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# ONTOGENY GROWTH AND RADIATION USE EFFICIENCY OF *HELIANTHUS ANNUUS* L., AS AFFECTED BY HYBRIDS, NITROGENOUS REGIMES AND PLANTING GEOMETRY UNDER IRRIGATED ARID CONDITIONS

**A. ZAHOOR[1], M. RIAZ[1], S. AHMAD[1]*, H. ALI[1], M.B. KHAN[1], K. JAVED[1], M.A. ANJUM[2], M. ZIA-UL-HAQ[3] AND M.A. KHAN[4]**

*[1]Departments of Agronomy, [2]Horticulture & [3]Chemistry, Bahauddin Zakariya University, Multan-60800, Pakistan, [4]In-Service Agricultural Training Institute, Sargodha-40100, Pakistan*
**Corresponding author's email: shakeel.agronomy@gmail.com*

**Abstract**

Response of sunflower (*Helianthus annuus* L.) hybrids in terms of ontogeny growth and radiation use efficiency (RUE) to nitrogenous regimes and planting geometries was studied in two field experiments conducted at Experimental Farm, Bahauddin Zakariya University (BZU), Multan, Pakistan during spring 2009. Variables included in this study were four hybrids and four nitrogenous regimes in experiment 1; three hybrids and three planting geometries in experiment 2. Overall, increasing nitrogenous regimes significantly increased LAI compared to control in experiment 1, while, in experiment 2, the ridge and bed sown crops yielded higher LAI as compared to the flat sown crop. The accumulative leaf, root, stem, head and total dry matter were 63, 51, 211, 58 and 349 g plant$^{-1}$, respectively for experiment 1, while, the respective values for experiment 2, were 59.6, 130.5, 135.9, 180.0 and 487.1 g plant$^{-1}$, respectively. In the present study, both experiments 1 & 2 resulted in a curvilinear trend for RUE over time of course. Overall, maximum value for RUE for total dry matter accumulation ranged from 1.47 to 2.72 g MJ$^{-1}$ in experiment 1, the respective values for experiment 2, were 1.38 to 2.83 g MJ$^{-1}$. For growers higher nitrogen rates and bed sowing are good management practices for newly developed sunflower hybrids under irrigated arid conditions.

## Introduction

Sunflower (*Helianthus annuus* L.) is the most dominant non-conventional oil seed crop in Pakistan. Local production of edible oil stood at 6.84 M tons during 2008-09, which was 24% of the total requirement of the country, while, the remaining 76% was made available through import costing approximately Rs. 80 billion (GOP, 2010). In Pakistan sufficient high quality sunflower can be grown to meet the domestic demand for edible oil and thus to reduce the import bill. In 2009, sunflower was planted on an area of 3.53 M ha with total seed production of 5.54 M tons and total oil production of 2.11 M tons (GOP, 2010). However, the yield of sunflower in Pakistan is very low. The possible reasons are use of low doses of nitrogenous fertilizer and in-appropriate planting geometries of newly adopted hybrids by the growers. Therefore, sowing of newly developed hybrids, higher nitrogenous regimes and appropriate planting geometries are still promising management recommendations in order to increase edible oil production for the low income farmers, improve food security and reduce the import bills.

Canopy radiation use efficiency (RUE) of various field growing crops including sunflower in the absence of biotic and a-biotic stresses has been found to be fairly conservative with species-specific behavior (Monteith, 1977; Kiniry *et al*., 1989; Hall *et al*., 1995 and references there in). Monteith (1977) defined RUE as the amount of biomass produced (g $m^{-2}$) per unit of intercepted solar radiation (MJ $m^{-2}$). Interception of PAR is regulated simultaneously by the canopy size (Leaf area index; LAI) and structure (Leaf angle and orientation). RUE is the net gain in assimilation in photosynthesis over respiratory losses by the crop canopy to the amount of intercepted radiation (Gimenez *et al*., 1994). The RUE may vary during the crop growth stages (Gallagher & Biscoe, 1978; Ferraris & Charles-Edwards, 1986; Trapani *et al*., 1992; Steer *et al*., 1993; Hall *et al*., 1995 and references there in). Nitrogen supply can affect plant growth and productivity by changing canopy size and structure, thus altering RUE (Novoa & Loomis, 1981; Sinclair, 1990; Muchow & Sinclair, 1994; Gimenez *et al*., 1994 and references there in). The planting patterns also affect RUE (Tollenaar & Aguilera, 1992). Sowing of newly developed hybrids, nitrogen fertility status and planting geometries are becoming increasingly important components in gaining the economic and environmental viability of various agro-ecosystems particularly under irrigated arid environments. Thus, exploring newly developed hybrids (genotypic variation) with proper planting geometry and optimum nitrogen supply ultimately resulting in higher RUE through exploiting available natural resources have been proposed as possible solutions for reducing the cost of production of the newly developed hybrids for the low income farmers of the arid areas (Gardner *et al*., 1994 and references there in).

Recent literature depicts that abundant data regarding single factor studies about effect on growth and RUE of sunflower are available, i.e., nitrogen response (Gimenez *et al*., 1994; Muchow & Sinclair, 1994; Hall *et al*., 1995; Ahmad *et al*., 2009 and references there in), hybrids behavior (Gardner *et al*., 1994), radiation environment (Bange *et al*., 1997 a & b) and plant population (Madakadze *et al*., 1998; Ahmad *et al*., 2009). However, very limited data is available having interactive effects of various agronomic factors for newly developed sunflower hybrids under irrigated arid environmental conditions. Therefore, in the present study, emphasis was made to evaluate the combined interactive effects of various crop husbandry practices, i.e., hybrids, nitrogenous regimes and planting geometries on the ontogeny growth and RUE of sunflower under irrigated arid agro-environmental conditions.

## Materials and Methods

**Experimental site and soil analysis:** Two field experiments were conducted at Experimental Research Farm, Bahauddin Zakariya University (BZU), Multan, Pakistan (Latitude = 30.15 °N; longitude = 71.30 °E; and 126.6 m from sea level) during spring season 2009. The experimental site belongs to silt loam (texturally) and Sultan Pur, soil class and series, respectively. Prior to sowing, soil analysis showed pH 8.02, EC 12.0 ds $m^{-1}$, organic matter content 0.76%, total nitrogen 0.039%, available phosphorus 5.1 ppm, available potassium 250 ppm, while, soil texture composed of sand 28%, silt 54%, and clay 18%.

**Experimental design and treatments:** The experiments were laid out in a randomized complete block design with factorial arrangements and replicated thrice. Sowing date for both experiments was 17$^{th}$ February, 2009, while final harvesting dates were 20$^{th}$ May and 01$^{st}$ June, 2009 for experiments 1 & 2, respectively. The experiment 1 comprised of four hybrids, $H_1$ = 00989; $H_2$ = 01087; $H_3$ = 00997; and $H_4$ = 010226 and four nitrogenous regimes, $N_0$ = control; $N_1$ = 75; $N_2$ = 150 and $N_3$ = 225 kg $ha^{-1}$. While, experiment 2 comprised of three hybrids, $H_1$ = 19012; $H_2$ = Hysun-33; and $H_3$ = DK-4040 and three planting geometries, $PG_1$ = flat sowing; $PG_2$ = ridge sowing; and $PG_3$ = bed sowing.

**Sampling protocols:** A total of five in experiment 1 and six in experiment 2 harvests were made to record the measurements relating to ontogeny growth and radiation use efficiency. Dry weight of each sample component (i.e., leaf, stem, root and head) was recorded by using an electronic balance. Appropriate sub-sample of fresh weight was dried to a constant weight at 75°C to a constant weight. A sub-sample of 10 g of leaf lamina was taken and leaf area was measured on an area meter. Leaf area index (LAI) was calculated as suggested by Watson (1947).

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area}}{\text{Land area}}$$

Leaf area duration (LAD) was estimated according to Hunt (1978).

$$\text{Leaf area duration (LAD)} = \left[\frac{(LAI_1 + LAI_2) \times (t_2 - t_1)}{2}\right]$$

where, $LAI_1$ and $LAI_2$ are the leaf area indices at times $t_1$ and $t_2$, respectively.

**Intercepted photo-synthetically active radiation (PAR):** The fraction of intercepted radiation ($F_i$) was estimated from LAI using the exponential equation as suggested by Monteith & Elston (1983).

$$\text{Fraction of intercepted radiation } (F_i) = 1 - \exp(-k \times LAI)$$

where, k is extinction co-efficient for total solar radiation (Monteith, 1977). K value of 0.90 was used as suggested by Gimenez *et al*., (1994). PAR was assumed to equal half (50%) of total incident radiation (Szcicz, 1974). Multiplying these totals by appropriate estimates of $F_i$ and $S_i$ gave the amount of intercepted radiation (Sa).

$$\text{Intercepted radiation (Sa)} = F_i \times S_i$$

where, Si is the incident PAR.

**Radiation use efficiency:** Radiation use efficiency (RUE) for total dry matter was calculated by following this equation.

$$\text{Radiation use efficiency for total dry matter } (RUE_{TDM}) = \frac{TDM}{\sum Sa}$$

where, $\sum$Sa is the cumulative PAR.

**Statistical analysis:** The data collected from two experiments were analyzed statistically for analysis of variance (ANOVA). The treatment means were compared by using least significant differences test. MSTATC computer software was used to carry out statistical analysis (Russel & Eisensmith, 1983).

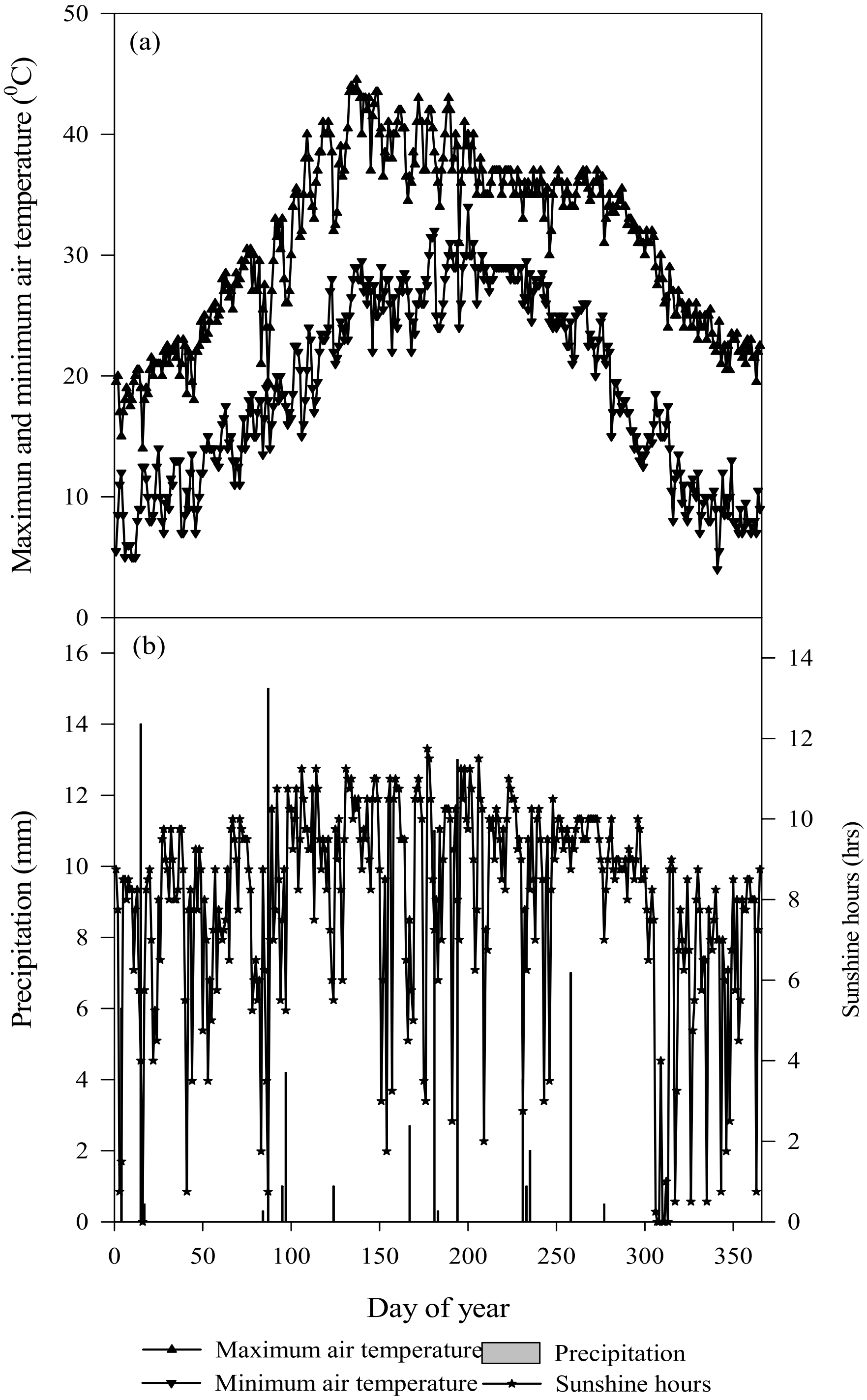


Fig. 1. Daily maximum and minimum air temperatures (a), precipitation and sunshine hours (b) during the year 2009.

## Results and Discussion

**Weather data:** The daily weather data collected at Central Cotton Research Institute (CCRI), Multan, Pakistan for year 2009. The daily maximum and minimum above air temperatures for spring sunflower growth period ranged from 19.5 to 44.0ºC and 11.0 to 28.0ºC, respectively. The daily sunshine hour's and precipitation values for spring sunflower crop season were 11.3 hours and 21.5 mm, respectively (Fig. 1).

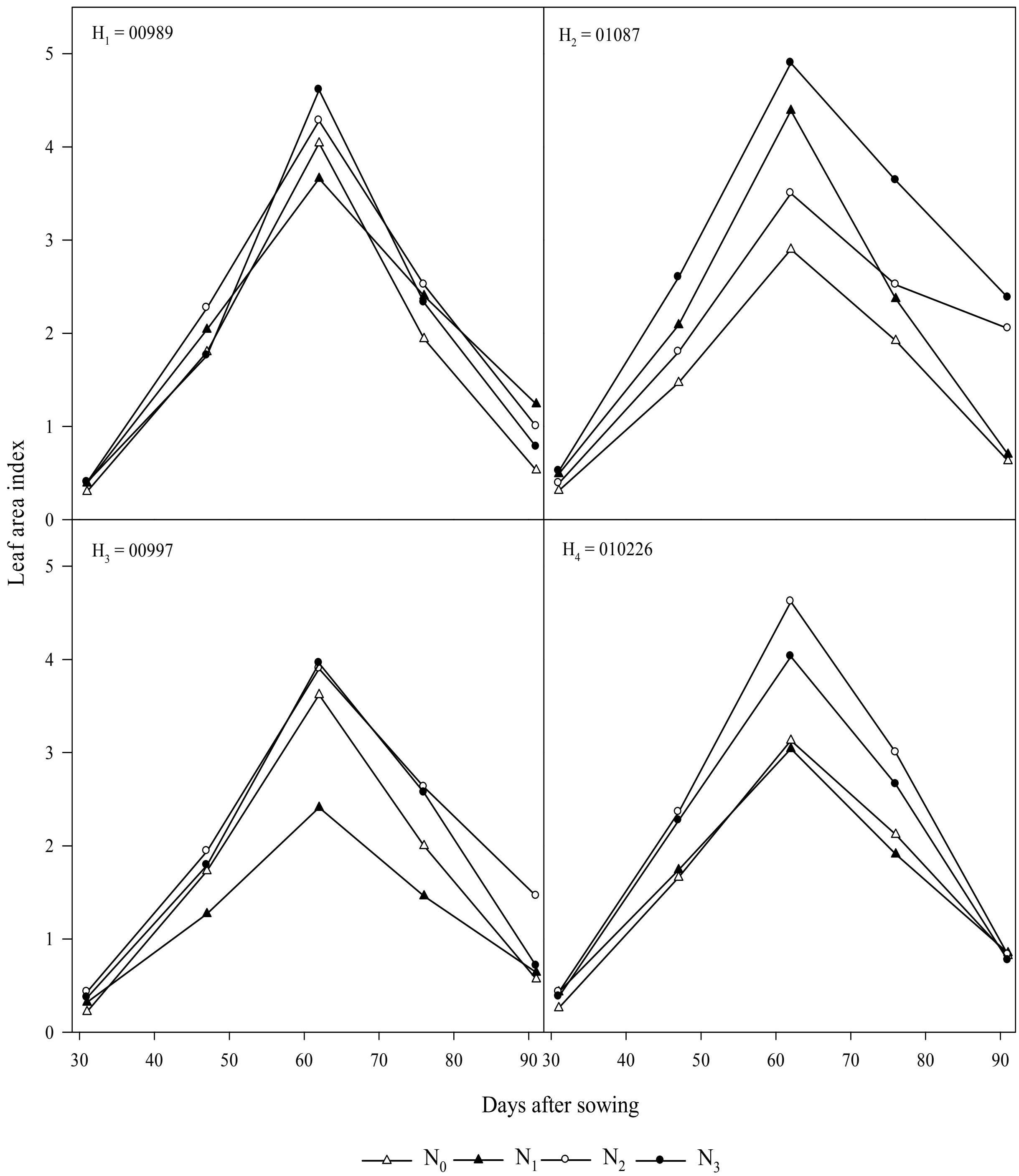


Fig. 2. Leaf area index of spring sunflower as affected by hybrids and nitrogenous regimes.

**Ontogeny leaf area index:** The interactive effect of treatments on leaf area index (LAI) is shown in Figs. 2 & 3, respectively (Experiments 1 & 2). LAI increased linearly from 31 DAS (Experiments 1 & 2) and reached at maximum on 63 DAS in experiment 1 and 60 DAS in experiment 2. Thereafter, it declined sharply until final harvest at 92 DAS and 103 DAS, respectively (Experiments 1 & 2), possibly due to accelerated senescence of older leaves and shading by the new and upper leaves. For experiment 1, the maximum LAI reached at 4.6, 4.9, 4.0, and 4.6 for hybrids $H_1$ (00989), $H_2$ (01087), $H_3$ (00997) and $H_4$ (010226), respectively for higher nitrogenous regimes (100 & 150 kg $ha^{-1}$), while the minimum values for the parameter were recorded at control (0) or lower (50 kg $ha^{-1}$) nitrogenous regimes (Fig. 2). Overall, increasing nitrogenous regimes significantly increased LAI compared to control ($N_0$) or lower rate of nitrogen (50 kg $ha^{-1}$). The significantly better performance of hybrids with respect to nitrogen may be due to its higher nitrogen use efficiency (NUE). In case of experiment 2, the maximum LAI reached at 6.26, 6.91 and 6.99 for hybrids 19012, HYSUN-33 and DK-4040, respectively at bed sown crop, while, the minimum values for the parameter were recorded at flat sown crop (Fig. 3). The superiority of bed sowing might be due to the fact that plants in bed sowing utilized the input resources efficiently, i.e., nutrients, water, space and light. Gimenez *et al*., (1994) concluded that for any given canopy size (LAI), canopy structure (leaf angle and orientation) determine both the interception of photo-synthetically active radiation (PAR) and its radiation use efficiency (RUE) with which that PAR drives photosynthetic gain.

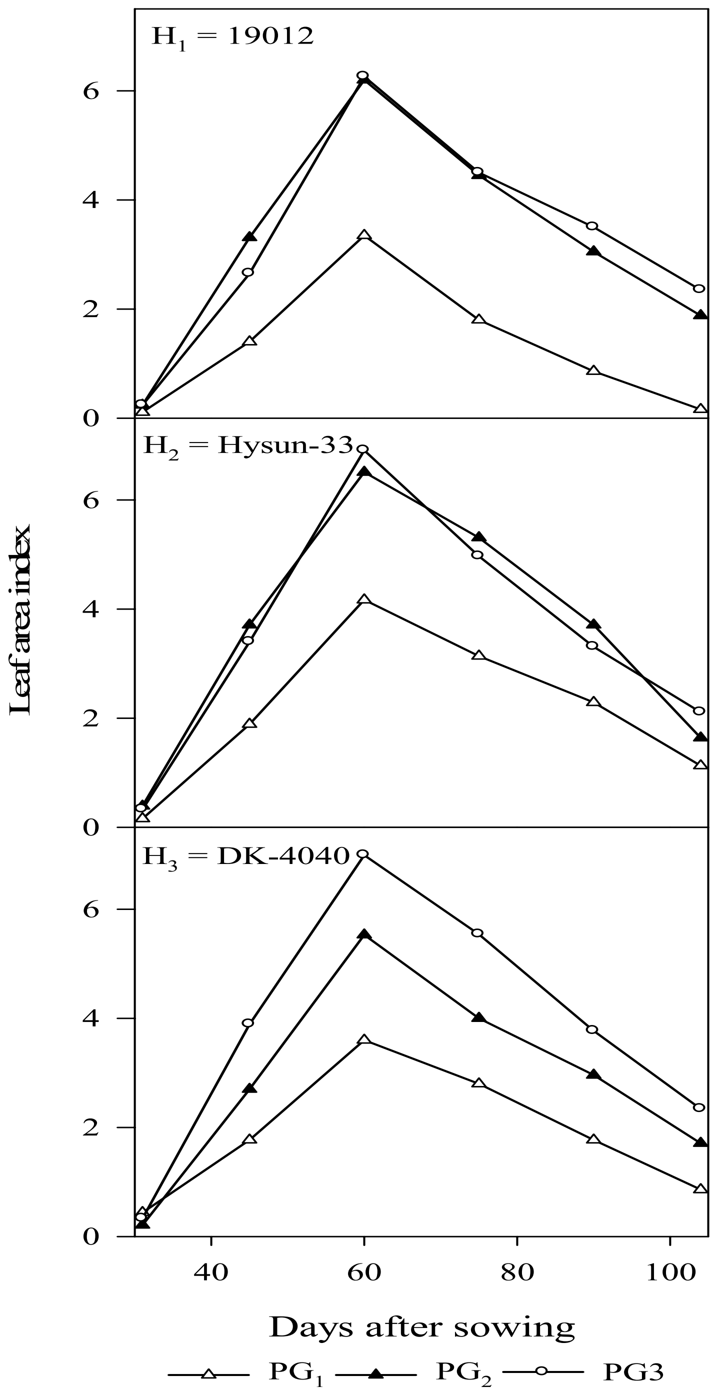


Fig. 3. Leaf area index of spring sunflower as affected by hybrids and planting geometries.

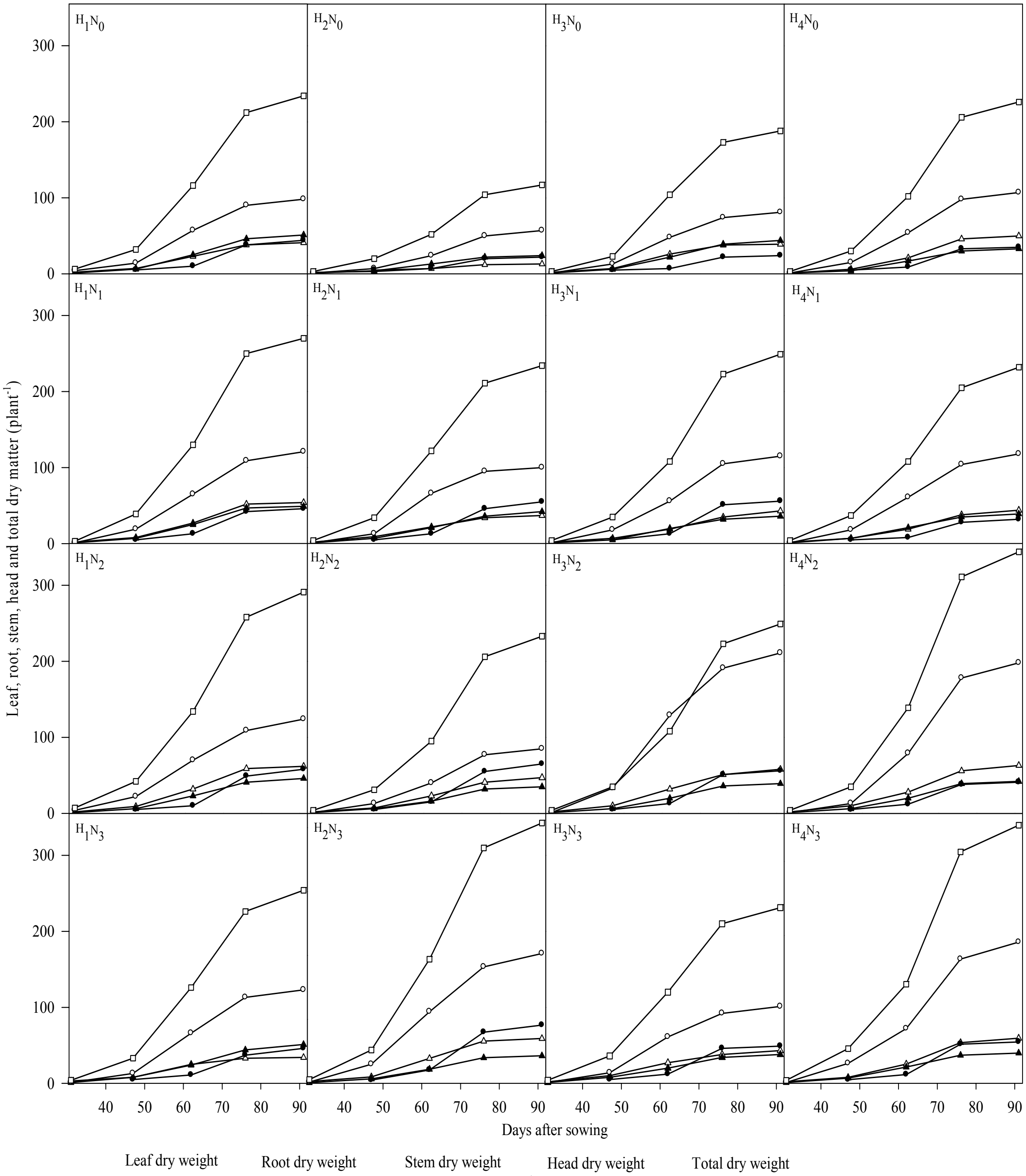


Fig. 4 Leaf, root, stem and total dry weight plant$^{-1}$ of spring sunflower as affected by hybrids and nitrogenous regimes.

**Ontogeny leaf, root, stem, head and total dry matter accumulation:** Leaf, root, stem and total dry matter accumulation was slow until 47 DAS and 45 DAS in case of experiments 1 and 2, respectively (Figs. 4 & 5). Head dry matter accumulation started at 47 DAS and was slow until 62 DAS (Experiment 1) and respective values for experiment 2 were 60 DAS and 77 DAS, respectively. Subsequently, there was a linear rise in the accumulation of leaf, root, stem, head and total dry matter accumulation (Figs. 4 & 5). The final maximum leaf, root, stem, head and total dry matter accumulation were 63, 51, 211, 58 and 349 g plant$^{-1}$, respectively for experiment 1, while, the respective values for experiment 2, were 59.6, 130.5, 135.9, 180.0 and 487.1 g plant$^{-1}$, respectively. Our findings are in agreement with the results of Hall *et al*., (1995), who found that total crop dry matter accumulation continued to increase up to physiological maturity in sunflower crop and thereafter may show some decline.

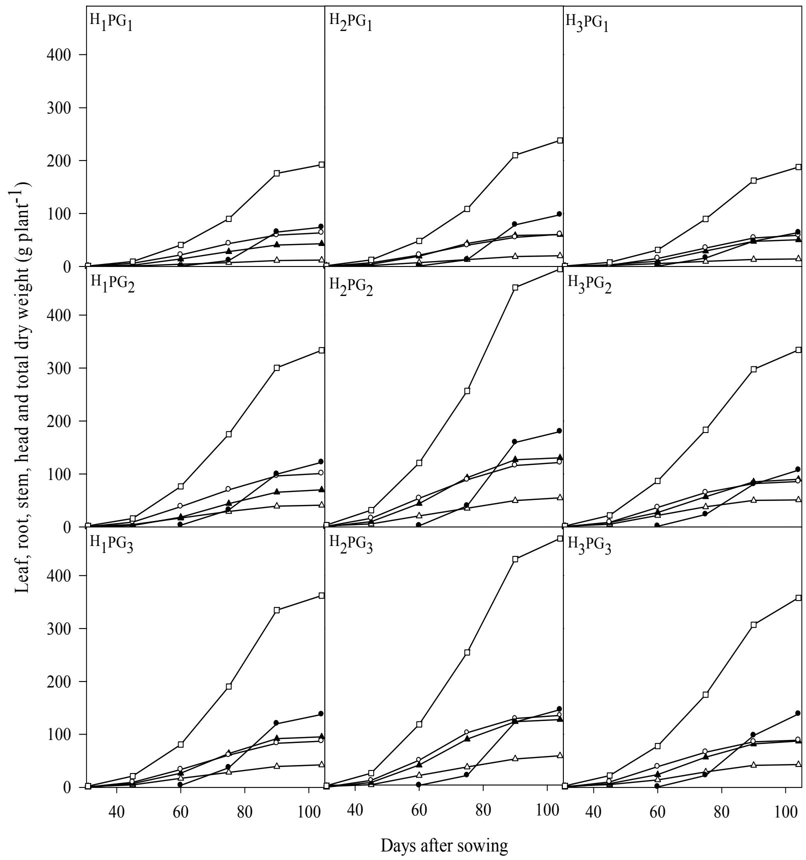


Fig. 5. Leaf, root, stem, head and total dry weight plant$^{-1}$ of spring sunflower as affected by hybrids and panting geometries.

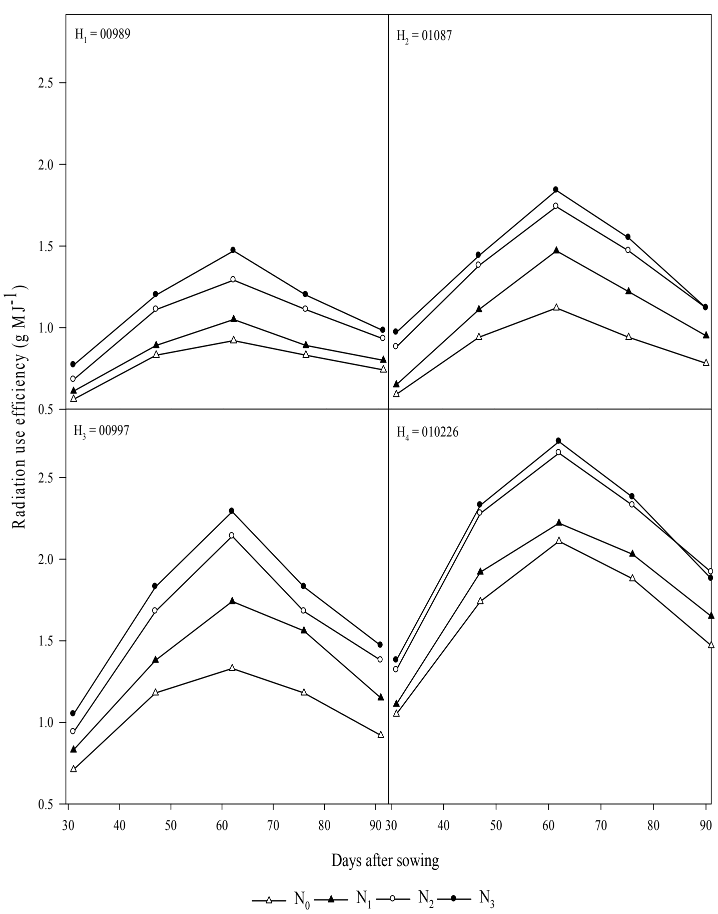


Fig. 6. Radiation use efficiency of spring sunflower as affected by hybrids and nitrogenous regimes.

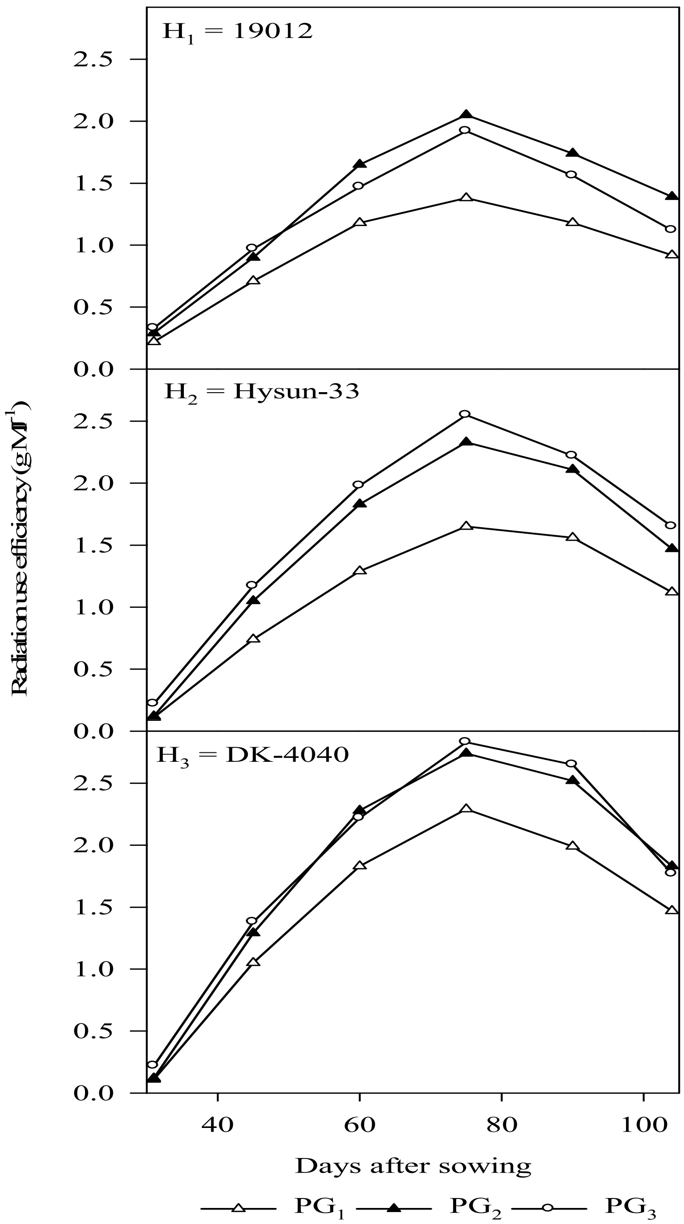


Fig. 7. Radiation use efficiency of spring sunflower as affected by hybrids and planting geometries.

**Ontogeny radiation use efficiency:** Interception of radiation is determined by the size and structure of the canopy; while, RUE expresses the net gain in assimilation by the canopy in photosynthesis over losses by respiration by the entire crop relative to the quantity of intercepted radiation (Gimenez *et al*., 1994). Ontogeny RUE for total dry matter accumulation for experiments 1 & 2 is presented in Figs. 6 & 7. The maximum values RUE in case of experiment 1 were achieved at higher nitrogenous regimes (100 & 150 kg ha$^{-1}$) as compared to control or lower rate (50 kg ha$^{-1}$). Differences in RUE might be a major cause of difference in growth of hybrids at various nitrogenous regimes and planting geometries. The differences in interception of PAR and RUE resulted from the production of fewer, smaller leaves at the lower nitrogenous regimes than higher nitrogenous regimes. RUE increased with higher rates of nitrogen applied (Muchow & Sinclair, 1994). Radiation use efficiency was small during early establishment phase as compared to the rapid growth phase (reproductive phase). Average RUE for all harvest dates followed a curvilinear relationship with time (Figs. 6 & 7). The mean RUE values were smaller during early harvests, then fairly stable and finally there was a sharp decline. Major possible reasons for such changes in ontogeny RUE included variations in the patterns of biomass partitioning among various components (Trapani *et al*., 1992), changes in the production of total biomass accumulation (Penning de Varies, 1983), alteration in leaf RUE resulting from the loss of nitrogen from source (Leaves) to sink (Grains) (Sinclair & Horie, 1989), and increase in crop respiratory load per leaf area (Gallagher & Biscoe, 1978; Whitfield *et al*., 1989; Hall *et al*., 1995 and references there in). In the present study, both experiments 1 & 2 showed curvilinear RUE over time of course for reproductive period (Figs. 6 & 7), indicating a variable respiration rate. This indicates a better description of changes in RUE with ontogeny, at least during reproductive phase affected by hybrids, nitrogenous regimes and planting geometries. This kind of trend (curvilinear) has been reported by scientists for sunflower crop (Steer *et al*., 1993; Hall *et al*., 1995 and references there in). Overall, maximum value for RUE for total dry matter accumulation ranged from 1.47 to 2.72 g $MJ^{-1}$ (Fig. 6). While, in experiment 2, RUE values were lower in flat sown crop as compared to ridge and bed sown crop (Fig. 7). Overall, maximum values for RUE ranged from 1.38 to 2.83 g $MJ^{-1}$ (Fig. 7). These results and overall trend pattern are in line with the findings of Gimenez *et al*., (1994), with maximum RUE of 2.3 g $MJ^{-1}$, and similar to values reported by Kiniry *et al*., (1989) but smaller than those (3.26 g $MJ^{-1}$) of Trapani *et al*., (1992).

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