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Nutrition and Physiology

Photosynthetic activity and productivity of durum wheat (*Triticum durum* Desf.) affected by certain preparations and various terms of sowing

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Abstract: *In 2019-2020, in the experimental field of the Field Crops Institute, Chirpan a field experiment with durum wheat cultivar Predel (Triticum durum Desf.) was conducted. Three sowing dates were tested: Early sowing (05 - 10 October), Normal sowing (20-25 October - standard) and Late sowing (05-10 November). In early sowing, 2 retardants were studied: Cearon 480 SL - 1 l/ha and Medax top - 1 l/ha and 2 insecticides: Proteus 110 OD - 625 ml/ha and Mageos - 100 g/ha, as well as the mixtures between them. During late sowing, 2 stimulants were studied: Naturamin plus - 1.5 l/ha and Raiza mix - 750 ml/ha and 2 foliar liquid fertilizers: Mix for cereal SC - 1.5 l/ha and Trimax SC - 1.5 l/ha, as well as the mixtures between them. These preparations and fertilizers are applied after stage 3-4 leaves of durum wheat, in the so-called "Closure of crops". In the case of early sowing variants, this stage occurs in autumn, and in the case of late sowing variants, the stage occurs in spring. In the early sowing of durum wheat, the leaf area, photosynthetic potential, biological and economic yield are the greatest in the combinations of retardants Cearon and Medax top with the insecticides Proteus and Mageos. In the late sowing of durum wheat, the leaf area, photosynthetic potential, biological and economic yield are the highest in the combinations of the stimulants Naturamin plus and Raiza mix with the leaf fertilizers Mix for cereals and Trimax. In these variants, the leaf area dies faster during the milk development stage. The net photosynthesis productivity in the combinations is lower than in the independent use of the respective preparations and fertilizers. The harvest index in the late and normal sowing variants is higher than in the early durum wheat sowing variants.*

Keywords: biological and economic yields, durum wheat, harvest index, leaf area, net photosynthesis productivity, photosynthetic potential

Introduction

The formation of durum wheat grain yield takes place throughout the growing season and depends on the genetic features of a variety, as well as on the cultivation technology and meteorological conditions (Singh and Jain, 2000; Sharma et al., 2003; Motzo et al., 2007). Obtaining more and higher quality grain is a consequence of the optimal combination between variety, cultivation technology related with mineral fertilization and foliar feeding with macro- and microelements, stimulation with growth regulators, norms, doses and terms of their introduction under the specific agro-ecological conditions (Abad et al., 2004; Simoglou and Dordas, 2006; Panayotova et al., 2014; Ropelewska et al., 2019).

Growth regulators and foliar fertilizers, properly selected and used at the appropriate level of mineral fertilization, increase the yields and quality of the obtained products in cases when the classical methods and means are ineffective or their possibilities are almost exhausted (Delchev, 2003; Cabrera-Bosquet et al., 2009; Blandino et al., 2009). There is evidence in the scientific literature that common and durum wheat react differently when treated with the same preparations (Franzen et al., 2008; Kononenko et al., 2020; Zhou et al., 2020). According to Haliniarz et al. (2018) with its reaction to a number of retardants durum wheat stands closer to barley than to common wheat.

The aim of the present experiment is to study the changes in the photosynthetic activity and productivity of durum wheat under the influence of certain pesticides, growth regulators and complex foliar fertilizers and different sowing dates.

Material and methods

In 2019-2020, in the experimental field of the Field Crops Institute, Chirpan a field experiment with durum wheat cultivar Predel (*Triticum durum* Desf.) was conducted, laid by the block method, in 4 replications, with the size of the harvest plot 15 m^2, after predecessor sunflower. The soil type is a leached resin poorly stocked with N_2, moderately stocked with P_2O_5 and very well stocked with K_2O. Three sowing dates were tested: Early sowing (05-10 October), Normal sowing (20-25 October - standard) and Late sowing (05-10 November). In early sowing, 2 retardants

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were studied: Cearon 480 SL - 1l/ha and Medax top - 1 l/ha and 2 insecticides: Proteus 110 OD - 625 ml/ha and Mageos - 100 g/ha, as well as the mixtures between them. During late sowing, 2 stimulants were studied: Naturamin plus - 1.5 l/ha and Raiza mix - 750 ml/ha and 2 leaf liquid fertilizers: Mix for cereal SC - 1.5 l/ha and Trimax SC - 1.5 l/ha, as well as the mixtures between them.

These preparations and fertilizers are imported after stage 3-4 leaves of durum wheat, in the so-called "Closure of crops". In the case of early sowing variants, this stage occurs in autumn, and in the case of late sowing variants, the stage occurs in spring.

The following parameters were determined:

1. Dynamics of the leaf area in m^2/ha by the weighting method.

2. Photosynthetic potential of the crop - by the method of Nichiporovich (1956, 1961) and calculated by the formula:

$PP = [(L_1 + L_2)/2].T,$

Where: PP - photosynthetic potential in m^2/ha; L_1 and L_2 - leaf area at the beginning and the end of the reporting period in m^2/ha; T - number of days in the reporting period.

3. Accumulation of dry biomass in kg/ha - by weight method.

4. Pure productivity of photosynthesis - according to the formula of Briggs, Kidd and West (1920):

$NPP = (B_2 - B_1)/[(L_1 + L_2)/2].T,$

Where: NPP - net photosynthesis productivity in g/m^2 LA/day (absolutely dry biomass in g, formed from 1 m^2 leaf area on average for 1 day); B_1 and B_2 - absolutely dry biomass at the beginning and end of the reporting period in g/m^2; L_1 and L_2 - leaf area at the beginning and at the end of the reporting period in m^2/m^2; T - the number of days in the reporting period.

5. Grain yield in kg/ha.

6. Harvest index.

The influence of the preparations and fertilizers has been established through their influence on grain yield. The math processing of the data was done according to the method of analyses of variance (Shanin 1977; Barov, 1982; Lidanski, 1988).

Results and discussion

The obtained data show that during the spring tillering stage, the leaf area is the smallest in late sowing, due to the shorter autumn vegetation (Table 1). The differences in leaf area between early and normal sowing are smaller. Despite the early sowing period, the seeds germinate almost simultaneously with normal sowing due to the drought in September. At the end of the tillering stage there are positive changes in the size of the leaf area under the influence of imported preparations and fertilizers.

Table 1. Leaf area affected by certain preparations and various terms of sowing, m^2/ha (mean 2019-2020)

Variants			Tillering	Stem elongation	Ear emergence	Milk development
Early sowing	-	-	16670	48535	76810	17395
		Proteus	16665	52675	81970	16855
		Mageos	16660	51505	81495	16855
	Cearon	-	16605	49510	78780	17665
		Proteus	16730	53945	85055	16565
		Mageos	16815	53985	85210	16695
	Medax Top	-	16565	49565	78825	17550
		Proteus	16780	53340	84940	16775
		Mageos	16725	53890	86400	16670
Normal sowing – St			16440	52085	83110	16925
Late sowing	-	-	15815	48865	76960	17345
		Mix for cereals	15995	50720	80655	17140
		Trimax	16005	50600	80580	17090
	Naturamin Plus	-	16025	51220	81135	17015
		Mix for cereals	16210	55445	88835	16600
		Trimax	16395	54125	86505	16885
	Raiza Mix	-	16010	53170	80850	17010
		Mix for cereals	16290	54325	86760	16695
		Trimax	16400	55275	88825	16670
		LSD 5%	111	202	304	123
		LSD 1%	224	333	456	241
		LSD 0.1%	356	478	579	372

During the stem elongation stage, the differences between the treated and untreated variants increase. In late sowing, the leaf area is the greatest in the combinations of the stimulants Naturamin plus and Raiza mix with the leaf fertilizers Mix for cereals and Trimax. In early sowing, the leaf area is the greatest in the combinations of the retardants Cearon and Medax top with the insecticides Proteus and Mageos.

The maximum size of the leaf area formed per unit area is expressed by the leaf area index. This indicator characterizes the productive capabilities of the variety and the condition of the crop as a photosynthetic system. The maximum leaf area is formed during the ear emergence stage. Its changes during this stage due to stimulants and foliar fertilizers are also more pronounced than those caused by retardants and insecticides. The maximum

of the leaf area index on average for the period was reported using Naturamin plus and Mix for cereals at late sowing - 88835 m^2/ha. In untreated variants and those with independent use of preparations and fertilizers, the growth rate of leaf area is lower.

After the ear emergence stage, the leaf mass gradually dries from the base to the top of the plants and the photosynthetic leaf area begins to decrease. In the variants with the highest leaf area index, the leaf mass dies faster. Dying is the fastest when combining the stimulants Naturamin Plus and Raiza mix with the foliar fertilizers Mix for cereals and Trimax for late sowing and combining the retardants Cearon and Medax top with the insecticides Proteus and Mageos for early sowing. In the untreated variants and those with independent use of Cearon, Medax top, Proteus, Mageos, Naturamin plus, Raiza mix, Mix for cereals and Trimax, the rate of death of the leaf area is slower, i.e. it functions longer.

The photosynthetic potential of the crop is an indicator that gives an idea of the size of the photosynthetic apparatus, its size and the duration of its assimilating activity. Changes in the photosynthetic potential under the influence of sowing dates, applied preparations and fertilizers follow the direction of increase of the leaf area under the influence of the same factors (Table 2). Retardants and insecticides have less effect than stimulants and foliar fertilizers. The combination of the stimulants Naturamin Plus and Raiza mix with the foliar fertilizers Mix for cereals and Trimax for late sowing and the combination of the retardants Cearon and Medax top with the insecticides Proteus and Mageos for early sowing increase the photosynthetic potential of durum wheat. The maximum size of the photosynthetic potential is reached when combining the stimulator Raiza mix with the combined foliar fertilizer Trimax - 2833825 m^2/ha.

Table 2. Photosynthetic potential affected by certain preparations and various terms of sowing, m^2/ha (mean 2019-2020)

Variants			Tillering - stem elongation	Steam elongation - ear emergence	Ear emergence - milk development	Tillering - milk development
Early sowing	-	-	831395	752195	942050	2525640
		Proteus	884050	807735	978250	2680035
		Mageos	869080	798310	983500	2650890
	Cearon	-	842950	769720	964450	2577120
		Proteus	901070	833890	1016200	2751160
		Mageos	902710	835345	1019050	2757105
	Medax Top	-	843065	769930	963750	2576745
		Proteus	894035	829700	1017150	2740885
		Mageos	900160	839490	1030850	2770500
Normal sowing – St			873715	811225	1000350	2685290
Late sowing	-	-	824630	754755	943050	2522435
		Mix for cereals	850760	789275	977950	2617985
		Trimax	849360	788130	976700	2599190
	Naturamin Plus	-	857460	794515	981500	2633475
		Mix for cereals	913610	865530	1054350	2833490
		Trimax	899595	847850	1033900	2781345
	Raiza mix	-	882645	806770	978600	2668015
		Mix for cereals	900670	849725	1034550	2784945
		Trimax	913945	864930	1054950	2833825
		LSD 5%	326	359	404	451
		LSD 1%	457	483	555	539
		LSD 0.1%	568	561	678	692

The accumulation of dry aboveground biomass shows an increasing trend from the beginning to the end of the growing season of durum wheat (Table 3). At the beginning of the vegetation, the amount of biomass in the individual variants does not differ significantly during the twinning stage. During the ear emergence stage, the positive effect of the applied preparations and fertilizers is already strongly distinguished. The highest biomass is reported when combining the stimulants Naturamin plus and Raiza mix with foliar fertilizers Mix for cereals and Trimax for late sowing and when combining the retardants Cearon and Medax top with the insecticides Proteus and Mageos for early sowing. These differences in the formed biological yield are preserved at the end of the vegetation during the ripening stage.

The net photosynthesis productivity is of particular importance in forming biological and economic yields of durum wheat. The larger leaf area and biomass formed during the growing season in the combinations of Naturamin plus and Raiza mix with Mix for cereals and Trimax in late sowing and the combinations of Cearon and Medax top with Proteus and Mageos in early sowing lead to shading of the leaves from the lower floors and suppression of the photosynthetic processes taking place in them (Table 4). On these floors, after the ear emergence stage, chlorophyll decomposes faster, the leaf mass dries out and the photosynthesis subsides. Due to these processes, the values of the Net photosynthesis productivity in the combination of Naturamin Plus, Raiza Mix, Cereal Mix, Trimax, Cearon, Medax Top, Proteus and Mageos are lower than in the independent use of these preparations and fertilizers, as in the individual interstage

periods and throughout the growing season. Despite the powerful photosynthetic potential, the combinations result in less efficient photosynthetically active radiation and the nutrient area.

Table 3. Dry biomass affected by certain preparations and various terms of sowing, kg/ha (mean 2019-2020)

Variants			Tillering	Stem elongation	Ear emergence	Ripening	Grain yield	Harvest index
Early sowing	-	-	660.5	4026.0	9050.5	13759.5	5008.5	0.364
		Proteus	696.5	4224.0	9501.5	15117.5	5608.5	0.371
		Mageos	697.5	4188.5	9440.5	15040.5	5580.0	0.371
	Cearon	-	670.5	4269.0	9447.0	14777.0	5395.0	0.365
		Proteus	759.5	4835.0	10049.0	16079.5	5950.5	0.370
		Mageos	760.5	4999.5	10177.0	16221.5	6002.0	0.370
	Medax Top	-	668.0	4120.5	9216.5	14682.5	53665	0.366
		Proteus	755.5	4941.5	10151.5	16094.5	5963.0	0.371
		Mageos	758.5	4940.5	10186.5	16153.0	5984.5	0.371
Normal sowing – St			561.0	4438.5	9847.5	15504.0	5853.0	0.377
Late sowing	-	-	439.0	4022.0	9001.0	13742.5	5197.0	0.373
		Mix for cereals	475.5	4241.5	9579.5	14893.5	5585.0	0.375
		Trimax	478.5	4195.5	9498.5	14802.5	5551.0	0.375
	Naturamin Plus	-	450.0	4211.5	9627.5	14968.0	5628.0	0.376
		Mix for cereals	499.5	5030.0	10350.5	16481.5	6213.5	0.377
		Trimax	512.5	4937.5	10251.0	16469.5	6209.0	0.377
	Raiza mix	-	453.0	4206.0	9627.0	14884.0	5611.0	0.377
		Mix for cereals	523.5	4924.5	10152.0	16210.5	6119.5	0.378
		Trimax	522.5	4996.0	10329.5	16470.0	6217.5	0.378
		LSD 5%	27.3	88.8	123.4	134.8	92.1	0.003
		LSD 1%	35.9	97.5	234.5	258.1	101.2	0.007
		LSD 0.1%	46.7	106.3	345.6	369.7	117.4	0.012

Table 4. Net photosynthesis productivity affected by certain preparations and various terms of sowing, g/m^2 LA/24 h (mean 2019-2020)

Variants			Tillering - stem elongation	Steam elongation - ear emergence	Ear emergence - milk development	Tillering - milk development
Early sowing	-	-	4.05	6.87	5.00	5.21
		Proteus	4.00	6.76	5.75	5.41
		Mageos	4.03	6.81	5.69	5.44
	Cearon	-	4.27	6.90	5.53	5.49
		Proteus	4.49	6.43	5.94	5.59
		Mageos	4.70	6.39	5.94	5.63
	Medax Top	-	4.10	6.69	5.68	5.46
		Proteus	4.69	6.56	5.84	5.62
		Mageos	4.65	6.41	5.79	5.57
Normal sowing – St			4.44	6.85	5.66	5.44
Late sowing	-	-	4.35	6.80	5.08	5.29
		Mix for cereals	4.43	6.97	5.44	5.54
		Trimax	4.38	6.95	5.43	5.54
	Naturamin Plus	-	4.40	7.01	5.44	5.54
		Mix for cereals	4.96	6.33	5.81	5.66
		Trimax	4.93	6.47	5.92	5.76
	Raiza mix	-	4.32	6.95	5.44	5.50
		Mix for cereals	4.89	6.37	5.86	5.66
		Trimax	4.90	6.31	5.82	5.65
		LSD 5%	0.07	0.10	0.09	0.08
		LSD 1%	0.15	0.18	0.17	0.16
		LSD 0.1%	0.23	0.26	0.25	0.25

As a result of the reasons described above, the combinations of the stimulants Naturamin Plus and Raiza Mix with the foliar fertilizers Mix for Cereals and Trimax for late sowing increase the proven grain yield compared to the untreated variant and compared to normal sowing. The combinations of the retardants Cearon and Medax top with the insecticides Proteus and Mageos in early sowing increase the proven grain yield compared to the untreated variant. Grain yields in the late sowing variants of durum wheat are higher than in the early sowing of this crop.

The harvest index shows that in the case of late sowing variants; the total production of dry biomass is more efficiently distributed between the grain and the vegetative mass - the values characteristic of durum wheat are preserved. Early sowing, especially without the use of insecticides and retardants, reduces the harvest index as a result of the less favorable grain:straw ratio. Foliar fertilization with foliar fertilizers and stimulation of growth processes in late sowing further improve the morphological structure of the plant.

Conclusion

In early sowing of durum wheat, the leaf area, photosynthetic potential, biological and economic yield are the greatest in the combinations of retardants Cearon and Medax top with the insecticides Proteus and Mageos. In the late sowing of durum wheat, the leaf area, photosynthetic potential, biological and economic yield are the highest in the combinations of the stimulants Naturamin plus and Raiza mix with the leaf fertilizers Mix for cereals and Trimax. In these variants, the leaf area dies faster during the milk development stage. The net photosynthesis productivity in the combinations is lower than in the independent use of the respective preparations and fertilizers. The harvest index in the late and normal sowing variants is higher than in the early durum wheat sowing variants.

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