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Agronomy

Effects of gibberellic acid and sowing date on harvest time and yields of seed-grown globe artichoke (*Cynara scolymus* L)

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Summary — A 2 year research project was carried out in Sicily (south Italy), in order to study the effects of gibberellic acid (GA_3) (0, 1, 2 or 3 plant applications at 60 ppm) and sowing date (from 1 July to 10 August) on the timing of production and head yield of globe artichoke variety Orlando, a new seed-grown F_1 hybrid. Regardless of sowing date, untreated plants of Orlando produced heads the next spring, confirming that in the Mediterranean environment seed-grown varieties have to overcome the winter season or part of it to meet their cold requirement for flower initiation. GA_3 application replaced this cold requirement, allowing autumnal production. GA_3 effectiveness, however, was more evident in early sowings than in later ones. In fact, a combination of early sowings (1 and 10 July) and GA_3 application (2 or 3 times) resulted in a pattern of head production of Orlando similar to that of Violetto di Sicilia (VS), a typical early vegetatively propagated variety. In addition, the total cumulative yield at the end of cycle was significantly higher in Orlando than in VS.

***Cynara scolymus* L = globe artichoke / seed-grown plant / sowing date / gibberellic acid / harvest time**

Résumé — Influence de l'acide gibbérellique et de la date de semis sur le calendrier de production et le rendement de l'artichaut multiplié par graines. *La multiplication de l'artichaut (*Cynara scolymus *L) par graines offre beaucoup d'avantages par rapport à la multiplication par voie végétative : diminution des frais de plantation, homogénéité du développement des plantes, garantie phytosanitaire, facilité et rapidité de diffusion des nouvelles variétés, obtention du rendement maximal des plantes dès la première année. Cependant l'introduction au champ sur une grande échelle des variétés par graines dans la zone méditerranéenne est limitée parce qu'il n'est pas possible d'obtenir la production en automne à cause des exigences en froid de ces variétés pour l'induction florale. Afin de mettre au point une technique pour la production automnale des variétés à multiplication par semences qui pourrait faciliter leur diffusion, on a étudié dans 2 localités de Sicile (Catania et Siracuse) l'influence de différentes dates de semis (du 1er juillet au 10 août) et traitements avec l'acide gibbérellique – GA_3 (0, 1, 2, 3 applications à une concentration de 60 ppm) sur le calendrier de production ainsi que sur le rendement d'Orlando, nouvelle variété à multiplication par semences. Pour toutes les dates de semis, les plantes du traitement témoin de la variété Orlando ont produit les capitules au printemps. Le traitement avec GA_3 a entraîné une anticipation de la date de maturation d'autant plus élevée que l'époque de semis a été précoce ; la combinaison de semis précoces (1, 10 juillet) et l'application de GA_3 (2 ou 3 fois) ont permis*

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d'obtenir un calendrier de production semblable à celui du «Violetto di Sicilia» (VS), variété à multiplication végétative. En outre, les rendements en capitules cumulés à la fin de la récolte ont atteint des valeurs significativement plus élevées pour Orlando que pour VS.

Cynara scolymus *L* = *artichaut / multiplication par semences / acide gibbérellique / calendrier de production*

INTRODUCTION

The globe artichoke (*Cynara scolymus* L) is a perennial rosette plant, native of the Mediterranean Basin. Traditionally it is propagated vegetatively by basal stem pieces (stumps) and suckers in a dormant or nondormant state. Recently, seed-grown varieties with plant uniformity have been introduced (Basnizki and Zohary, 1987, 1994). These are mainly spring-producing varieties (Mauromicale *et al,* 1989; Elia *et al,* 1991; Mauromicale, 1994), while traditional varieties cultivated in the Mediterranean Basin like Violetto di Sicilia (VS), Violet de Provence, Blanca de España, Spinoso Sardo, start their production in autumn (Pécaut, 1993).

Globe artichokes behave like biennials, since they require low temperatures, followed by long days for flower formation and stem elongation (Basnizki, 1985; Foury, 1987; Pécaut, 1993). In the Mediterranean areas, plants are sown in summer, complete their juvenile phase before winter, and produce in the next spring. This production period counteracts the economic advantages of seed planting, such as reduction of the planting costs, easier mechanization, full production in the first year of planting, improvement of crop sanitation, and easier and quicker introduction of new varieties (Pécaut *et al,* 1981; Basnizki and Zohary, 1987; Foury and Pécaut, 1988; Mauromicale *et al,* 1989). Harvesting in autumn is, therefore, an absolute requirement to ensure a successful introduction of seed-grown varieties.

Gibberellic acid (GA_3) treatment causes earlier harvest in vegetatively propagated varieties (Marzi and Dellacecca, 1969; Snyder *et al,* 1971; De Malach *et al,* 1976; Foury, 1977; Foti and La Malfa, 1981; Mangano and Signorelli, 1981; Patourel and Foury, 1981; Foury *et al,* 1983). Recent research performed on seed-grown varieties indicated that GA_3 effectiveness on earliness depends on sowing dates, the sensitivity of each variety to GA_3, and the number of GA_3 treatments (Elia *et al,* 1992; Schrader, 1992; Basnizki and Goldschmidt, 1994; Mauromicale, 1994).

The purpose of this study was to evaluate the effects of different GA_3 applications and sowing dates on harvest time and yield of a new seed-grown hybrid.

MATERIALS AND METHODS

Localities

Field experiments were conducted in 1990–1991 in Sicily at Siracusa (36°58' N, 15°11' E, 10 m above sea level) and in 1991–1992 at Catania (37°27' N, 15°04' E, 10 m above sea level), which are highly representative of the areas of globe artichoke cultivation in Italy. These areas are characterized by mild winters and dry, hot summers. The mean daily temperature from December to March ranges from 10.7°C to 12.1°C. Frosts are virtually absent in Siracusa (2 events in 30 years) but quite frequent (20 events in 30 years) in Catania. In both areas, temperatures above 35°C are encountered every year during the summer. These climates make it possible to harvest early vegetatively propagated varieties during the period autumn–winter–spring.

Experimental design and GA_3 application

The experiments were set up in randomized split–plot design with 4 replications and involved the treatments reported in table I. In 1990, sowing date was the main plot, GA_3 treatment the sub-plot. In 1991, sowing or planting date was the main plot, variety the sub-plot and GA_3 treatment the sub-sub-plot. To simplify the text, we will use the sowing date also as the planting date. In both years, each plot consisted of 12 plants.

Aqueous solutions of 60 ppm of GA_3 (Berelex, ICI Soplant) were acidified to pH 4 by urea phosphate (Basnizki *et al,* 1986) and then applied early in the morning when plants were turgid. A single application was made using a hand-sprayer on leaves until run-off. According to the different plant dimensions, the spray volume was 100, 300, 400 ml $plant^{-1}$, when application was at the stage of the 8th, 15th and 25th expanded leaf, respectively. The first, second and third GA_3 applications were made on 14 and 29 September and 14 October (sowing of 10 July 1990), on 8 and 25 October and 10 November (sowing of 10 August 1990), on 6 and 21 September and 6 October (sowing of 1 July 1991), on 21 September and 6 and 22 October (sowing of 20 July 1991) and on 20 December and 9 and 31 January (sowing of 20 August, 1991).

Table I. Treatments under study.

Sowing date	*Variety*	*GA_3 application*
1990–1991		
10 July	Orlando	Untreated plants (control)
10 August	Orlando	GA_3 applied once at 8-leaf stage GA_3 applied twice at 8+15-leaf stage GA_3 applied 3 times at 8+15+25-leaf stage
1991–1992		
1 July	Orlando and VS	Untreated plants (control)
20 July	Orlando and VS	GA_3 applied twice at 8+15-leaf stage
10 August	Orlando and VS	GA_3 applied three times at 8+15+25-leaf stage

Plant material and management practices

VS is the main Italian variety and is cultivated for over 70% of the total artichoke production area (Mauromicale, 1987). It is vegetatively propagated and produces head when irrigated, from October–November to May, with a peak in March–April. Hybrid Orlando (previous name HU 271) is a seed-grown variety from the Department of Evolution, Systematics and Ecology, The Hebrew University of Jerusalem, Israel, which is harvested in March–April (Basnizki, personal communication).

Crop planting by ovoli (dormant suckers) for VS and sowing by seed (achenes) for Orlando were carried out directly in the field on the same dates (table I).

Data collection

Heads (capitules) were harvested at marketing stage regardless of size. During the fall–winter harvest period (from October to February), harvesting was once a week. In the spring (from March to May) harvesting was done every 3–4 d. All heads were weighed without scape (stalk). In this work, only marketable heads were considered.

Data analysis

Results were analyzed by ANOVA and means compared by the LSD test, provided the *F* test was significant. A separate analysis was conducted for each sowing date. Only the data of cumulative yield at end of harvest were analyzed including sowing dates.

RESULTS

Harvest time

The combination between early sowings and appropriate treatments with GA_3 was able to modify substantially the harvest period of seed-grown Orlando F_1. The effectiveness of GA_3 proved greater with an earlier sowing date.

Siracusa 1990–1991

The harvest of untreated plants from the first and the second sowing date started on 11 and 22 March, respectively, and continued until 16 April. From the 10 July sowing, plants treated with GA_3 began to produce on 31 October (113 d after sowing) and continued until 16 April regardless of the number of applications (fig 1). From the 10 August sowing, in contrast, the beginning of the harvest was correlated with the number of GA_3 applications. A single GA_3 application enabled harvesting on 12 March, while, 2 or 3 consecutive applications caused the start of harvest as early as 5 January, 66 d before (fig 1).

Catania 1991–1992

In this trial, the response of hybrid Orlando to GA_3 and sowing date was substantially similar to that of the Siracusa trial. The harvest of GA_3-

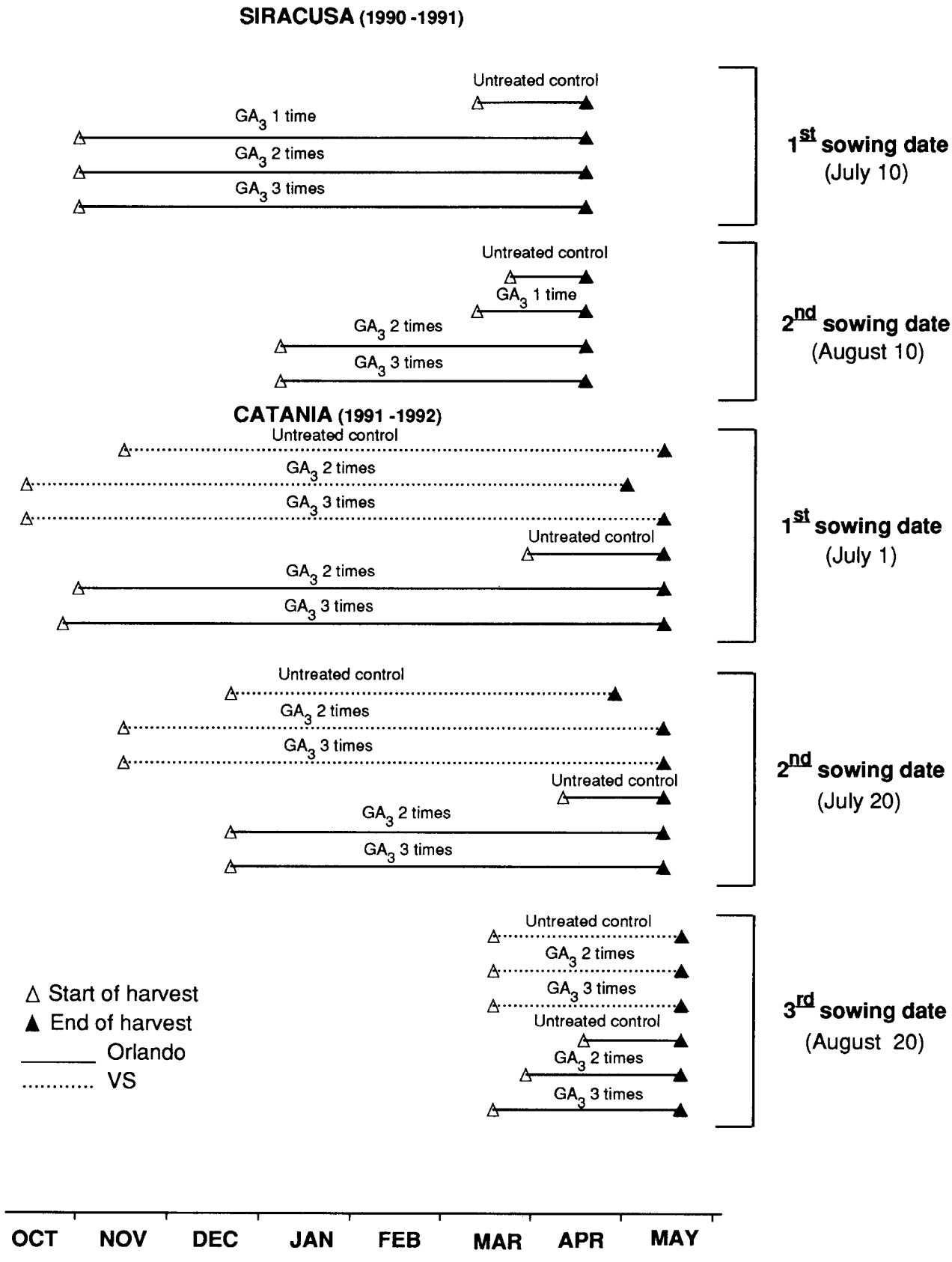

Fig 1. Effects of sowing dates and GA_3 treatments on the harvest period.

treated Orlando sown on 1 July started at the end of October. This is about 2 weeks later than vegetatively propagated VS with GA_3 treatments and 2 weeks earlier than VS without GA_3. Sowing on 20 July delayed the start of harvest until 20 December in GA_3-treated Orlando and in untreated plants of VS. When sowing was only on 10 August, the harvest of GA_3-treated Orlando began on 17 March after 3 applications and on 28 March after 2 applications. This is only one month before untreated plants, and is contemporary with GA_3-treated or untreated plants of VS (fig 1).

In other words, delay in sowing from 1 July to 10 August retarded harvests of GA_3-treated Orlando or VS by 5 months (fig 1).

Monthly yield accumulation and cumulative yield at the end of harvest

In both trials, sowing dates and GA_3 also significantly affected the monthly harvests and yields, either in number or weight of heads per plant.

Siracusa 1990–1991

On both sowing dates, the increase in the number of GA_3 applications (from 1 to 3 applications) resulted in a significant increase in head production during the autumn and winter (figs 2 and 3). On 31 December (still a profitable marketable date for production in Mediterranean areas) plants sown on 10 July and treated 3 times with GA_3, produced 2.4 heads corresponding to 0.333 kg plant^{-1}. This is an increase of 104% in number and 134% in weight compared with the production of plants which received 2 GA_3 applications, and of 443 and 324% compared with those with 1 GA_3 application. On 31 March, differences due to the different numbers of GA_3 applications were even more remarkable: 6.8 heads plant^{-1} corresponding to 0.940 kg plant^{-1} with 3 GA_3 applications, 2.4 heads plant^{-1} (0.303 kg plant^{-1}) with 2 applications, and 0.75 heads plant^{-1} (0.135 kg plant^{-1}) with 1 application.

Untreated plants produced only 0.62 heads plant^{-1} (0.082 kg plant^{-1}) until 31 March (figs 2 and 3).

Regarding the 10 August sowing, only repeated applications of GA_3 were effective. Three applications significantly increased yields obtained in February and March in comparison to 2 applications (figs 2 and 3). Plants with a single application of GA_3 and the untreated control produced approximately 97% of the total yield (in number or in weight) only in April.

The delay of sowing from 10 July to 10 August weakened GA_3 effect on early yield. From the first sowing, 3 applications of GA_3 resulted in a harvest of 2.4 heads plant^{-1} (0.333 kg plant^{-1}) at the end of December. From the second sowing, the yield reached approximately the same level only at the end of February (figs 2 and 3).

In both sowings, GA_3 had opposite effects on cumulative yield at the end of harvest (fig 4). In the first sowing, 1 or 2 GA_3 treatments reduced the yield significantly in comparison to control (untreated plants) but 3 applications did not. However, in the second sowing, GA_3 treatments significantly increased yield (fig 4).

Catania 1991–1992

For the 1 July sowing, during the period October–January, in GA_3-treated Orlando (regardless of the number of applications), the yield (in number or in weight of heads) was similar to that of GA_3-treated VS, and significantly higher than untreated VS (figs 5 and 6). During the period February–March, the yield of Orlando treated 3 times was higher than that of the plants which received 2 treatments and not significantly different from that of treated or untreated VS. Untreated Orlando produced 1, 87 and 12% of heads (in number or in weight) at the end of March, and in April and May, respectively.

The yield of GA_3-treated Orlando from the July 20 sowing (regardless of number of applications) was significantly lower during November–January, than that of GA_3-treated VS, but it was not different from that of untreated VS (figs 5 and 6). During March, the yield of Orlando treated 3 times increased considerably to 5.8 heads plant^{-1} (0.924 kg plant^{-1}), significantly overcoming yields of VS treated or untreated plants. Untreated plants of Orlando yielded 81 and 19% of their heads in April and May, respectively (figs 5 and 6).

Treatment with GA_3 was less effective in the August 10 sowing, where there was a spring harvest only. In both varieties, GA_3 allowed a generally higher rate of head production at an earlier date: March–April instead of May compared with the control. However, Orlando with 3 GA_3 applications exhibited a higher yield during April and May (figs 5 and 6).

Total yield cumulated at the end of the harvest was significantly higher for the third than for the

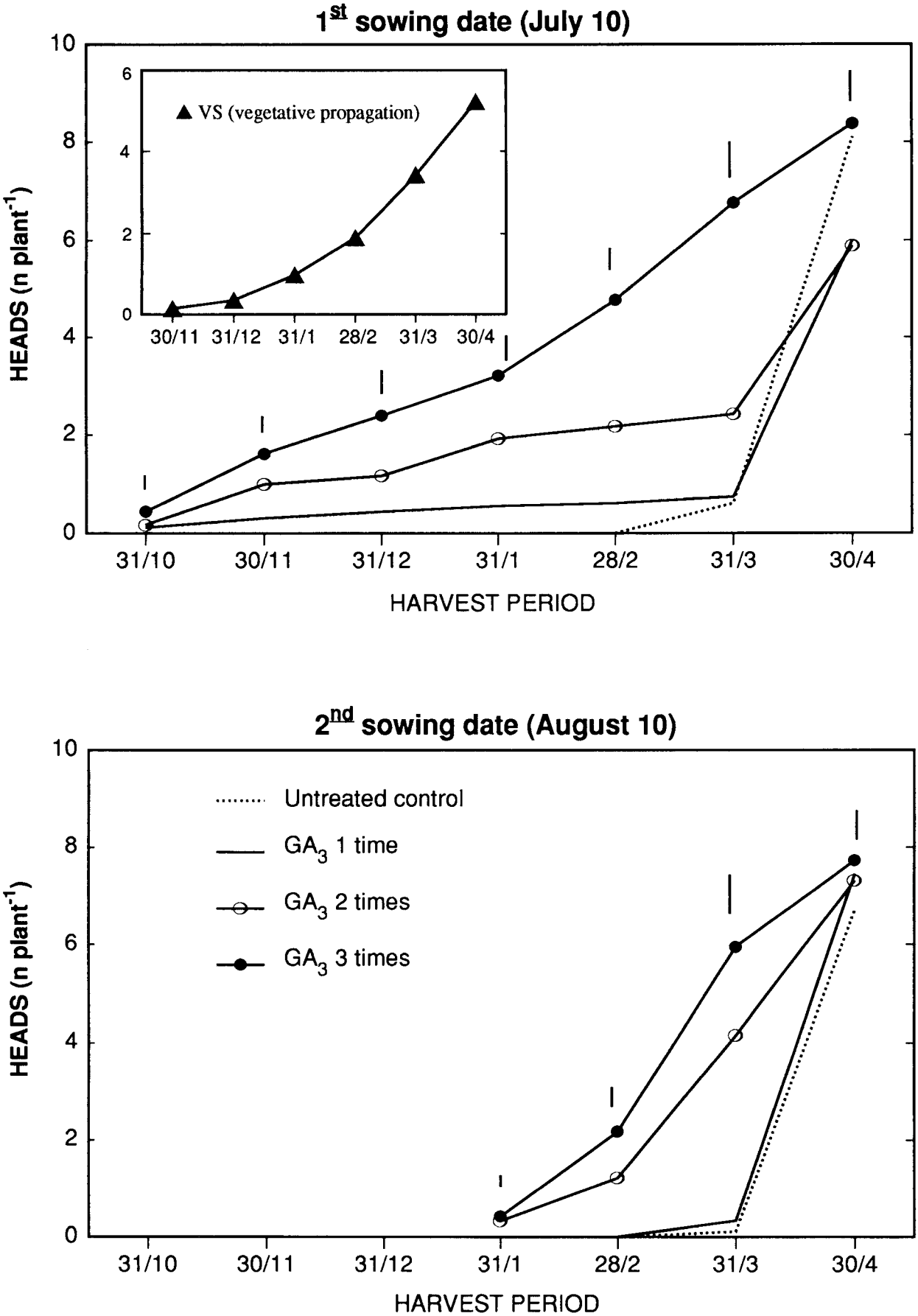

Fig 2. Siracusa, 1990–1991. Effects of sowing dates and GA_3 treatments on monthly number of heads accumulation of seed-grown variety Orlando. The vertical scale bar indicates LSD ($P \leq 0.05$). The inset shows an usual production pattern of the vegetatively propagated variety VS.

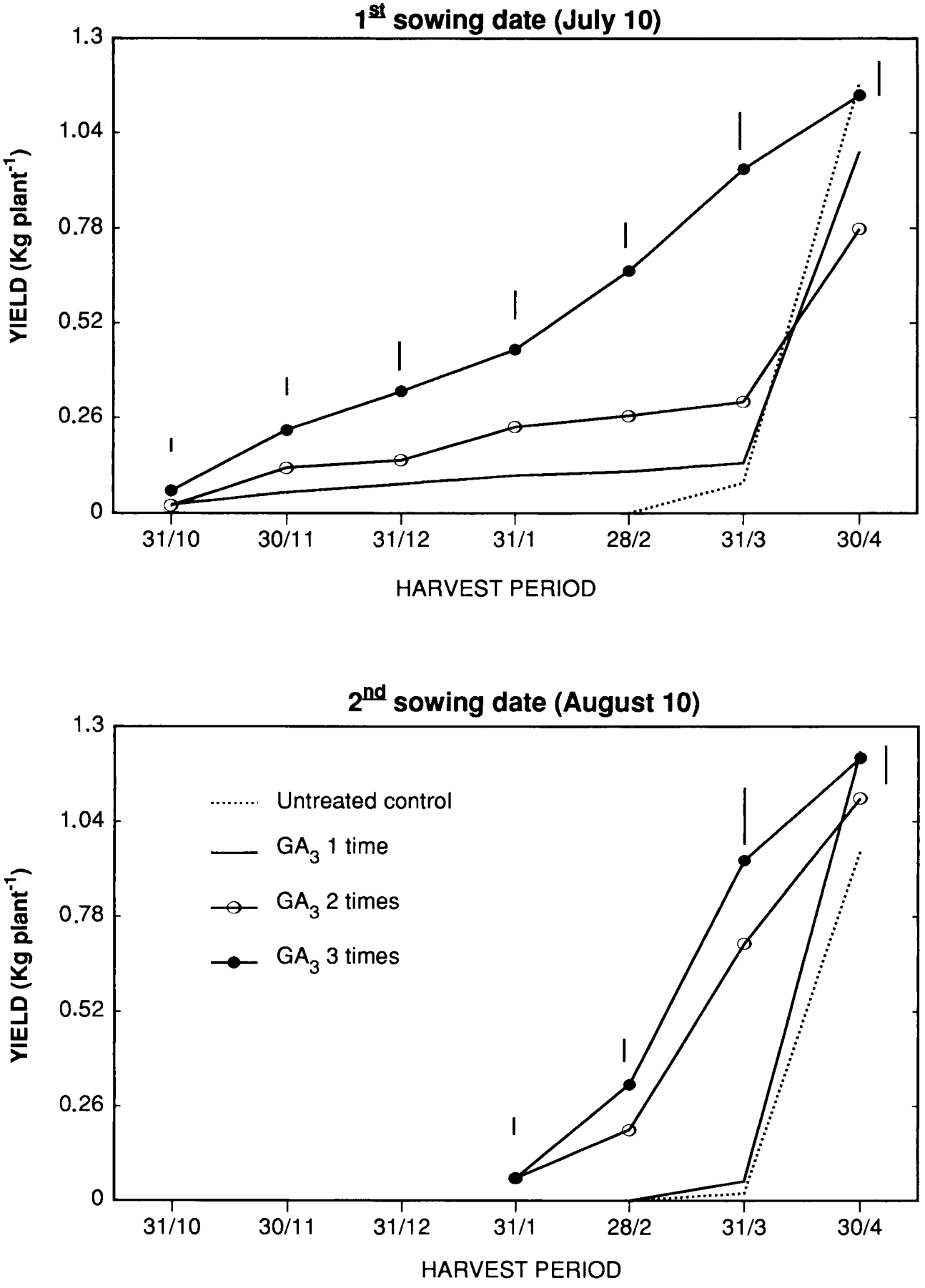

Fig 3. Siracusa, 1990–1991. Effects of sowing dates and GA_3 treatments on monthly heads yield accumulation of seed-grown variety Orlando. The vertical scale bar indicates LSD ($P \leq 0.05$).

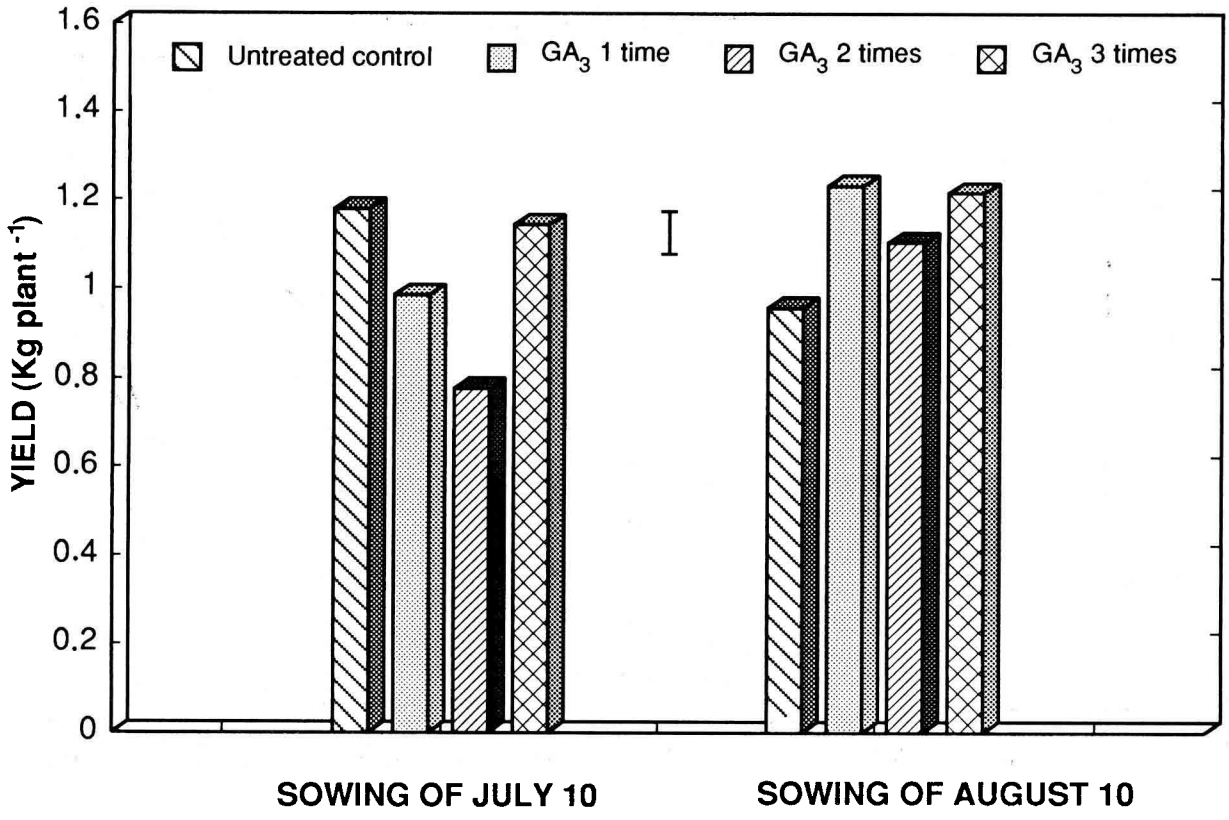

Fig 4. Siracusa, 1990–1991. Effects of sowing date x number of GA_3 treatments on cumulative heads yield of Orlando at the end of harvest. The vertical scale bar indicates LSD ($P \leq 0.05$).

second and for the second than for the first sowing date, for Orlando than for VS, and for plants treated 3 times with GA_3 or untreated than for the plants treated twice (fig 7). No significant interactions between the factors studied were detected.

Some observations

Plant homogeneity and vigour of Orlando were satisfactory and always higher than VS values.

GA_3 application increased plant vigour more in Orlando than in VS and it did not influence the marketable fitness of the heads.

Head characteristics (weight, shape, dimensions and scape height) were significantly influenced by variety, sowing date, GA_3 treatment and maturation date. We are still working on these results to present them in a future paper in this journal.

DISCUSSION AND CONCLUSIONS

The results of this research confirm that in the Mediterranean environment seed-grown varieties have to be subjected to the winter season or part of it to produce heads, but they also demonstrate that it is possible to obtain autumn production by combining sowing dates with GA_3 treatments. The correct combination between sowing date and GA_3 enabled uninterrupted harvesting of seed-grown Orlando from end of October to mid-May. The monthly productions were similar to those of VS.

For autumn harvesting, it is necessary to sow Orlando not later than 10 July and to apply 2 or 3 consecutive GA_3 treatments. In the Catania trial, sowing on 20 July and applying GA_3 2 or 3 times allowed a production starting in winter, almost at the same time and with the same monthly production as at Siracusa with sowing on 10 August. The longer duration from sowing to the beginning of the harvest at Catania in comparison to Siracusa is probably due to a slow plant growth during October–December as a result of lower mean minimum or maximum temperatures by 2.5 or 1.5°C, respectively.

The negative effect of late sowing on the earliness was evident when sowing was only on 10 August. In this case, harvesting of GA_3-treated plants was delayed until the early spring.

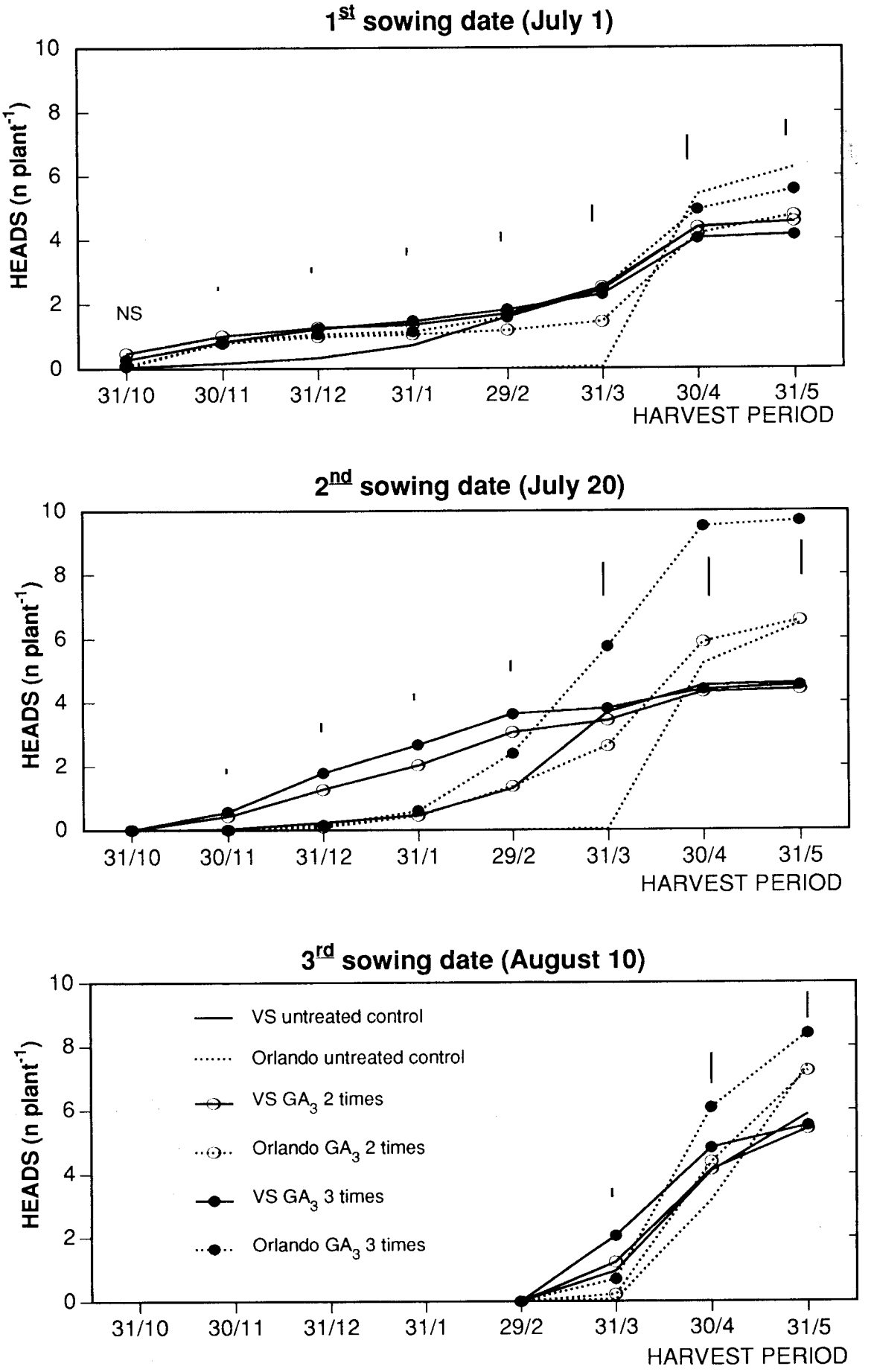

Fig 5. Catania, 1991–1992. Effects of sowing dates and GA_3 treatments on monthly number of heads accumulation of seed-grown variety Orlando and vegetatively propagated variety VS. The vertical scale bar indicates LSD ($P \leq 0.05$).

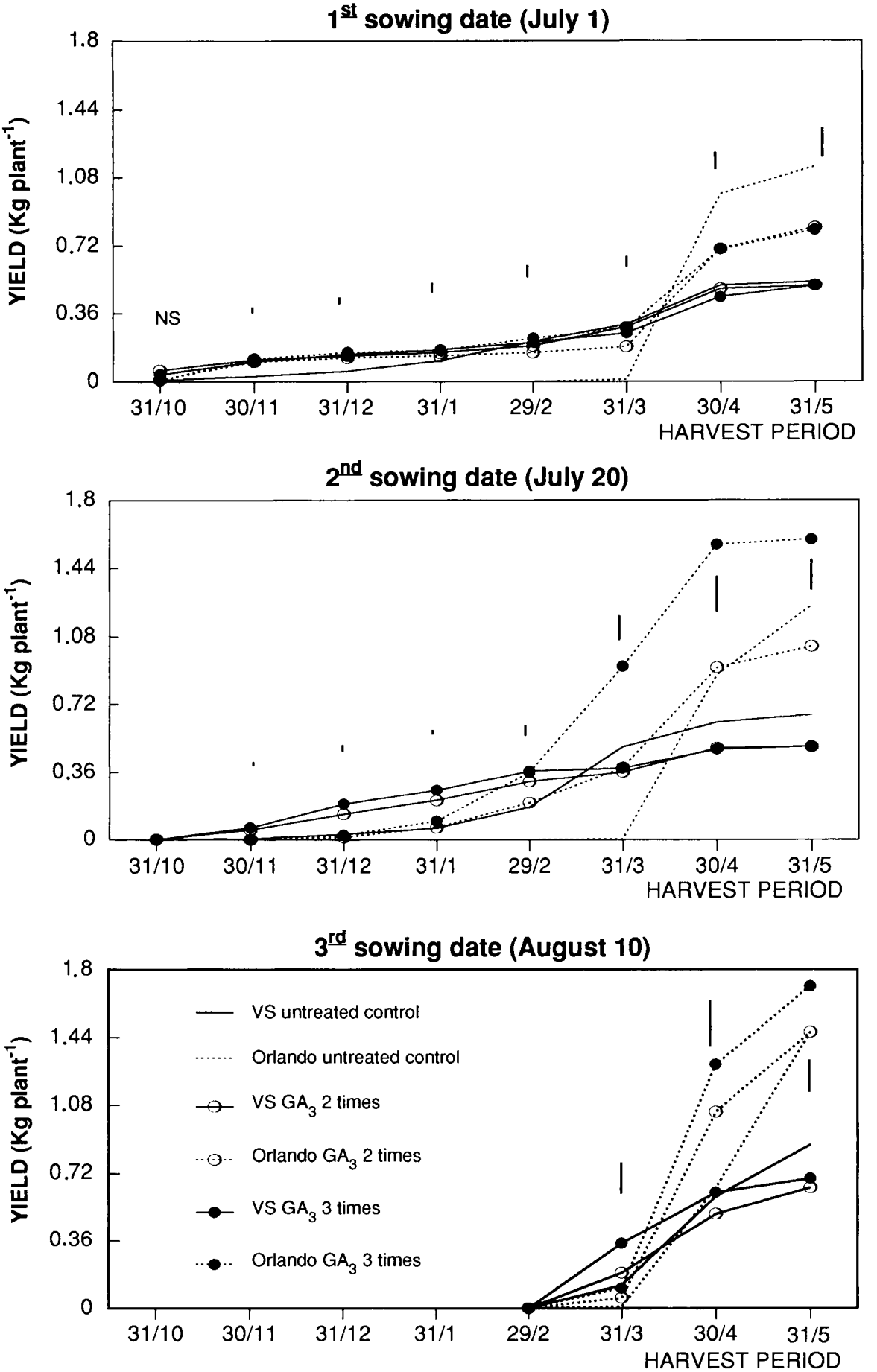

Fig 6. Catania 1991–1992. Effects of sowing dates and GA_3 treatments on monthly heads yield accumulation of seed-grown variety Orlando and vegetatively propagated variety VS. The vertical scale bar indicates LSD ($P \leq 0.05$).

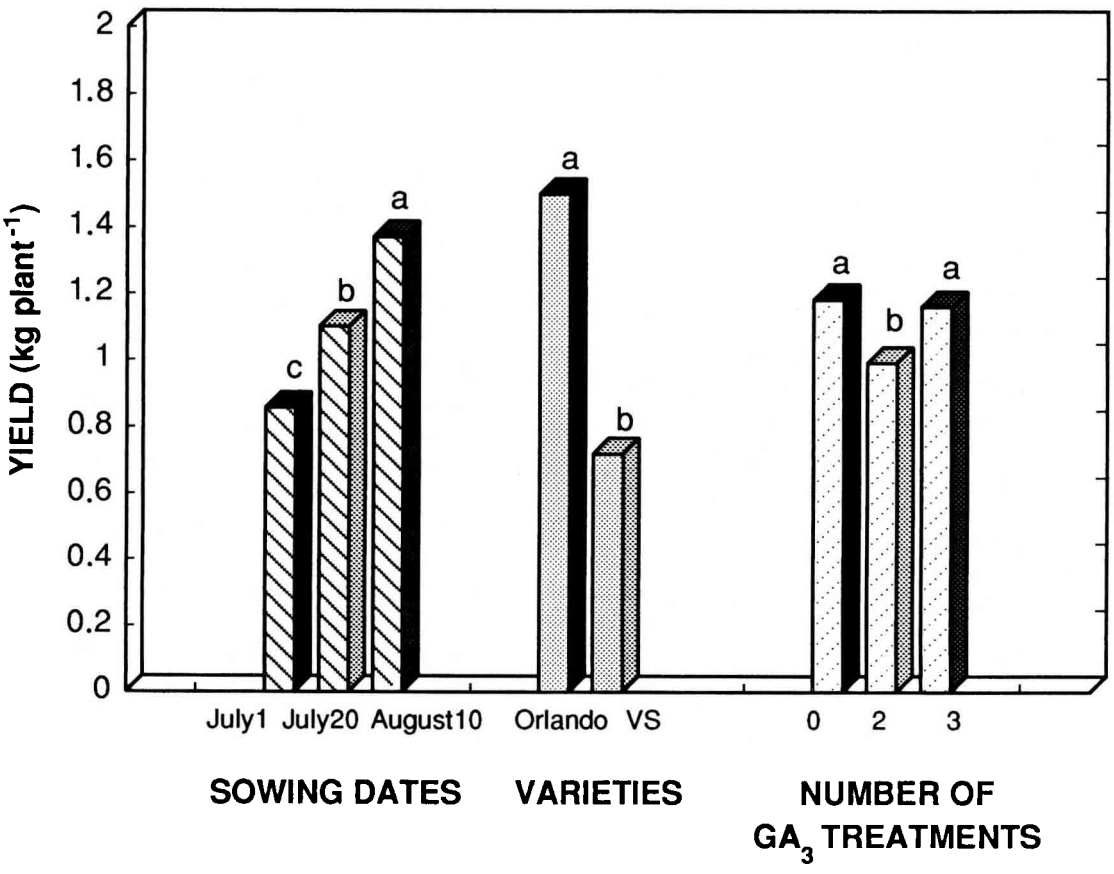

Fig 7. Catania, 1991–1992. Effects of sowing dates, number of GA_3 treatments and varieties on cumulative heads yield at the end of harvest. Yield, within a single factor, with different letters are significantly different ($P \leq 0.05$).

The results reported here contribute to knowledge on the possibility of exogenous GA_3 to stimulate flowering in the seed-grown globe artichoke. The floral induction of seed-grown plants requires a chilling of about 250 h at temperatures below 7°C (Foury and Pecaut, 1988). At high temperatures (≥ 18°C), in fact, plants grown under different day lengths (8 and 16 h light) remain vegetative (Basnizki, 1985; Basnizki and Goldschmidt, 1994). In the first seed-grown varieties, manipulations like seed vernalization, GA_3 treatments and different sowing dates were unable to replace cold requirements for autumnal harvest (Foury and La Malfa, 1976; Mauromicale, 1994). The present study has demonstrated, on the contrary, that exogenous GA_3 applications can replace cold requirements in Orlando, which is a genetically improved variety.

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