Evaluating Wheat Germplasm and Wheat Varieties for Waterlogging Tolerance

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Research Questions

Waterlogging (WL) stress affects wheat growth and wheat yield. Selecting wheat WL tolerance germplasm and breeding for wheat WL tolerance variety are the most effective and economic way to solve the problem. Using a constant water level control device and measureable parameters indicating wheat water and nutrient status, it is possible to speed up the screening process and rank the germplasm and variety that are more tolerant than others.

Results

Two seasons of experiments were conducted to pre-screen the WL tolerance of 40 wheat germplasms and varieties during the study period. In the first season with sufficient nitrogen fertilizer application, the results showed that all 40 wheat germplasms survived a prolonged 33 day WL conditions. The wheat with WL treatment showed a better growth. However, the root systems exhibited a significant difference between the WL and non-waterlogged (Non-WL) conditions (Figure 1). Comparing wheat growth in two totes, one with WL treatment and the other without, the fresh wheat biomass with WL was 68% higher than that with Non-WL, but the root length with WL was 67% shorter than that with Non-WL treatment, probably due to easy access of water in WL treatments. This also proved that with WL condition, sufficient nitrogen in the soil can reduce the damage caused by excess water, and application of nitrogen fertilizer to field after WL stress is an effective practice for recovery.

In the second season, nitrogen fertilizer was not applied, while the only nutrient for wheat growth came from the field soil used in the experiment. After wheat was germinated and in 3-4 leaves, WL treatments started. Stomatal conductance was measured with a SC-1 Leaf Porometer (Decagon Devices, Inc., Pullman, WA).Leaf chlorophyll content was measured with a SPAD-502DL Plus Chlorophyll Meter (Spectrum Technologies Inc., Aurora, IL) every 2-3 weeks. In general, crop growth and yield increased with stomatal conductance and chlorophyll content in linear or non-linear relationships. Table 1 shows the average stomatal conductance and leaf chlorophyll content for the 40 wheat germplasms and wheat varieties and their ranks according to an index value. The index value was estimated from the weighted average of 40, 30, and 30% from the 1st, 2nd, and 3rd measurement. The heavier weight was assigned to the first measurement on May 15 because young wheat was more vulnerable to WL stress than those more matured. Stomatal conductance represents crop in response to excess water, while chlorophyll content indicates the crop growth in response to excess water induced lack of nutrient supply. Therefore, combining the two measureable parameters and ranking them together, the top 10 ranked germplasms and varieties to WL stress are XWC12-2, XWC12-4, Faller, XWC13-109, Glenn, XC04A-1030, XWC11-65, Prosper, XWC12-6, and XWC12-1.

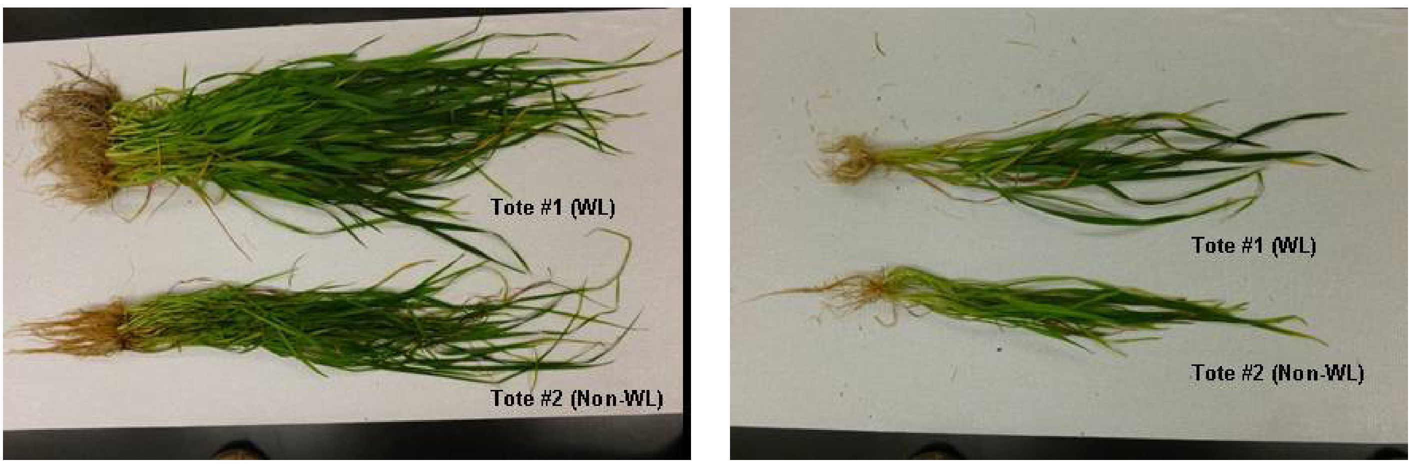

Figure 1. Comparison of wheat growth difference between waterlogged (WL) and non-waterlogged (Non-WL) plants with sufficient nitrogen fertilizer application.

continued on page 92

continued from page 91

Table 1. Comparison and rank of wheat germplasm and variety based on stomatal conductance and leaf chlorophyll.

Entry	Stomatal Conductance (mmol/m²/s)					Entry	Chlorophyll (SPAD unit)				
	5/15	6/5	6/23	Index	Rank		5/15	6/5	6/23	Index	Rank
XWC12-4	410	326	371	373	1	XWC12-2	36	42	22	34	1
XWC12-2	206	672	132	324	2	XWC13-109	44	26	22	32	2
Faller	381	495	49	316	3	XWC12-4	46	25	17	31	3
Alsen	610	120	45	293	4	XWC12-8	35	28	24	30	4
XWC12-6	315	245	306	291	5	XWC11-003	30	26	29	29	5
XWC11-65	480	125	166	279	6	Faller	35	27	21	28	6
Prosper	371	248	166	273	7	Glenn	30	23	24	26	7
XC04A-1030	266	242	261	257	8	Barlow	35	23	14	25	8
Glenn	333	98	247	237	9	XC04A-1030	32	20	21	25	9
XWC11-002	411	127	106	234	10	XWC11-69	36	16	19	25	10
XWC11-63	80	187	470	229	11	XWC12-1	37	27	6	25	11
XWC13-109	243	236	183	223	12	XWC11-65	32	13	25	24	12
XC02B-121	209	121	335	220	13	XC02B-130	35	21	12	24	13
XWC11-67	326	173	116	217	14	Prosper	26	30	16	24	14
XWC12-1	276	235	79	205	15	XC02B-121	35	11	20	23	15
XWC11-68	372	91	83	201	16	XWC11-008	37	5	19	22	16
XC02B-130	265	97	206	197	17	XC02B-120	26	18	20	22	17
XWC11-005	295	115	148	197	18	XWC12-6	31	13	19	22	18
XWC11-007	278	202	56	189	19	XWC11-68	36	11	14	22	19
XWC11-004	285	72	176	188	20	XWC11-72	29	12	21	22	20
XC02B-116	237	219	90	188	21	XWC12-9	26	13	22	21	21
XWC12-8	186	228	137	184	22	CS	29	17	15	21	22
XWC11-59	271	133	104	180	23	XWC12-7	30	11	19	21	23
XWC12-5	286	168	41	177	24	XWC12-3	32	14	12	21	24
Barlow	207	133	168	173	25	XWC11-002	30	14	14	20	25
XWC11-72	246	102	138	170	26	XWC11-63	26	14	19	20	26
XWC12-7	208	102	173	166	27	XWC11-75	28	16	14	20	27
XWC12-3	187	200	93	163	28	XC02B-116	29	13	15	20	28
XC02B-126	213	170	67	156	29	XWC11-59	31	13	11	20	29
XC02B-120	138	230	100	154	30	XWC11-61	27	11	18	19	30
XWC11-75	176	123	151	153	31	XWC11-006	30	14	9	19	31
XWC11-69	165	85	162	140	32	XWC12-5	28	14	12	19	32
XWC11-62	126	185	109	139	33	XC02B-115	32	9	12	19	33
XWC11-008	95	32	295	136	34	XWC11-004	27	11	16	19	34
CS	81	209	120	131	35	XWC11-67	25	18	12	19	35
XWC11-61	139	97	140	127	36	XWC11-62	26	16	10	18	36
XC02B-115	161	92	93	120	37	Alsen	23	20	10	18	37
XWC12-9	146	80	108	115	38	XWC11-007	28	13	9	18	38
XWC11-006	143	78	67	101	39	XC02B-126	26	15	10	18	39
XWC11-003	104	50	33	66	40	XWC11-005	23	11	17	18	40

Application/Use

The primary drive force for this project is to help collaborator Cai's research group to speed up their germplasm selection process and improve wheat waterlogging tolerance by introducing genes from wild species into the wheat genome. The experimental results were applied by the group immediately in their follow-up research. The performance of five wheat varieties provided useful and immediate information to local production farmers when choosing appropriate varieties in their 2015 spring season. Instead of focusing on crop yield only, if the fall soil moisture is high, and field has poor drainage, three varieties, Faller, Glenn, and Prosper, showed better growth and higher tolerance to waterlogging conditions.

Material and Methods

The two experiments were conducted in two large growth chambers, located at the Plant Sciences Department, North Dakota State University with automatic light, temperature, and relative humidity control. In each chamber, three totes, each with 40 growth cones in two racks, were setup side by side, but each tote had its own individual water control device that was located near the edge of the chamber. A split random design experiment was performed in each tote, which resulted in two treatments (WL and Non-WL) and three replicates. A total of 240 growth cones, each planted with three wheat seeds, were used in each experiment. Water level was automatically controlled by a constant head device, and crop water consumption was measured by an automatic ET-gage. Pictures were taken 2-3 times per week to monitor wheat response to water. Stomatal conductance was measured by SC-1 Leaf Porometer and leaf chlorophyll content was measured by SPAD-502DL Plus Chlorophyll Meter three times in the season. Due to large number of plants and small space in the growth chamber, each measurement took 1-2 days for two persons to accomplish. All wheat germplasm materials were provided by Cai. Wheat varieties were supplied by the Plant Sciences Department. Lab experiments on seed survival rate under waterlogging conditions are current in progress.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Comparing spring wheat yield in 2011 and 2012, the yield difference was 10 bu/ac for the northwest region of Minnesota. The difference was probably mainly caused by excess moisture conditions in 2011. Using $7/bu current wheat price as a starting point, the economic benefit to a typical 500 acre wheat enterprise is $35, 000 when maintaining all other conditions the same.

Related Research

Cai's group is working on alien gene introgression for waterlogging tolerance from wild species into wheat. This research has provided significant information to develop an efficient screening procedure of waterlogging tolerance in the alien gene introgression project and wheat breeding programs. Jia also received funds from ND State Board of Agricultural Research & Education and Wheat Commission to assess ND wheat varieties and germplasm for waterlogging tolerance. In addition, Jia's major research is on impact of drainage water management on crop yield and soil/water quality that she often observed various crop responses to waterlogging conditions in field situations. The lab and field research project provided a full picture of waterlogging stress effect on farming.

Recommended Future Research

Trait evaluation is a critical procedure for wheat germplasm and variety development. Little research has been done in the assessment of wheat's response to waterlogging conditions. This initial study has generated important information for developing an efficient waterlogging screening procedure in wheat and identified wheat genotypes with different responses to waterlogging conditions. I would like to continue this research to develop an accurate selection criterion for wheat germplasm/variety development by evaluating the response of the adaptive physiological traits to different water stress and help wheat research programs screen germplasm and breeding materials for waterlogging tolerance. I will use measureable and visible physiological traits, such as stomatal conductance, chlorophyll content, tiller number, kernels, and grain yield, to assess wheat germplasm stress tolerance under different growing stages. In addition, I will extend the project to a complete full season in a greenhouse environment in order to measure tiller number, kernels, and grain yield. Along the road, field testing of wheat waterlogging tolerance can be conducted using lysimeters in fields with drainage control.