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COMPARISON OF CROP ROTATION VS. MONOCULTURE: A SUNFLOWER CASE

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Abstract

The influence of the crop rotation on sunflower (Helianthus annuus L.) yield and yield components is limited. Therefore a study in three consecutive growing seasons of sunflower (2018, 2019, and 2020) was conducted. The trial was performed on the experimental field of the department of "Agriculture and herbology" at the Agricultural University of Plovdiv, Bulgaria. The experiment was performed by the long plots method. Two crop rotations were evaluated: 1. Winter wheat - sunflower and 2. Sunflower - sunflower (monoculture). All evaluated parameters of sunflower as plant height at the end of the vegetation, head diameter, seed yield, seed oil content, as well as the absolute mass of 1000 seeds and hectoliter seed mass were influenced by the preceding crop. The highest results for the rotation of winter wheat - sunflower were reported, while statistically lower results for the sunflower monoculture were found.

Key words*: sunflower, preceding crop, yield.*

INTRODUCTION

It is considered that the sunflower is the fourth oilseed crop in the world (Nisar et al., 2011). It is also found that the percentage of oil and protein in seeds is 40-55% and 23% respectively (Jadaan et al., 1999). The seeds also contain linoleic acid, oleic acid, and linoleic acid (Nasralla et al., 2014).
In Bulgaria, sunflower is the main oilseed crop. In 2021 the total harvested area was 703 985 ha with a total production of 1 682 491 tones and an average seed yield of 2.39 t ha^{-1} (www.mzh.government.bg).
Sunflower brings diversity to dryland crop rotations as warm-season and intermediate water-use crops (Anderson et al., 1999; Johnston et al., 2002). According to Lecomte and Nolot (2011) sunflower have rotational benefits for winter crops. Crop rotation plays a major role in crop yielding (Hilton et al., 2018). The preceding crops must be carefully chosen for obtaining higher yields and seed quality. Several authors are working for identifying optimal rotations and the influence of the preceding crop (Christen and Sleling, 1995; Sieling and Christen, 1997; Ma et al., 2003; Rathke and Diepenbrock, 2006; Sieling and Kage, 2010; Stobart, 2012; Stobart and Bingham, 2013; Sieling and Christen, 2015; Basa et al, 2016; Fordoński et al., 2016; Cherkasova and Rzaeva; 2021; Neshev, 2022). According to Johnston et al. (2002) and Lecomte and Nolot (2011), sunflower is usually grown in 3-4 year rotations with cereals, oilseed rape and legumes.
The yield and the yield components are specific to each sunflower hybrid, but they are influenced by the growing factors - environmental and technological (Ion et al., 2015). The causes of yield decrease are complex and many factors have been implicated such as alteration of soil physicochemical properties by land management practices and changes in the composition of soil microorganisms (Bennett et al., 2012). Some authors suggest shorter rotations when disease-resistant hybrids are used. Many sunflower producers apply 3- or 2-year rotation and some are considering monoculture. Monoculture is the crop rotation antithesis - growing the same crop for several years in the same area (Robinson et al., 1979).
Having in mind the above-mentioned facts, the present study was conducted to enrich the knowledge of the sunflower grown as monocrop and in rotation with winter wheat.

MATERIALS AND METHODS

The trial was conducted in three consecutive vegetation seasons of sunflower (2018, 2019, and 2020). The research was performed on the experimental field of the department of "Agriculture and herbology" at the Agricultural University of Plovdiv, Bulgaria.

The following crop rotations were under evaluation: 1. Winter wheat - sunflower and 2. Sunflower - sunflower (monoculture).

The experiment was conducted by the long plots method.

The following parameters were evaluated:

- Plant height before harvest (m). Measurements were done on 4 samples of 25 plans per rotation = 100 plants total;
- Head diameter (cm). Measurements were done on 4 samples of 25 plans per rotation = 100 plants total;
- Sunflower seed yield (t ha^{-1}) by harvesting the whole plots with plot harvester of Wintersteiger Company;
- Absolute mass of 1000 seeds (g) (in four replications) (Tonev et al., 2018);
- Hectoliter seed mass (kg) (in four replications) (Tonev et al., 2018);
- Seed oil content (%) was determined by the Soxhlet method as described by Ivanov and Popov (1994). The analyses were performed in three replications per rotation.

The soil on the experimental field is classified as Mollic Fluvisols, with average sandy-clay mechanical composition, not high humus content, and weak-alkaline reaction. The nitrogen content is low, the content of phosphorus varies from low to average and the potassium content is high (Popova et al., 2012).

The sunflower (*Helianthus annuus* L.) hybrid grown in the study was SY Bacardi CLP - Clearfield Plus® (Syngenta Company). The hybrid is selected to be grown by Clearfield® Plus Technology of sunflower.

On the experimental field deep ploughing, two times disc harrowing, and two times cultivation before sowing were accomplished.

On the whole experimental area, basic combine fertilization with 250 kg ha^{-1} NPK (15:15:15) and spring dressing with 200 kg ha^{-1} NH_4NO_3 was done. The sunflower plants were sown at a planting distance of 20 x 70 cm.

The agrometeorological data is provided by the department of "Botany and Agrometeorology" at the Agricultural University of Plovdiv, Bulgaria.

The presented data is for the average monthly minimum and maximum air temperatures (°C) as well as precipitation (mm) for the vegetation periods of sunflower (from April till August) during the three study years (2018, 2019, and 2020).

For statistical analysis of the collected research data the independent samples t-test was applied by using IBM SPSS statistics 26 software.

RESULTS AND DISCUSSIONS

In Tables 1 and 2, the data for the average daily precipitation and temperatures during the sunflower's vegetation in the three experimental years (2018, 2019, and 2020) is presented.

According to the meteorological data for the individual years, it can be assessed how climatic conditions affected the herbicide efficacy, as well as the growth and development of the plants.

The precipitation was not equally distributed during the sunflower's vegetation in the three years of research but was enough for the plant's growth and development.

Table 1. Average monthly precipitation for the vegetation periods of sunflower, mm

Years/ Month	2018	2019	2020
April	24.0	68.9	92.9
May	98.4	22.8	60.1
June	116.4	89.7	81.9
July	89.6	79.4	45.3
August	31.2	33.8	25.5

The average minimum and maximum air temperatures differed during the growing seasons of sunflower.

The air temperatures were suitable for sunflower's growth.

Throughout the three study years, no extreme values affecting the crop were recorded.

Table 2. Average monthly precipitation for the vegetation periods of sunflower, mm

Years/ month	2018		2019		2020	
	max t°	min t°	max t°	min t°	max t°	min t°
April	23.9	8.9	20.1	8.6	18.6	4.1
May	27.1	12.6	24.8	11.5	17.9	5.7
June	28.0	16.4	28.0	18.5	31.2	10.8
July	29.1	18.8	31.2	19.3	32.1	16.2
August	30.2	17.5	31.4	21.0	31.9	20.7

In the next six tables the results concerning plant biometry, productivity and seed quality are presented.

According to a several authors, plant growth and development is influenced by the previous crop in the rotation (Arihara and Karasawa, 2000; Haase et al., 2007; Rieger et al., 2008; Friberg et al., 2019). These findings correspond with the obtained data related to the current study. The average height of the plants from Rotation 1 was 1.72 m and did not differ in wide ranges in the different years of the study. When growing sunflower as monocrop the height of the plants decreased from 1.67 m in 2018 to 1.31 m in 2020 (Table 3).

Table 3. Sunflower plant height, m

Rotations	2018	2019	2020	Average
1. Winter wheat - sunflower	1.73	1.67	1.76	1.72
2. Sunflower - sunflower	1.67	1.42	1.31	1.47
Rotation 1 / Rotation 2	ns	*	*	*

Asterisks (*) indicate significant differences between the averages of both tested cultivars by independent samples t-test at $P \leq 0.05$, ns-non significant difference.

The sunflower head diameter followed the tendency of the plant height (Table 4). The differences in the sunflower heads from the plants of rotation 1 did not differ to a great extent. Average for the period of the study the sunflower heads of this rotation were 18.62 cm in diameter. The sunflower heads decreased their diameter in the mono-cropping system (Rotation 2) from 18.25 cm in 2018 to 16.12 cm in 2020.

Table 4. Sunflower head diameter, cm

Rotations	2018	2019	2020	Average
1. Winter wheat – sunflower	18.45	19.04	18.38	18.62
2. Sunflower – sunflower	18.25	17.46	16.12	17.28
Rotation 1 / Rotation 2	ns	*	*	*

Asterisks (*) indicate significant differences between the averages of both tested cultivars by independent samples t-test at $P \leq 0.05$, ns-non significant difference.

In Table 5 is presented the sunflower seed yield. As well as the growth parameters, the productivity of the plants was also influenced by the preceding crop. Anderson et al. (1999) found that the highest sunflower seed yield was obtained in the wheat-corn-sunflower-fallow rotation. In the present experiment higher and stable yields were found when the sunflower was sown after winter wheat (Rotation 1) - 2.54 t ha^{-1}. Severe yield decrease was observed when the sunflower was grown as monoculture (Rotation 2). In the first year of the study (2018) the seed yields were 2.53 t ha^{-1} and diminished to 1.64 t ha^{-1} in the third experimental year (2020).

Table 5. Sunflower seed yield, t ha^{-1}

Rotations	2018	2019	2020	Average
1. Winter wheat - sunflower	2.57	2.64	2.41	2.54
2. Sunflower - sunflower	2.53	2.18	1.64	2.12
Rotation 1 / Rotation 2	ns	*	*	*

Asterisks (*) indicate significant differences between the averages of both tested cultivars by independent samples t-test at $P \leq 0.05$, ns-non significant difference.

The indicator absolute seed mass is crucial for the yield's formation (Georgiev et al., 2014). There were negligible differences observed in the different years of the trial when the sunflower was grown after preceding crop winter wheat (Rotation 1). The absolute mass of the sunflower seeds from this rotation was 62.14 g on average for the period. The mono-cropping system of sunflower (Rotation 2) led to a severe decrease of the evaluated parameter also. In the first trial year, the absolute seed mass was 61.85 g and 51.78 g in the last experimental year (Table 6).

Table 6. Absolute seed mass, g

Rotations	2018	2019	2020	Average
1. Winter wheat – sunflower	62.41	60.57	63.43	62.14
2. Sunflower – sunflower	61.85	57.42	51.78	57.02
Rotation 1 / Rotation 2	ns	*	*	*

Asterisks (*) indicate significant differences between the averages of both tested cultivars by independent samples t-test at $P \leq 0.05$, ns-non significant difference.

The seed hectoliter mass and yield depend on the production year (Vujaković et al., 2014). In the current research, the indicator hectoliter seed mass was influenced by the crop rotation. In Rotation 1, as the other studied parameters, the highest results were obtained. Average for the research years the hectolitre seed mass was 41.17 kg.

For Rotation 2 the average result of 38.44 kg was a function of the decrease of the indicator's values in the second and third year of growing sunflower as monocrop (Table 7).

Table 7. Hectoliter seed mass, kg

Rotations	2018	2019	2020	Average
1. Winter wheat - sunflower	41.33	40.67	41.50	41.17
2. Sunflower - sunflower	41.67	38.33	35.33	38.44
Rotation 1 / Rotation 2	ns	*	*	*

Asterisks (*) indicate significant differences between the averages of both tested cultivars by independent samples t-test at P ≤ 0.05, ns-non significant difference.

Seed oil percentage amounted to an average of 42.8% and was affected by the year, rather than sowing date or preceding crop (Hemeid and Zeid, 2020). Reverse results were obtained in the present research. The preceding crop affected the seed oil content of sunflower. Robinson et al. (1967) reported that the seed oil content of sunflowers in rotation with soybeans was higher than the seed oil content of sunflowers grown as a monoculture. These findings correspond to the results obtained in the current research.

Table 8. Sunflower seed oil content, %

Rotations	2018	2019	2020	Average
1. Winter wheat - sunflower	45.14	46.41	45.87	45.81
2. Sunflower –- sunflower	44.89	41.31	38.70	41.63
Rotation 1 / Rotation 2	ns	*	*	*

Asterisks (*) indicate significant differences between the averages of both tested cultivars by independent samples t-test at P ≤ 0.05, ns-non significant difference.

The seed oil content of the plants from Rotation 1 (winter wheat - sunflower) was lower than those of the plants grown as a mono-cropping system (Table 8). The seed oil content of sunflower of Rotation 1 was 45.81% on average for the two research years. In contrast, the seed oil content of the plants from Rotation 2 decreased from 44.89% in 2018 to 38.70% in the third research year.

CONCLUSIONS

The obtained results confirmed that the preceding crop influences the growth and development of the sunflower. If sown after winter wheat the highest results for all studied parameters were obtained.

The growing sunflower as a mono-cropping system is not a good farmer practice. In the second and third years of the study, the results of the studied indicators (vegetative, productive, and qualitative) for the monoculture of sunflower were diminished.

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