DIRECT AND INDIRECT EFFECTS OF VARIABLES ON GRAIN YIELD OF SOME NOVI SAD SUNFLOWER HYBRIDS

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Seed yield of sunflower is a resultant of a complex process of actions and interactions of many factors. A number of researchers have studied the effects of these factors. They not only calculated correlations but also used the path coefficient analysis to determine direct and indirect effects of individual factors on seed yield of sunflower. The objective of this study was to assess the effects of six factors on seed yield of three sunflower hybrids grown in five densities and three row-to-row distances.

The aim of this investigation was to determine direct, indirect, and total effects of leaf area index (LAI) at the stage of flower (x_1), leaf area duration (LAD) from flowering to physiological maturity (x_2), the number of plants per hectare (x_3), the mass of 1,000 seeds (x_4), oil percentage (x_5), and kernel percentage (x_6) on seed yield of sunflower as well as to determine mutual relations among these variables.

Three genetically diverse domestic sunflower hybrids were tested: NS-H-10, NS-H-33-RM, and NS-H-62-RM. The hybrids differed in plant height, leaf number and size, leaf area duration, seed yield, oil content in seed, resistance to diseases and lodging, vegetation period, etc.

NS-H-10 is an early hybrid, with the vegetative period of 125 days, plant height from 160 to 180 cm, the average number of leaves of 24, the leaf area index of 3.7 m^2/m^2, and the oil content in seed of 42.0%. The hybrid is resistant to lodging and it starts to lodge only at high densities (70 - 80,000 plants/ha).

NS-H-33-RM is a medium early hybrid with the vegetative period of about 130 days. Its resistance to lodging is on the level of NS-H-10 in spite of plant height from 190 to 209 cm. The average number of leaves per plant is 26, the leaf area index is 4.6 m^2/m^2, and the oil content ranges around 45.0%.

NS-H-62-RM belongs to the group of late hybrids. Its vegetative period is about 135 days. The plant height from 230 to 246 cm makes it susceptible to lodging, especially when grown at increased densities. The number of leaves per plant reaches 34, the leaf area index is 4.8 m^2/m^2, and the oil content is 47.0%.

The hybrids were tested in five densities (40, 50, 60, 70, and 80,000 plants/ha) and three row-to-row distances (50, 60, and 70 cm).

Correlation coefficients between seed yield and the six yield components were calculated by the analysis of variance. Mutual correlations were calculated too. The path coefficient analysis was used to estimate direct and indirect effects of the components on seed yield.

The analysis showed that the leaf area duration (LAI) had a negative direct effect on seed yield (- 0.30 and - 0.28) while the simple correlation coefficients were positive ($r = 0.22$ and $r = 0.24$) on account of the high positive effects via stand density (0.49 and 0.57) and LAD (0.20 and 0.18).

The leaf area duration (LAD) had a positive direct effect on seed yield (0.21 and 0.22) while the total effect was somewhat higher (ry = 0.35* and ry = 0.33*) due to the high positive indirect effect via plant number (0.56 and 0.65). The total effect of LAD was diminished by the negative indirect effects via LAI (- 0.28 and - 0.33), oil content (- 0.13), and 1,000 seed mass (- 0.35).

The highest direct effect on seed yield was exhibited by the number of plants per ha (stand density) (0.75 and 0.85). The effect was magnified by the indirect effect via LAD (0.16 and 0.17) and diminished by the effects via LAI (- 0.19) and 1,000 seed mass, so that the total effect of stand density was somewhat lower than the direct effect (ry = 0.69 and ry = 0.50).

Depending on the year of growing, the mass of 1,000 seeds had either a negative (- 0.13) or a positive direct effect (0.47). The total effect was negative (ry = - 0.33 and ry = - 0.27) on account of the negative indirect effects via LAI (- 0.05), stand density (- 0.11 and - 0.67), and oil content in seed (- 0.06).

The direct effect of the oil content in seed was similar to that of the mass of 1,000 seeds. Depending on the year of growing, the direct effect could be negative (- 0.22) while the total effect could be negative (ry = - 0.17) or positive (ry = 0.22).

The content of kernels exhibited no important direct of total effects on seed yield of sunflowers.

The simple correlation coefficients for the six sunflower yield components indicated the existance of highly significant correlations between LAI and LAD ($r = 0.93^{**}$ and $r = 0.82^{**}$), LAI and plant number ($r = 0.65^{**}$ and $r = 0.67^{**}$), LAI and oil content ($r = 0.70^{**}$ and $r = 0.27$), LAI and 1,000-seed mass ($r = -0.56^{**}$). Highly significant correlations were also found between LAD and oil content ($r = 0.57^{**}$ and $r = 0.42^{**}$) and LAD and 1,000-seed mass ($r = 0.74^{**}$). Highly significant correlations were found between plant number and 1,000-seed mass ($r = 0.79^{**}$), plant number and oil content ($r = 0.44^{**}$), 1,000-seed mass and oil content ($r = 0.57^{**}$).

Among the six examined factors, the number of plants per hectare exhibited the highest direct effect on seed yield (0.75 and 0.85) as well as the highest total effect ($ry = 0.69^{**}$ and $ry = 0.50^{**}$).

The leaf area duration from flowering to physiological maturity was in the second place regarding the magnitude of its effect on seed yield. The direct effect was 0.21 and 0.22 while the total effect was higher (ry = 0.35* and ry = 0.33*) because of a high indirect effect of LAD via plant number (0.56 and 0.65).

The leaf area index exhibited a negative direct effect on seed yield (- 0.30 and - 0.28) but the total effect was positive on account of the high indirect effects via plant number (0.49 and 0.57) and LAD (0.20 and 0.18).

The other examined factors demonstrated variable and less important effects on the seed yields of the tested sunflower hybrids.