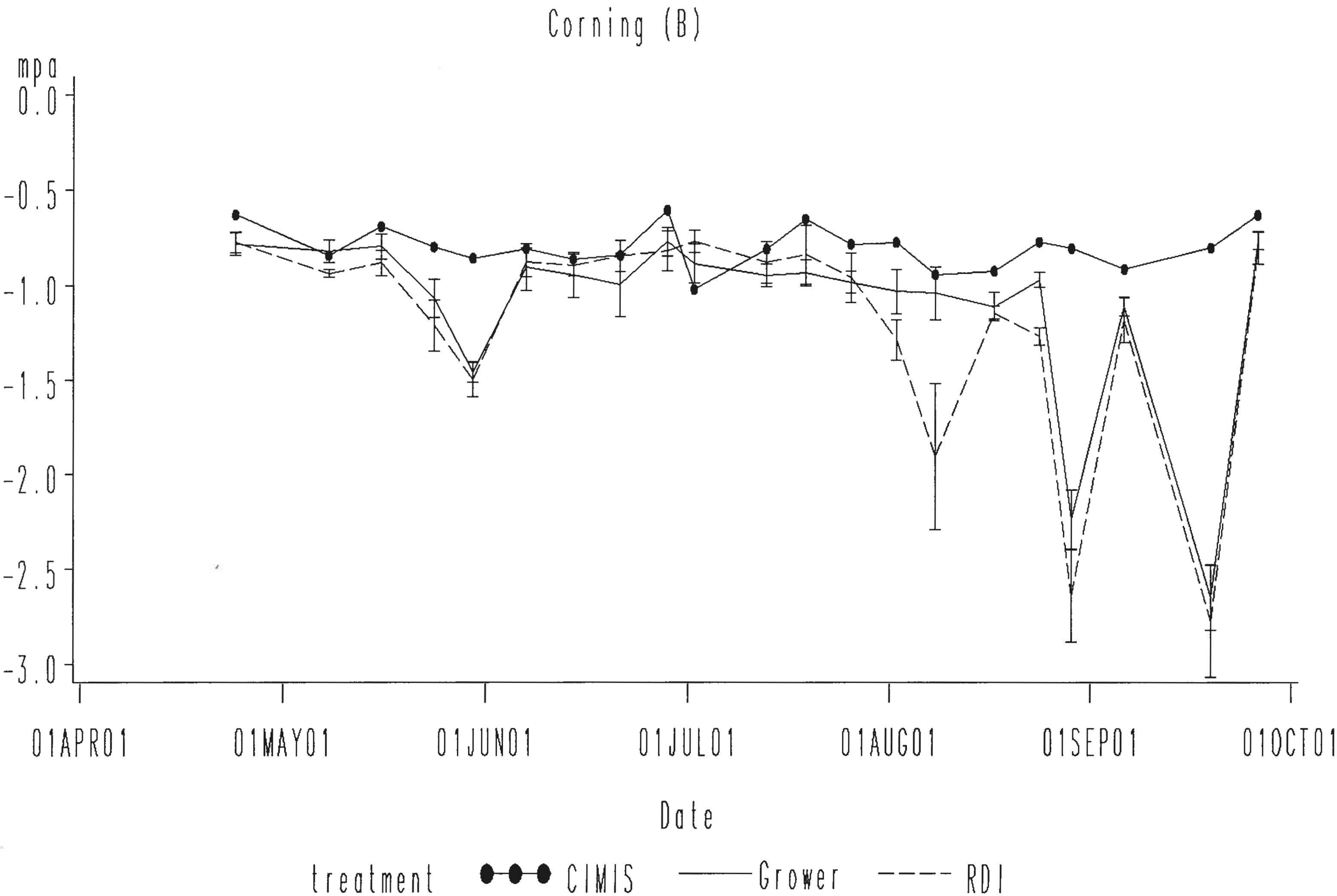
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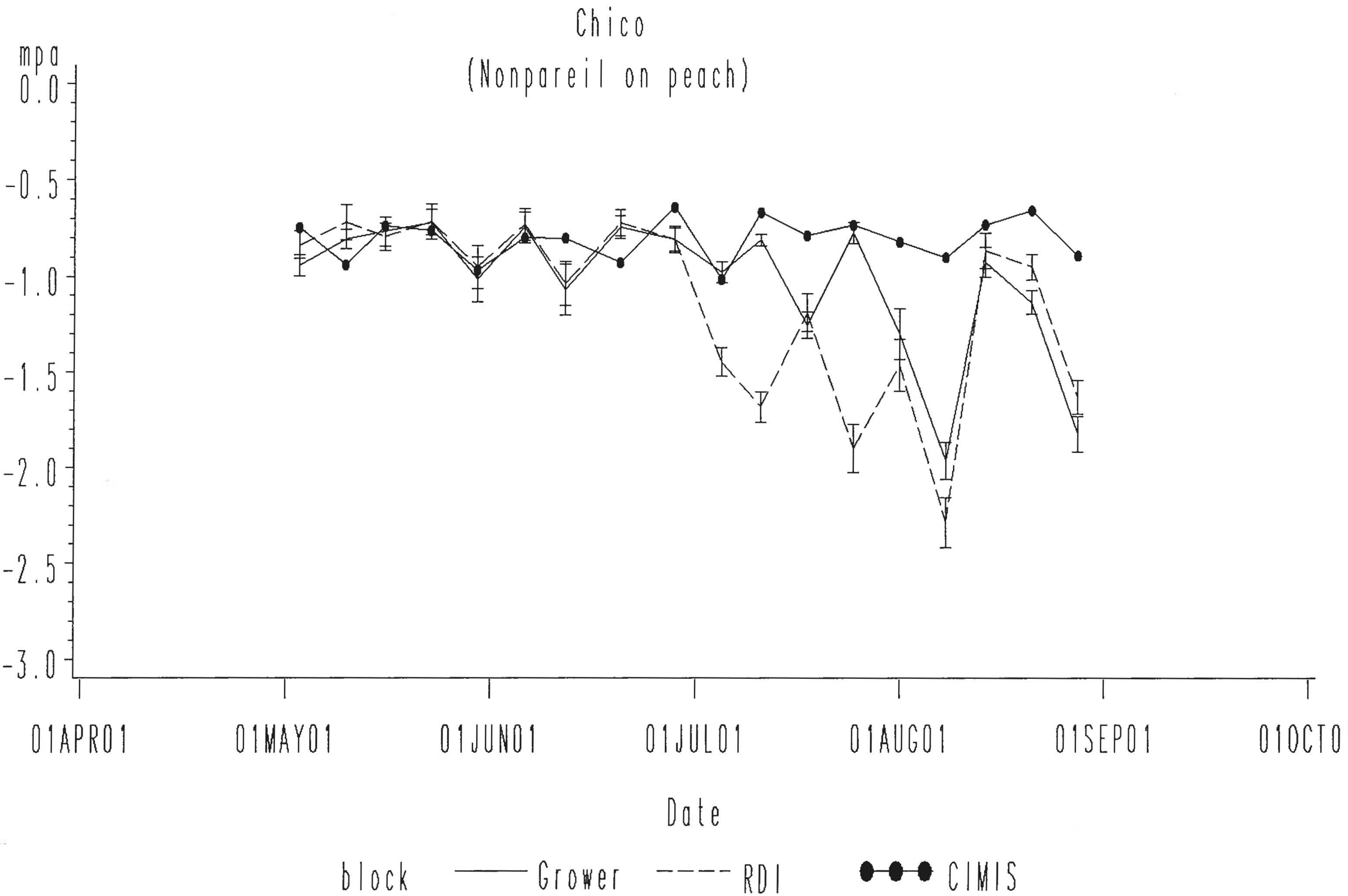
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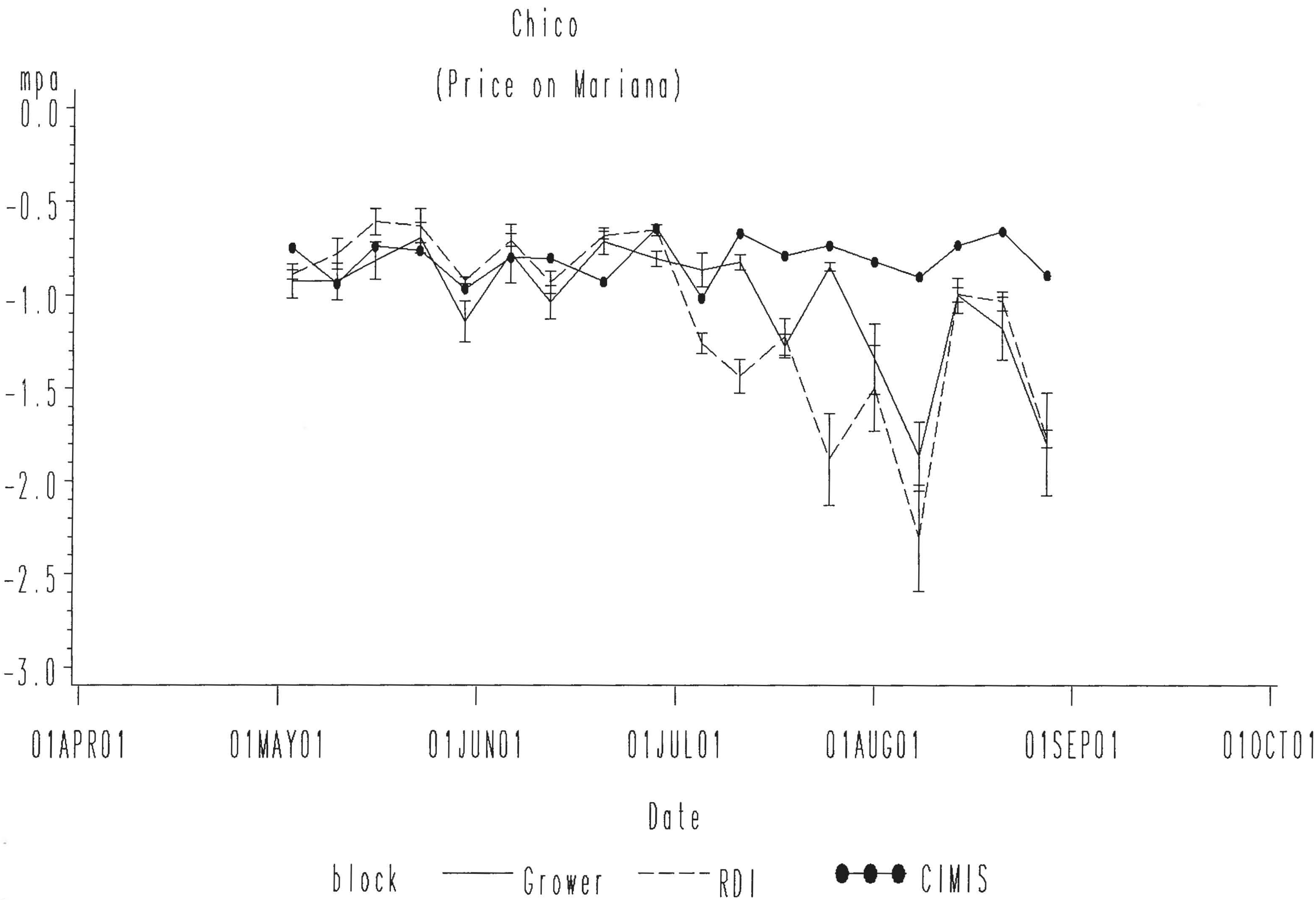
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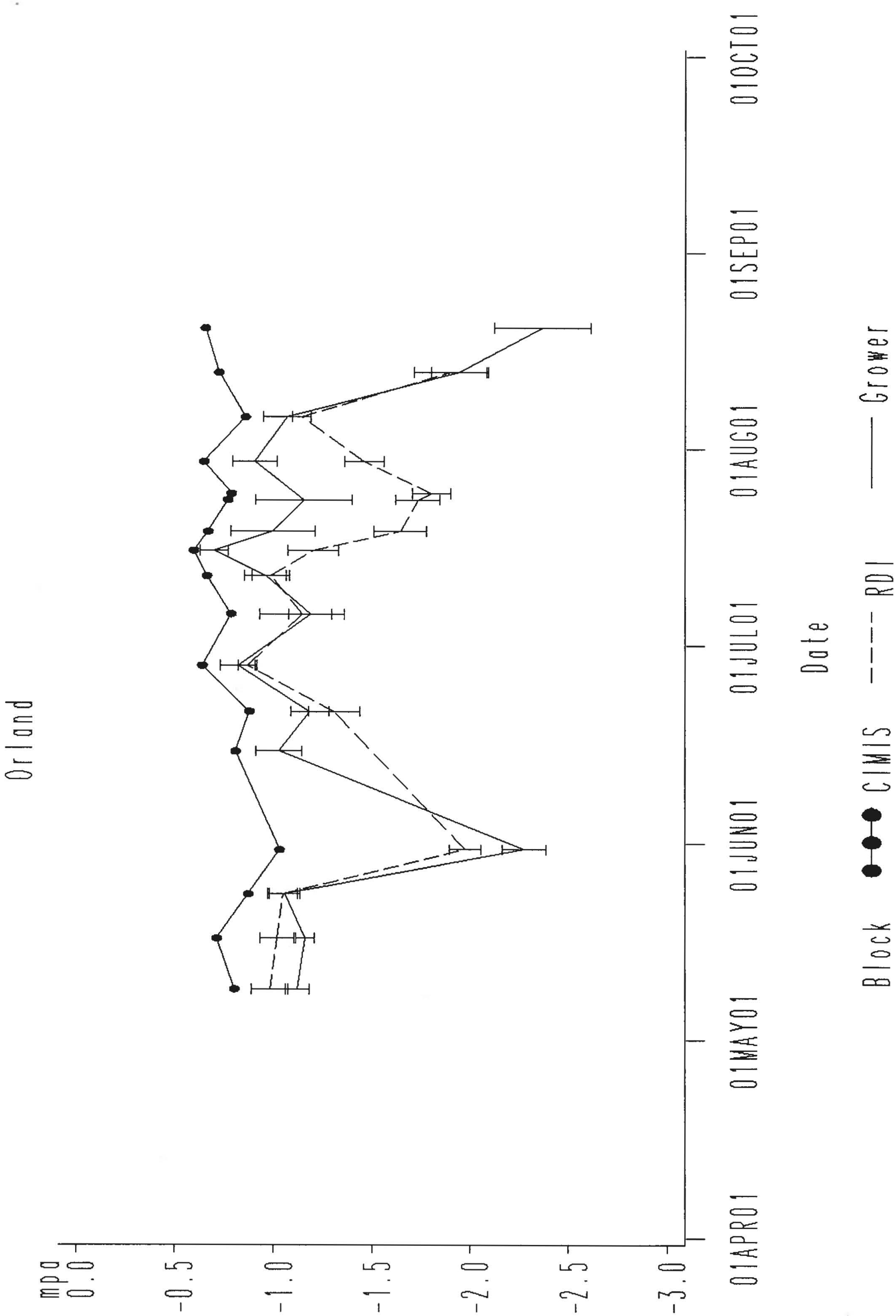
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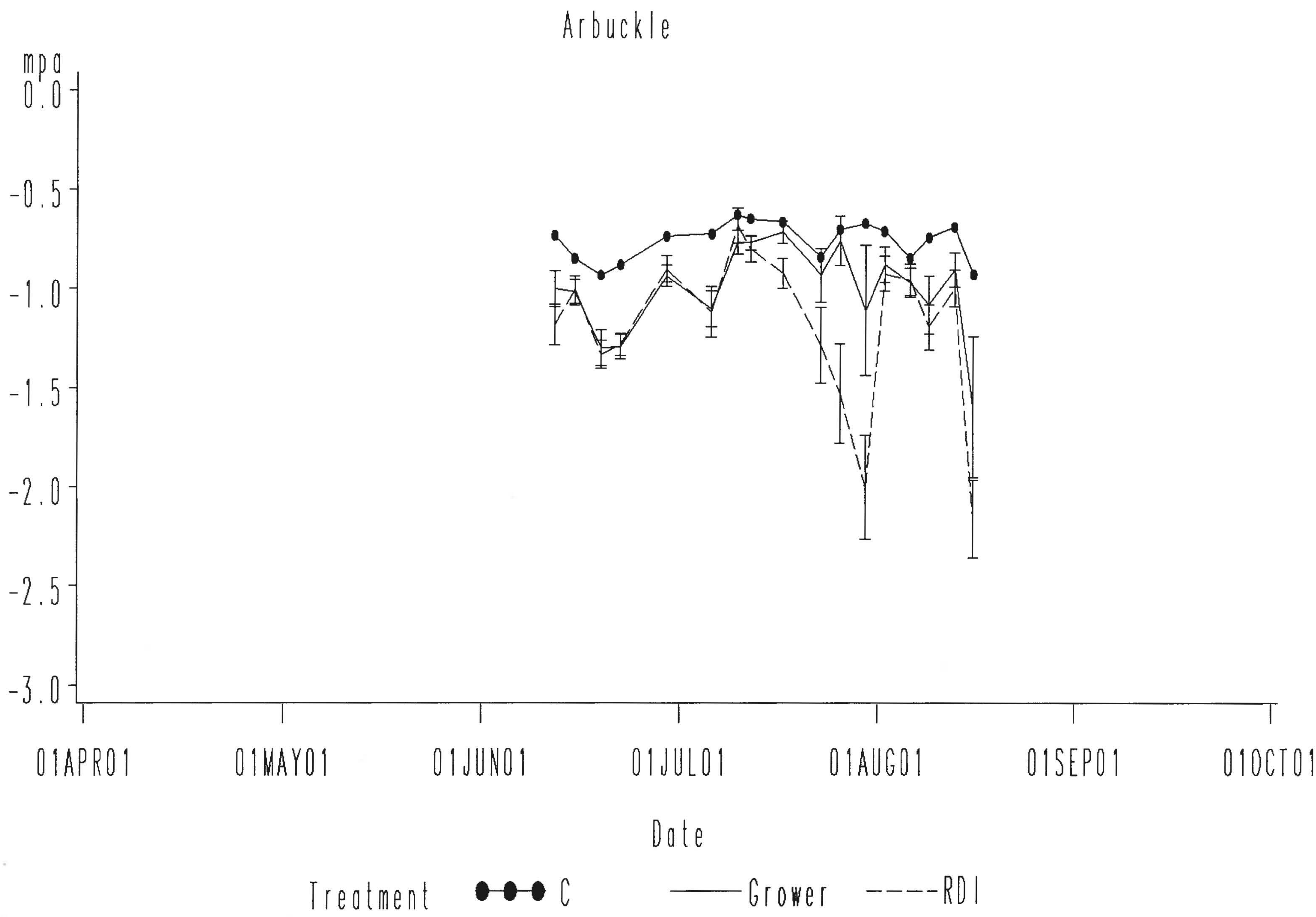
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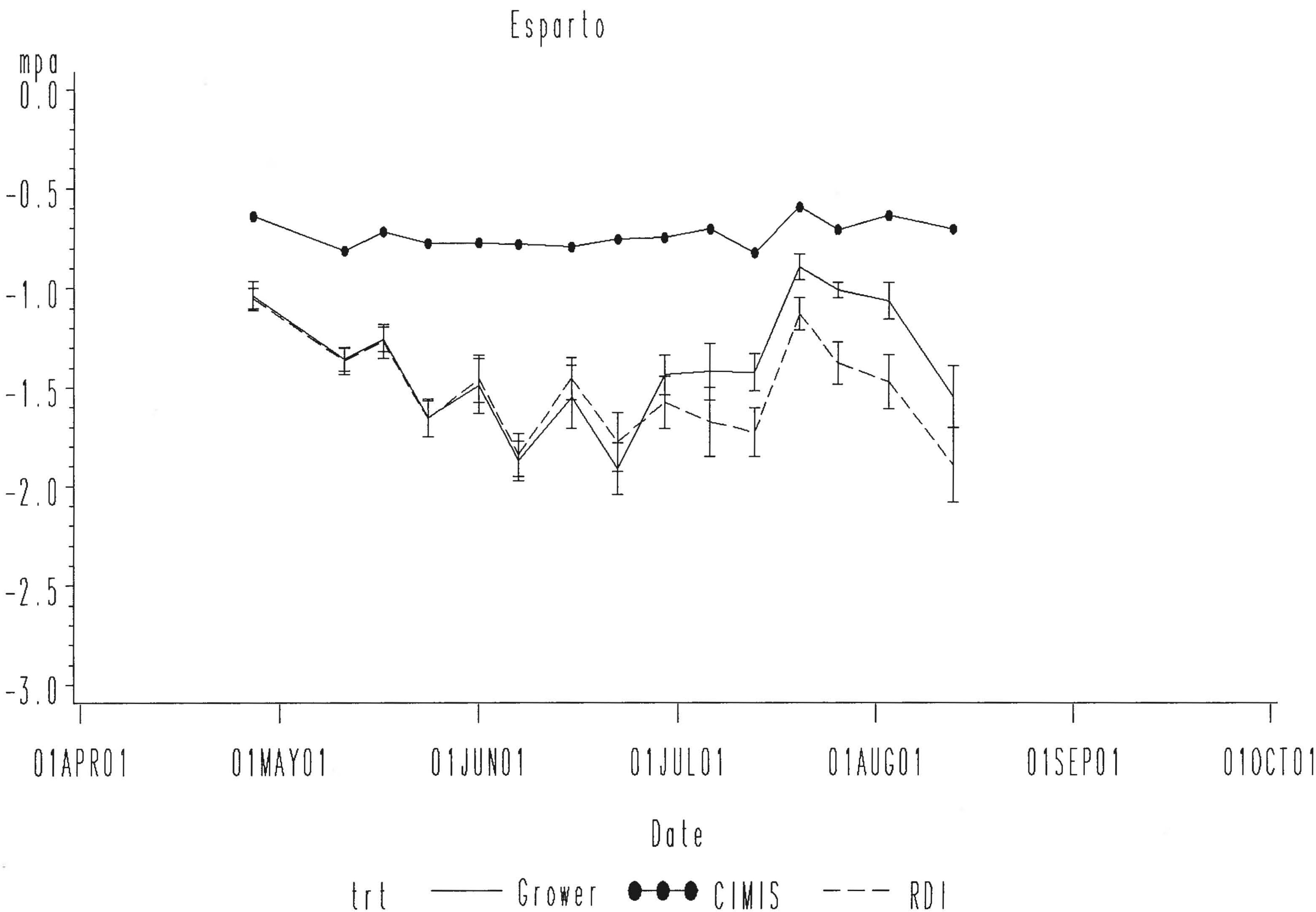
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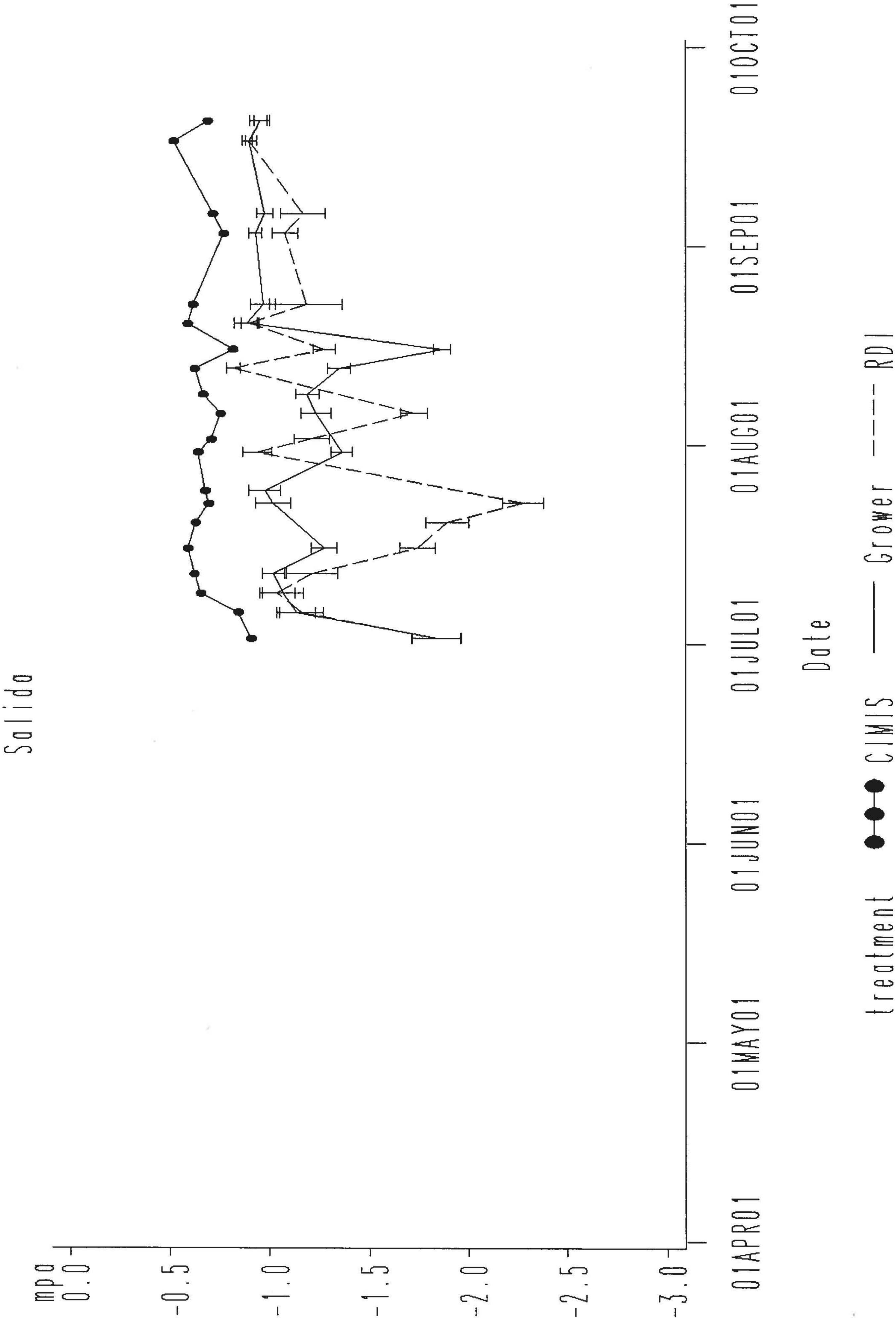
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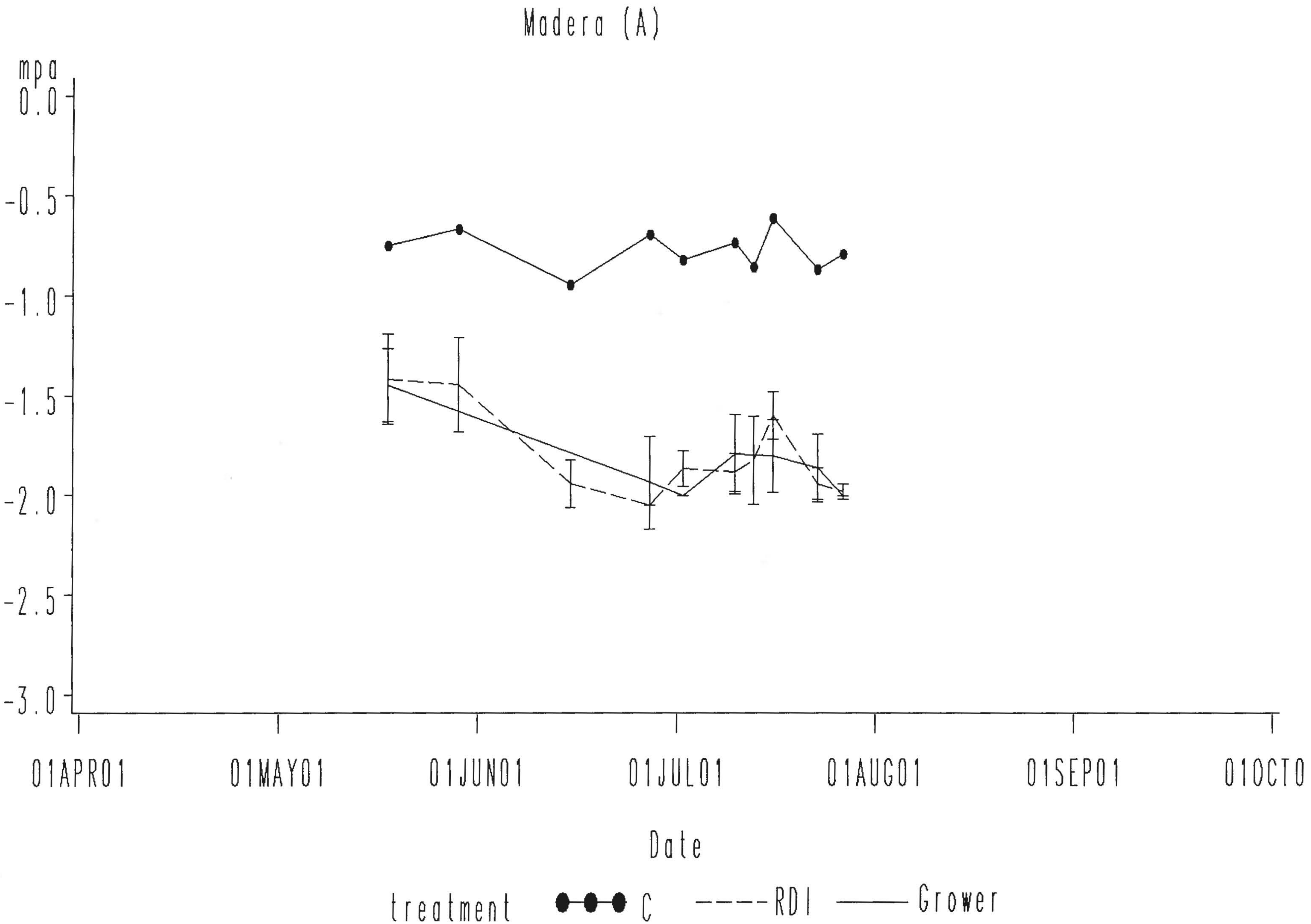
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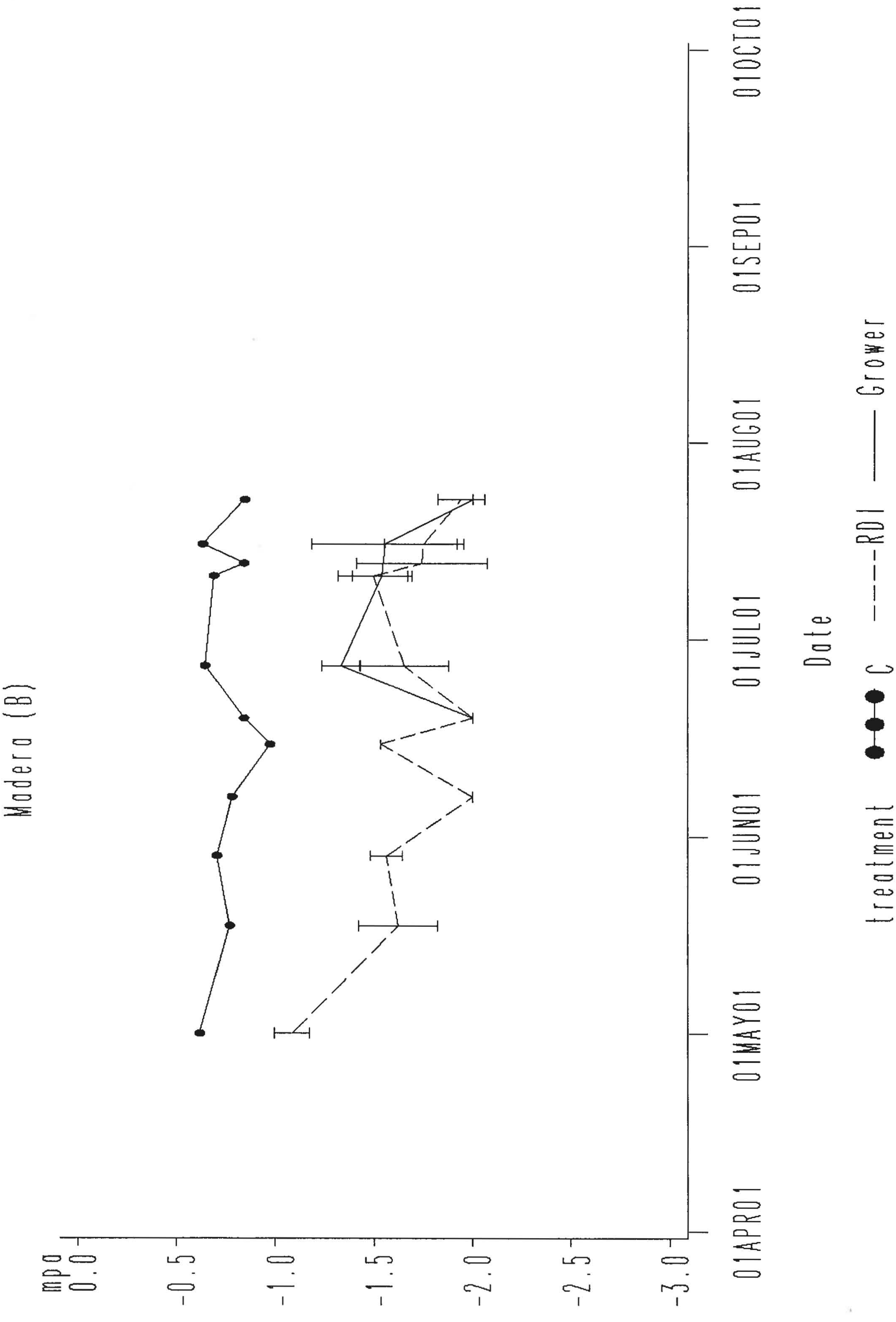
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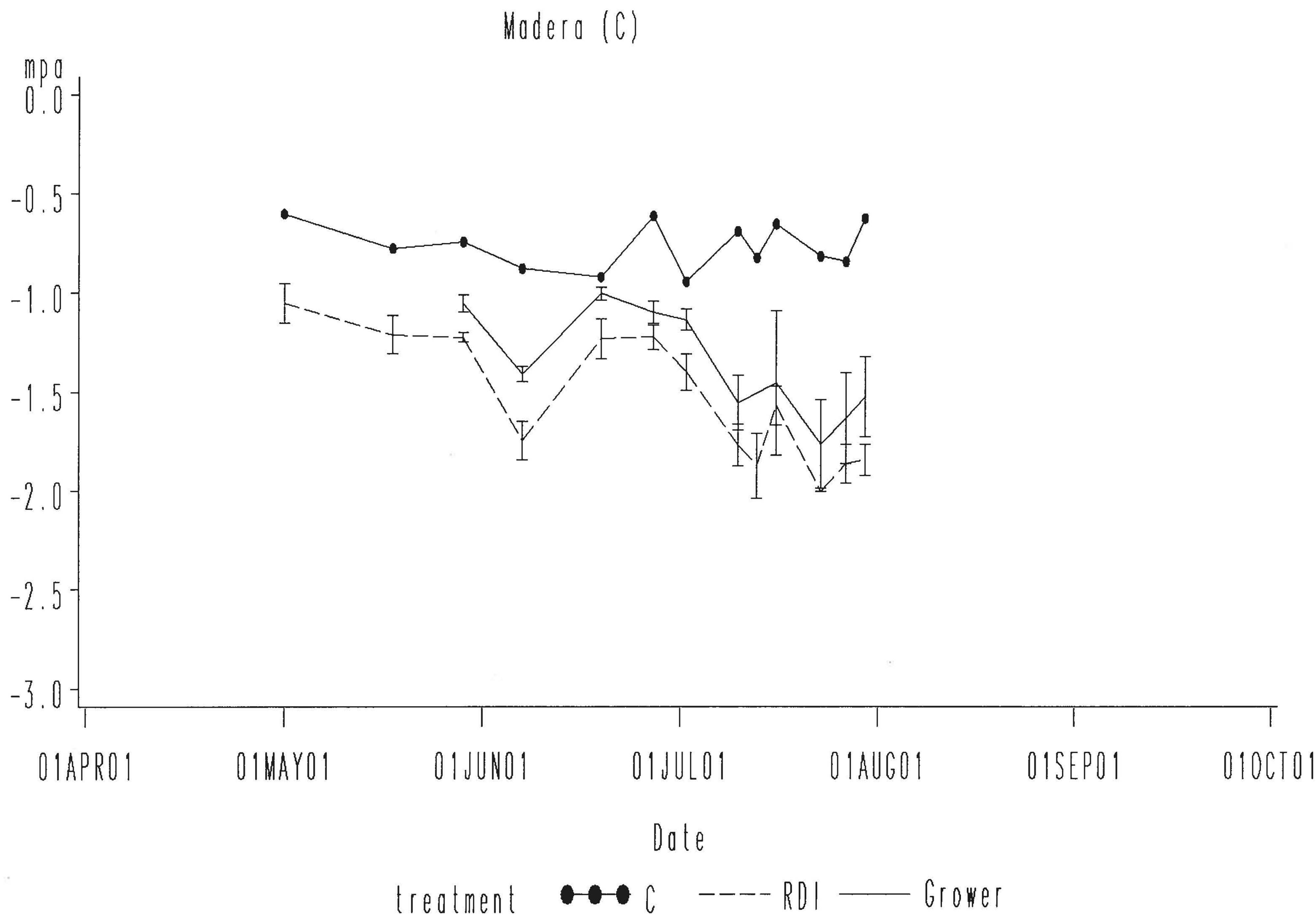

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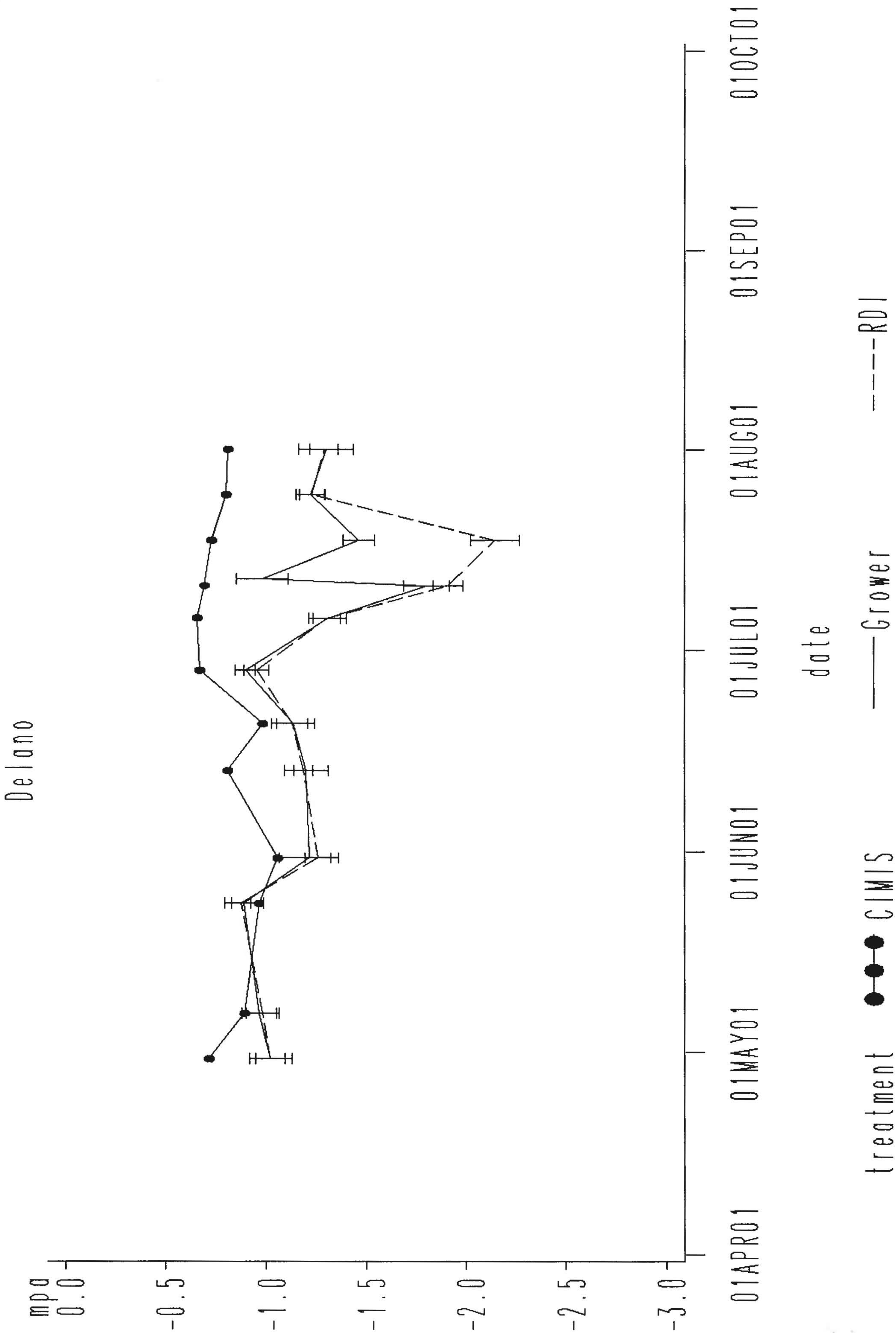
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