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SOLAR RADIATION CONVERSION EFFICIENCY AND GROWTH OF SOYBEAN PLANTS TREATED WITH HERBICIDES[1]

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1. INTRODUCTION

Although weed control includes several methods, herbicides are widely used in soybean production. Their effects on soybean plant growth have not been entirely established, though. Quantitative determination of soybean growth and development using growth analysis has been made by several researchers (*10,12*). Growth analysis techniques were used by MORAES *et alii* (*10*) to evaluate the effect of metribuzin on soybean growth and development.

The conversion efficiency of solar radiation (ξ) is an important parameter to evaluate the effect of agronomic practices on plant growth. The application of metribuzin at rates of 30 mg/m^2 a.i. did not affect the conversion efficiency of solar energy in soybean plants (10). At higher rates, however, this herbicide reduced the ξ values. This study was undertaken to determine the effects of chlorimuron, trifluralin and

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clomazone on growth and conversion efficiency of solar radiation in soybean plants.

2. MATERIALS AND METHODS

Soybean seeds (*Glycine max* (L.) Merrill cv. Uberlandia), inoculated with *Bradyrhizobium japonicum*, were grown under greenhouse conditions. Temperature ranged from 21 to 23°C at night to a maximum of 33 to 39°C during the day; relative humidity varied from 38 to 60% during the day to a maximum of nearly 100% at night; photoperiod was 14 ± 1 h. Plants grew in 4-L pots on a moderately fertile red-yellow latossol (oxisol), collected from 0 to 0.2 m depth. After emergence, the seedlings were thinned to two per pot to give an average of 15 plants per square meter. Other experimental conditions were established according to MARENCO and LOPES (*8*).

The experimental design was a complete randomized block with treatments in split-plot replicated three times, with sampling dates and herbicide treatments as the main plots and sub plots, respectively. The herbicides tested were chlorimuron (0.7, 1.05 and 1.4 mg/m^2 a.i.), trifluralin (80, 120 and 160 mg/m^2 a.i.) and clomazone (80, 120 and 160 mg/m^2 a.i.); there was also an untreated control. Herbicides were applied with a backpack sprayer operated with a boom pressure of 230 kPa delivering a spray volume of approximately 40 mL/m^2 through flat fan nozzles. Trifluralin was incorporated immediately after application; clomazone was applied to soil surface just after planting, whereas chlorimuron was applied 14 days after emergence (DAE). At each sampling date leaf area was measured (Licor^R 3000A area meter), and all plant parts separated, dried at 75 °C until constant mass, and weighed. The growth stage of plants was recorded according to FEHR *et alii* (*3*).

Weighing data were transformed to log(Y) before being subjected to analysis of variance. Mean values of total plant dry matter (W_t) were fitted by a logistic model, $Wt = W_m/(1 + Be^{-Ct})$, where W_m is the estimated value of the maximum total plant dry matter accumulation, *B* and *C* are fitting coefficients, and *t* is time in days after emergence. The mean values of leaf area (A_f) and leaf dry weight (W_f), throughout plant development, were fitted by polynomial equations using least squares techniques in the regression analysis. Dry matter accumulation rate (C_t) and leaf area growth rate (C_A) were obtained by differentiating W_t and A_f with respect to time (*11*). Instantaneous values of the relative growth rate (R_W) was obtained as follows: $R_W = C_t/W_t$. Net assimilation rate (E_A) was obtained as $E_A =$

C_t/A_f. Leaf area, W_t and W_f instantaneous values were used to calculated leaf area ratio ($F_A = A_f/W_t$), leaf weight ratio ($F_W = W_f/W_t$,) and specific leaf area ($S_A = A_f/W_f$). Soybean solar radiation conversion efficiency (ξ) was calculated as: $\xi = (100xC_tx\delta)/R_a$, where R_a is the solar radiation and δ is the calorific value of dry matter. Since there were no differences among the δ values of plants over time, the mean value, 16.63 kJ/g (3970 cal/g), was used.

3. RESULTS AND DISCUSSION

The total plant dry matter accumulation (W_t) was influenced ($P = 0.05$) by herbicides during the first four weeks after plant emergence. Trifluralin treatments caused reduction in W_t from 0.63 to 0.40 g/plant at 14 DAE (Figure 1A), and from 4.44 to 3.13 g/plant at 28 DAE (Figure 1B). Similar results were observed by BEHRAN *et alii* (1) and KUST and STRUCKMEYER (*5*). Reductions in W_t caused by trifluralin treatments may have been a consequence of its detrimental effect on the growth of lateral roots, which may have reduced both nitrogen concentration (*7*) and nitrogen fixation (*9*) in treated plants. Clomazone reduced W_t from 0.63 to 0.52 g/plant at 14 DAE (Figure 1C), whereas chlorimuron decreased the W_t values from 4.44 to 3.50 g/plant at 28 DAE (Figure 1D). Effect of chlorimuron on W_t may have been a consequence of its influence on leaf growth, considering that visible leaf chlorosis and leaf epinasty were still observed at 14 days after its application. This herbicidal effect on dry matter accumulation, may be important in soybean production because such period is considered to be critical for weed competition with soybeans (13).

There was no effect of herbicides on W_t after four weeks from plant emergence. Therefore, the data were pooled to show the effect of time in growth parameters throughout plant development. Dry matter accumulation (W_t) showed a logistic trend with three phases (Figure 2). The first one from planting up to 50 DAE, during the vegetative phase; an intermediary phase, from 50 up to 100 DAE; and the final, from 100 DAE until the end of the crop cycle. The greatest W_t value (66.92 g/plant) was observed at 126 DAE. At the R_8 growth stage, there was an increase on W_t which was attributed to a late production of seeds in lateral branches, that accumulated dry matter even during the last two growth stages. The crop growth rate (C_t) increased during the vegetative period, with the greatest C_t values (0.9 g/plant.day) observed at the R_4 stage (Figure 2).

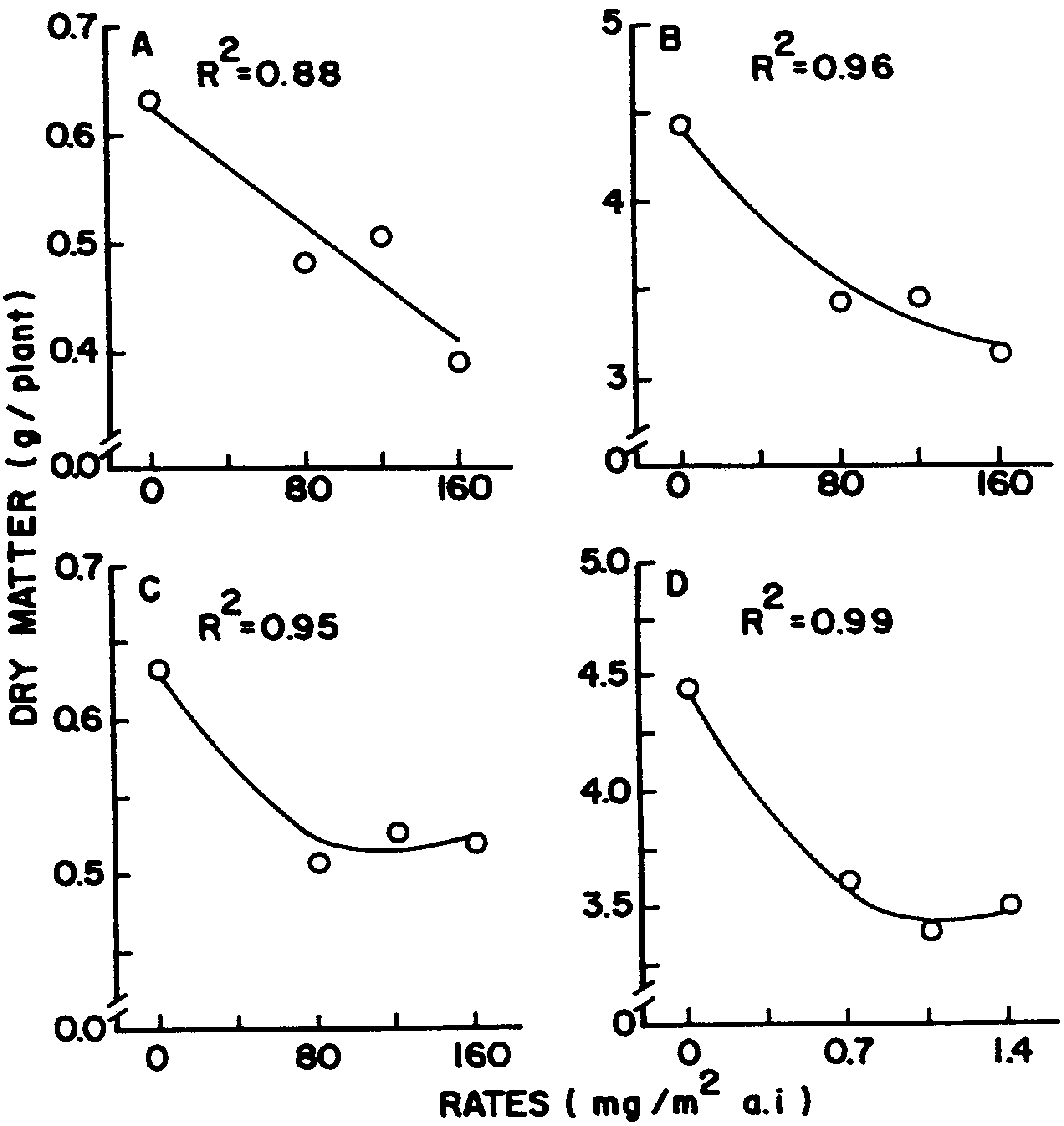

FIGURE 1 - Dry matter accumulation of soybean plant treated with herbicides and evaluated at 14 and 28 days after emergence (DAE). Trifluralin at 14 (A) and 28 DAE (B); Clomazone at 14 DAE (C) and Chlorimuron at 28 DAE (D).

Trifluralin and clomazone, but not chlorimuron, reduced leaf area (A_f) significantly (P=0.01) at 14 DAE (Figure 3). Trifluralin reduced the A_f values linearly, from 1.5 to 0.9 dm^2/plant, whereas a curvilinear effect on A_f, with a mean reduction of about 15%, was observed in clomazone treated plants. For the positive effect of higher rates of clomazone on leaf area no explanation was found, because no hormonal properties have been related to this herbicide. At 28 DAE, there were no herbicide effects on leaf area. Therefore, the data were averaged to show the effect of plant age on leaf area and leaf area growth rate (C_A). The greatest A_f value (53 dm^2/plant) was observed at 98 DAE, during the R_6 growth stage, whereas C_A was maximum (0.9 dm^2/plant.day) at 56 DAE (Figure 4).

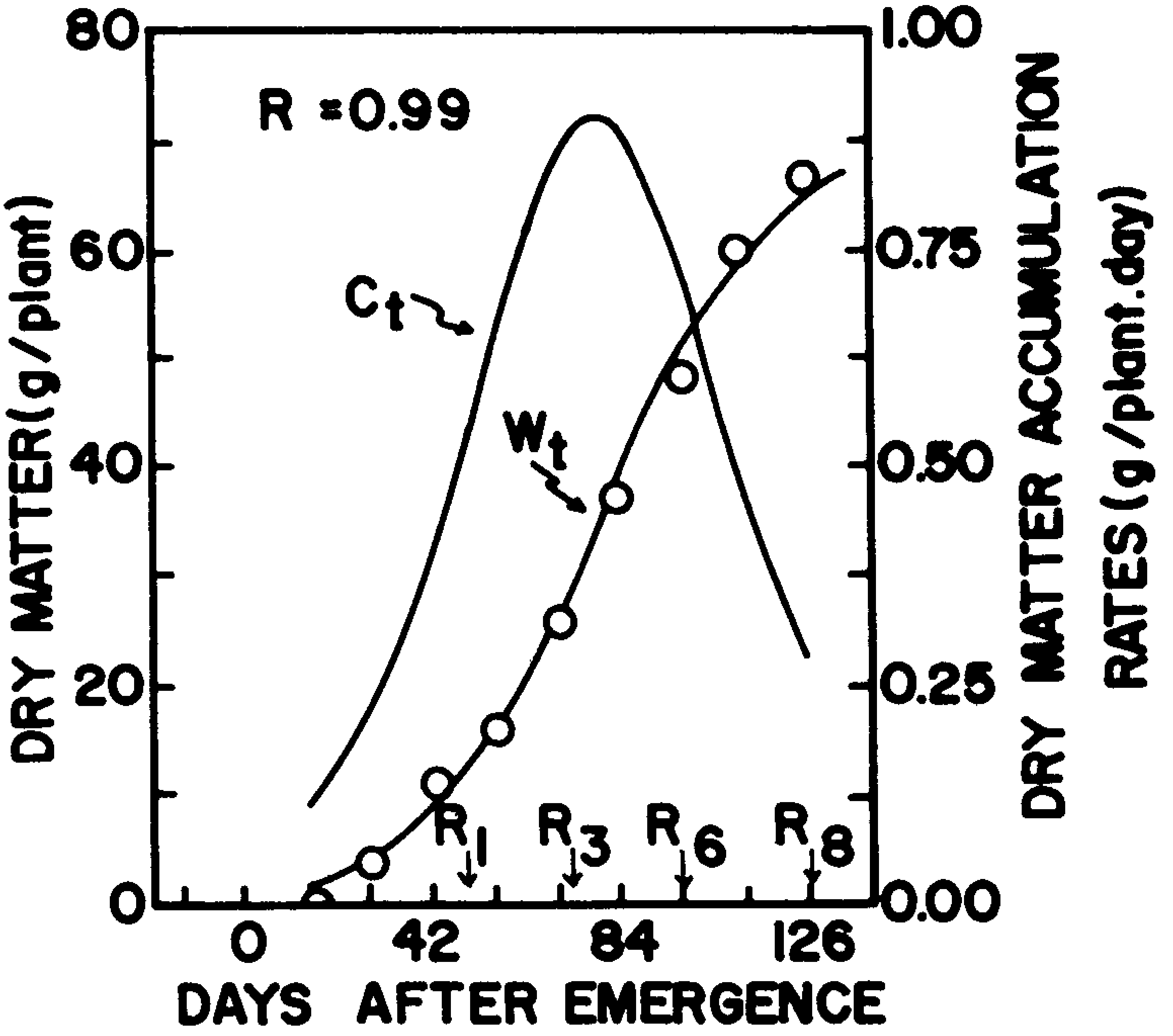

FIGURE 2 - Average of dry matter (Wt) and rates of dry matter accumulation (Ct) of soybeans throughout plant development. Each point, mean of 30 observations. Reproductive growth stages are indicated by arrows on the *x* axis.

During the first six weeks of plant development, there was no effect of herbicides on net assimilation rate (E_A), relative growth rate (R_W), leaf area ratio (F_A), leaf weight ratio (F_W) (Figure 5A-D) and specific leaf area (S_A) (Figure 6). Since trifluralin, clomazone and chlorimuron rates showed similar effects on these growth indices, only data from chlorimuron application are shown. The greatest E_A values (6.6 g/m^2.day) were observed at 14 DAE at chlorimuron rates of 1.4 mg/m^2 a.i., and differences between treated and untreated plants decreased with time (Figure 5A). The E_A increased in herbicide treated plants, suggesting a trend towards greater efficiency in assimilating production in stressed plants. The net assimilation rate declined steeply during the first four weeks of plant development remaining at about 2 g/m^2.day from 42 up to 84 DAE, and thereafter, decreasing with time (Figure 5A), the reduction of E_A values with time was probably due to leaf self shading (12). On the other hand, the photosynthetic efficiency usually decreases with leaf aging (2).

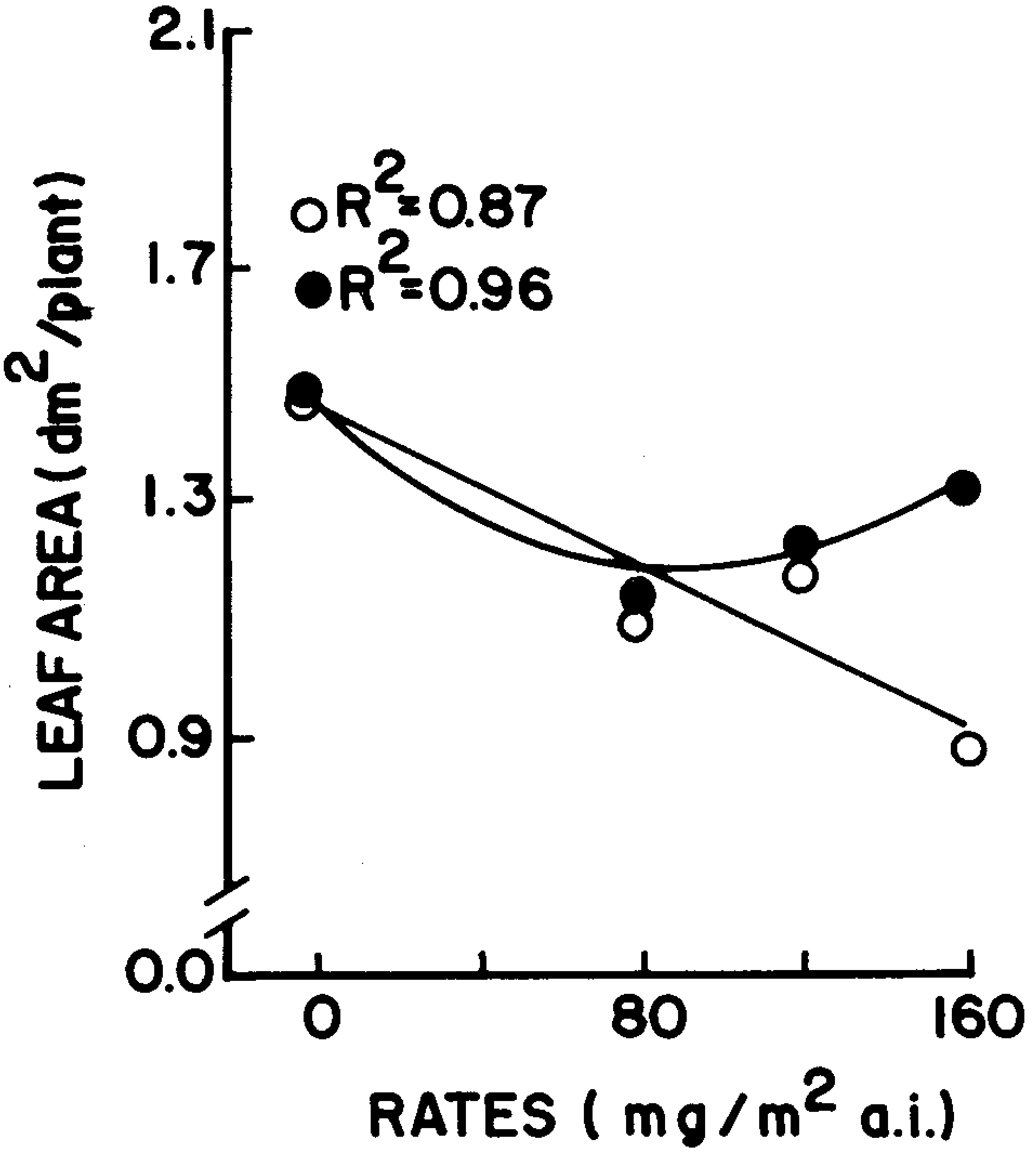

FIGURE 3 - Leaf area in soybean plants treated with trifluralin (o) and clomazone (•) assessed at 14 days after emergence.

The relative growth rate (R_W) was lower at higher rates of herbicides (Figure 5B). At 14 DAE, the R_W ranged from 48 to 55 mg/g.day in chlorimuron (1.4 mg/m^2 a.i.) and untreated plant, respectively. Reductions on R_W observed in herbicide treated plants were probably due to its detrimental effects on leaf area growth. Even when chlorimuron did not affect leaf area, it caused reduction on R_W, what confirms the usefulness of this growth index to compare effects of different treatments on plant growth. R_W is one of the most sensitive parameters available to be studied by plant growth analysis (4). The R_w values declined with plant ontogeny, because of a greater proportion of non-assimilatory tissues. Declining of R_W with time has been reported previously (12). From emergence up to about the first six weeks, the high R_w values observed were mainly caused by high E_A values (Figure 5A), that offset the low F_A values (Figure 5D) observed at those stages. At vegetative stages, from sowing up 42 DAE, F_A (Figure 5C) and F_W (Figure 5D) were lower in herbicide treated plants, the effects being proportional to the applied rates of herbicides. Reductions in F_A and F_W showed that leaf area was more affected than W_t.

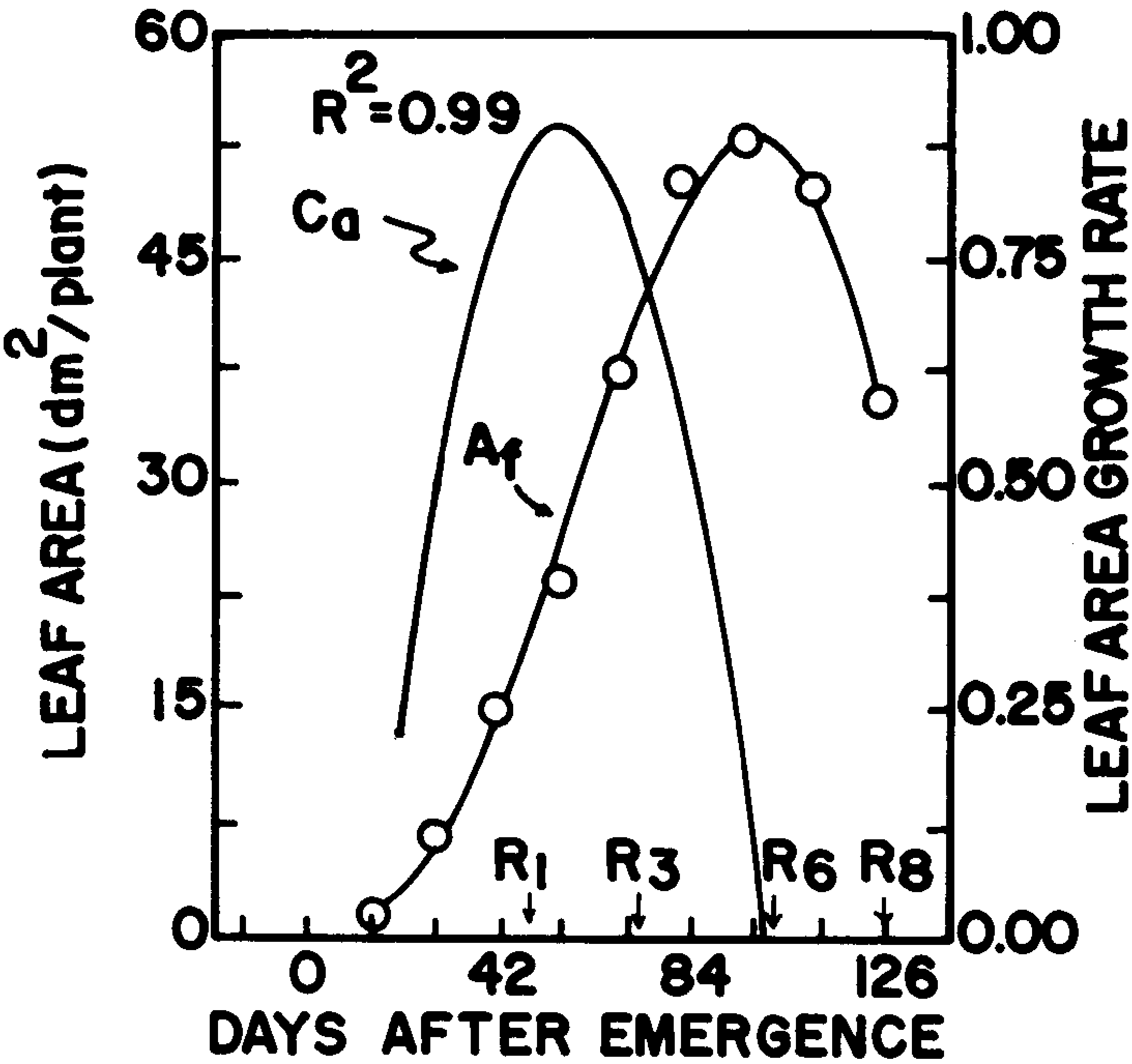

FIGURE 4 - Average of leaf area (A_f) and leaf area growth rates (C_A) of soybean plants throughout plant development. Each point, mean of 30 observations. Reproductive growth stages are indicated by arrows on the *x* axis.

The greater F_A and F_W values were observed at about 42 DAE. Then the F_A values ranged from 1.7 to 1.9 dm²/g (Figure 5C), and the F_W values ranged from 0.44 to 0.48 g/g (Figure 5D), in chlorimuron (1.4 mg/m² a.i.) and untreated plants, respectively. After six weeks from emergence, F_A and F_W decreased with plant ontogeny, which confirms that compared with the F_A and F_W values observed during the vegetative period, a smaller proportion of assimilates was allocated to leaf production during the reproductive stages, even when leaf area values were greater between 80 and 90 DAE (Figure 4).

Specific leaf area (S_A) was increased by higher rates of herbicide application during the first four weeks after plant emergence, thereafter it remained nearly constant, at about 4 dm²/g, up to the end of plant development (Figure 6). As $F_A = F_W x S_A$, and considering that S_A remained nearly constant during almost the whole plant cycle, it may be concluded that the changes observed in F_A values throughout plant development were mainly caused by changes occurred in F_W.

There were no effects of herbicide treatments on conversion efficiency of solar radiation. The greatest values (4.5%) were observed at about 80 DAE (Figure 7), when low levels of solar radiation were also observed. At the beginning of plant cycle, ξ increased in a similar pattern as leaf area, declining more rapidly than A_f from 84 to 126 DAE (Figure 7). The ξ mean value was 2% throughout plant development. The greater ξ values shown in Figure 7, were probably due to a mathematical upper estimation of C_t, because during days with uncommon levels of solar radiation, C_t either upper or under estimates the actual crop growth rate, and as a result ξ is also affected. Finally, declining in solar radiation use efficiency with time is probably due to metabolic alterations in the leaf metabolism, making degradation rates overcome synthesis rates. On the other hand, the photosynthetic efficiency of the system declined when plants initiate the senescence processes (6), verified by E_A reductions with time.

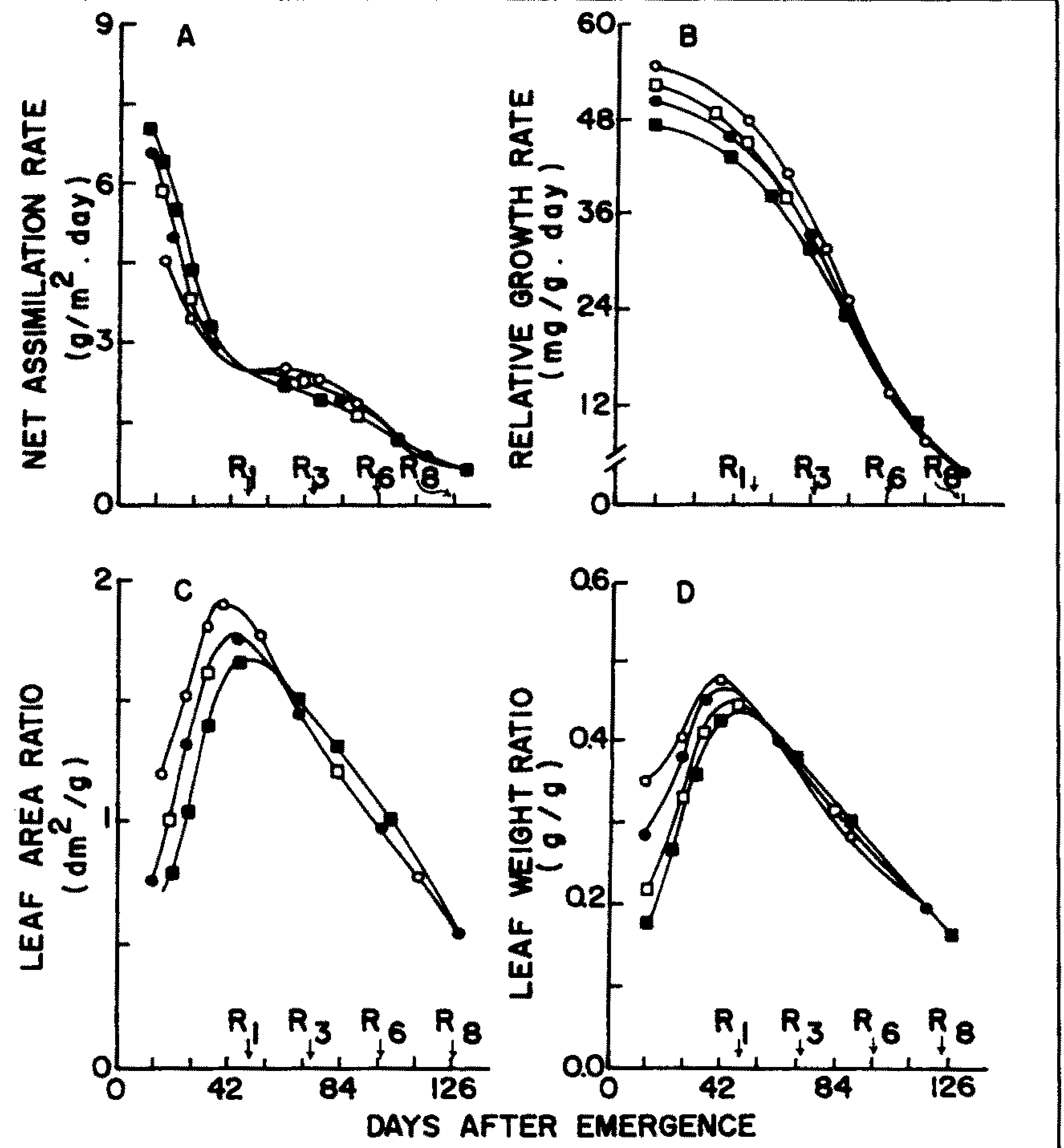

FIGURE 5 - Effect of chlorimuron on net assimilation rates (A), relative growth rate (B), leaf area ratio (C), and leaf weight ratio (D) in soybean plants throughout plant development. Control plants (o), chlorimuron at 0.7 (•), 1.05 (□) and 1.40 mg/m^2 a.i. (□). Reproductive growth stages are indicated by arrows on the *x* axis.

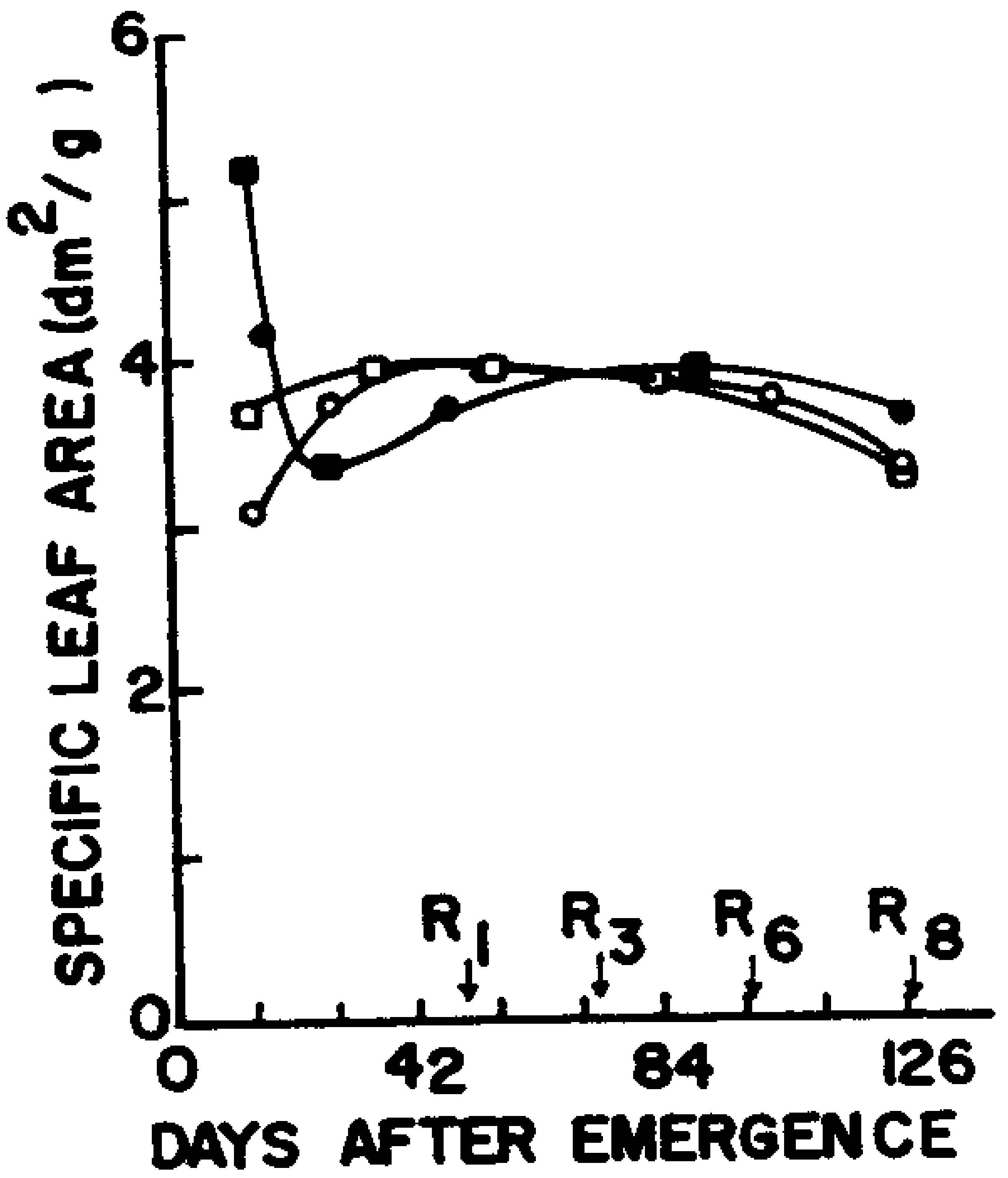

FIGURE 6 - Specific leaf area in soybeans treated with chlorimuron. Control plants (o), chlorimuron at 0.7 (•), 1.05 (□) and 1.40 mg/m^2 a.i. (□)

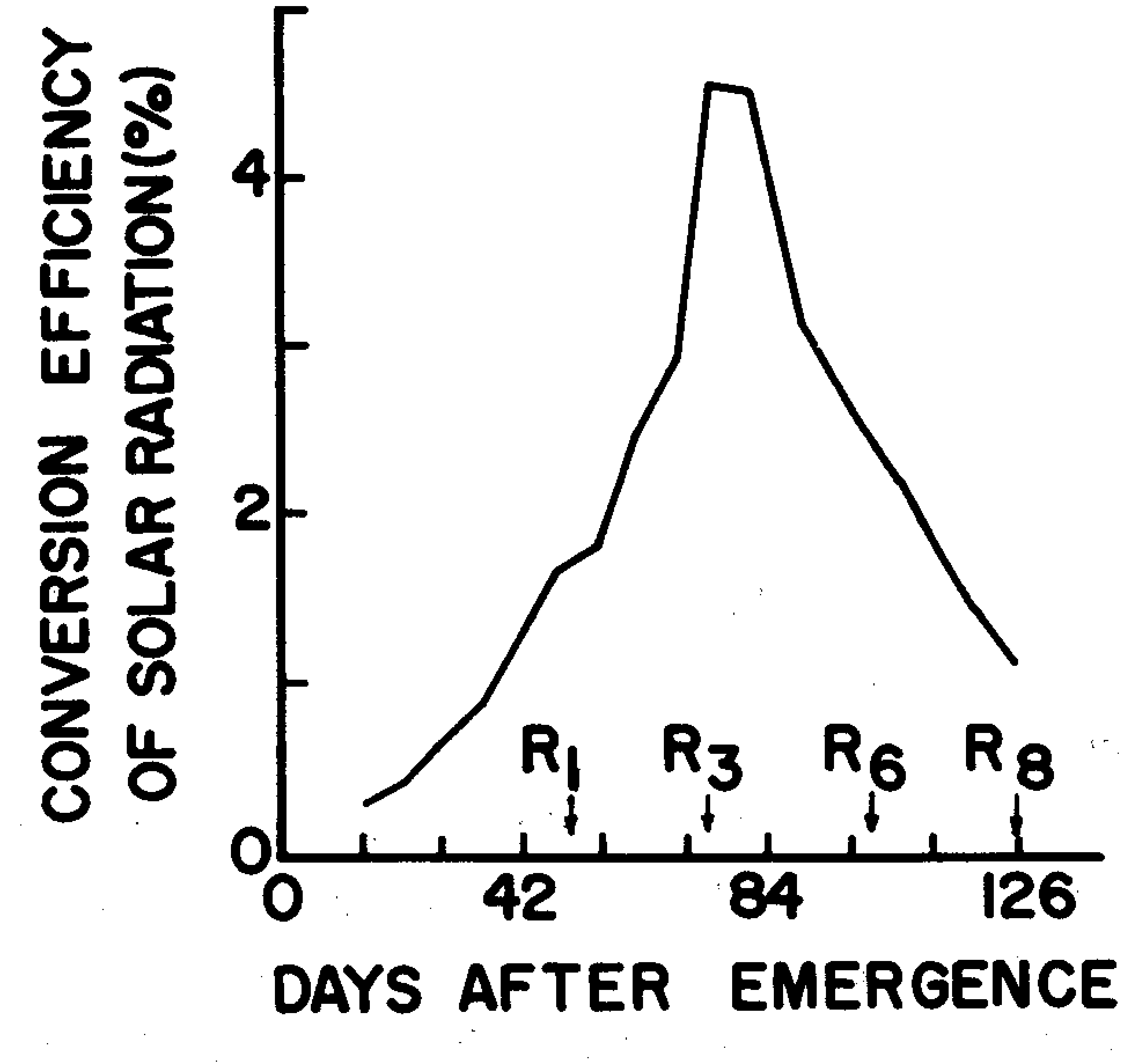

FIGURE 7 - Means values of conversion efficiency of solar radiation in soybean plants in relation to days after emergence. Each point, mean of 30 observations. Reproductive growth stages are indicated by arrows on the x axis.

4. SUMMARY

(GROWTH AND CONVERSION EFFICIENCY OF SOLAR RADIATION IN SOYBEANS BY HERBICIDE APPLICATION)

This research was conducted to evaluate the effects of trifluralin, chlorimuron and clomazone on growth and conversion efficiency of solar radiation in soybeans (*Glycine max* (L.) Merr. cv. Uberlandia), under greenhouse conditions. Plant samples were collected at 14 day intervals, up to 126 days after emergence (DAE). Leaf area was reduced in trifluralin and clomazone treated plants up to 14 DAE, whereas chlorimuron caused no effect on leaf area expansion. The total plant dry matter accumulation was reduced by the herbicide treatments up to 28 DAE. During the vegetative stages the net assimilation rates and specific leaf area were greater in herbicide treated plants, whereas the contrary was true for the leaf area ratio, leaf weight ratio, and relative growth rate. The conversion efficiency of solar radiation was not affected by herbicide application.

5. RESUMO

(CRESCIMENTO E EFICIÊNCIA DE CONVERSÃO DA RADIAÇÃO SOLAR EM PLANTAS DE SOJA TRATADAS COM HERBICIDAS)

Esta pesquisa foi realizada para avaliar o efeito dos herbicidas trifluralina, chlorimuron e clomazone no crescimento e na eficiência da conversão da energia solar na soja (*Glycine max* (L.) Merr. cv. Uberlândia), em condições de casa de vegetação. As plantas foram coletadas em intervalos de 14 dias, durante 126 dias após a emergência (DAE) da cultura. A área foliar foi menor nas plantas tratadas com trifluralina e clomazone até 14 DAE, enquanto os herbicidas reduziram o acúmulo de matéria seca total até 28 DAE. Durante a fase vegetativa, a taxa assimilatória líquida e a área foliar específica foram maiores nas plantas tratadas com herbicidas. O contrário foi observado para a relação de área foliar e de peso foliar e para a taxa de crescimento relativo. Não houve efeito dos herbicidas na eficiência de conversão de energia solar.

6. ACKNOWLEDGMENTS

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