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GROWTH ANALYSIS USING CURVE FITTING METHOD IN EARLY AND LATE SOWN SUNFLOWER

ABSTRACT

Effect of sowing time on productivity of sunflower was studied. Sunflower seeds were first sown in August (early) and the second sowing was done in September (late). Growth analysis was done at an interval of 5–6 days from germination to maturation. Growth was measured in terms of dry weight and leaf area. Various growth indices like RGR, RLGR, NAR, LAR, LWR, SLA, etc. were calculated. Cubic polynomial was the best fit for all the growth parameters. The dry matter accumulation, leaf area, leaf dry weight and leaf number were significantly more in late grown crop than early grown one. The rate of total dry weight, leaf area and leaf dry weight were higher in late grown crop as compared to early grown one. RGR, RLGR and NAR were higher in the late grown crop from the beginning, which gradually decreased later on, in both the crops. LAR was distinctly more in late grown crop between d 30–40. Changes in SLA were similar to LAR while LWR was more in the beginning and decreased afterwards. RGR showed more correlation with NAR and very low correlation with LAR in both the crops. Thus it is concluded that the late sown crop had better growth, but still, to obtain maximum productivity in sunflower, improvement in RGR and NAR is required.

Key words: growth analysis, leaf area, leaf area ratio, leaf weight ratio, net assimilation rate, relative growth rate, specific leaf area, sunflower

Abbreviations: relative growth rate – RGR, relative leaf growth rate – RLGR, net assimilation rate – NAR, leaf area ratio – LAR, specific leaf area – SLA, leaf weight ratio – LWR

INTRODUCTION

To cope with the food requirements of the ever increasing population, the developing countries are left with no other alternative than to intensify agricultural systems rapidly to increase production. The increase in yield has got to come from more intensive cultivation from the existing available arable land. This can be achieved only by enhancing the full physiological potential of individual crops. Sunflower has become a crop of major economic importance world–wide. It is grown mainly for its oil and now ranks second among oil seed crops in the world as a source of edible oil. Significant amount of sunflower seed is also

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consumed, other than oil, in many parts of the world. Sunflower produces two kinds of oils: one high in polyunsaturates (high in linoleic acid) and another high in monounsaturates (high in oleic acid) depending primarily on the temperature during the growing season.

Planting date strongly affects the proportions of linoleic and oleic acid in sunflower oil. Sunflower yield is the product of 3 components: a) Number of heads per ha; b) Number of seed per head; and c) Average weight per seed. Since most cultivars produce one head per plant, component (a) is determined by plant population. The other two components are affected by the first component and by cultivar, weather, soil, pests, etc.

Generally, for quantification of growth, parameters like dry weight, leaf area, plant height, etc are taken into account. But the determination of RGR, NAR and LAR have special significance as these parameters provide distinct information about some of the physiological functions like rate of dry matter accumulation, net photosynthetic rate, photosynthetic area, respectively (Hunt 1978)

Techniques used to quantify the components of growth are collectively known as "Growth Analysis". Growth analysis involves sampling of plants at different time interval during the growing season. However, most growth traits are complex and must be explained in terms of its components for eg RGR = LAR × NAR and LAR = SLA × LWR, each of them again is a complex trait.

It appears that traditional agronomic practices need reevaluation in view of the changing genotype and management practices now available. Phenology of the plant should also receive adequate attention in developing new agronomic practices to provide a sound scientific basis. It seems that genetic potential of the cultivar is likely to have a considerable influence on time of maturity, but maturity may also be influenced by the time of sowing. Therefore, in the present work, effect of sowing time on productivity of sunflower was investigated.

Considering the aforesaid, the main aim of the present study was to study the following:

1) growth in terms of total dry weight, leaf area and leaf dry weight
2) effect of sowing time on the above growth parameters
3) to work out various growth indices viz. RGR, RLGR, NAR, LAR, SLA, LWR

MATERIAL AND METHODS

Seeds of sunflower (*Helianthus annuus* L. cultivar MSFH – 8) were sown in black cotton soil (vertisol) adjacent to Department, at two different times. The first sowing was done in August (early) and the second sowing in September (late) 1992. All cultural practices at both the sowings were same except the sowing time. The experimental plots were mechanically ploughed and layered with farmyard manure. At the time of sowing, it was fertilized with 10 g × m^{-3} of diammonium phosphate as a basal dose. After 30 days, another dose of fertilizer in the form of urea was added (6 g × m^{-3}). Same was repeated after another 20 days. Cultural practices including irrigation, weeding, insecticides application, etc. were conducted to optimize plant growth and yield. Anthesis took place after 38–39 days of sowing.

Growth analysis was performed at 5 – 6 d interval from germination to maturation. On each sampling day, 7 – 10 plants of equal size were cut at the soil level and transported to the laboratory. Leaves and stems were separated and total length (l) and maximum width (w) of all leaves on the plant were measured. Leaves and stem of each plant were separately oven dried at 60 °C to a constant weight for dry weight determination. Leaf area was calculated using the formula:

$$Y = 0.60 \times LW$$

where
Y = leaf area,
L = length,
W = maximum width of the leaf
and 0.60 = constant (Chanda and Singh, 1997).

Similar method has been employed for determining leaf area in other crop plants (Chanda *et al.* 1985; Ma, *et al*. 1992). Average leaf area per plant was obtained by summing areas of individual leaf of each plant. Number of green leaves per plant was also recorded. Beginning with the second sampling date, the plants were separated into leaves and stem during vegetative stage and also into bud/flower during reproductive stage.

Growth Analysis

Polynomial function were fitted to total plant dry weight, leaf dry weight and leaf area. The selection of an appropriate polynomial regression model was made statistically by “Lack of Fit” method (Nicholls and Calder 1973). The formulae used to calculate growth indices were as per Radford (1967) and Chanda *et al.* (1986).

RESULTS AND DISCUSSION

A cubic polynomial was the best fit curve for all the growth parameters studied. The main feature of total dry matter accumulation was the relative superior performance of the late grown crop over the early grown crop. Dry matter accumulation showed a similar trend in both, early and late grown crops (Fig. 1a). They showed a typical sigmoidal curve. There was an initial lag phase up to 30 days in both the crops; subsequently, the dry matter accumulation was significantly more in late grown crop than early grown one. Maximum dry weight was on day

85 in late grown crop, the total dry weight was almost same after day 80. In both the crops, the rate was almost negligible till day 20; then there was a steady increase which reached to a maximum level on day 45 in late grown crop. Subsequently, the rate decreased gradually, reaching almost to zero by day 85. The rate in late grown crop was almost 4 times more as compared to early grown one. Otherwise, the early grown crop showed a trend similar to that of late grown crop.

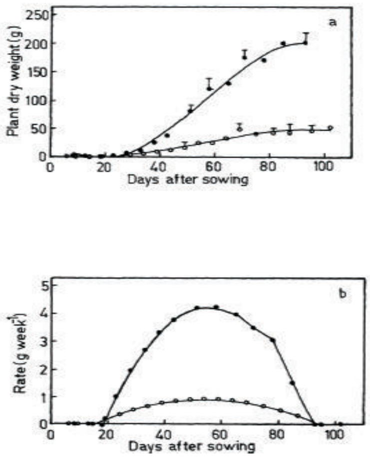

Fig. 1
a) Total plant dry weight during the entire season in early (o——o) and late (●——●) sown crops.
b) The rate curve for total dry weight. Vertical bars represent ″SD. (Where ever the bar is absent the

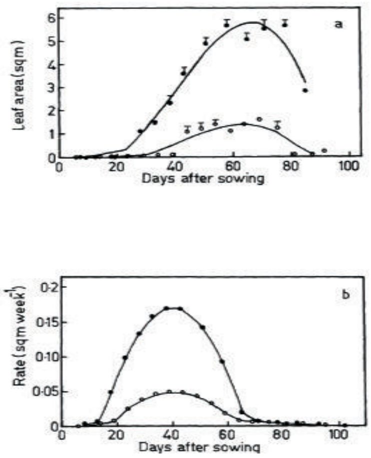

Fig. 2
a) Leaf area per plant during the entire season in early (o——o) and late (●——●) sown crops.
b) The rate curve for leaf area. Vertical bars represent ″SD. (Where ever the bar is absent the SD is very small).

Estimation of leaf area is an essential part of growth analysis (Ma *et al.* 1992). Initially very low leaf area was present in both early and late grown crops (Fig. 2a). Leaf area in early grown crop started increas–ing from day 30 while, in late grown crop, it was from day 20 itself. The rate of increase was significantly more in late grown crop as compared to early grown one (Fig. 2b). Maximum rate of leaf area accumulation was on day 40 which is almost 3.5 times more than the early grown crop.

Both early and late grown crops had same leaf dry weight till day 20 (Fig. 3a). Subsequently the leaf dry weight, in late grown crop steadily increased and maximum weight was on day 70 and decreased consider–ably thereafter. The leaf dry weight was 5 times more in late grown crop than in early grown crop. The rate of leaf dry weight increase in early grown crop was almost same from day 20 to day 45 and it slightly de–creased thereafter reaching almost to zero level by day 75 (Fig. 3b). While in late grown crop, it showed a steady increase from day 20 on–wards, reaching a peak level on day 40 and it decreased steadily reach–ing to almost to zero level by day 80. The difference in rate of leaf dry weight accumulation in early and late grown crop was almost 6 times.

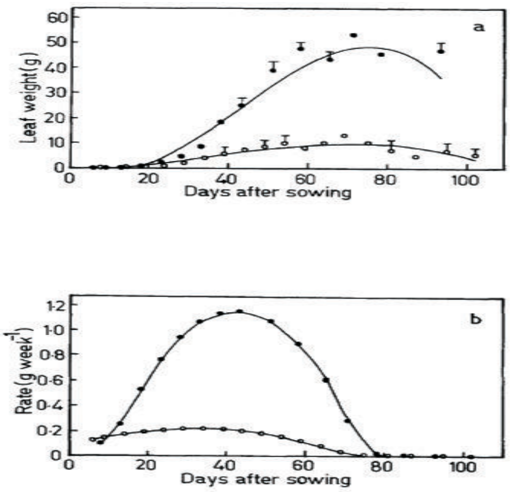

Fig. 3

a) Leaf dry weight per plant during the entire season in early (o——o) and late (•——•) sown crops.

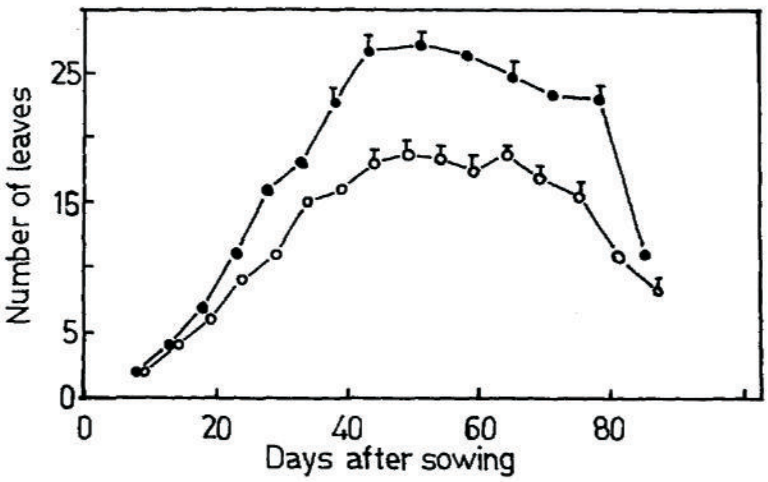

Fig.4 Average number of leaves produced per plant during the entire season in early (o——o) and late (•——•) sown crops. Vertical bars represent ˝ SD. (Where ever the bar is absent the SD is very small)

Increase in number of leaves correspondingly increases leaf area. As seen in Fig. 4, till day 30 both the crops had almost equal number of leaves. The leaf number started varying considerably from day 35 on–wards. In early grown crop, the leaf number was same (almost) till day 60 after which it decreased. In late grown crop, the leaf number in–creased significantly from day 23 reaching a peak level on day 45; sub–

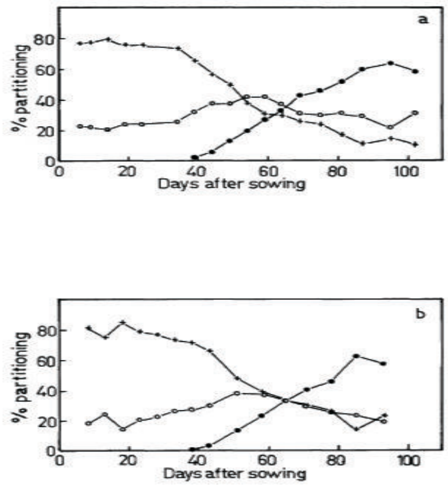

Fig. 5 Percent partitioning of total dry weight to different plant parts.
a) early and b) late sown. (+——+) leaf; (o——o) stem; (•——•) flower

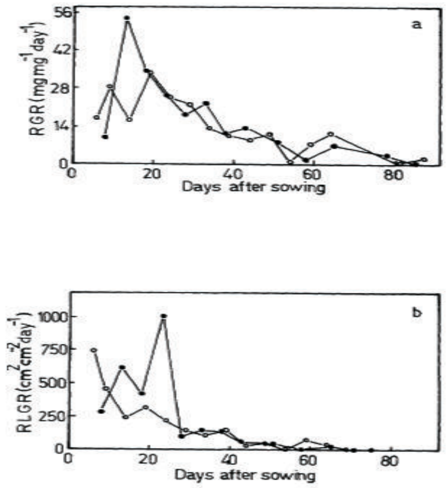

Fig. 6 Variation in the
a) mean relative growth rate (RGR) and
b) mean relative leaf growth rate (RLGR) in both early (o——o) and late (•——•) sown crop

sequently the leaf number decreased slowly till day 78 and by day 83 it decreased drastically.

Total dry weight is the product of growth rate and growth duration (Takeda and Frey, 1979) and it was clearly affected by sowing time and late sowing was clearly beneficial. It had better growth (higher weight and area) at all times. This can be attributed to the number of leaves. Number of leaves were reduced drastically by early sowing (Fig. 4). The delayed sowing showed very large increase in number of leaves and this was clearly an important factor in enabling the late sown cultivar to have higher dry weight and area. It is known that leaf area production is essential for energy transfer and mass accumulation processes in crop canopy. Leaf area is indicative of light interception and growth (Burstal and Harrish, 1983, Boote *et al.* 1988), photosynthesis (Monteith 1977, Heilamn *et al.* 1977), transpiration (Encho and Hurd 1979) and growth rate (Lieth *et al.* 1986).

Though it is known that higher yields of improved cultivars in several species resulted from changes in partitioning (Evans 1983), the mecha–nisms controlling the partitioning of assimilate between vegetative and reproductive growth are poorly understood (Loomis *et al.* 1979, Gifford and Evans 1981). During early stages of growth (up to 35 days) leaves accumulated nearly 80% of the dry weight but decreased with advancing age irrespective of whether the crop was early or late sown (Fig. 5). The dry matter in the stem, on the other hand was quite low initially (i.e. only about 20%) but increased significantly during later stages. How–ever, after day 60, in both the crops, the dry matter in stem decreased.

With the onset of reproductive phase, major accumulation of dry matter was into flower, which showed a steady increase till the end, when the plant was harvested.

Initially, in both the crops, RGR (Fig. 6a) was more and it decreased gradually as the season progressed, reaching almost to zero level by 80 days; the late grown crop always maintained a higher RGR. The maxi–mum difference was between day 30–50. RLGR as a function of time was similar to RGR (Fig. 6b). Here also the late grown crop always main–tained higher rate from the beginning.

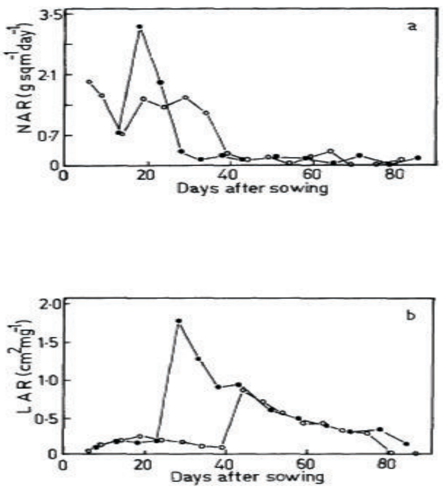

Fig. 7
a) Variation in the mean net assimilation rate (NAR) and
b) changes in leaf area ratio (LAR) in both early (o——o) and late (•——•) sown crop

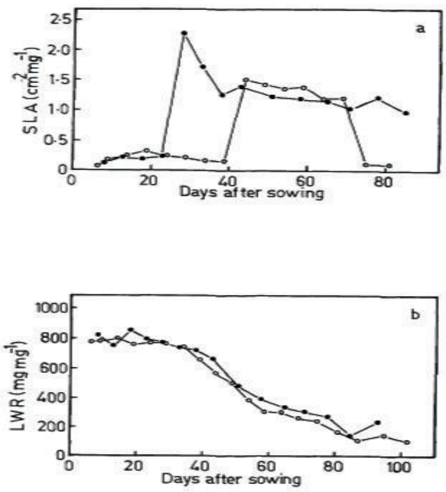

Fig. 8 Changes in
a) specific leaf area (SLA) and
b) leaf weight ratio (LWR) in both early (o——o) and late (•——•) sown crop

Changes in growth indices like NAR, LAR, SLA and LWR, are shown in (Figs. 7 – 8). NAR was more in the early growth stages reaching to a maximum level by 30–35 days in both the crops and then they showed a declining trend. LAR, on the other hand, showed a slightly different trend in both the crops (Fig. 7b). The early and late grown crops had similar LAR till about 20 days after which the LAR of late grown crop showed a significant rise on d 43 and then it showed a declining trend reaching almost to zero level by d 90. While in early grown plants, the increase was around 50 days and then it declined. The trend of SLA (Fig. 8a) was almost similar to that of LAR while LWR (Fig. 8b) showed an entirely different trend. Maximum LWR was in the beginning and it al–most remained same till 30 days and then it showed a progressive de–cline as advancement of age took place; no difference between early and late grown crop could be visualized, though the late sown crop had slightly more ratio (LWR) at all times.

Since RGR = NAR x LAR (Brigg *et al.* 1920a, b) drifts in RGR may be explained by changes in the efficiency of the leaves as producers of dry matter i.e. NAR and changes in the leafiness of the plant i.e. LAR. The LAR is more easily considered in terms of its components, the proportional allocation of total dry matter to leaves i.e. LWR and leaf thickness i.e. SLA. A high NAR can be achieved by a high rate of photosynthesis. This requires a large amount of enzymes and light harvesting complexes per unit leaf area and possibly an extra layer of palisade parenchyma, all of which decrease SLA and thus LAR (Konings 1989). LAR decreased as the season progressed indicating that production of leaf area per unit of dry matter decreased with time.

It can be concluded from this study that sowing time for sunflower in semi–arid area like Rajkot is September. The late grown crop had distinctly higher leaf area, leaf weight and total dry weight. It also had more number of leaves. However, further improvement in yield in sunflower may come from improvement in RGR and NAR.

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