Effect of Rust Disease on Photosynthetic Rate of Wheat Plant

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Abstract: The purpose of this research was to study the influence of rust diseases on photosynthetic rate of the created local varieties and introduced variety samples of wheat. Experiment was carried out with two variants—control and 25% Tilt treatment. The 25% solution of Tilt was used to prevent disease infection. The photosynthetic rate was measured by T-type URAS-2 infrared gas analyzer (made in Germany). Disease infection rate was determined based on the Cobby balling scale. Ontogenetic and daily rate of photosynthesis by effect of the disease were decreased. The amount of assimilated CO₂ during the day and vegetation period linearly depends on the disease infection degree. At the same time, the activation of non-infected parts' photosynthetic rate of some varieties was observed. The difference reaches up to 87% between the variants as a result of the rapid aging of photosynthesis apparatus.

Key words: Wheat plant, breeding, photosynthesis, productivity.

1. Introduction

The food shortage has become a global problem of the world. According to the United Nations, until 2050 the planet's population will reach nine billion, while the food demand will increase twice. The growth of productivity of major crops in recent years has decreased significantly [1]. Especially is apparent for wheat, the most important crop in the food security of the most regions of Eurasia, America and Australia [2]. In 2013, world production of wheat was 713 million tons, making it the third most-produced cereal after maize (1,016 million tons) and rice (745 million tons) [3].

Currently, the rust diseases are threat to the food security of the world. Rust disease is one of the key biotic factors reducing wheat productivity. Resistance to wheat rust is often under the simple genetic control of one or several genes for resistance [4]. Stripe (yellow) rust, caused by *Puccinia striiformis* f. sp. *tritici* (*Pst*), is a serious disease of wheat occurring in most wheat areas with cool and moist weather conditions during the growing season [5]. The main

control method of the rust disease is to create new rust-resistant, productive and high quality genotypes and then introduce them to the farms. The proper selection of the initial parental genotypes in order to create resistant varieties is a main term for hybridization. The proper selection of the parental forms for resistance to various symptoms of the disease is necessary. The study of the physiological processes in plants influenced by pathogenic factors for creation and selection of resistant forms is important. Various disease resistant symptoms can be identified in investigated plants.

The purpose of the study was to select genotypes with different morphophysiological traits causing high productivity under stress factors and to recommend these forms as an initial material in breeding. Also, the following issues was intended to clarify:

- (1) Determination of disease (yellow and leaf rust) infection rate of genotypes with different morphophysiological traits;
- (2) Determination of disease infection rate effect on wheat plant photosynthetic rate during ontogeny;
- (3) Clarification of disease effect on daily course of exchange of CO₂.

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2. Materials and Methods

The study was carried out in experimental field of the Research Institute of Crop Husbandry in Absheron Peninsula. As object of the study, six bread wheat genotypes with different diseases infection rates were used:

- (1) Giymatly 2/17: relatively early headed and moderately resistant to diseases;
- (2) Azamatly 95: relatively early headed, susceptible to yellow rust, resistant to leaf rust;
- (3) Gyrmzy gul-1: late headed, resistant to yellow rust, susceptible to leaf rust;
- (4) Tale 38: late headed, moderately susceptible to diseases;
- (5) The 4th FEFWSN 50: late headed, moderately susceptible to diseases;
- (6) The 2nd FAWWON 97: late headed, moderately resistant to diseases.

Experiment was carried out with two variants—control and 25% Tilt treatment. Each genotype was grown with three replications. The CO₂ gas exchange of flag leaf was measured by T-type URAS-2 infrared gas analyzer (Germany) supplied with leaf chamber (1 cm × 10 cm). And 10 plants from each genotype were used for gas exchange measurements. Disease infection rate was determined based on the Cobb's balling scale [6].

3. Results and Discussion

3.1 Effect of the Diseases on Exchange of CO₂ during Ontogeny

The strategy of improving crop yield by increasing the productivity of photosynthesis is widely debated in the world [7-9]. Photosynthesis is the main physiological process that affects plant growth and productivity. Photosynthesis value varies depending on many external and internal factors. Rust greatly affects the assimilation surface of the leaves and biomass accumulation, resulting in decrease of productivity [10]. The impact of the pathogen on plant depends on many related factors. Infection of plants

causes morphophysiological traits violation and acceleration of respiratory intensity, which leads to more assimilation to be used up.

The disease affects on the photosynthesis pigments, in particular, the amount of chlorophyll decreases and chlorophyll biosynthesis breaks down [1]. It was found that the amount of assimilated CO₂ linearly depends on the degree of leaf infection. So the yellow rust was observed at the beginning of vegetation, and with the increase of temperature stops, the development of brown rust starts.

The infection degree of the control group of Giymatly 2/17 was 5MS (5% of leaf surface was in medium sensitive level), 10MS and 20MS, during heading stage, flowering stage and grain formation stage, respectively, while the difference of assimilated CO₂ between control and Tilt treated variants was 12.5%, 18% and 26%, respectively. During milky ripe stage, development of yellow rust stopped, the brown rust was observed with 20MR (20% of leaf surface was in medium resistant level) infection degree and the differences between control and Tilt treated plants on assimilated CO₂ was 40%. During wax ripening stage, the difference between control and Tilt treated plants in amount of assimilated CO₂ was 55% (Table 1).

The maximum infection of highly susceptible variety Azamatly 95 with yellow rust was observed during grain formation stage (70%), and the difference between control and Tilt treated plants in amount of assimilated CO₂ was 53%. In wax ripening stage, disease development was stopped; by activation of uninfected parts of leaves, the difference between control and Tilt treated plants in amount of assimilated CO₂ declined to 31%; and then as a result of rapid fading of leaves, it has reached up to 62%. The variety Gyrmzy gul-1 was resistant to yellow rust, but susceptible to leaf rust. At the beginning of vegetation, the difference between variants for infection was not observed; in grain formation stage, 10S (10% of leaf surface was in sensitive level) infection degree was observed and the difference between control and Tilt

Table 1 Change of photosynthetic rate depending on disease infection rate of wheat plant vegetation cycle.

Variety	Variants	Development stages														
		Heading			Flowering			Grain formation			Milk ripening			Wax ripening		
		DIR			DIR			DIR			DIR			DIR		
		YR	LR	PI	YR	LR	PI	YR	LR	PI	YR	LR	PI	YR	LR	PI
Giymatly 2/17	I	5MS	R	16	10MS	R	22	20MS	R	19	-	20MR	15	-	20MR	8
	II	R	R	18	R	R	26	5MR	R	24	-	5MR	21	-	5MR	14
Azamatly 95	I	5MS	R	18	50S	R	20	70S	R	17	-	R	16	-	R	8
	II	R	R	19	R	R	28	10MR	R	26	-	R	21	-	R	13
Gyrmyzy gul-1	I	R	R	18	R	R	27	R	10S	23	-	70S	14	-	80S	8
	II	R	R	18	R	R	27	5MR	R	25	-	5MR	22	-	5MR	15
Tale 38	I	5MS	R	19	10MS	R	25	20MS	R	24	-	R	18	-	R	14
	II	R	R	20	R	R	28	5MR	R	26	-	R	20	-	R	16
4th FEFWSN 50	I	R	R	17	5MR	R	24	10MR	R	21	-	10MS	19	-	10MR	7
	II	R	R	17	R	R	25	5MR	R	23	-	R	20	-	R	13
2nd FAWWON 97	I	R	R	15	5MS	R	25	10MS	R	21	-	R	20	-	R	8
	II	R	R	15	R	R	26	5MR	R	22	-	R	21	-	R	11

I: natural background (infected plant), II: treatment (healthy), DIR: disease infection rate, YR: yellow rust, LR: leaf rust, PI: photosynthesis intensity (mg CO₂/dm²·h).

Table 2 Effect of disease infection rate on daily exchange of CO₂ (mg CO₂/dm²·h) of different wheat genotypes (grain formation and milk ripening stages).

Variety	Variants	DIR		Hours					
		YR	LR	9:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00	17:00-19:00	19:00-21:00
Giymatly 2/17	I	20MS	R	21.2	25.2	18.4	11.6	12.9	7.8
	II	R	R	24.3	27.8	22.3	14.4	16.4	9.2
Azamatly 95	I	50S	R	19.2	22.8	16.7	9.5	10.8	5.1
	II	R	R	26.7	30.2	23.9	14.4	15.7	9.8
Gyrmyzy gul-1	I	R	30S	21.2	24.2	10.8	10.0	11.1	7.3
	II	R	R	25.1	28.2	22.9	13.2	15.1	10.7
Tale 38	I	10MS	R	24.8	25.3	20.0	15.6	17.2	10.3
	II	R	R	25.4	26.2	20.8	16.7	18.3	11.7
4th FEFWS N50	I	10MS	R	23.2	26.1	21.1	14.9	15.3	8.7
	II	R	R	24.6	27.3	22.4	15.8	16.3	9.1
2nd FAWWON 97	I	10MS	R	19.1	21.8	18.8	10.4	10.9	8.2
	II	R	R	21.3	24.2	21.4	11.6	12.8	9.8

I: natural background (infected plant), II: treatment (healthy), DIR: disease infection rate, YR: yellow rust, LR: leaf rust.

treated plants in amount of assimilated CO₂ was 8.6%. At the following stages, the disease was observed strengthening with 70S, 80S infection degree, and the difference in photosynthesis rate was constituted of 57% and 87%, respectively. Similar development of disease was detected in other genotypes.

3.2 Effect of Diseases Infection Rate on Daily Exchange of CO₂

The research was carried out at 9:00-11:00,

11:00-13:00, 13:00-15:00, 15:00-17:00, 17:00-19:00, 19:00-21:00 and comparative analysis was conducted (Table 2). The amount of daily CO₂ fixation is the biological characteristics of the variety which depends on degree of infection.

At Giymatly 2/17 in 9:00-11:00, the assimilated CO₂ content was constituted of 21.2 mg CO₂/dm²·h in infected plants and 24.3 mg CO₂/dm²·h in healthy plants, the difference between the variants was 14.6%. The first maximum assimilation value of CO₂ was

observed in 11:00-13:00 and the difference between the variants reached up to 10%. Next hours occurred the depression of photosynthesis, so the amount of absorbed CO₂ reduced. It should be noted that there happened deeper depression at infected variants. The amount of assimilated CO₂ at 17:00-19:00 started to rise again and the second maximum value of photosynthesis is derived.

At this time, the second maximum value of depression was 11%-14% in infected plants compared with the healthy ones. During the studies, Azamatly 95 with high rate of diseases infection noted similar situation and some few differences appeared among the variants. In early hours of research, at 9:00-11:00 houses, the difference between healthy plants and infected plants was 39%; while during the first maximum (11:00-13:00) of photosynthesis, the difference between healthy plants and infected plants was 32%. The depression of CO₂ absorption within 17:00-19:00 interval started to rise and reached the second highest value. The difference between variants depending on disease infection degree reached up to 45%. Similar cases recorded for other genotypes.

The amount of assimilated during the day and vegetation period CO₂ linearly depended on the disease infection degree. After completion of disease (yellow rust) development, the influence of infection was impressively noted in the last development stage. The difference between the variants because of the rapid aging of photosynthesis apparatus reached up to 87%.

Leaf rust reduced net photosynthesis rate at light saturation through reduction in gross photosynthesis (average reduction of 6.1 µmol CO₂/m² green areas) rather than through increase in dark respiration rate (average increase of 0.7 µmol CO₂/m² green areas) [11]. As a result of research, it could be noted that selection of the proper initial material is a basic term for the creation of new productive and disease-resistant forms. Less disease infection and donation of high rate of photosynthesis in other non-damaged parts limit the decline in productivity.

Taking into consideration the above-mentioned, use of genotypes, such as Azamatly 95, Gyrmyzy gul-1 and Tale 38 are reasonable for creation of new varieties.

4. Conclusions

Rust diseases lead to reduction of assimilating area of leaves and the amount of fixed CO₂. Yellow rust strongly affects plant photosynthesis area at early stages of vegetation and is replaced by brown rust with increasing temperature. There was difference between genotypes for infection degree and CO₂ assimilation rate between control and Tilt treated plants. Assimilation surface area was greater affected by yellow rust, which led to a decrease in the rate of photosynthesis. It is recommended to use genotypes (such as Gyrmyzy gul-1) that are resistant to yellow rust in breeding programmes.

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