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DEVELOPMENT OF DURUM WHEAT (*Triticum turgidum* subsp. *durum* (Desf.) Husn.) GROWN AFTER A DIFFERENT PREDECESSOR UNDER ORGANIC FARMING CONDITIONS

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Abstract

During the period 2019-2022a field experiment was carried out with durum wheat variety 'Progress', grown after three predecessors - peas, cotton and sunflower on the experimental field in Field Crops Institute - Chirpan under the conditions of organic farming. The beginning and duration of the following phenological phases were tracked: emergence, third leaf, tillering, spindle, outgrowth and full maturity. In organic cultivation of durum wheat after a pea predecessor, the phenological phases from budding to full maturity occur 6 days earlier than in the other two predecessors. It was found that during the study period the yield was greater after the predecessor pea. In the same variant, durum wheat plants are taller and have higher values of the reported indicators. The highest number of emerged 539 and recovered plants 492 was reported after predecessor cotton in the 2019/2020 crop year.

Key words*: durum wheat, organic farming, predecessors.*

INTRODUCTION

World wheat production for the last five years averaged 38 Mt and made up about 8% of total production. Although it is grown in different regions of the world, the main areas and production are concentrated in the Mediterranean basin and North America (Popov, 2019). The main producers of durum wheat in Europe are Italy, France, Spain and Greece; in North Africa - Algeria, Morocco and Tunisia; across the ocean are Canada and the USA; and in the Middle East - Turkey and Syria. Other producers of durum wheat are Russia, Kazakhstan, Mexico and India (Boyacioglu, 2017; Morgan, 2017; FAS/USDA, 2018; Arkova et al., 2019).

Most Bulgarian varieties of durum wheat are characterized by very good economic qualities, relatively high protein content, good milling and medium culinary potential (Petrova, 2013; Petrova et al., 2015).

The entry of dietary and medical nutrition into the daily life of a person becomes a tradition in countries with a high standard of living. The favorable conditions for the increasing interest in food from ecologically clean production imply a demand for durum wheat products, especially in the countries of the European Union (Kryuchkov et al., 2016; Maksyutov et al., 2018). This, in turn, leads to a search for ways to increase the grain quality and yields of durum wheat from organic farming.

Due to the biology of durum wheat (Gridnae, 1975; Blanco et al., 1998; Shewry, 2009) and the need to increase the quality of the grain, the inclusion in the crop rotation with other crops is required. The lack of studies in our country on the influence of the predecessor on the yield and quality of the grain of durum wheat grown in the conditions of organic production necessitated the study of this problem.

MATERIALS AND METHODS

The study was conducted in the period 2019-2022. A two-factor field experiment using the method of fractional plots with a reporting plot size of 10 m^2, in three repetitions, was implemented. The seed material is durum wheat variety 'Progress' of the Field Crops Institute, Chirpan (FCI Chirpan), accompanied by the relevant required documents for organic farming.

The following factors were studied: Factor A – Vegetation year: A1 - 2019/2020; A2 –

2020/2021; A3 – 2021/2022; Factor B – Precursor: B1 – Peas; B2 – Cotton; B3 – Sunflower.

The experiment was conducted in a crop rotation after peas, cotton and sunflower. Depending on the climatic conditions, immediately after harvesting the predecessor and the area freed from plant residues, it is disked two - three times diagonally with disk harrows at a depth of 8-12 cm. Sowing was carried out in the optimal period for southern Bulgaria, November 1-10, with a sowing rate of 550 seeds per m^2 (Wood, 1960; Kovachev, 1972). Fertilization was carried out on the basis of soil analyzes for soil reserves with NPK. The organic fertilizer Italpollina was used in a dose of 50 kg/day.

The experimental plots are located immediately next to each other (Figure 1) within the boundaries of the organic field of FCI Chirpan. The field is divided into 7 sections. 1 indicates the area left for sunflower sowing, 2 pea plot after durum wheat predecessor, 3 durum wheat area after cotton predecessor, 4 cotton plot area, 5 durum wheat plot after pea predecessor, with 6 durum wheat field after sunflower predecessor and 7 pea field after sunflower predecessor.

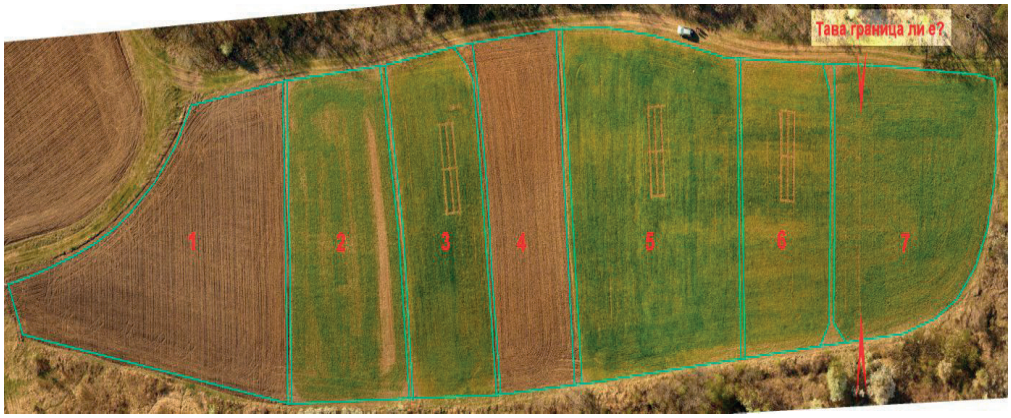

Figure 1. Distribution of the organic field of FCI Chirpan

The dates of the occurrence of the phenophases: emergence, third leaf, bracting, spindle, tillering, flowering and milky, waxy and full maturity and the duration of the interphase periods were tracked. The beginning of each phenophase is considered the moment when 70% of the plants have entered it.

Plant heights were recorded in three phases: tillering, spindle and full maturity. The heights of 40 marked plants from each replicate were measured.

Number of emerged and number of recultivated plants per m^2 were determined for each replicate in four plots of 0.25 m^2.

RESULTS AND DISCUSSIONS

In the first year of conducting the research, the rainfall in October (57.7 mm) had a favorable effect on the implementation of good pre-sowing soil treatment and sowing of durum wheat (Table 1). These rainfalls, as well as temperatures close to the average for this month (Table 2), proved to be sufficient for seed germination and plant emergence was recorded on 16.11.2019.

In the November-January period, the amount of precipitation was less by 32.6 mm; 27.6 mm and 15.4 mm above the multi-year norm and higher temperatures did not prevent normal durum wheat plant development in all three predecessors.

In autumn, the twining phase began on 15.12.2019, gradually with a decrease in temperatures during the second and third ten days of December, the growth processes of durum wheat also subsided. The average monthly temperatures in the winter months - December, January and February were equal to 1.3^0C; 0.5^0C and 1.0^0C higher than the multi-year period.

Table 1. Amount of precipitation by ten days and months (mm)

Year	Ten days	*X*	*XI*	*XII*	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*
2019-2020	I	27.1	0.8	4.2	2.8	1.2	9.7	21	21	22	17
	II	18.7	11.2	5.2	5.2	18.1	37.8	17	27	22	11
	III	11.9	5.4	15.6	15.6	19.3	16.7	29	19	29	10
	Total for the month	57.7	17.4	27.4	23.6	38.6	64.2	67	67	73	38
2020-2021	I	39.7	28.4	16.7	8.6	32.2	31.0	19	17	21	16
	II	12.3	21.4	13.2	12.3	11.8	17.3	16	23	17	9
	III	34.8	10.4	12.8	14.2	11.7	18.7	26	16	28	11
	Total for the month	76.8	60.2	42.7	35.1	45.7	67.0	61	56	66	36
2021-2022	I	25.7	25.4	17.7	8.6	30.2	20.0	15	20	18	13
	II	15.3	18.4	14.2	10.3	9.8	20.3	13	20	20	13
	III	29.8	12.4	10.8	12.2	13.7	15.7	26	14	24	11
	Total for the month	70.8	66.2	42.7	31.1	43.7	56.0	54	54	62	37
Average over a 30-year period		*52.0*	*50.0*	*45.0*	*39.0*	*37.0*	*38.0*	*61*	*62*	*77*	*44*

Table 2. Average daily temperatures by ten days and months in ^{0}C

Year	Ten days	*X*	*XI*	*XII*	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*
2019-2020	I	18.0	9.1	6.8	3.8	-1.8	4.3	10.7	9.8	17.1	20.1
	II	11.8	10.2	1.3	2.6	3.6	5.2	11.2	11.5	19.4	21.9
	III	12.1	7.4	3.4	-3.1	8.2	11.9	8.9	14.9	18.6	21.7
	Total for the month	13.9	8.9	3.8	1.9	3.3	7.1	10.2	12.1	18.3	21.2
2020-2021	I	12.3	12.1	7.1	0.5	4.8	3.4	10.2	10.1	16.8	20.4
	II	13.3	11.7	-0.5	5.1	3.1	9.7	10.9	11.7	18.6	21.6
	III	10.8	9.8	3.0	2.1	-0.6	12.2	11.2	13.9	18.1	20.8
	Total for the month	12.1	11.2	3.2	2.6	2.4	8.4	10.8	11.9	17.8	20.9
2021-2022	I	11.3	12.5	6.5	0.6	4.6	3.2	10.4	10.3	16.9	21.4
	II	12.3	12.0	0.5	5.0	3.0	9.5	10.5	10.7	18.5	22.6
	III	9.8	8.8	3.1	2.3	-0.4	11.5	11.0	13.7	18.6	21.9
	Total for the month	11.1	10.2	3.1	2.7	2.3	8.2	10.5	12.2	18.1	22.3
Average over a 30-year period		*13.1*	*9.8*	*2.5*	*1.4*	*2.3*	*6.5*	*10.8*	*11.2*	*18.3*	*21*

During the third ten-day week of March, as temperatures rose, the plants resumed their vegetation. Rainfall in February, March and April was above normal, which favored the growth of durum wheat. Precipitation totals during the months of May and June are below normal, while temperature totals during these months are higher, resulting in accelerated development of durum wheat.

The pouring and ripening phases of the grain took place under less favorable conditions in terms of rainfall. Less and unevenly distributed rainfall is observed.

Durum wheat was harvested on 18.07.2020 at full maturity.

In the second year, the precipitation of 70.8 mm in the month of October is a prerequisite for performing a good pre-sowing soil treatment and sowing in an optimal agrotechnical period (Table 1). These rainfalls were favorable for the harmonious and even germination of the plants (20.11.2021).

Gradually, as the temperatures drop during the second and third ten days of December, the growth processes of durum wheat also slow down. In the month of January, when the plants are in winter rest, the amount of precipitation is less by 7.9 mm, and in February and March, respectively, c 6.7 and 18 mm more than the norm for a multi-year period. During these two months, the temperatures are close to the norm, and in the second ten days of March, with an increase in temperatures, the plants resumed their vegetation. Rainfall in April, May and June is above normal, resulting in enhanced wheat growth.

In the third year, the rainfall from the month of October (70.8 mm) had a favorable effect on sowing (Table 1). These rainfalls, as well as temperatures close to those of the multi-year period (Table 2), led to uniform germination of the crop (21.11.2021).

Gradually, with the drop in temperatures during the second and third ten days of December, the processes in the development of durum wheat also slow down. In the month of January, when the plants are in winter rest, the amount of precipitation is less by 3.9 mm, and in February and March by 8.3 and 29 mm, respectively, more than in the perennial period. During these two months, the temperatures are close to the norm, and in the second ten days of March, with an increase in temperatures, the plants resumed their vegetation. Precipitation in April, May and June is above normal, which leads to an increase in wheat growth. In the phases of pouring the grain (milky, waxy maturity) to full maturity, temperatures are close to the values of the long-term period.

The harvest was carried out on 26.07.2022.

Of the three years of research, the 2019/2020 crop year is the one with more favorable conditions for the growth and development of durum wheat.

Table 3 presents the results for number of sprouted and number of harvested plants/m^2.

Table 3. Number of sprouted and number of harvested plants/m^2

Predecessor	Number of sprouts /m^2			Number harvested plants/m^2		
	2019/2020	2020/2021	2021/2022	2019/2020	2020/2021	2021/2022
Peas	411	458	434	335	346	368
Cotton	539	445	492	492	418	455
Sunflower	443	427	435	384	368	356

In 2019/2020, in the germination phase of durum wheat after predecessor pea, 411 pieces/plant/m^2 were recorded, after cotton - 539 pieces/m^2 and after sunflower - 443 pieces/m^2. In the second year, the number of sprouted plants/m^2 also varies in values above 400. It is the largest in the variant with a pea predecessor – 458. The number of sprouted plants in 2021/2022 in all three variants is over 400. With the largest number of plants is the version with predecessor cotton - 492.

These values of more than 400 units allow normal crop top dressing for each of the predecessor variants studied in all three years of the study (Koedzhikov, 1960; Djumalieva, 1980).

The number of harvested plants per m^2 in 2019/2020 is from 335 in predecessor pea to 492 in cotton. In the second year, values ranged from 346 for peas to 418 counts/m^2 for cotton. And in the third year of the study, the number of plants varied from 356 for sunflower to 455 plants/m^2 for cotton.

On average for the period of the study, durum wheat stands out with the highest number of sprouted and therefore harvested plants/m^2, after its predecessor cotton.

Table 4 presents data on entering the individual phenological phases and the duration of the interphase periods in the different test options.

Sowing was done on 03.XI., on 08.XI. and on 06.XI. respectively in 2019; 2020 and 2021. All three sowing dates fall within the optimum wheat sowing period.

During the three years, the emergence of the plants (70%) after the three predecessors occurred respectively on the 13th day; 14 days and 15 days after sowing.

During the studied period from the fraternization phase to the phenophase classification, differences between the individual variants are reported. The duration of the interphase periods remains the same. This shows that in the conditions of organic farming, the phenological development of durum wheat depends on the type of the predecessor.

In 2019/2020, the third leaf phase was reported on 01.XII, which is 28 days after sowing, in 2020/2021 on 09.XII. - 32 days after sowing and in 2021/2022 on 05.XII. - 29 days after sowing.

In the first year of research, the interphase period third leaf-twining lasted 14 days, while in the second and third it was only 10 days. This difference for the second year is explained by unfavorable environmental conditions. In 2019, the tillering phase occurs with the predecessor pea on 15.XII, and with the other two predecessors on 21.XII. In 2020 and 2021,

this trend is maintained, with the predecessor pea occurring on 14.XII and 15.XII, and with the others again with a difference of 6 days on 20.XII for 2020/2021 and 21.XII for 2021 /2022

The duration of the period from sowing to harvesting of durum wheat after predecessor peas was 42 days in the first year, 36 days in the second and 39 days in the third year. In predecessor cotton and sunflower, this period is 48, respectively; 42 and 45 days.

In 2019/2020, the twinning-spinning interphase period is 128 days and occurs on 23.IV.2020. In 2020/2021, it is 132 days and occurs on 26.IV.2021 (Table 4) and for 2021/2022 it is 130 days and occurs on 22.IV.2022.

Differences in durum wheat after the different predecessors and in the three years of the study were observed from the onset of the brazing phase to the full maturity phase. In 2019/2020, ranking occurs simultaneously for cotton and sunflower (20.V), and for peas it is earlier at 14.V. In 2020/2021, the two types of predecessors again enter the phenophase ranking together (22.V), and for peas it is again 6 days earlier - 16.V. This is also preserved in the 2021/2022 harvest year. The grading phase occurs simultaneously for predecessor cotton and sunflower (24.V), and for peas it is 6 days earlier - on 18.V.

The length of the spindle-to-heading interphase period was 27 days for the three predecessors in 2019/2020, 26 days in 2020/2021 and 31 days in 2021/2022, with durum wheat in predecessor pea again 6 days ahead of the other two cotton and sunflower.

The duration of the phenological phases and interphase periods is strongly influenced by the external conditions of the environment. The uneven distribution of precipitation or its lack combined with high temperatures shortens the interphase periods and negatively affects the duration of the vegetation and vice versa.

Table 4. Phenological phases by entry dates for the studied precursor species

Phenological phases of development	2019/2020			2020/2021			2021/2022		
	predecessor			Predecessor			predecessor		
	Peas	Cotton	Sunflower	Peas	Cotton	Sunflower	Peas	Cotton	Sunflower
Sowing date	03.XI	03.XI	03.XI	08.XI	08.XI	08.XI	06.XI	06.XI	06.XI
Germination	16.XI	16.XI	16.XI	22.XI	22.XI	22.XI	21.XI	21.XI	21.XI
Third leaf	01.XII	01.XII	01.XII	09.XII	09.XII	09.XII	05.XII	05.XII	05.XII
Tillering	15.XII	21.XII	21.XII	14.XII	20.XII	20.XII	15.XII	21.XII	21.XII
Spindle	17.IV	23.IV	23.IV	20.IV	26.IV	26.IV	16.IV	22.IV	22.IV
Classing up	14.V	20.V	20.V	16.V	22.V	22.V	18.V	24.V	24.V
Flowering	21.V	26.V	26.V	23.V	28.V	28.5	25.V	29.V	29.V
Milky ripeness	04.VI	04.VI	04.VI	06.VI	06.VI	06.VI	07.VI	07.VI	07.VI
Waxy maturity	13.VI	13.VI	13.VI	15.VI	15.VI	15.VI	17.VI	17.VI	17.VI
Full maturity	18.VII	18.VII	18.VII	23.VII	23.VII	23.VII	26.VII	26.VII	26.VII

The duration of the vegetation period in 2019/2020 and 2020/2021 of the hard pennywort in the three predecessors is 257 days, and in 2021/2022 it is 262 days.

Table 5 presents the results of durum wheat height for the three progenitors in the twining, spindle and full maturity phenophases.

In 2019/2020, in the twinning phase, the height of the plants with the predecessor pea is the largest - 12.33cm, followed by the plants with the predecessor cotton - 10.24 cm and the lowest with the predecessor sunflower - 9.63 cm.

The results of 2020/2021 show lower values of the indicator of the height of the plants in the twining phase in all variants compared to the results of 2019/2020. Again the highest are the plants after peas with 11.25 cm, followed by

those after cotton - 9.14 cm and the lowest are after the predecessor sunflower - 8.86 cm.
In 2019/2020, when counting the height in the spindle phase, the highest value of the plants after peas was again observed - 56.93 cm, followed by those after cotton - 52.28 cm and the lowest after sunflower - 49.9 cm.
The results of the reading of the height in the spindle phase in 2020/2021 show lower values compared to the previous year. After predecessor pea, the height of the plants is 52.63 cm, followed by those after cotton - 48.94 cm and finally those after sunflower - 47.20 cm.
The measurement of the height of the plants in the spindle phase in 2021/2022 show that the highest are after peas with 54.78 cm, followed by those after cotton with 50.61 cm and the lowest plants are reported for sunflower - 48.55 cm.
At full maturity, the average height of durum wheat plants in all three variants was greater in 2019/2020 compared to the same in 2020/2021 and 2021/2022.

Table 5. Height of plants in the phenological phases of budding, spindle and full maturity by year in cm

Predecessor	Phenological phase								
	Tillering			Spindle			Full maturity		
	2019/2020	2020/2021	2021/2022	2019/2020	2020/2021	2021/2022	2019/2020	2020/2021	2021/2022
Peas	12,33	10,25	11,29	56,93	52,63	54,78	93,80	75,80	84,80
Cotton	10,24	9,14	9,69	52,28	48,94	50,61	86,40	63,70	76,55
Sunflower	9,36	8,86	9,11	49,90	47,20	48,55	80,20	60,00	72,00

In 2019/2020, when measuring the height at full maturity, the highest plant values were recorded for the predecessor pea - 93.80 cm, followed by those after cotton - 86.40 cm and the lowest plants after sunflower - 80.20 cm.
For the second year, the plants are significantly lower. The measured heights show that this year the plants after peas are the tallest - 75.80 cm, followed by those after cotton and sunflower with 63.70 cm and 60.00 cm, respectively. Konneoke (1960), Evenary (1979) and Arkova et al. (2019) found similar data for conventional durum wheat cultivation.
When considering the height in the phenophase, full maturity in 2021/2022 values show that the tallest plants of durum wheat are after predecessor pea - 84.80 cm, followed by those after cotton and sunflower with 76.55 cm and 72.00 cm, respectively.
The results in 2020/2021 and 2021/2022 show a reduction in plant height at full maturity in all test variants. These changes are due to the differences in the weather conditions of the two years and the distribution of precipitation during the individual phases of wheat development.

CONCLUSIONS

As a result of the research, we can draw the following conclusions:
In organic cultivation of durum wheat after a pea predecessor, the phenological phases from tillering to full maturity occur 6 days earlier than in the other two predecessors.
The duration of the interphase periods remains the same for all three precursors.
The highest number of emerged 539 and recovered plants 492 was reported after predecessor cotton in the 2019/2020 crop year.
Durum wheat plants are highest after predecessor pea 93.80 cm, followed by those after cotton 86.40 cm and lowest after sunflower 80.20 cm.

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