

AGRONOMIC EVALUATION OF SUNFLOWER HYBRIDS (*Helianthus annuus* L.) BY THE QUANTITY AND QUALITY INDICES

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Abstract

Sunflower is one of the most important oilseed crops on a global scale. The aim of the present study was to determine the productivity of four sunflower hybrids and to establish the influence of the factor hybrid in accordance with the specific climatic conditions of the year on the seed yield, as well as on some qualitative and quantitative indicators. The experiment was conducted during the period 2021-2023 in the region of Targovishte on soil type chernozem and an experimental area of 25 m² in four replications, after predecessor wheat. The following hybrids sunflower were tested: "P64LE136", "LG 50.549 SX", "Subaro" and "P64HE118". The results showed that the tallest plants were formed from P64LE136 hybrid and the lowest one - from LG 50.549 SX. The highest values of head diameter (20.4 cm), number of seeds per head (1513), seed weight of head (240.0 g), seed yield (3593 kg/ha) and 1000 seed weight (204.0 g) was reported for Subaro hybrid. Hybrid LG 50.549 SX was distinguished by the highest values of oil content (48.4%) and oil yield (1548 kg/ha) as well as test weight (43.2 kg).

Key words: sunflower, hybrids, seed yield, quality, oil.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the main oil crops in the world and one of the principal sources of vegetable oil, which is a key component of human nutrition. Sunflower seeds possess a significant oil content, with most sunflower hybrid varieties containing 40-50% (Jocić et al., 2015; Naeem et al., 2019). Sunflower oil is considered a premium-quality oil. Standard sunflower oil is usually composed of polyunsaturated linoleic acid (18:2) and monosaturated oleic acid (18:1) in ratios of 70%:20% (Radanović et al., 2018). The quantitative and qualitative indicators are specific to each sunflower hybrid, but they are influenced by the different growing factors (environmental and technological factors). Soil and climatic conditions are among the environmental factors with a great influence on the sunflower seed yield and the yield attributes of the head (Dalle et al., 2016; Ion et al., 2015; Manhart & Manilov, 2024; Mijić et al., 2017). Sunflower is predominantly cultivated under dry conditions and in rainfed areas worldwide (Kaya, 2020). Under drought conditions, especially during the grain-filling period, oil content is reduced in sunflower seeds (Kaya et al., 2016; Pekcan et al., 2022). In arid and semi-

arid regions, sunflower productivity is significantly reduced by drought stress (Hussain et al., 2018). García-López et al. (2016) reported that the distribution and quality of water have a major impact on sunflower seed and oil yield. Seed yield and yield components are significantly affected by irrigation treatments applied to sunflower hybrids under arid and semi-arid environments (García-López et al., 2016; Sher et al., 2022; Surucu et al., 2020). According to González et al. (2013), hybrid yield is conditioned by the capacity of the genotype to efficiently utilize environmental variables during different phenophases, while Hossam (2012) reported that sunflower productivity per unit area is determined by multiple factors, including plant population density and genotype.

Agronomic practices and high-yielding hybrids are the two most important factors for enhancing sunflower crop productivity (Beg et al., 2007). Selecting the most appropriate hybrid for a specific region based on environmental conditions and cultivation technology facilitates the achievement of desired outcomes and guarantees consistent yields, representing a viable adaptation strategy in agriculture to climate change (Anton et al., 2015; Canavar et al., 2010; Garapova & Kirchev, 2023;

Delibaltova & Dallev, 2018; Drumeva & Yankov, 2020; Tanchev & Georgiev, 2025; Tanchev & Kirchev, 2025).

The aim of the present study was to define the productivity of four sunflower hybrids and to establish the influence of the factor hybrid in accordance with the specific climatic conditions of the year on the seed yield, as well as on some qualitative and quantitative indicators.

MATERIALS AND METHODS

The experiment was conducted in the period 2021-2023 in the region of Targovishte on soil type chernozem and an experimental area of 25 m² in four replications, after predecessor winter wheat. The following hybrids sunflower were tested: “P64LE136”, “LG 50.549 SX”, “Subaro” and “P64HE118”. Deep ploughing, two times disc harrowing, and two times cultivation were done on the trial field before seeding. Basic combination fertilization used 250 kg/ha N:P:K 15:15:15, while spring dressing used 200 kg/ha NH₄NO₃ (Neshev et al., 2020).

The sowing was performed in the second decade of March with planting distance 25 x 70 cm. The herbicide Express 50 SG (containing 500 g/kg tribenuron-methyl) was applied at a rate of 40 g/ha during the 4th-6th true leaf stage of sunflower development (BBCH 14-16). The sunflower crop was grown without irrigation

conditions adopted for region technology. For realizing the aim of the study account was taken following parameters: plant height (cm), head diameter (cm), number of seeds per head, seed weight of head (g), seed yield (kg/ha), 1000 seed weight (g), test weight (kg), oil content (%) and oil yield (kg/ha).

For the purpose of determining the quantitative and qualitative relationships among the studied indicators, the experimental data were processed using analysis of variance (ANOVA). The differences between the variants were determined using Duncan’s Multiple Range Test.

The major climatic factors determining the growth, development, and productivity of sunflower are temperature and rainfall, as well as their interaction and distribution throughout the growing season. The years of the study (2021-2023) differed significantly in terms of the amount and distribution of rainfall during the vegetation period (Figure 1).

The amount of rainfall in the first experimental year was 402.0 mm, i.e. 28.0 mm higher than the long-term average. During the March-September period of the second experimental year, total precipitation amounted to 357.0 mm, which was 45.0 mm lower than in 2021. The lowest amount of precipitation was recorded in the 2022 growing year, with 273.4 mm compared to 374.0 mm for the long-term average.

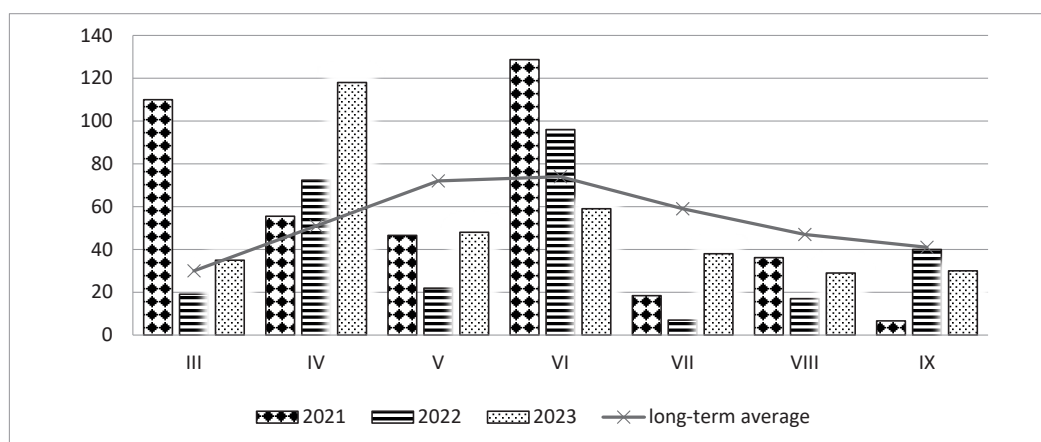


Figure 1. Precipitation, mm

The 2022 growing season was characterized by an uneven distribution of rainfall, which was

insufficient to meet plant water requirements during the critical growth stages. A comparison

of the average monthly air temperatures during the study period showed that temperature values were very similar across all three years and were consistently higher than the long-term averages (Figure 2).

These temperature conditions, in combination with the recorded precipitation during the growing season, influenced the growth and development of the sunflower plants.

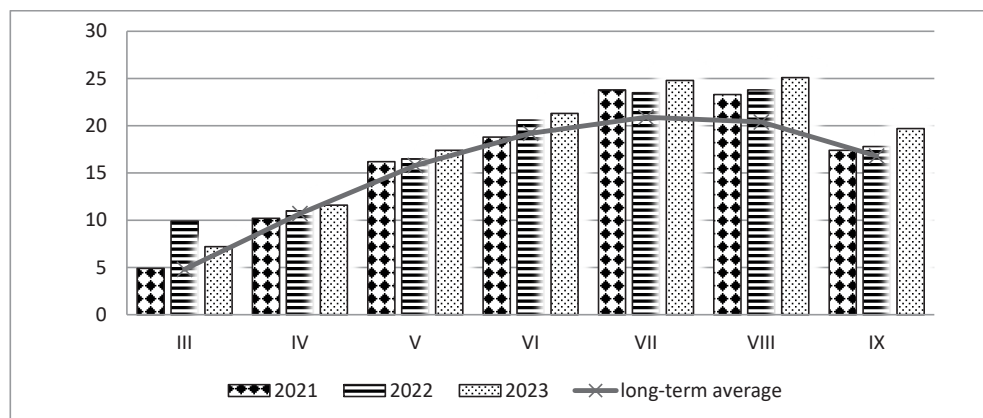


Figure 2. Average monthly air temperature, °C

The first experimental year (2021) was the most favorable for sunflower growth and development, followed by the third (2023), and the second (2022) was the least favorable, all of which had an impact on the productive potential of the sunflower hybrids tested.

RESULTS AND DISCUSSIONS

The seed yield findings (Table 1) reveal that the Subaru hybrid surpassed all other hybrids in the study in terms of seed yield, both by years and on average across the experimental period. The highest yields were recorded in the favorable sunflower year of 2021, when the temperature and precipitation totals fully satisfied the plant requirements throughout the vegetation period, compared to 2022 and 2023. The Subaru hybrid had yields of up to 3730 kg/ha. Referring to yield that hybrid surpassed LG 50.549 SX, P64LE136 and P64HE118 hybrids by 11.7 %, 23.9% and 26.2 %, respectively, the differences are statistically significant.

In the third experimental year (2023), seed yields ranged from 2923 kg/ha in the P64LE136 hybrid to 3640 kg/ha in the Subaru hybrid, or 2.4% lower on average than in 2021. Data analysis revealed that LG 50.549 SX, P64HE118, and P64LE136 hybrids behind

Subaro hybrid by 432, 680, and 717 kg/ha, respectively.

The lowest seed yields during the study period were observed in the second year of the experiment (2022), which was attributable to an insufficiency of moisture during the critical stages of sunflower plant development.

The yields obtained were within the limits of 2786 to 3410 kg/ha. Statistically proven, the lowest were P64HE118 hybrid and the highest were Subaru, with averages of 240 and 164 kg/ha lower than the first and third years, respectively.

During the experimental period (2021-2023), the Subaru hybrid produced an average yield of 3593 kg/ha, beating the hybrids LG 50.549 SX, P64LE136, and P64HE118 by 12.3%, 23.0%, and 23.8%.

The analysis of variance (Anova) shows a strong statistically proven influence on both the tested Hybrid and the Years with their specific climatic conditions on the indicator seed yield. An interaction between Hybrid and Year was proven (Table 2).

Oil yield is an important trait in sunflower which depends on the oil content of the genotype (Ahmed et al., 2021; Pekcan et al., 2022).

Data in Table 1 show that, on average for the experimental period, the LG 50.549 SX hybrid outperformed the other hybrids included in the

experiment. Under the conditions of the first-year oil yield varied from 1037 kg/ha for P64HE118 hybrid to 1647 kg/ha for LG 50.549 SX hybrid. Subaro and P64LE136 hybrids received yields, which were 110 and 359 kg/ha

lower compared to LG 50.549 SX hybrid. Mathematical processing of data showed that the differences between all the studied hybrids were significant (Table 1).

Table 1. Quantitative and morphological traits in sunflower hybrids

Hybrids	Year	Seed yield (kg/ha)	Oil yield (kg/ha)	Seed weight of head (g)	Number of seeds per head	Plant height, (cm)	Head diameter (cm)
P64LE136	2021	3010 ^c	1288 ^c	224.0 ^b	1318 ^c	218.0 ^a	20.0 ^b
	2022	2831 ^c	1110 ^c	207.9 ^c	1240 ^b	196.5 ^a	17.3 ^b
	2023	2923 ^c	1193 ^c	217.3 ^c	1286 ^c	203.6 ^a	18.4 ^b
	Avarage	2921	1197	216.4	1281	206.0	18.6
LG 50,549 SX	2021	3340 ^b	1647 ^a	231.6 ^b	1453 ^b	180.5 ^d	17.0 ^c
	2022	3050 ^b	1452 ^a	218.4 ^b	1212 ^b	164.2 ^c	15.2 ^c
	2023	3208 ^b	1546 ^a	221.2 ^b	1353 ^b	172.0 ^d	16.6 ^c
	Avarage	3199	1548	223.7	1339	172.2	16.3
Subaro	2021	3730 ^a	1537 ^b	257.0 ^a	1600 ^a	195.0 ^b	22.8 ^a
	2022	3410 ^a	1309 ^b	217.0 ^a	1425 ^a	170.0 ^b	18.0 ^a
	2023	3640 ^a	1438 ^b	245.0 ^a	1513 ^a	183.7 ^c	20.5 ^a
	Avarage	3593	1428	240.0	1513	182.9	20.4
P64HE118	2021	2955 ^d	1037 ^d	214.7 ^c	1400 ^b	187.0 ^c	19.6 ^b
	2022	2786 ^d	881 ^d	203.0 ^d	1146 ^c	175.0 ^b	16.8 ^b
	2023	2960 ^c	1002 ^d	208.5 ^d	1279 ^c	190.2 ^b	18.0 ^b
	Avarage	2900	973	208.7	1275	184.1	18.1

*Means within columns followed by different lowercase letters are significantly different ($P < 0.05$), according to the LSD test.

The experimental year 2022 was characterized with less amount of precipitations compared to 2021 during the vegetation period – 273.4 mm, and the obtained oil yield were within the bounds from 881 to 1452 kg/ha. In the last year of the experiment, the oil yield ranged from 1002 to 1546 kg/ha.

On average for the three-year experimental period, the highest yield of oil was obtained from the LG 50.549 SX hybrid - 1548 kg/ha and it surpassed the other hybrids from 8.4 to 59.0%. The results of the analysis of variance for the effects of the factors Hybrid and Year, as well as their interaction, on oil yield (Table 2) show a statistically significant effect of the studied factors and a non-significant effect of their interaction.

Across different years and on average for the studied sunflower hybrids, seed weight per head varied between 203.0 and 257.0 g, depending on the hybrid and climatic conditions (Table 1). The highest values were recorded for the Subaro

hybrid, amounting to 257 g in 2021, 217 g in 2022, and 245 g in 2023. The lowest values of this characteristic were recorded for the hybrid P64HE118 - 208.7 g. On average for the years of the study, this hybrid had 15.3% lower seed weight per head compared to Subaro and from 3.7 to 7.2% lower seed weight per head compared to the hybrids P64LE136 and LG 50.549 SX.

The analysis of variance for the influence of the factors – Hybrid and Year, as well as their interaction on the indicator "seed weight per head" shows a significant influence of the factors on the change of the indicator.

Data on the number of seeds per head of the studied hybrids showed that during the first experimental year the values ranged from 1318 in P64LE136 to 1600 in Subaro, while in 2022, which was unfavorable for sunflower production, the values were approximately 185 seeds lower (Table 1).

On average for the period 2021-2023, the number of seeds per head in the studied hybrids ranged from 1275 to 1513. The lowest values of this characteristic were recorded for the hybrid P64HE118, while the highest were observed for the Subaru hybrid. The hybrids P64LE136 and

LG 50.549 SX had an average number of seeds per head of 1281 and 1339, respectively. The Subaru hybrid exceeded the hybrids LG 50.549 SX, P64LE136, and P64HE118 in this characteristic by 12.9%, 18.1%, and 18.6%, respectively.

Table 2. Analysis of variance ANOVA

Parameter	Source of Variation	Sum of Square	df	Mean Square	F	P-value	F crit
Seed yield (kg/ha)	Hybrid **	3730939.73	3	1243646.58	5485.50	0.00	2.87
	Year**	460959.04	2	230479.52	1016.60	0.00	3.26
	Interactions *	56610.46	6	9435.08	41.62	0.00	2.36
	Within	8161.75	36	226.72			
Oil yield (kg/ha)	Hybrid **	2335949	3	778649.80	263.83	0.00	2,87
	Year*	287879.30	2	143939.60	48.77	0.00	3,26
	Interactions ^{ns}	9650.54	6	1608,42	0.54	0.77	2,36
	Within	106247.50	36	2951.32			
Seed weight of head (g)	Hybrid *	6369.47	3	2123.16	63.93	0.00	2.87
	Year*	2918.65	2	1459.33	43.94	0.00	3.26
	Interactions *	1207.19	6	201.20	6.06	0.00	2.36
	Within	1195.53	36	33.21			
Number of seeds per head	Hybrid *	442148	3	147382.67	100.77	0.00	2.87
	Year*	280568.67	2	140284.33	95.92	0.00	3.26
	Interactions *	39426	6	6571	4.49	0.00	2.36
	Within	52652	36	1462.56			
Plant height, (cm)	Hybrid **	7231.75	3	2410.58	32.87	0.00	2.87
	Year*	2709.29	2	1354.64	18.47	0.00	3.26
	Interactions ^{ns}	400.875	6	66.81	0.91	0.50	2.36
	Within	2640	36	73.33			
Head diameter (cm)	Hybrid *	80.88	3	26.96	7.76	0.00	2.87
	Year*	67.12	2	33.56	9.67	0.00	3.26
	Interactions ^{ns}	8.01	6	1.36	0.38	0.88	2.36
	Within	124.99	36	3.47			

*F-test significant at P<0.05; **F-test significant at P<0.01; ns non-significant

The results of the analysis of variance regarding the effect of the studied factors and their interaction on the number of seeds per head showed a statistically significant effect of both factors, as well as a statistically significant interaction between them (Table 2).

The studied hybrids differed significantly in plant height. The lowest values of this indicator were reported in 2022, when climatic conditions were less favorable for sunflower growth and development compared to 2021 and 2023. The sunflower hybrid P64LE136 had the tallest

plants, while LG 50.549 SX had the shortest plants. Statistical analysis showed that the differences among all studied hybrids were significant. On average for the study period, the plant height of the hybrid P64LE136 was 206.0 cm and exceeded that of P64HE118 by 11.9%, Subaru by 13.2%, and LG 50.549 SX by 19.6% (Table 1).

The analysis of variance (ANOVA) showed that the factors hybrid and year had a statistically significant effect on plant height, whereas their

interaction was not statistically significant (Table 2).

In the studied sunflower hybrids, head diameter varied between 15.2 and 22.8 cm, depending on the hybrid and climatic conditions during the individual agricultural years (Table 1). The highest values were obtained in 2021 and ranged from 17.0 to 22.8 cm, while under less favorable growing conditions in 2022, the values of this characteristic decreased by 11.8 to 26.7%. The lowest values of head diameter were recorded for the hybrid LG 50.549 SX, and the highest for the hybrid Subaru. During the three experimental years, these differences were statistically significant.

On average for the period 2021-2023, the hybrids P64HE118 and P64LE136 exceeded the hybrid LG 50.549 SX by 13.1% and 14.1%, respectively, but lagged behind Subaru by 9.7% and 12.6%.

The results of the analysis of variance regarding the effect of the factors Hybrid and Year, as well as their interaction, on head diameter (Table 2) showed a statistically significant effect of the studied factors and a non-significant effect of their interaction.

Differences in climatic conditions during the years of the experiment were among the reasons for the formation of seeds with different qualitative indices. The 1000-seed weight is one of the most important quality indicators. This trait varies between different hybrids and growing conditions (Radić et al., 2013). Joksimović et al. (2004) reported that 1000-seed weight is a variable trait and, as such, is influenced by both genetic and environmental factors.

According to the results presented in Table 3, the highest 1000-seed weight was obtained in 2021, when there was a good reserve of winter moisture and total rainfall (402 mm), and when its monthly distribution during the growing season was exceptionally favorable. Under these conditions, the values ranged from 181 to 215 g. In 2023, the 1000-seed weight was up to 5.4% lower. In 2022, a less favorable year for sunflower cultivation, the values of this indicator ranged from 163 to 197 g.

On average for the study period, the lowest 1000-seed weight was recorded for the hybrid P64HE118 and the highest was observed for the hybrid Subaru. The hybrids P64LE136 and LG

50.549 SX had values of 189.3 g and 185.3 g, respectively.

The hybrid Subaru exceeded the hybrids P64HE118, LG 50.549 SX, and P64LE136 in 1000-seed weight by 17.0%, 10.1%, and 7.7%, respectively.

The analysis of variance (ANOVA) showed the impact of factors A (year) and B (hybrid), as well as their interaction, on the indicator 1000-seed weight. The results indicated a statistically significant influence of the examined factors and a statistically significant effect of their interaction.

Data on the test weight of the studied hybrids showed that during the years of the experiment, values ranged from 36.0 to 45.3 kg (Table 3). The lowest values of this characteristic were recorded for the hybrid P64HE118, while the highest were observed for the hybrid LG 50.549 SX, and the differences were statistically significant. On average for the period 2021-2023, the hybrid LG 50.549 SX exceeded the hybrids Subaru, P64LE136, and P64HE118 in this characteristic by 4.8%, 12.7%, and 15.5%, respectively. The results of the analysis of variance regarding the effect of the factors Hybrid and Year, as well as their interaction, on test weight (Table 3) showed a statistically significant effect of the studied factors.

The oil content of sunflower is one of the most affected yield traits (Pekcan et al., 2022). The highest oil content was achieved in 2021 (42.1%), which was a favorable year for sunflower cultivation, while the lowest value was recorded in 2022 (39.2%) due to insufficient moisture during the critical stages of sunflower growth and development (Table 3). In the third experimental year (2023), oil content ranged from 31.8% in the hybrid P64HE118 to 48.2% in the hybrid LG 50.549 SX.

On average for the study period, the highest oil content of sunflower seed was recorded for the hybrid LG 50.549 SX (48.4%), followed by P64LE136 and Subaru (40.9% and 39.7%, respectively), while the lowest values were reported for the hybrid P64HE118 (32.8%).

The analysis of variance (ANOVA) shows a strong statistically proven influence on Hybrid and the Year with their specific climatic conditions on the indicator oil content (Table 3). An interaction between Hybrid and Year was unproven.

Table 3. Qualitative components in sunflower hybrids

Variable		1000 seed weight (g)	Test weight (kg)	Oil content (%)
Years (A)	2021	198.0 ^a	42.0 ^a	42.1 ^a
	2022	178.7 ^c	37.7 ^c	39.2 ^c
	2023	188.0 ^b	40.6 ^b	40.1 ^b
Hybrid (B)	P64LE136	189.3	38.3	40.9
	LG 50.549 SX	185.3	43.2	48.4
	Subaro	204.0	41.2	39.7
	P64HE118	174.3	37.4	32.8
2021	P64LE136	200 ^b	39.7 ^c	42.8 ^b
	LG 50.549 SX	196 ^b	45.3 ^a	49.3 ^a
	Subaro	215 ^a	44.2 ^b	41.2 ^b
	P64HE118	181 ^c	38.9 ^c	35.1 ^c
2022	P64LE136	180 ^b	36.5 ^c	39.2 ^b
	LG 50.549 SX	175 ^b	40.7 ^a	47.6 ^a
	Subaro	197 ^a	37.5 ^b	38.4 ^b
	P64HE118	163 ^c	36.0 ^c	31.6 ^c
2023	P64LE136	188 ^b	38.8 ^c	40.8 ^b
	LG 50.549 SX	185 ^b	43.5 ^a	48.2 ^a
	Subaro	200 ^a	42.0 ^b	39.5 ^b
	P64HE118	179 ^c	37.2 ^d	31.8 ^c
Anova	A	*	*	*
	B	*	*	**
	AB	*	*	n.s

*Means within columns followed by different lowercase letters are significantly different ($P < 0.05$) according to the LSD test

*F-test significant at $P < 0.05$; **F-test significant at $P < 0.01$; n.s non-significant.

CONCLUSIONS

The results of the present study demonstrate that the quantitative and qualitative indices of the tested sunflower hybrids are significantly influenced by the genetic characteristics of the hybrid, as well as by the weather conditions of the year, and above all by the the amount and distribution of vegetative rainfall.

The highest seed yield was obtained from the hybrid Subaro (3593 kg/ha), which was associated with higher values of the yield structural components, including head diameter, number of seeds per head, seed weight per head, and 1000-seed weight. Oil content ranged between 32.8% (P64HE118) and 48.4% (LG 50.549 SX). The hybrid LG 50.549 SX exhibited significantly higher mean values of test weight, oil content, and oil yield compared to the other studied hybrids.

The study's findings could be useful in selecting sunflower hybrids for the region. Out of the researched sunflower hybrids for the Targovishte region, it is recommended to cultivate hybrids Subaro and LG 50.549 SX, which have balanced quantity and quality indices under the contrast conditions of the studied years.

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