



ESTIMATION OF RELATIVE GROWTH RATE OF TEN FIELD-GROWN HERBACEOUS SPECIES: THE EFFECTS OF LAR AND NAR DEPEND ON TIME SCALE AND TYPE OF ANALYSIS

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Abstract- Ten herbaceous species were grown under field conditions to assess their relative growth rate (RGR) and if the differences in RGR amongst species were more associated with morphological or physiological traits. Nine harvests (every 14 days) were carried out in both years. Factors explaining RGR differences between species varied, depending on whether short (14 days) or longer periods (56 and 112 days) were considered and whether analysis was performed by single relationships or by a multivariate linear equation system using the three-stage least squares simultaneous estimation method. When the data were analyzed by single relationships, RGR for short periods (14 days) always showed a positive correlation with net assimilation rate (NAR). In contrast, when growth was investigated over two months, RGR was positively correlated also with morphological traits (LAR, SLA and LMR) in the first two months, only with NAR in the second two months, but considering all the 4 months period, RGR was not correlated with all the traits under observation. When the data were analyzed by multivariate relationships, both NAR and LAR were correlated with RGR, but the key role is attributable to LAR, which together with temperature was found to condition NAR. It is concluded that under field conditions, for short time periods, the differences in RGR values among species seem to be explained by NAR. For longer periods, the plasticity of the plant morphological traits reduces the importance of NAR, and LAR becomes more relevant to plant growth.

Key words- biomass allocation, growth analysis, RGR, leaf area ratio, SLA, NAR.

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Introduction

In recent decades agricultural has been increasingly oriented towards ecologically sustainable cropping systems for the recovery of so-called marginal areas. In this context cereals and grain legumes play a major role due to the importance of these species both in the human diet and for livestock purposes. Hence most of the studies concerning this issue have considered agronomic techniques which allow a reduction in technical inputs with a view to protecting the environment and recovering soil fertility. However, little is known about species response, in terms of plant growth, to the farming environment, given that the literature shows a fairly close relationship between growth and production.

Growth is an important determinant of plant survival and reproduction. Relative growth rate (RGR) is a measure of growth efficiency, and is the result of plant genetic features and environmen-

tal conditions. When the environment is constant, interspecific differences in RGR are to be ascribed to interspecific differences in plant physiology and morphology. In recent decades there has been increasing interest to evaluate the potential RGR of plant species, and to assess whether the differences are mainly caused by morphological or by physiological traits. For herbs and grasses, variation in leaf area ratio (LAR) is considered the major determinant of interspecific variation in RGR [1-5]. This variation in LAR is commonly considered the result of variation in specific leaf area (SLA) [2, 5-9] and in a few cases by leaf mass ratio (LMR) [10-16]. Other studies found NAR to be an important correlate of RGR [16-19]. It is now known that growth components and their relative contribution to RGR are affected by temperature [20-23], irradiance [24-29], nitrogen availability [19, 30-34], leaf-root interactions [35] and plant functional traits or group [6, 8, 36-39].

Most of these studies used plants grown under controlled, usually constant, environmental conditions and often in hydroponic or sand-culture systems. Such controlled conditions simplify the complexity of growth, have the advantage of repeatability and facilitate monitoring, control and change of environmental parameters, and access to roots. In contrast, field conditions are quite different, with light and temperature fluctuations, with values differing from the optimum for plant growth, and variable water and mineral nutrient resources. Moreover, soil physical and chemical properties are not always suitable for good plant growth.

There are few studies investigating the growth patterns and related traits such as LAR, SLA, NAR and biomass allocation under field conditions [40, 2, 14]. In general, RGR values measured under field conditions are much lower than those achieved in controlled experiments under more favourable growing condition [41, 40, 14]. The contrasting growing condition will affect both RGR values and the relative contribution of LAR and NAR to the resulting RGR [21, 27, 42].

Moreover, few experiments have produced data for long periods. In this regard Sack and Grubb [43] and Villar et al. [14] report contrasting results depending whether short or longer periods were considered.

At the same time, in accordance with Kruger and Volin [12], since RGR is the interaction of several plant traits, such single-factor analyses rarely explain the true role of an individual determinant, because its influence is confounded or obscured by variation in its counterparts. In this case it would be necessary to analyze the data and consider these interactions by multivariate relationships.

The aim of this paper was to evaluate the contribution of the plant traits LAR, NAR, SLA and biomass allocation (LMR, SMR, RMR) to RGR of 10 field-grown annual herbaceous species, both for short (14 days) and long periods (56 and 112 days). In order to have more data we carried out the experiment for two consecutive years. Besides single-factor analysis, the data were examined through a multivariate linear equation system using the three-stage least squares simultaneous estimation method.

Materials and methods

A. Field trial

The research was carried out during the years 2008 and 2009 in the district of San Giorgio la Molara (41° 16' 0" N, 14° 55' 0" E), in a hill area (580 m a. s. l.) of Campania (southern Italy), on the species listed in Table 1. The seeds came from commercial sources. The species in the field were arranged in a complete random design with 6 replications with plots of 40 m². Sowing was done on October 15, in 2007 and October 17 in 2008. Before sowing, the soil (clay-loam) was prepared by ploughing and harrowing to a depth of 35 cm, and fertilized with superphosphate (80 kg ha⁻¹ of P₂O₅) for all the species, and calcium cyanamide (100 kg ha⁻¹ of N) only for grasses. As the grasses started to shoot in the latter plots 50 kg ha⁻¹ of N were added as urea.

Considering the different plant size of the species, each plant was separated from its nearest neighbour by a different distance: 0.20x0.10 m for grasses, 0.40x0.10 m for *Lens esculenta*, *Lathyrus sativus*, *Cicer arietinum*, *Pisum sativum* and *Vicia faba minor*, 0.80x0.20 for *Vicia faba major*. Nine harvests were carried out, starting from January 21 and 19, respectively for 2008 and 2009, (with grasses at the beginning of tillering and legumes at the five-

leaf stage) until full earing for grasses and early seed pod for legumes, at two-week intervals.

B. Measurement and calculation

At every harvest for each plot, 15 plants for the grass crops and *Lens esculenta*, eight for *Pisum sativum*, *Vicia faba minor*, *Cicer arietinum*, and *Lathyrus sativus*, and five for *Vicia faba major* were selected at random. Each plant was excavated carefully with a shovel, at 30 cm depth, and the soil was then washed off its roots. The plant was separated into leaves (including tendrils for *Pisum sativum*), stems (including the leaf sheaths for grasses) and roots. Leaf area was measured using a Licor 3000 Leaf area Meter. Dry mass was determined from material oven-dried at 70 °C for at least 54 h.

From these data we calculated relative growth rate (RGR), leaf area ratio (LAR), specific leaf area (SLA), leaf mass ratio (LMR), net assimilation rate (NAR), stem mass ratio (SMR) and root mass ratio (RMR). Data analysis followed the classical approach [44, 45, 46,47] and was carried out: separately for the eight short growth periods (2 weeks) and for periods of 56 and 112 days, for every replication.

The growth response coefficients (GRC) were calculated according to Poorter and Van der Verf [25] as the slope estimated from a linear regression where ln LAR, ln NAR, ln SLA and ln LMR were the dependent variables, and ln RGR the independent variable.

Plasticity index was calculated for RGR, NAR, LAR, SLA, LMR, RMR and SMR for each species as the ratio: (maximum value-minimum value)/(maximum value), using the values of the eight periods for each year [48].

C. Statistical analysis

We analyzed the data through regression analysis for the short period (2 weeks), for the first four growth periods (56 days), corresponding to the beginning of shooting for grasses and to first flower buds for legumes, the second (56 days), corresponding to full earing for grasses and early seed pod for legumes, and total growth period (112 days). In addition, all data were analysed by a multivariate linear equation system using the three-stage least squares simultaneous estimation method, which combines two-stage least squares with seemingly unrelated regressions [49, 50]. The model adopted was to place each of RGR, NAR, LAR, SLA and LMR simultaneously as a variable dependent on all the other parameters, including growth period, year and temperature.

Results

A. Weather conditions

As regards the weather conditions during the study period (Fig. 1), total rainfall during the 112 days was 442 mm for 2008 and 398 mm for 2009, but with a different distribution during the eight periods considered: during the first four periods we had more rain in 2009 (255 vs. 156 mm), while in the second four periods rainfall was higher in 2008 (286 vs. 143 mm). Mean temperature was almost the same for the two years, with lower minimum values during the second month for 2009 and higher maximums in the third and fourth month, also for 2009. In general, although temperatures were at times low, with some days below 0 °C, we observed only slight frost effects on the plants.

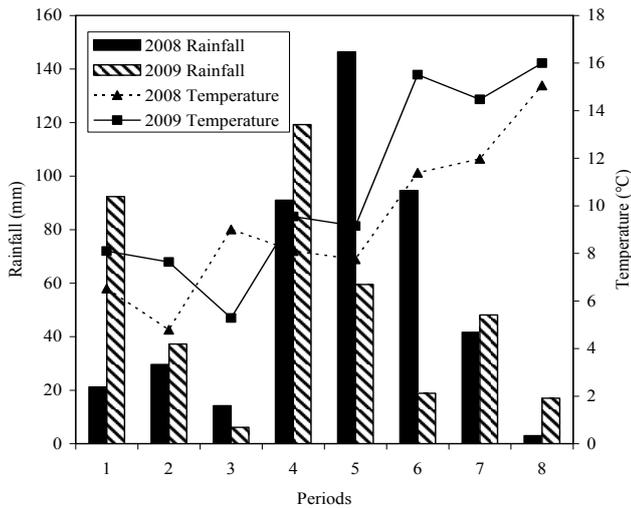


Fig. 1- Cumulated rainfall (histograms) and average daily mean temperature (lines) for the eight periods and for the two years.

B. Analysis by single relationships

Given that the relationships between RGR and the other parameters and those among the various parameters in the two years appeared very similar, we report only the global two-year relationships, using the mean of the two years.

a. Growth during the whole period

Over the total growth period of 112 days (Table 1), RGR values were higher in 2008 than in 2009. However both RGR and NAR, LAR, SLA and LMR values in 2008 correlated with those of 2009. Between species, RGR had small variations and showed no significant differences. RGR values were weakly correlated with all the trait values under observation and never significantly (Table 2). However, the highest correlation coefficient was observed with LAR, the lowest with the LMR values. NAR values were negatively correlated with LAR due mainly to the negative correlation between NAR and SLA. The value of the growth response coefficient (GRC) was higher for LAR than for NAR and, between LAR components, was higher for SLA (Table 3).

For all the data, the highest plasticity was observed for NAR and RGR, the lowest for SMR and LMR (Figure 2).

Table 2- Pearson correlation coefficients between growth components in each of the growth periods of 112, 56 and 14 days. Values in bold are significant at 5% level

Growth period	Components									
	NAR RGR	SLA RGR	LAR RGR	LMR RGR	RMR RGR	SMR RGR	NAR SLA	NAR LMR	NAR LAR	SLA LMR
1-8	0.17	0.41	0.45	0.08	-0.14	-0.08	-0.76	-0.30	-0.93	-0.28
1-4	0.69	0.89	0.92	0.81	-0.41	-0.22	0.39	0.23	0.39	0.83
5-8	0.66	-0.79	-0.35	0.61	-0.27	-0.70	-0.82	0.14	-0.92	-0.67
1	0.68	0.17	0.90	0.88	-0.71	-0.81	0.21	0.76	0.35	0.48
2	0.99	0.37	0.64	0.64	-0.61	-0.57	0.33	0.65	0.55	0.41
3	0.87	0.32	0.41	0.64	-0.51	-0.55	-0.81	-0.39	-0.67	0.79
4	0.48	0.65	0.44	-0.22	-0.10	0.30	-0.26	-0.70	-0.54	0.14
5	0.93	-0.50	-0.62	-0.10	-0.10	-0.40	-0.82	-0.10	-0.83	-0.41
6	0.66	-0.53	-0.27	0.69	-0.42	-0.72	-0.82	0.81	-0.52	-0.69
7	0.91	-0.53	-0.45	0.10	0.26	-0.10	-0.90	0.10	-0.74	-0.74
8	0.85	-0.52	0.47	0.80	-0.26	-0.84	-0.85	0.80	-0.49	-0.75

Table 3- Growth response coefficients for each component for the eight growth periods.

Growth period	Components			
	NAR	LAR	SLA	LMR
1-8	-0.38	1.38	1.17	0.21
1-4	0.29	0.71	0.38	0.33
5-8	1.32	-0.32	0.86	-1.18
1	0.29	0.71	0.19	0.52
2	0.86	0.14	0.06	0.08
3	0.40	0.60	0.29	0.31
4	0.55	0.45	0.55	-0.10
5	1.54	-0.54	-0.45	-0.09
6	0.73	0.27	0.80	-0.53
7	1.13	-0.13	-0.41	0.28
8	0.59	0.41	-0.51	0.92

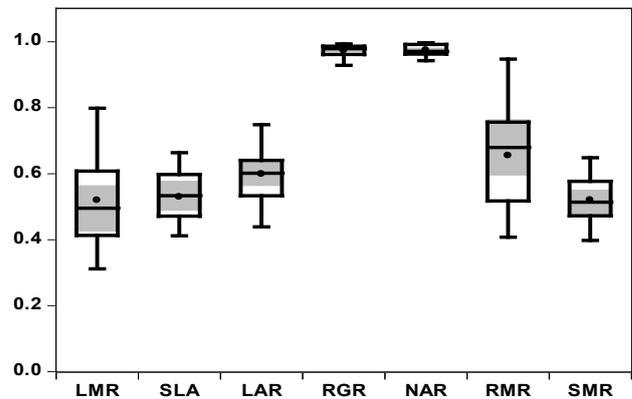


Fig. 2- Mean plasticity index for LMR, SLA, LAR, RGR, NAR, RMR and SMR for the 10 species studied. Plasticity index was calculated for each species as the ratio: (maximum value – minimum value) / (maximum value) for the two years

b. Growth during the first period

As regards the first growth period of 56 days, the highest RGR was observed for *Triticum dicoccon* whereas the lowest occurred in *Pisum sativum* and *Cicer arietinum* (data not reported). The variables most closely associated with RGR were LAR, SLA and LMR (Table 2), while NAR was less associated, but with r values statistically also significant. This is confirmed by the growth response coefficient (GRC) which was higher for LAR than for NAR and within the LAR it was almost the same (Table 3).

c. Growth during the second period

As regards the second growth period of 56 days, the maximum RGR was observed for *Lathyrus sativus*, the minimum for *Hordeum vulgare* (data not reported). The variable most closely associated with RGR differences was NAR (Table 2). Between RGR and LAR the correlation was statistically not significant. As a result, for this period the growth response coefficient was higher for NAR than for LAR. Within the LAR, it was higher for LMR than for SLA (Table 3).

d. Growth during each two-week period

Comparing the RGR (Fig. 3a) for all the species during the eight growth periods considered, maximum RGR occurred during Period 6, whereas the minimum was registered during the second growth period, both in the first and second years. The variable

most closely associated with RGR, for each growth period, was NAR (Table 2) with a statistically non-significant correlation coefficient only in Period 4. The r values of the correlations between LAR and RGR values were found statistically significant only for the first and second period. Among LAR components, except for Period 4, SLA was always weakly correlated with RGR values. LMR was strongly correlated with RGR in Periods 1, 2, 3, 6 and 8, and weakly in the others.

The values of GRC calculated for each of the eight periods (Table 3) are affected by such relations: they were always higher for NAR than for LAR, except for the first and third periods, when GRC was higher for LAR. GRC values for SLA and LMR in some periods were found negative, as for LAR. Only in Periods 1 and 8 for LMR were these values found higher than those of NAR.

In addition, values of RGR were correlated with temperature ($r = 0.50$, $P \leq 0.05$), but this as effect of legumes ($r = 0.68$, $P \leq 0.05$), while the RGR values for grasses were not significantly correlated. Mean daily temperature also positively affected the NAR values of both groups of species ($r = 0.86$ and 0.66 , respectively for legumes and grasses, $P \leq 0.05$). The effects of temperature on LAR were always negative (respectively -0.59 and -0.62), whereas on SLA they were positive for grasses (0.63) and negative for legumes (-0.14); always negative on LMR (-0.46 and -0.91). However, for both traits, the correlations were statistically significant only for grasses.

e. Temporal variations in RGR and their components

In general, mean RGR of all the species increased with time until Period 6, and then decreased. This trend was similar both for grasses and for legumes: the first group had higher values, with respect to legumes, in the first part of the growth period, but lower in the second. Almost the same trend was observed for the two years (Fig. 3a). However, the variability over time and between species was high, such that the growth pattern between the species varied from a short time interval (two weeks) to the next. Thus, RGR between periods was positively correlated only in Period 2 vs. 4 ($r = 0.65$; $P < 0.05$) and negatively in 2 and 4 vs. 7 ($r = -0.72$, $r = -0.80$; $P < 0.01$) with the result that species that had a high RGR in the first period showed lower values afterwards. This occurred in the first year, while in the second the variability was higher, for all combinations. In this last year significant correlations between RGR values were never observed.

The variations in NAR (Fig. 3b) between species were also very dynamic with time, showing the same trends as those of RGR values.

Average LAR values (Fig. 3c), except the last three periods of the second year, were higher for grasses, which showed a different trend in the two years, increasing until Period 7 and then decreasing, in the first year, always decreasing in the second year, while legumes showed the same trend in the two years, almost constant until Period 6 and then decreasing. Overall, the LAR values were conditioned much more by SLA than by LMR values ($r = 0.60$ vs. 0.49 , $n = 960$). In the first year the ranking of the species was stable until Period 4 when LAR values were significantly and positively correlated between all two-week periods (r from 0.83 to 0.97 ; $P < 0.01$). In Period 5 the ranking changed and then became stable once again, but with a different ranking and less stability than in the first four periods. The ranking of species was stable

not only between two consecutive periods, but also throughout the 42-day period. In the second year the ranking of the species was more stable, with some changes after Period 5, with a stability of 56 days, except for the periods 1 vs. 5, 3 vs. 7 and 4 vs. 8.

Means SLA values (Fig. 3d), except for the first two periods of the first year, were higher for grasses, which showed increasing values until Period 7, while legumes showed almost constant values in both years. The ranking of the species by SLA from the first period onwards was almost as stable as LAR values, but slightly less, with a higher stability for the second year.

Mean LMR values (Fig. 3e) were almost stable until Period 4 and then decreasing, both for the first and the second year and for the two groups of species, with slightly higher values for legumes. The ranking of the species was stable until Period 4 and was then reversed, that is, some species with higher LMR values during early growth had lower LMR in the second. This held for both years, but even more so in the first. The change occurred at the end of Period 4, probably with the shooting of grasses.

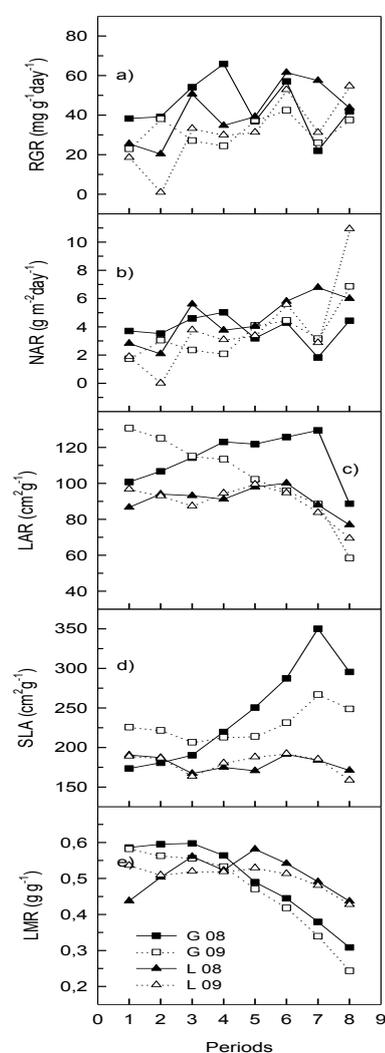


Fig. 3- Trend of: RGR (a), NAR (b), LAR (c), SLA (d), LMR (e) values for grasses and legumes during the eight growth periods for the two years. G = Grasses, L = Legumes, 08= 2008, 09 = 2009.

C. Multivariate data analysis using three-stage least squares estimation

The results of a simultaneous system with three-stage least squares estimation show, for all the data (Table 4), that RGR is positively and significantly associated with NAR and LAR. SLA is significantly and positively associated with LAR and temperature, negatively with LMR. The latter is associated significantly and positively with LAR and temperature, negatively with SLA. LAR is associated significantly and positively with SLA and LMR, negatively with temperature. NAR is associated significantly and positively with temperature and negatively with LAR. This applies equally to the two growth periods (1-4 and 5-8), years and species.

Discussion

Two important aspects in this study are worth stressing: first, the plants were grown under common field conditions, and secondly the study itself covers a large span of plant life and was repeated for two years. In the relevant literature, plants are largely grown under controlled conditions, in growth chambers or glass-houses, and trials are conducted over short periods. In few cases is growth analysis carried out with time as a variable [14].

Overall, this experiment confirms that open-field RGR values are much lower than those measured in controlled conditions [40, 41, 40]. In the first year the RGR values were higher than in the second. In this case mean temperature was almost the same, total rainfall was higher in the first than in the second year, but with more rain during the first part of the growth period in the second year. As regards the soil features, in the second year the plants are highly likely to have suffered flooding in the early growth period.

As regards mean RGR, the species under observation showed no significant differences. On average, the grasses showed higher RGR during the first four periods, until shooting. This could well be due to ontogenesis, but could also stem from the better adaptation of these species to lower temperatures typically occurring in the Mediterranean area, during this period. By contrast, legumes showed higher RGR values in the second four growth periods when temperature was higher. This could also be due to ontogenesis or to higher temperature requirements in this group of species with respect to grasses. This is confirmed by the positive correlation between RGR and temperatures. Besides RGR values, as temperature also influenced its component values (NAR, LAR, SLA and LMR), but in different ways for the different groups of species, it could be argued that generalizations cannot be made and that the contribution of the different components to RGR values is not the same for all plant species and that it changes with time, in this case with the change in climatic factors.

Reich et al. [51] found higher RGR values for seedlings of C_3 grasses than for legumes. As this research was conducted in a glass-house at a day/night temperature of 25-20 °C, in terms of temperature our results are different, with higher RGR for legumes. However, since Reich et al. [51] report data for the first period of plant growth, in this case our results agree with their results, with lower RGR values for legumes than for C_3 grasses in the first stage of growth. Also Marañón and Grubb [52] found lower RGR values for some *Fabaceae* than for *Poaceae* for plants kept during the first three weeks of the plant cycle in a growth

chamber at a day/night temperature of 20-10 °C. In this case the lower RGR values proved correlated with a lower SLA. Also Elias and Chadwick [53], for plants grown in sand culture, found lower RGR for legumes with respect to grasses.

In this research, following the classical approach, taking the single variables independently of each other, we observed contrasting results over time. For the first period of 56 days both NAR and LAR influenced RGR positively, with a correlation coefficient higher for LAR than for NAR. Between LAR, both components SLA and LMR were highly correlated with RGR values. For the second period, NAR was the component which proved much more correlated with RGR, while SLA was strongly, but negatively, correlated with RGR, influencing LAR behaviour, whose correlation with RGR was found negative, although statistically not significant like that of LMR, which was positive and had a high value. In our case LMR appeared an important factor, while the literature on this topic considers this parameter less important than SLA [25].

These results highlight the effect of environmental conditions on the contributions of LAR and NAR on RGR values. Medek et al. [22], for six *Poa* species grown in controlled conditions, found an increase in RGR, with an increase in temperature from 7 to 12 °C, attributable to an increase in LAR (SLA and LMR), whereas the increase in RGR from 12 to 17 °C was attributable to an increase in NAR. These data, as a whole, are in agreement with ours, with higher influence on RGR values of LAR in the first cooler growth period and of NAR in the second.

For the total growth period of 112 days, none of the growth parameters were significantly correlated with RGR values, while LAR and SLA showed the highest r values.

As regards the eight 14-day periods, NAR values were almost always correlated with RGR. LAR and SLA values were significantly and positively correlated with RGR in very few cases, while LMR values were more often. GRC values were almost always much higher for NAR than for LAR, due partly to the lower contribution of both components LMR and SLA, but mainly the lower values of SLA growth response coefficient, particularly in the second part of the overall growth period. These results support the hypothesis that without radiation limitation, as in the open field, RGR variations are mostly explained by variation in NAR [26, 27, 24, 14, 28], albeit for short periods, when temporal changes in RGR are mostly explained by temporal changes in NAR, as reported also by Antúnez et al. [54] and Villar et al. [14]. However, in the long run the plants show their inherent differences, and then LAR and its components contribute to RGR variations, although in this trial we noted no SLA predominance, but an LMR prevalence. This could stem from the variations in the parameter examined during time. An explanation could be that the RGR values were highly dynamic over time, following the course of NAR values. LAR, SLA and LMR values in the short term had little variability, their variation being displayed after more time, namely 42 or 56 days in this trial. Hence their effects only emerged when we considered the data for long periods [43, 27, 14, 34].

Nevertheless, from these results we may note that time is an important factor, and that the conclusions that may be drawn differ depending on whether short or longer periods are considered.

So as to obtain coefficients of equations which may be compared, the data of the single parameters were analysed after normalizing them to the average. With the normalized values of the equations

reported in table 4 we plotted figure 4, which reports the relations and coefficients for the parameters involved in the five equations. The model emerging from these results is that RGR is determined by both NAR and LAR and with a weight higher for LAR than for NAR. LAR plays a key role in determining the RGR value, influencing RGR positively and NAR, SLA and LMR negatively, which conversely influence LAR. At the same time, LAR is influenced by temperature, both directly and through SLA and LMR.

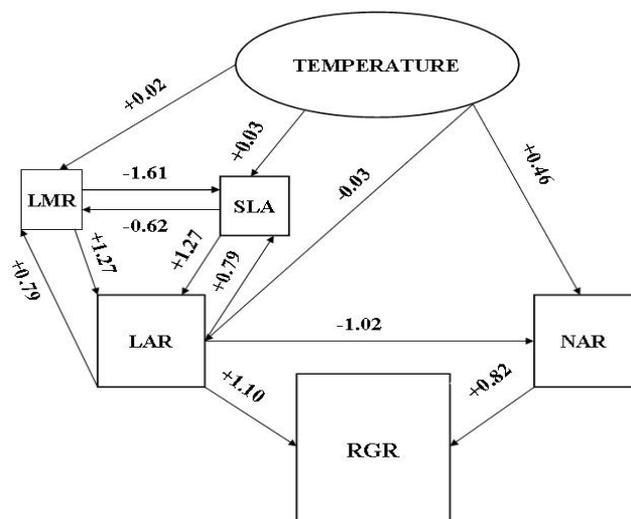


Fig. 4 - Cause-effect relationships among growth variables, data for the whole period. The numbers are the parameter coefficients of the equations tested by the three-stage least squares simultaneously estimation method; analysis carried out with data values normalized on the average of the single parameter. The constants of the equations are: -1.03 for RGR, +1.25 for SLA, +0.77 for LMR, -0.98 for LAR, and +1.26 for NAR

NAR is positively highly influenced by temperature, which is a highly variable factor. This may explain why RGR, for short periods, is strictly related with NAR. Conversely, on LAR and its components the temperature effect is low. Thus only in the long run is it possible to note their effects on RGR. At the same time, the considerable negative effect of LAR on NAR should be noted. This may well occur due to the negative effect of SLA on NAR or for the leaves self shading, which in turn causes an SLA increase. In agronomic terms, this underlines the importance of the right plant density in the crop system or, generally, the most appropriate leaf area per unit of plant dry weight or per unit of land area (LAI).

SLA and LMR are not associated directly to RGR, but as LAR components. The relations of SLA with temperature could well be a direct effect of temperature on SLA, but could also be an ontogenetic effect: an ontogenetic decrease of SLA has been generally found as leaves get older [55, 47]. In our case the temperature increase is strictly associated with plant age. However, the SLA time course does not show decreasing values with plant age (Fig. 3), but increasing values. In this regard, Poorter et al. [23] report an SLA increase with temperature increase. The same result was observed for LMR, which was positively influenced by temperature, but for this parameter we observed a decrease in LMR values with plant age. In the literature there are some studies report-

ing a decrease in LMR; others failed to report such a decrease or even observed an increase in LMR with plant age [46, 55].

Table 4- Results of three-stage least squares data analysis (Number of observations = 960). The numbers are the parameter (a and b) of each equation. For the variables not present in the equations the parameters b are not significant at 5% level. Temp = temperature

RGR = -47.2+0.51*LAR+8.5*NAR			
R-squared	0.82	Mean dependent var	37.60
Adjusted R-squared	0.82	S.D. dependent var	26.60
S.E. of regression	11.35	Sum squared resid	123245.1
Durbin-Watson stat	1.09		
SLA = +211+2.14*LAR-447*LMR+0.88*TEMP			
R-squared	0.93	Mean dependent var	203.42
Adjusted R-squared	0.93	S.D. dependent var	56.94
S.E. of regression	15.06	Sum squared resid	216511.9
Durbin-Watson stat	0.57		
LMR = +0.47+0.005*LAR-0.002*SLA+0.002*TEMP			
R-squared	0.91	Mean dependent var	0.50
Adjusted R-squared	0.91	S.D. dependent var	0.11
S.E. of regression	0.034	Sum squared resid	1.08
Durbin-Watson stat	0.57		
LAR = -98+0.47*SLA+209*LMR-0.41*TEMP			
R-squared	0.94	Mean dependent var	98.52
Adjusted R-squared	0.94	S.D. dependent var	29.18
S.E. of regression	7.03	Sum squared resid	47210.8
Durbin-Watson stat	0.65		
NAR = +5.6-0.05*LAR+0.32*TEMP			
R-squared	0.28	Mean dependent var	4.07
Adjusted R-squared	0.28	S.D. dependent var	3.27
S.E. of regression	2.77	Sum squared resid	7324.2
Durbin-Watson stat	1.37		

Conclusions

This research point out that, under field conditions, the relative importance of the factors driving RGR changes with time scale and with the analysis method used. In our case growth analysis for long periods and with methods which consider the interactions of several plant traits explain more clearly, than single-factor analysis, as they are involved on RGR changes. Finally, it should be noted that in such environments both temperature and the drainage of surplus water during winter are two severely limiting factors for relative growth rate.

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Table-1 - Two-year RGR mean values of the growth parameters for all species and for the total growth period of 112 days

Species	RGR mg g ⁻¹ d ⁻¹	NAR g m ⁻² d ⁻¹	SLA cm ² g ⁻¹	LMR g g ⁻¹	LAR cm ² g ⁻¹	RMR g g ⁻¹	SMR g g ⁻¹
	2008-09	2008-09	2008-09	2008-09	2008-09	2008-09	2008-2009
<i>Avena sativa</i> L.	49 31	4.2 2.8	234 230	0.53 0.55	118 101	0. 0.09 0.12	0.38 0.33
<i>Cicer arietinum</i> L.	42 25	5.8 3.9	156 166	0.43 0.42	67 69	0.13 0.15	0.45 0.43
<i>Hordeum vulgare</i> L. exasticum	40 29	3.1 3.2	284 230	0.48 0.46	127 101	0.07 0.11	0.45 0.42
<i>Lathyrus sativus</i> L.	42 32	4.3 2.7	178 200	0.52 0.57	93 111	0.10 0.10	0.38 0.33
<i>Lens esculenta</i> Moench	43 33	4.3 2.6	182 232	0.56 0.56	100 129	0.08 0.08	0.36 0.36
<i>Pisum sativum</i> L.	44 29	4.7 4.7	164 132	0.60 0.55	95 72	0.07 0.08	0.31 0.35
<i>Triticum dicoccon</i> L.	44 38	4.1 3.7	217 249	0.51 0.47	107 117	0.08 0.14	0.41 0.38
x <i>Triticosecale</i> Wittm.	44 31	4.0 4.2	239 219	0.47 0.38	104 79	0.08 0.12	0.45 0.47
<i>Vicia faba major</i> Harz	40 32	4.4 4.5	177 179	0.51 0.47	91 83	0.10 0.10	0.37 0.39
<i>Vicia faba minor</i> Beck	44 32	4.7 4.7	205 174	0.48 0.48	97 78	0.11 0.12	0.42 0.40