# EFFECT OF SOWING DENSITY ON THE DYNAMICS OF LEAF AREA DEVELOPMENT IN SUNFLOWER

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## SUMMARY

The paper deals with the effect of sowing density on the dynamics of leaf area development in sunflower. The experiment was established on a chernozem soil, in a six-crop rotation, according to the two-factorial split-plot design. The main plots were three approved or experimental hybrids: NS-Dukat, NS-H-111 and NS-H-103. The subplots were six densities: 30,000, 40,000, 50,000, 60,000, 70,000 and 80,000 plants per hectare. Leaf area per plant decreased with the increase in density, while the leaf area index increased. Leaf area reaches the maximum at the stage of flowering. Leaf area growth was most intensive from the stage of six leaves to budding.

**Key words**: *sunflower, leaf area, leaf area index, plant density*

## INTRODUCTION

Leaf area index represents a ratio between leaf area size and soil surface size. It is desirable for leaf area index to increase intensively, especially in the first half of the vegetative period, to reach its maximum as soon as possible, and to remain at that level as long as possible. To achieve a maximum yield, it is necessary to maximize leaf area, regarding both, its size and the dynamics of formation. In favorable ecological conditions, leaf area increases rapidly in the first half of the vegetative period, reaching its maximum at the stage of flowering. The longer the leaf area duration, the longer the period of seed filling. It affects favorably grain yield level per plant and sunflower crop (Merrien, 1992).

According to Rawson *et al*. (1980), leaf area per different strata of sunflower crop is highly variable. A mature sunflower plant has simultaneously leaves at different stages, from developing leaves to the old leaves which are no longer active, turning yellow and drying up.

Number of leaves, an important component in leaf area formation, is determined early, 10 to 20 days after emergence. During that phase, sunflower plants are sensitive to environmental factors, especially soil water content, because low content reduces the number of leaf buds. With modern hybrids, the total number of leaves ranges from 20 to 30. Maximum leaf area per plant depends on stand density, ranging between 4,000 and 7,000 $cm^2$. At flowering, the medium and upper leaf strata comprise 60 to 80 % of the total leaf area. At that time, bottom leaves are mostly dry. Stand density is negatively correlated with leaf area per plant (Merrien, 1986).

The objective of this paper was to see how different stand densities affect the dynamics of leaf area development in three sunflower hybrids that differ considerably in the growth habit.

## MATERIALS AND METHODS

Field experiments were conducted at the Rimski Šancevi experiment field of the Institute of Field and Vegetable Crops in 1994, 1995 and 1996. The experiment was established on a chernozem soil, in a six-crop rotation, according to the two-factorial split-plot design. The main plots were three approved or experimental hybrids: NS-Dukat, NS-H-111 and NS-H-103.

NS-Dukat is an early hybrid that will mature in 90 to 95 days. The average stem height is 145 to 155 cm, the genetic potential for seed yield 4 t $ha^{-1}$, the oil content in seed from 47 to 49 %. The hybrid is genetically resistant to downy mildew, broomrape and the sunflower moth. It is recommended for late sowing (15 May to 15 June), in fields that could not be sown timely for any reason.

NS-H-111 is a new, medium early hybrid that matures in 105 to 115 days. The stem is firm, 165 to 185 cm tall on average. The genetic potential for seed yield is 5 t $ha^{-1}$, the oil content in seed from 48 to 50 %. The hybrid is genetically resistant to downy mildew, rust, broomrape and the sunflower moth, tolerant to *Phomopsis*. The hybrid is adaptable to a wide range of agroecological conditions.

NS-H-103 is an experimental hybrid that matures in 120 to 130 days. The stem is firm, 90 to 100 cm tall on average. The genetic potential for seed yield is 4 t $ha^{-1}$, the oil content in seed ranges up to 50 %. The hybrid is genetically resistant to downy mildew, rust, broomrape and the sunflower moth. Because of a short stem, it is suitable for additional chemical treatment during growing season.

The experiment subplots were six stand densities: 30,000, 40,000, 50,000, 60,000, 70,000 and 80,000 plants per hectare. Manual planting was done in early April, by placing 3-4 seeds per hill. At the stage of 1-2 pairs of leaves, the stand was thinned to one plant per hill, to obtain the desired number of emerged plants. Cultural practices were performed timely, applying the conventional technology. The experiment was conducted in four replications. The elementary plots consisted of six 10-meter rows.

Leaf area size was measured at the following stages:

1. 6 pairs of leaves
2. budding
3. flowering
4. seed forming
5. 30 days after flowering

The sample was consisted of 12 plants (3 plants of every replications) from following subplots: 30000 and 80000 plants per hectare for every hybrids, 60000 plants per hectare for NS-Dukat, 50000 plants per hectare for NS-H-111 and 70000 plants per hectare for NS-H-103. The latter are optimal plant densities for these hybrids.

***DMP AREA METER, Model 3100,*** was used for leaf area measurements.

## RESULTS AND DISCUSSION

Leaf area size per plant and per unit area varied in dependence of year, hybrid, stage of development and stand density *(Table 1).*

For the stage of 6 pairs of leaves, the largest leaf area was achieved in 1994 with the hybrid NS-H-111. During that growth stage, stand density had no effect on the leaf area size per plant. In this period, plants develop slowly, the newly formed leaves are in the growth stage, and the daily leaf area increment is relatively small. As the leaf area size per hectare, expressed via leaf area index (LAI), is directly dependent on the number of plants per unit area, the observed differences among the treatments were significant in most cases. Similar results were reported by Stanojevic (1982).

A considerable increase in leaf area size was registered at the stage of budding. The largest leaf area per plant was achieved in 1995 with the hybrid NS-H-111. Stand density begins to affect leaf area size per plant already at that stage. Leaf area per plant decreased significantly with the increase in the number of plants per unit area, because plants formed smaller leaves. This is in agreement with the results of Merrien *et al.* (1981). Leaf area growth is most intensive from the stage of 6 pairs of leaves to budding. It should be mentioned here that, in that period, the plants grown in the higher densities formed a major portion of their maximum leaf area. Also, the daily leaf area increment was much larger in the lower than in the higher densities.

Differences existed in the dynamics of leaf area formation per individual plant and per crop. Crop’s leaf area is more important for agricultural production because crop is a production system which determines yield performance per unit area of soil. At the stage of budding, leaf area per unit area of soil, expressed via leaf area index, was inversely proportional to the leaf area per plant. The variants of stand density were clearly differentiated regarding the leaf area per plant and the leaf area index. This was evidently due to the plants' competition for light, i.e., the shading. In the higher densities, the leaf area increment per plant was reduced, but the leaf area per hectare was increased because of a larger number of plants.

Leaf area reached its maximum size at the stage of flowering regardless of stand density. This is in accordance with the results of Saftic *et al.* (1987), Merrien (1992) and Rizzardi *et al.* (1992). On average for all hybrids and densities, leaf areas per plant were almost identical in 1995 and 1996, but significantly larger than in 1994. On average for all hybrids and densities, the hybrid NS-H-111 had the largest leaf area per plant, the hybrid NS-Dukat the lowest. In that phase too, the effect of stand density on leaf area size per plant was significant~~.~~

The largest area was registered in the lowest stand, the lowest area in the highest stand. According to Merrien (1986), plant competition in high stands reduces leaf size and causes the drying of bottom leaves. Here it should be emphasized that during this period, the plants grown in the lower densities formed a major portion of their maximum leaf area. Also, the daily leaf area increment was much larger in the lower than in the higher densities.

The hybrid NS-Dukat had the highest leaf area efficiency, expressed in mg of seed formed per $cm^2$ of leaf area at the stage of flowering, the hybrid NS-H-103 had the lowest efficiency. The leaf area efficiency decreased as the stand density increased. Similar results were reported by Merrien (1986***).*** To form a fully filled seed, the hybrids NS-Dukat, NS-H-111 and NS-H-103 needed the average leaf areas at the stage of flowering measuring 4,17 $cm^2$, 4,52 $cm^2$ and 5,19 $cm^2$, respectively. These figures are much larger than those reported by Picq (1986).

Just as at the stage of budding, the values of the leaf area index and the leaf area per plant were inversely proportional. The leaf area indexes of all three hybrids were highest in the highest density and lowest in the lowest density. In the variants of high density, the leaf area increment per plant was reduced, but the leaf area per hectare was increased because of a larger number of plants. The larger difference in the leaf area increments in the lowest and in the highest stand is the result of a slower dynamics of the growth and development of top leaves during the period of intensive growth in the latter stand. At the stage of full flower, however, when the vegetative growth was completed, the numbers of leaves per variant of stand density became equal again.

Because of a less intensive competition among plants before the stage of budding, the plants in the higher stands formed a much larger portion of their maximum leaf area than the plants in the lower stands. After budding, the competition became more intensive and the plants in the higher stands had difficulties in expanding their leaf area. Conversely, the plants in the lower stands grew lavishly and their daily leaf area increment remained high.

After the stage of flowering, the size of leaf area diminished in consequence to the drying and shedding of bottom leaves. Similar results were reported by Miller and Roath (1982). The extent of leaf area reduction at the stage of seed forming in relation to the stage of flowering depended more on the hybrid than on the variant of stand density. The reduction was largest in the hybrid NS-Dukat, which is understandable if the length of its growing season is considered. Again, the values of the leaf area index and the leaf area per plant were inversely proportional.

Further reduction in leaf area size was registered 30 days after flowering. At this stage too, all three hybrids had largest leaf areas in the lowest stand. As the density increases, the proportion of active leaf area in relation to the maximum size at the stage of flowering becomes less.

When considering the year as a factor, it may be seen that the largest leaf area before flowering was achieved in 1995, if we disregard the largest value at the stage of 6 pairs of leaves registered in 1994. In 1995 and 1996, the leaf areas at the stage of flowering were almost identical, with a larger leaf area remaining after flowering in 1996. The smallest leaf area in the period from budding to 30 days after flowering was found in 1994. These results may be associated with the dynamics of soil moisture in the experiment years. Rawson *et al.* (1980) and Blanchet *et al*. (1988) reported similar results**.**

If the leaf area sizes are compared for hybrids and stand densities, it may be noticed that the hybrid NS-Dukat had the lowest leaf area size at all stages and in all densities. When comparing the other two hybrids in the variant with the least intensive competition (30,000 plants $m^{-2}$), it may be seen that the hybrid NS-H-111 had a larger leaf area before the stage of flowering. It retained the advantage in the period after flowering, although the difference was much smaller. In the variant with the largest number of plants and the most intensive competition, the hybrid NS-H-103 had the largest leaf area starting from the stage of budding. It may be an indication that this dwarf hybrid tolerates high density and plant competition, which may be a potentially useful characteristic. Unfortunately, superior values of leaf area and leaf area index do not mean automatically the superiority in seed yield potential. This is in agreement with the results of Aquirrezábal *et al.* (1988) and Merrien (1992).

## CONCLUSION

Following conclusions may be drawn on the basis of the obtained results.

- With increase in stand density, leaf area per sunflower plant decreases while the leaf area index increases.
- Leaf area growth is most intensive from the stage of 6 pairs of leaves to budding and reaches its maximum at the stage of flowering.
- The hybrid NS-Dukat had the highest leaf area efficiency, expressed in mg of seed formed per $cm^2$ of leaf area at the stage of flowering, the hybrid NS-H-103 had the lowest efficiency.
- Leaf area efficiency decreases with increase in stand density.
- Reduction of leaf area size occurs after flowering, in consequence of the drying and shedding of bottom leaves.

## LITERATURE


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Tab. 1. Leaf area and LAI per sunflower growth stages

| Hybrid | Stand | Year | 6 pairs of leaves | | Budding | | Flowering | | Seed forming | | 30 days after flowering | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LA ($cm^2$) | LAI | LA ($cm^2$) | LAI | LA ($cm^2$) | LAI | LA ($cm^2$) | LAI | LA ($cm^2$) | LAI |
| NS - Dukat | 30000 | 1994 | 1866 | 0.56 | 4668 | 1.4 | 8070 | 2.4 | 5564 | 1.7 | | |
| | | 1995 | 1116 | 0.33 | 6251 | 1.9 | 11330 | 3.4 | 6606 | 2.0 | | |
| | | 1996 | 995 | 0.30 | 4789 | 1.4 | 8846 | 2.7 | 7620 | 2.3 | 5758 | 1.7 |
| | | $\bar{x}$ | 1326 | 0.40 | 5236 | 1.6 | 9415 | 2.8 | 6597 | 2.0 | 5758 | 1.7 |
| | 60000 | 1994 | 1777 | 1.07 | 3298 | 2.0 | 4827 | 2.9 | 4257 | 2.6 | | |
| | | 1995 | 1109 | 0.67 | 5325 | 3.2 | 7011 | 4.2 | 4353 | 2.6 | | |
| | | 1996 | 1067 | 0.64 | 3370 | 2.0 | 5730 | 3.4 | 3933 | 2.4 | 3135 | 1.9 |
| | | $\bar{x}$ | 1318 | 0.79 | 3998 | 2.4 | 5856 | 3.5 | 4181 | 2.5 | 3135 | 1.9 |
| | 80000 | 1994 | 1610 | 1.29 | 3201 | 2.6 | 4426 | 3.5 | 3402 | 2.7 | | |
| | | 1995 | 968 | 0.77 | 4237 | 3.4 | 5843 | 4.7 | 3327 | 2.7 | | |
| | | 1996 | 985 | 0.79 | 3028 | 2.4 | 4823 | 3.9 | 3551 | 2.8 | 2438 | 2.0 |
| | | $\bar{x}$ | 1188 | 0.95 | 3489 | 2.8 | 5031 | 4.0 | 3427 | 2.7 | 2438 | 2.0 |
| NS – H – 1 1 1 | 30000 | 1994 | 2465 | 0.74 | 5686 | 1.7 | 9057 | 2.7 | 7897 | 2.4 | | |
| | | 1995 | 1217 | 0.37 | 8044 | 2.4 | 9705 | 2.9 | 8320 | 2.5 | 6063 | 1.8 |
| | | 1996 | 2039 | 0.61 | 7625 | 2.3 | 13106 | 3.9 | 11435 | 3.4 | 8570 | 2.6 |
| | | $\bar{x}$ | 1907 | 0.57 | 7118 | 2.1 | 10623 | 3.2 | 9217 | 2.8 | 7317 | 2.2 |
| | 50000 | 1994 | 2400 | 1.20 | 4341 | 2.2 | 6117 | 3.1 | 5342 | 2.7 | | |
| | | 1995 | 1238 | 0.62 | 7114 | 3.6 | 8371 | 4.2 | 6449 | 3.2 | 3910 | 2.0 |
| | | 1996 | 2266 | 1.13 | 6597 | 3.3 | 8987 | 4.5 | 8297 | 4.1 | 6452 | 3.2 |
| | | $\bar{x}$ | 1968 | 0.98 | 6017 | 3.0 | 7825 | 3.9 | 6696 | 3.3 | 5181 | 2.6 |
| | 80000 | 1994 | 1798 | 1.44 | 3496 | 2.8 | 4831 | 3.9 | 3727 | 3.0 | | |
| | | 1995 | 1159 | 0.93 | 5527 | 4.4 | 5543 | 4.4 | 4513 | 3.6 | 2102 | 1.7 |
| | | 1996 | 1768 | 1.41 | 4561 | 3.6 | 5617 | 4.5 | 5362 | 4.3 | 3271 | 2.6 |
| | | $\bar{x}$ | 1575 | 1.26 | 4528 | 3.6 | 5330 | 4.3 | 4534 | 3.6 | 2687 | 2.1 |
| NS – H – 1 0 3 | 30000 | 1994 | 1924 | 0.58 | 5369 | 1.6 | 11286 | 3.4 | 9846 | 3.0 | | |
| | | 1995 | 1741 | 0.52 | 6282 | 1.9 | 9961 | 3.0 | 8573 | 2.6 | 6565 | 2.0 |
| | | 1996 | 1605 | 0.48 | 6495 | 1.9 | 10446 | 3.1 | 9580 | 2.9 | 7612 | 2.3 |
| | | $\bar{x}$ | 1757 | 0.53 | 6049 | 1.8 | 10564 | 3.2 | 9333 | 2.8 | 7089 | 2.1 |
| | 70000 | 1994 | 1366 | 0.96 | 4531 | 3.2 | 6344 | 4.4 | 5537 | 3.9 | | |
| | | 1995 | 1699 | 1.19 | 5040 | 3.5 | 6080 | 4.3 | 4580 | 3.2 | 3515 | 2.5 |
| | | 1996 | 1201 | 0.84 | 4885 | 3.4 | 6995 | 4.9 | 5739 | 4.0 | 4236 | 3.0 |
| | | $\bar{x}$ | 1422 | 1.00 | 4819 | 3.4 | 6473 | 4.5 | 5285 | 3.7 | 3876 | 2.7 |
| | 80000 | 1994 | 1525 | 1.22 | 3970 | 3.2 | 5751 | 4.6 | 4759 | 3.8 | | |
| | | 1995 | 1906 | 1.52 | 5216 | 4.2 | 6824 | 5.5 | 4985 | 4.0 | 3301 | 2.6 |
| | | 1996 | 1008 | 0.81 | 4484 | 3.6 | 6207 | 5.0 | 4110 | 3.3 | 3311 | 2.6 |
| | | $\bar{x}$ | 1480 | 1.18 | 4557 | 3.6 | 6261 | 5.0 | 4618 | 3.7 | 3306 | 2.6 |