International winter wheat yield trials in semi-arid and irrigated conditions of Uzbekistan

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Abstract. Global climate change is leading to water shortages in irrigated areas. This, in turn, requires the selection of crop varieties that are resistant to arid conditions. Thirty varieties of winter soft wheat from the international nursery IWWYT-SA were evaluated under water-deficient conditions. The selection was based on parameters such as grain yield, biomass, growing season, yield components, and yield index. Most of the samples analyzed showed good results under water deficit conditions (without irrigation), with yields ranging from 4 to 5 tons per hectare. In all samples, plant height was average, ranging from 90 to 100 cm, with a biomass of 1600 g/m² and an average of 550 spikelets per square meter. The average weight of a thousand grains was 37.9 grams, although some samples showed significantly lower values. The average harvest index was about 30. Ten promising genotypes were selected for further propagation and implementation in relatively arid areas of the republic.

1 Introduction

In recent years, wheat production in Uzbekistan has been increasing year on year thanks to the introduction of high-yielding intensive winter wheat varieties. At the same time, due to climate change, the construction of the Afghan Canal in Amudarya, and a number of other factors, the irrigation water supply is decreasing. This requires the introduction of wheat varieties that are resistant to water shortages.

CIMMYT germplasm is recognized for its multiple disease resistance, high yield potential and stability [1]. Estimated that nearly 70 % of the spring wheat growing regions in developing countries either grow CIMMYT germplasm as a direct release or have used CIMMYT germplasm as a parent in their varieties, thereby contributing to substantial economic benefits [2]. Wheat cultivation is limited by many abiotic and biotic factors. Abiotic factors often include high temperatures and drought [3]. In recent years, many countries have experienced a shortage of irrigation water. Climate change affects the global economy and creates a number of problems in providing food for a growing population [4]). One of the important products ensuring food security is wheat. Wheat production is increasing every year worldwide, although there are a number of problems that are

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exacerbated by limited irrigated areas and an annual reduction in the amount of water used for irrigation, as well as abnormal conditions such as short-term frosts in early spring and a sharp increase in temperature during the grain filling period for wheat. In order to find solutions to these problems, the international CIMMYT-Turkey project is testing varieties of winter soft wheat for arid and irrigated lands in different geographical areas. Good practical results have been obtained [5].

The drought resistant varieties selected by breeders from the SIMMIT nursery sometimes suffer from winter frosts or abnormal spring cold spells. In this regard, the search for and selection of drought resistant varieties from the winter variety nursery is promising. Analyzing samples of soft wheat from the IWWIP nursery under different conditions in Turkey, Kaya et al. [6] revealed several genotypes that produce high and stable yields under different conditions. The evaluation of winter wheat genotypes under different conditions will give the opportunity to select genotypes for use in breeding programs in different countries. The aim of this study was to evaluate winter wheat collection samples adapted to arid conditions and samples adapted to limited irrigation.

2 Materials and Methods

2.1 Experimental conditions

Trials were conducted in 2025 growing seasons the experiments were carried out at the experimental station Durmen of the Institute of Genetics and Experimental Plant Biology Uzbekistan (latitude of 41°22'N; longitude of 69°23'"E; altitude 444m.). There were used two CIMMYT-Turkey nurseries 26 th IWWYT-SA 2024-2025 for arid areas and 27 th IWWYT-IRR 2024-2025 for irrigation. Sowing was made by hand at a rate of 400-450 seeds per 1 m² at the end of October. At the IWWYT-SA nursery, the seeds were sown in six rows per 1 m2 and cultivated without irrigation. Seeds from the IWWYT-IR nursery were sown in four rows between rows 60/15. At this nursery, irrigation was carried out after sowing in the fall and twice during growth in March and April.

2.2 Experiment Design

Seeds from IWWYT-IRR nursery sowing was done by hand in plots with four rows, 1 m length, and 0.2 m inter-row spacing and 400 seeds m–2 sowing density. Sowing carried out in two repetitions. Seeds from the IWWYT-SA nursery sown on one square meter in six rows on dry soil without watering. The sowing rate was 400 seeds/m2, the sowing depth was 3-5 cm, and the row spacing was 15 cm. Before sowing, the fields fertilized with 200 kg/ha of phosphorus. The fields were cultivated without any irrigation. The nursery IWWYT-IRR sown in the conventional method in dry soil in two replicates in a one-meter plot, four rows with 15/60 cm between rows. They irrigated after sowing. During vegetation, they irrigated twice in the tillering phase and in the flowering phase, and nitrogen fertilizers applied. Harvesting was carried out in both nurseries by hand. Threshing was performed using a threshing machine, and winnowing was performed manually at a moisture content of 13%.

2.3 Agronomic characteristics

During the growing season, the days to heading were determined from January 1 until the emergence of 50% of the spikelets on the main stem. Plant height, including the spike, was measured at the end of the season before harvesting. The weight of 1,000 seeds, spike length,

number of grains per spike, and grain weight per plant were also determined. The total yield was calculated by weighing the seeds from one square meter.

2.4 Statistical processing

The data were analyzed statistically using Fisher's ANOVA and the variance was compared using the Least Significant Difference (LSD) test at a probability level of 5%.

3 Result and discussion

3.1 Climatic parameters

In Uzbekistan, the vernalization period for winter wheat continues until early March, and stem elongation begins in early March. The main growing season for winter wheat is from March to June. In this regard, rainfall and air temperature are very important, which can be observed through the hydrothermal coefficient, which is calculated as the ratio of the sum of precipitation (R) to the sum of active temperatures (Σt) above 10°C for a certain period of time, divided by 10. The formula looks like this: HTC = R / (0.1 * Σt). Low HTC values indicate dry conditions, high values indicate excessive moisture, and a value of 1 indicates a balance of moisture and heat. The average temperature in March was 17.3°C, with the temperature in the first ten days of March being 5.8°C lower than the monthly average, but in the last ten days, the temperature rose to 29°C. Precipitation this month was 56.1 mm, and the hydrothermal coefficient was 1.57, indicating excessive moisture. Such weather is considered optimal for the start of wheat growth. Rainfall in April and May was about 13-14 mm, but the temperature was high, which led to a drop in the HTC below 0.5, which is characterized as drought (Fig. 1).

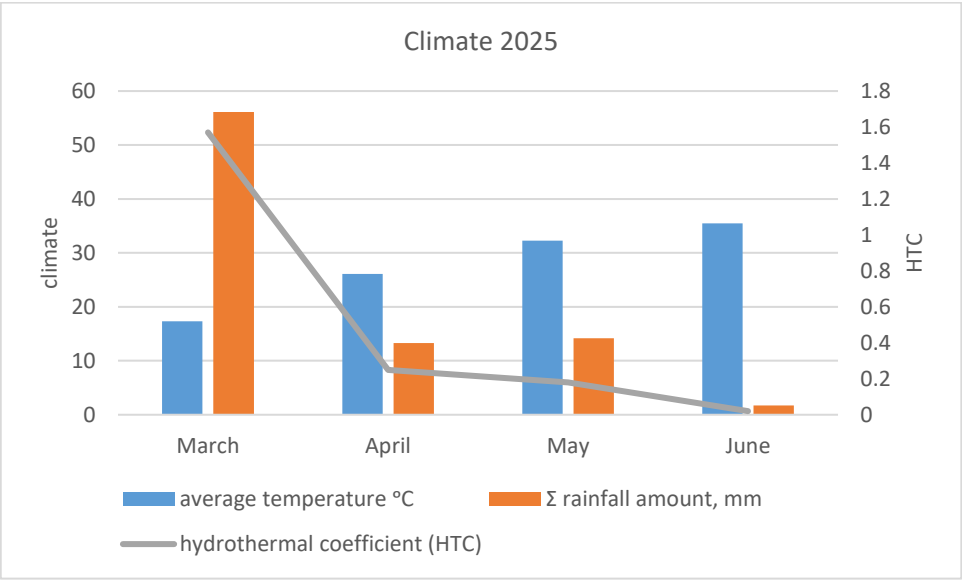

Fig. 1. Average temperature, precipitation, and hydrothermal coefficient of the wheat growing season in 2025.

3.2 Yield indicators

In conditions of moisture deficiency, one of the main limiting criteria for selecting drought-resistant varieties was also the length of the growing season. The heading phase is considered a criterion for early maturity. In early-maturing forms, the sprouting and heading phases occur under more favorable conditions of temperature and air humidity. The heading of drought-resistant samples from the IWWYT-SA nursery, calculated from January 1, ranged from 109 to 120 days. The earliest heading began in samples 9928 and 9929, while the latest heading was observed in samples 9913 and 9921. No positive correlation between yield and heading time was observed (r=-0.30).

The average yield per hectare of samples from the IWWYT-SA nursery without irrigation was 4.9 t/ha, with a yield range of 3.63 to 5.77 t/ha, which is quite high for this conditions.

The weight of 1,000 seeds is an indicator of seed size and maturity. It is influenced by various abiotic factors, such as drought, waterlogging, lodging of the variety, and the use of mineral and organic fertilizers. The weight of 1,000 seeds has a positive effect on seed germination, tillering, and total grain yield. [7]. It has been demonstrated that an increase in the seed index is proportional to their quality, and if farmers take this factor into account and use high-quality seeds, it will be possible to achieve the potential grain weight [8].

Table 1. Genotypes and grain yield 26th IWWYT-SA

PLOT No.	CROSS	Cross ID	Origin	GY in g/m2
9901	GEREK		TR-ESK	511
9902	SONMEZ	TE4732	TCI-ESK	577
9903	TANER		TR-KON	574
9904	LOCAL CHECK (Sharaf)		UZB	473
9905	OK81306//ANB/BUC/3/[SAULESKU 43]/4/SHARK-1/QT9684	TCI141196	TCI	353
9906	FRET2/TUKURU//FRET2/3/TAM107//ATAY/GALVEZ87	TCI141008	TCI	485
9907	VORONA/KAUZ//1D13.1/MLT/4/CHAPIO/3/BORL95/2*EXCALIBUR//EXCALIBUR	TCI131062	TCI	568
9908	PAMUKOVA-97*3/3/88 ZHONG257//CNO79 /PRL/5/2*CUPRA-1/3/CROC1/AE.SQUARROSA (224)/ /2*OPATA/4/PANTHEON	TCI122004	TCI	450
9909	TAM200/KAUZ//SHARK-1/3/KRISTAL/4/ SAULESKU#44/TR810200	TCI141208	TCI	530
9910	RSK/CA8055//CHAM6/4/NWT/3/TAST/SPRW//TAW12399.75/5/MV-18-2000	TCI141268	TCI	497
9911	RSK/CA8055//CHAM6/4/NWT/3/TAST/SPRW//TAW12399.75/5/MV-18-2000	TCI141268	TCI	550
9912	OK09634/BURBOT-4	TCI141303	TCI	533
9913	OK09634/BURBOT-4	TCI141303	TCI	379
9914	HBK0935W-24/KS84W063-9-34-3-2//KARL	TCI141331	TCI	404

	92/4/SHARK/F4105W2.1/3/F02106G2-1FZ101			
9915	PEREYASLAVKA/02106G2-2//F02106G2-1FZ101	TCI142091	TCI	363
9916	00*0100-51/2*NACIBEY	TCI142113	TCI	379
9917	OWL//OMBUL/ALAMO/3/FIORINA/4/TAM200/KAUZ//BECUNA-6	TCI142137	TCI	461
9918	LUKILLUS/6/ROLF07*2/5/REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA(213)//PGO/4/HUITES	TCI141109	TCI	454
9919	CTK/3/ATL66/CMN//TX2607-6/4/SS8/LLFN/3/BEZ/NAD/ /KZM74/BB//CC/CNO*2/3/TOP156/BB/5/GUN91/6/TAM200/KAUZ/7/SELYANKA/MERCAN-1	TCI141292	TCI	443
9920	933 (KU7676)/ARF5 (SOLH 02)	TCI141506	TCI	450
9921	KAUZ*2/4/CAR//KAL/BB/3/NAC/5/KAUZ/6/MILAN/7/TILHI/8/ZCL/3/PGFN//CNO67/SON64(ES86-8)/4/KA../4/BEZ/NAD/ /KZM(ES85.24)/3/F900K/9/PRONGHORN	x1320896-1B	US-UNL-TCI	539
9922	ST.ERYHTR 1282-08/NACIBEY	TCI12SP046	TCI	560
9923	ST.ERYHTR 1282-08/NACIBEY	TCI12SP046	TCI	443
9924	ST.ERYHTR 1282-08/NACIBEY	TCI12SP046	TCI	557
9925	SHI#4414/CROWS"//GKSAGVARI/CA8055/3/KS82142/PASTOR	TCI106185	TCI	566
9926	BEZOSTAJA-1//MV-17/UNK/3/Aldane/4/BEZOSTAJA-1//MV-17/UNK/3/PAMUKOVA 97	SM-8207 F 0P 99P 99P 1P 19P 0P	TR-ADP	368
9927	MOMTCHIL/MURGA	SM-8249 0P 99P 99P 1P	TR-ADP	544
9928	BOW//VRE/VEE PB20387/3/2*MARTAR/4/Rus Bezostaya 1/5/BOW//VRE/VEE PB20387/3/2*MARTAR/4/Aldane	SM-8213 F 0P 99P 99P 1P 18P 0P	TR-ADP	425
9929	DRAGANA/4/CHAPIO/3/BORL95/2*EXCALIBUR//EXCALIBUR	TCI131015	TCI	555
9930	EKIZ/3/OK95616-1/HICKOK//BETTY F4:11/4/HBK0935-29-15/KS90W077-2-2/VBF0589-1	TCI142088	TCI	386

The average thousand-grain weigh in the analyzed accessions was 37.9 g. Four genotypes, G-9912, G-9916, and G-9920, had small grains, with a weight of less than 30 g per thousand-grain weigh. The largest seeds were found in genotype G-99,29, with a total

grain yield of 555 g/m². In 10 samples from this nursery, KW < 40-46 g. The correlation between quantitative traits and wheat yield has been well studied. No positive correlation was found between grain yield and spike length or number of spikelets per spike. High positive correlations with grain yield were observed between the number of grains per spike (r = 0.57–0.73) and grain weight per spike (r = 0.50–0.68). A weak positive correlation was observed with the weight of 1000 grains (r = 0.30–0.42) [9].

Table 2. Characteristics of a set of IWWYT-SA and IWWYT-IRR nursery in two regimes in 2025 growing season at Tashkent, Uzbekistan

Trait	26 th IWWYT-SA			27 th IWWYT -IRR		
	Av	Min	Max	Av	Min	Max
GY, kg/ha	4.9	3.63	5.77	8.2	6.6	9.9
TGW, g	37,6	28	40,1	40.9	33.4	48.5
Spike length	9.25	7.54	11.8	10.6	8.8	12.3
Spikelet per spike	17	14.6	20.4	18	16.2	21
Grain per spike	23,7	20,5	28,7	52	46.5	68.4
Grain weight per spike	0,89	0,6	1,15	2,1	1,5	3,3
Days to heading	113	109	120	122	115	128
Plant height	101.1	90	115	102.3	94.2	114

In 16 samples, the total grain yield was lower than the average for all samples. At the same time, the average grain weight per spike was 0.9 g, and the average number of grains per spike was 23.7. The highest-yielding varieties were G-9902 SONMEZ, as well as genotypes G-9907 and G-9926, which had relatively large seeds, with a thousand-grain weight ranging from 39-41 g. Only one sample, G-9921, had a yield mainly due to the density of the spike, with a thousand-grain weight of only 33.4 g, but the number of spikes per square meter was 668.

The samples from nursery 27 th IWWYT –IRR (Table 3) were relatively high-yielding. The average yield of this nursery was 820.5 g/m2. The highest yielding were Genotype 9816, G-9816, G-9824, and G.9825. Thirteen samples had less yield than the average for the nursery, and the local standard variety also had less than average yield.

Table 3. Genotypes and grain yield 27 th IWWYT –IRR

PLOT No.	**CROSS**	**Cross ID**	Origin	Yield (g,m2)
9801	BEZOSTAYA			835
9802	NACIBEY			855
9803	KATE A-1			870
9804	KONYA 2002			850
9805	LOCAL CHECK			730
9806	VICTORYA/6/KACHU #1/4/CROC_1/AE.SQUARROSA (205)//BORL95/3/2*MILAN/5/KACHU	TCI141173	TCI	760

9807	BLUEGIL-2/BUCUR//SIRENA/3/WBLL1*2/KURUKU//HEILO	TCI141113	TCI	790
9808	BLUEGIL-2/BUCUR//SIRENA/3/WBLL1*2/KURUKU//HEILO	TCI141113	TCI	799
9809	BLUEGIL-2/BUCUR//SIRENA/3/WBLL1*2/KURUKU//HEILO	TCI141113	TCI	710
9810	BLUEGIL-2/BUCUR//SIRENA/3/WBLL1*2/KURUKU//HEILO	TCI141113	TCI	830
9811	VICTORYA/6/KACHU #1/4/CROC_1/AE.SQUARROSA(205)//BORL95/3/2*MILAN/5/KACHU	TCI141173	TCI	980
9812	VORB/4/D67.2/PARANA 66.270//AE.SQUARROSA(320)/3/CUNNINGHAM/5/D67.2/PARANA66.270//AE.SQUARROSA(320)/3/CUNNINGHAM/6/DMITRY	TCI141184	TCI	830
9813	PANTHEON/BLUEGIL-2//F498U1-1021/BOEMA	TCI141188	TCI	790
9814	MNCH/ATTILA//TAM400/3/N87V106/2180(OK97401)/4/TAM200/KAUZ//BECUNA-6	TCI141370	TCI	755
9815	VICTORYA//KAMBARA1/KALYOZ-17/3/SHARK-1/QT9684	TCI142106	TCI	775
9816	CH111.14511/4/BACANORA/3/MASON/JGR//PECOS/5/NIKIFOR	TCI142119	TCI	990
9817	SNI/YACO//BAV92/3/2145/6/SHARP/3/PRL/SARA//TSI/VEE#5/5/VEE/LIRA//BOW/3/BCN/4/KAUZ	TCI141110	TCI	685
9818	PROTON/6/VORB/4/D67.2/PARANA 66.270//AE.SQUARROSA(320)/3/CUNNINGHAM/5/D67.2/PARANA 66.270//AE.SQUARROSA(320)/3/CUNNINGHAM	TCI141118	TCI	905
9819	VORB/4/D67.2/PARANA 66.270//AE.SQUARROSA(320)/3/CUNNINGHAM/5/D67.2/PARANA 66.270//AE.SQUARROSA(320)/3/CUNNINGHAM/6/NIKIFOR	TCI141084	TCI	870
9820	OTILIA/6/ROLF07*2/5/FCT/3/GOV/AZ//MUS/4/DOVE/BUC	TCI131047	TCI	880
9821	OTILIA/6/ROLF07*2/5/FCT/3/GOV/AZ//MUS/4/DOVE/BUC	TCI131047	TCI	910
9822	KATIA1/4/ATTILA/3/AGRI/NAC//MLT/5/BONITO-34	TCI122188	TCI	715
9823	BATERA//KEA/TOW/3/TAM200/4/494J6.11//TRAP#1/BOW/5/TX96V2427/6/KARL/OR8300764//RINA-6	TCI141301	TCI	890
9824	SPN/NAC//ATTILA/3/SHARK/F4105W2.1/4/GUL96/SHARK-1	TCI106126	TCI	975

9825	Mv C410-90/GkKalaka//MvC410-90/Ftm/4/Pehl//Rpb 8-68/Chrc/3/506/88-113	TE 7549	TR-EDR	895
9826	KACHU/BECARD//WBLL1*2/BRAMBLING/4/TAM200/KAUZ//SHARK-1/3/KRISTAL	TCI141081	TCI	796
9827	F00628G34-102/3/PRINIA/BERKUT//PFAU/MILAN	TCI141106	TCI	785
9828	SHI#4414/CROWS"//GKSAGVARI/CA 8055/3/KS82142/PASTOR	TCI106185	TCI	830
9829	OTILIA/4/JI5418/MARAS//SHARK/F4105W2.1/3/SHARK/F4105W2.1	TCI141372	TCI	660
9830	VORONA/3/TOB*2/7C//BUC/4/CHAM6//1D13.1/MLT/3/SHI4414/CROW/5/PFAU/MILAN//FUNG MAI 24	TCI141317	TCI	670

4 Conclusion

Thus, screening of two IWWYT nurseries under conditions of simulated drought without irrigation and under optimal conditions with two irrigations during the growing season showed that among the nursery samples of the 26th IWWYT-SA, genotypes G-9902, G-9907, and G-9926 were selected as drought-resistant in all yield indicators, while samples of genotypes G-9811, G-9816, G-9821, and G-9824 from the 27th IWWYT-IRR nursery were selected as promising samples due to their high yield. The most productive varieties were G-9902 SONMEZ, as well as genotypes G-9907 and G-9926, which had relatively large seeds with a thousand-grain weight of 39 to 41 g.

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