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Stem Rust Disease Effect on Grain Yield, Yield Components, and Quality Parameters in Bead Wheat Lines at Lowland Areas

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Abstract

Stem rust attacks the above-ground part of the plant, such as the stem, leaf, and inflorescence. Moreover, it affects crop vigour and yields, and depending on its reaction and severity on susceptible variety may partially or completely shrivels the grain, thereby reducing the quality of the grain. Fifty bread wheat genotypes were planted in alpha lattice design with two replications at Melkasa as the 20th High-Temperature Wheat Yield Trial (20HTWYT) in 2022 main cropping season. Stem rust score on the field and quality parameters such as GPC = grain protein content, WG = wet gluten content, ZSV = Zeleny sedimentation value, SC = starch content, and MCT=Moisture content measured using Near Infrared (NIR) Spectroscopy technique taken in Food Science and Nutrition Laboratory at Kulumsa. The ANOVA table showed the significant differences among tested genotypes for all traits except for stem rust diseases and moisture content .Also, the protein content of the genotypes in the study ranges from 14.45 for EBW222090 to 18.05 for EBW222062, and the moisture content of the genotypes in the study ranges from 11.5% to 12.35%. In the study genotypes, the lowest starch content, 61.45%, was gained on genotype EBW222062, and the highest starch content, 67.25%, was recorded on genotype EBW222078. Most of the genotypes in the study had around 65% starch in the grain. Which fall to the bottom values of the range in the starch content in the wheat grain, 60% to 75%. It was probably due to the wheat stem rust diseases that affected the trial during the grain-filling period.

Keywords: Stem Rust; Protein; Starch; Moisture; NIR; Genotypes

Abbreviations

DTH: Days to Heading; DTM: Days to Maturity; PHT: Plant Height; SRCI: Stem Rust Coefficient of Infection; TKW: Thousand Kernel Weight; HLW: Hectoliter Weight; GYLD: Grain Yield; GPC: Grain Protein Content; WG: Wet Gluten Content; ZSV: Zeleny Sedimentation Value; SC: Starch Content; MC: Moisture Content.

Introduction

Wheat (*Triticum aestivum* L.) is among the staple food crops for billions of people. Also, it is the most cultivated crop. The wheat grain has a high nutritional value. It consists of about

70% starch, 14% protein, and, for example, high-quality amino acids, unsaturated fatty acids, fiber, vitamins, and minerals. Globally, wheat provides about 20% of all human dietary protein and calories. The production in the world was about 785 million metric tons in 2023 Statista [1].

Wheat is the third important food crop in Ethiopia, and, grown in 1.95 mha, the production was about 5.7 million MT with the productivity of 2.85t/ha during 2022/2023 Tefera A [2]. Targeting wheat self-sufficient, the country has brought more areas for wheat production in low land areas of the country under irrigation, and then, additional wheat produced in addition to the main production season, under rain fed condition. Consequently, in 2023 Ethiopia met wheat self-sufficient for the first time in history [3]. It is consumed in different form of end products in the country for which the quality wheat is required. It is used to produce traditional flat bread ("difo dabo") in most rural areas and urban sometimes, for industrial bread production, for production of confectionary products (like biscuits, cakes, etc).

The production treated by biotic and abiotic stresses. Wheat rusts are among the major biotic wheat production constraints in the world as well as in Ethiopia [4-6]. Leaf, Yellow, and stem are the three types of wheat rust diseases. Wide distribution across wheat growing areas, capacity to form new strains frequently that can attack previously resistance variety, the ability to disperse easily and traveling long distance, and the capacity to develop easily under favorable condition make them the most problematic diseases of wheat [7-9]. In Ethiopia, the Stem and yellow rusts are the most common of the three diseases Olivera Firpo PD, et al. [10,11].

Stem rust is a fungi diseases caused by the pathogen *Puccinia graminis* f. sp. Tritici. It is one of the most challenging wheat diseases for the farmers Eshete BB [12-14]. The outbreak of this disease in 2013 break the resistant and popular variety, Digelu, then, caused up to 100 % yield loss [11].

Stem rust attacks all above ground part of the plant such as stem, leaf, and inflorescence. Moreover, on susceptible varieties the pathogen change the stem in to black tangle of broken stem less than a month prior to harvest on healthy looking plant [15]. Furthermore, the disease affects crop vigour and yield, and, depending on its reaction and severity on susceptible variety, may partially or completely shrivels the grain, thereby reducing the quality of the grain [16].

Materials and Methods

Material and Design

A total number of 50 genotypes, thus 49 genotypes introduced from CIMMYT, Mexico and one local check bread wheat variety, Hidasse were evaluated. The genotypes were planted using alpha lattice design with two replications at Melkasa in 2022 main cropping season. The name of the trial was 20th High Temperature Wheat Yield Trial (20HTWYT). The rep had five sub-blocks; a sub block had ten plots. A size of the plot was six rows of 1.2m width by 2.5m length. All agronomic practices such Urea and NPS fertilizer applied as per area recommendations.

Entry	Genotypes	Pedigree
1	Hidase	Local check
2	EBW222050	NADI #1
3	EBW222051	WADER #1
4	EBW222052	BORL14*2//BECARD/QUAIU #1
5	EBW222053	ND643/2*WBLL1//VILLA JUAREZ F2009/3/KACHU//KIRITATI/2*TRCH
6	EBW222054	KAKURU/BORL14
7	EBW222055	KAKURU//SUP152/BAJ #1
8	EBW222056	KACHU*2/SUP152/3/WBLL1*2/BRAMBLING*2//BAVIS
9	EBW222057	FRANCOLIN #1/NELOKI/3/PRL/2*PASTOR//KACHU
10	EBW222058	KACHU/4/WHEAR/SHAMA/3/C80.1/3*BATAVIA//2*WBLL1/5/CIRO16/6/WBLL1*2/ BRAMBLING*2//BAVIS
11	EBW222059	TOH #1//KFA/2*KACHU
12	EBW222060	HARTOG_SUMAI3 (LINE B)/2*NAVJ07/4/MUTUS//KIRITATI/2*TRCH/3/WHEAR/KRONSTAD F2004
13	EBW222061	BECARD/FRNCLN//BAJ #1/TECUE #1

14	EBW222062	BORL14*2/3/WBLL1*2/BRAMBLING*2//BAVIS
15	EBW222063	KACHU/DANPHE*2//MUTUS*2/HARIL #1
16	EBW222064	BAJ #1/3/KIRITATI//HUW234+LR34/PRINIA/4/KIRITATI//HUW234+LR34/PRINIA/5/ MUTUS*2/HARIL #1/6/BAJ #1*2/TINKIO #1
17	EBW222065	BAJ #1/3/KIRITATI//HUW234+LR34/PRINIA/4/KIRITATI//HUW234+LR34/PRINIA/5/ MUTUS*2/HARIL #1/6/BAJ #1*2/TINKIO #1
18	EBW222066	BAJ #1/3/KIRITATI//HUW234+LR34/PRINIA/4/KIRITATI//HUW234+LR34/PRINIA/5/ MUTUS*2/HARIL #1/6/BAJ #1*2/TINKIO #1
19	EBW222067	BAJ #1/3/KIRITATI//HUW234+LR34/PRINIA/4/KIRITATI//HUW234+LR34/PRINIA/5/ SWSR22T.B./2*BLOUK #1//WBLL1*2/KURUKU/6/BAJ #1/3/2*HUW234+LR34/PRINIA//PFAU/ WEAVER
20	EBW222068	WBLL1*2/BRAMBLING*2//BAVIS*2/3/SUP152/BAJ #1
21	EBW222069	PFAU/MILAN/3/BABAX/LR42//BABAX/11/CROC_1/AE.SQUARROSA (213)//PGO/10/ ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/7/VEE#10/8/ OPATA/12/2*BORL14
22	EBW222070	WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1*2/4/NIINI #1/5/KACHU// KIRITATI/2*TRCH/6/KACHU//KIRITATI/2*TRCH
23	EBW222071	PFAU/WEAVER*2//TRANSFER#12,P88.272.2/3/WHEAR//2*PRL/2*PASTOR/4/2*WBLL1*2/ BRAMBLING*2//BAVIS
24	EBW222072	SUP152/BAJ #1//KIDEA
25	EBW222073	SUP152/KENYA SUNBIRD/3/KACHU//KIRITATI/2*TRCH
26	EBW222074	SOKOLL/3/PASTOR//HXL7573/2*BAU/4/SOKOLL/WBLL1/5/MUCUY
27	EBW222075	KISKADEE #1/5/KAUZ*2/MNV//KAUZ/3/MILAN/4/BAV92/6/WHEAR//2*PRL/2*PASTOR/7/ KACHU//KIRITATI/2*TRCH
28	EBW222076	DANPHE/3/ROLF07/YANAC//TACUPETO F2001/BRAMBLING/4/ROBINK
29	EBW222077	TOH #1//MUTUS*2/TECUE #1
30	EBW222078	PFAU/MILAN/3/BABAX/LR42//BABAX*2/4/NIINI #1/7/W15.92/4/PASTOR// HXL7573/2*BAU/3/WBLL1/6/VEE/MJI//2*TUI/3/2*PASTOR/4/BERKUT/5/PFAU/MILAN
31	EBW222079	HD 2967/3/SWSR22T.B./2*BLOUK #1//WBLL1*2/KURUKU
32	EBW222080	KACHU/BECARD//WBLL1*2/BRAMBLING*2/3/ABLEU
33	EBW222081	WBLL1*2/KIRITATI//FRNCLN/3/BECARD/4/2*KACHU/DANPHE
34	EBW222082	WBLL1*2/KIRITATI//FRNCLN/3/BECARD/4/2*KACHU/DANPHE
35	EBW222083	WBLL1*2/KIRITATI//FRNCLN/3/BECARD/4/2*KACHU/DANPHE
36	EBW222084	TAM200/PASTOR//TOBA97/3/HEILO/4/PAURAQ/5/BRBT1*2/KIRITATI*2//KINGBIRD #1/6/ KACHU/KIRITATI
37	EBW222085	BAJ #1/KISKADEE #1/3/WBLL1*2/BRAMBLING*2//BAVIS/4/BAJ #1/KISKADEE #1
38	EBW222086	BAJ #1/KISKADEE #1/3/WBLL1*2/BRAMBLING*2//BAVIS/4/BAJ #1/KISKADEE #1
39	EBW222087	PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI/5/2*PAURAQUE #1*2/6/ FRNCLN*2//TAM200/TUI
40	EBW222088	SHORTENED SR26 TRANSLOCATION//2*WBLL1*2/KKTS/3/BECARD/4/2*BORL14
41	EBW222089	SHORTENED SR26 TRANSLOCATION//2*WBLL1*2/KKTS/3/BECARD/4/2*BORL14
42	EBW222090	MUTUS//KIRITATI/2*TRCH/3/WHEAR/KRONSTAD F2004/4/2*WBLL1*2/BRAMBLING*2// BAVIS
43	EBW222091	MUNAL*2/CHONTE*2/3/SWSR22T.B./2*BLOUK #1//WBLL1*2/KURUKU

44	EBW222092	MUNAL #1*2/4/HUW234+LR34/PRINIA//PBW343*2/KUKUNA/3/ROLF07*2/5/WBLL1*2/BRAMBLING*2//BAVIS
45	EBW222093	WBLL1*2/4/YACO/PBW65/3/KAUZ*2/TRAP//KAUZ/5/KACHU #1*2/6/KINGBIRD #1/7/COPIO/8/WBLL1*2/4/YACO/PBW65/3/KAUZ*2/TRAP//KAUZ/5/KACHU #1*2/6/KINGBIRD #1
46	EBW222094	ORION/5/2*FRNCLN/4/WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1
47	EBW222095	ESTOC/7/2*KISKADEE #1/5/KAUZ*2/MNV//KAUZ/3/MILAN/4/BAV92/6/WHEAR//2*PRL/2*PASTOR
48	EBW222096	CROC_1/AE.SQUARROSA (205)//BORL95/3/PRL/SARA//TSI/VEE#5/4/FRET2/5/CIRO16*2/6/SUP152*2/TECUE #1
49	EBW222097	NADI#2/MUCUY
50	EBW222098	MUNAL #1/SUJATA//CHIPAK

Table 1: Pedigree of fifty bread wheat genotypes tested at Melkasa.

Description of the Study Area

The Trial was conducted at Melkasa Agricultural Research Center in 2022 during the main crop growing season. The research center is located in the Central Rift Valley at 8°24′N latitude, 39°21′E longitude, and altitude of 1,550 meters above sea level. The area is among the semi-arid regions and characterized by erratic rainfall, frequent drought and a harsh cropping environment. The mean minimum and maximum monthly temperatures of the area are 22°C and 34°C respectively. The soil was an Andosol, had weak wet aggregate stability and was prone to crusting.

Data Collection and Analysis

Data collected on the Field and Breeding Laboratory: Days to heading (DTH), Days to maturity (DTM), Plant Height (PHT), Yellow Rust (YR), and Stem Rust (SR) collected on the field. Post-harvest data such as thousand kernel weight (TKW), Hectoliter weight (HLW), and Grain Yield (GYLD) were taken in the wheat breeding laboratory after harvest.

Quality Data Collection in Food Science and Nutrition Laboratory: About 500 gram of seed delivered to Food Science and Nutrition Laboratory for quality parameters analysis. Then, the sample was cleaned and arranged in triplicated ways prior to analysis in the laboratory. Constituents of the grain were determined from the 300 g grain sample of each bread wheat genotype sample for the GPC = grain protein content; WG = wet gluten content; ZSV = Zeleny sedimentation value and SC = starch content; MCT=Moisture content were taken using Near Infrared (NIR) Spectroscopy technique by running the grain samples through FOSS Infratec 1241 as per method No. 39-11 (AACC, 2000). The Infractec 1241 Grain Analyser is a Near Infrared Transmission (NIT) instrument capable of simultaneous and accurate determination of several constituents in grain samples and is a standard method for wheat quality analysis. In this technique, the light source's light strikes a diffraction grating in the monochromatic, generating monochromatic light. Turning the grating creates a spectrum of monochromatic light ranging from 570 to 1100 nm at a wavelength. The sample size used for the test was 300 grams of wheat grain and the tests were done in triplicate so that the mean values of quality data were recorded.

Wheat Rust Diseases Data collection on the Field: Stem rust diseases score was recorded using modified Cobb scale as suggested by Rennie SJ [17,18]. It is a combination of number and English alphabets, where the number stands for the severity, and the letters for host reactions.

Severity is a percentage of rust infection on the plant. It relies upon visual observations. The following intervals commonly used to score severity of stem rust diseases.

Trace, for severity less than 5%; For 5% and above, 5%, 10%, 20%....100% used Field response is type of disease reaction which is recorded using the 0 (zero) and following letters: 0= No visible infection on the plant; R= resistant: visible chlorosis or necrosis, no uredia are present; MR= Moderately Resistant: small uredia are present and surrounded by either chlorotic or necrotic areas; M=Intermediate: variable sized uredia are present; some with chlorosis, necrosis, or both; MS= Moderately Susceptible: medium sized uredia are present and possible surrounded by chlorotic areas; S= Susceptible: Large uredia are present, generally with little or no chlorosis and no necrosis; Severity and field response readings are usually combined. For example: tR = Trace severity with a resistant field response; 5MR = 5% severity with a moderately resistant.

For the purpose of analysis, the diseases data changed to Coefficient of infection (CI) as outlined by (Stubbs, R. W., 1988; Roelfs et al., 1992) in which the host reaction changed to numeric and then multiplied by severity. Immunity (O)

= 0.05, resistant (R) =0.1, moderately resistant (MR) = 0.2, intermediate (M) =0.4, moderately susceptible (MS) =0.6, and susceptible (S) =1. For example: CI for 10MS= 10*0.6= 6; CI=6.

Data analysis: Genotypic and phenotypic correlations between wheat rust diseases and other trait computed to see the association using a method suggested by Rennie SJ, et al. [19,20].

$$rg = \frac{gcovx - y}{d\sqrt{\delta^2 gx\delta^2 gy}} \text{ and } rp = (\frac{pcov - y}{d\sqrt{\delta^2 px\delta^2 py}})$$

Where rg and rp are genotypic and phenotypic correlation coefficients, respectively; g cov x*y and pcovx * y are genotypic and phenotypic covariances between variables x and y, respectively; δ2gx and δ2px are genotypic and phenotypic variances, respectively, for variable x; and δ2gy and δ2py are genotypic and phenotypic variances, respectively, for variable y.

ALL the analysis computed using R software version 3.6.0 and META-R [21,22].

Result and Discussion

ANOVA and Mean of the Traits

The ANOVA table showed the significant differences among tested genotypes for all traits except for stem rust diseases and moisture content (Table 2). The levels of significance among the genotypes for the traits were different. The result revealed significant variation for PHT at P<0.05, highly significant variation for TKW and GYLD at p<0.01, and very highly significant variation for DTH, DTM, HLW, GPC, SC, WG, and ZSV at P< 0.001. Thus, the selection among the tested genotypes for the traits was effective.

Source of variation	DF	PHT	DTH	DTM	TKW	HLW	SR	GYLD	GPC	MSC	SC	WG	ZSV
REP	1	3406	4.00*	1	1.96	0.15	352.18	5.34**	0.41	1.45***	0.3	5.8	7.32
Genotype	49	324*	2.44***	5.79***	16.4**	14.8***	1115.2	1.41**	1.25***	0.078	3.71***	10.7***	51.3***
Residuals	47	54.1	0.76	1.84	7.18	3.75	204.46	0.61	0.38	0.01	1.45	3.28	16.99

Table 2: Table of ANOVA for agronomic and quality traits of fifty bread wheat genotypes tested at Melkasa.
DTH=Days to heading; DTM=Days to maturity; PHT=Plat height in centimeter; TKW=Thousand kernel weight in gram; HLW= Hectoliter weight in kilogram per hectoliter weight; GYLD= grain yield in tone per hectare; GPC = grain protein content in percent; MCT=Moisture content in percent SC = starch content in percent; WG = wet gluten content in percent; ZSV = Zeleny sedimentation value in milliliter

High grain yield with better quality is the main goal for any wheat breeding program. Crossing of parents with different merits, selection of elite lines and adaptation are breeding activities that target the development and release of the noble bread wheat variety with high grain yield and disease resistance quality. In the study materials, genotypes EBW222078, EBW222070, EBW222088, and EBW222090 delivered the four top grain yields of 5.27 t/ha, 4.64 t/ha, 4.33 t/ha, and 4.09 t/ha consecutively. Besides, these genotypes were moderately resistant to moderately susceptible for the stem rust diseases with lower coefficient of infections 17,17,8 and 35 consecutively (Table 3).

Wheat protein is one of the main components of the grain for all end products (uses of wheat), from bread baking to noodles, pasta, cakes, and biscuits. The protein content of the genotypes in the study ranges from 14.45 for EBW222090 to 18.05 for EBW222062 (Table 3). It was relatively high and met the requirement, ranging between 7 to 18%, which is acceptable by industries. However, acceptance by wheat processors depends on different factors [23]. Generally, Lower protein content is suitable for biscuits, cookies, etc., and medium and high protein for bread and pasta production.

Also, the higher price is associated with the high-protein content of bread wheat. However, the gluten content of the protein is matter. The wet gluten content of the wheat flour should be higher than 24 % Singh RP [4]. Besides, the gluten content for the genotypes in the study was from 32.70 for EBW222065 to 43.5 for EBW222062. Thus, all the genotypes showed higher than 24% wet gluten content. In conclusion, the wheat rust disease had no significant effect on protein and gluten contents in the study material.

The moisture content of flour is a shelf-life and stability indicator. About 9% to 10% moisture content is suitable for storage stability and longer shelf life of wheat flour [24]. Low moisture levels inactivate enzymatic activity and microbial growth (fungal and bacterial). Wheat flour with greater than 14% moisture is unstable at room temperature. Also, Organisms naturally present in the flour will start to grow at high moisture, producing off odors and flavors. The higher the moisture content in the flour, the lower the amount of dry soil. Therefore, keeping close to 14% is the miller's interest. The moisture content of the genotypes in the study ranges from 11.5% to 12.35%. Most of the values were around 12%, which was not too low or high; it was intermediate, suitable for longer shelf life, and acceptable by wheat processors.

Starch is the most abundant carbohydrate component in wheat and wheat flour. About 70% of endosperm and 60%-75% of the wheat grain are composed of starch. It is the main component of wheat in which the difference in the quality and quantity affects the flour processing characteristics [25]. Starch is more sensitive to wheat rust diseases compared to storage proteins. The rust affects the grain filling period and anthesis. As a result, the starch synthesis will be disturbed. In the study genotypes, the lowest starch content, 61.45% gained on genotype EBW222062, and the highest starch content, 67.25% recorded on genotype EBW222078. Most of the genotypes in the study had around 65% starch in the grain. Which fall to bottom values in the starch content range in the wheat grain, 60% to 75%. It was probably due to the wheat stem rust diseases that affected the trial during the grain-filling period.

GENOTYPE	DTH	DTM	PHT	SR	TKW	HLW	GYLD	GPC	MSC	SC	WG	ZSV
Hidasse	53.5	94	65	60	24	55.2	0.97	16.5	11.6	64.4	35.4	58.2
EBW222050	52	96	67.5	50	26	60.9	2.89	15	11.5	64.8	33.3	55.7
EBW222051	51	97	65	30	25	63.1	2.52	15.5	12	65.7	35.6	60.1
EBW222052	51.5	95	67.5	45	26	61.6	2.1	17.4	11.9	62.2	40.7	70
EBW222053	52.5	97	70	8	24	62	2.06	15.4	12.1	64.4	34.3	58.7
EBW222054	51.5	97	70	17	24	64.2	3.26	15.5	12.1	64.8	37	61
EBW222055	52.5	97	57.5	27	25	63.1	1.6	16.1	12.2	64.3	38.9	64.1
EBW222056	53	98	65	4	28	66.7	2.38	15.8	12.3	66.4	37.9	63.9
EBW222057	54	93	72.5	40	28	58.7	1.83	17.1	11.9	62.8	40.2	67.8
EBW222058	51.5	94	72.5	45	27	56.5	2.08	16.3	12.2	64.3	38.3	65.5
EBW222059	52	95	70	22	26	64.2	3.57	16.1	12.2	64.5	38.2	65.6
EBW222061	53	97	80	40	30	63.4	3.85	15.2	12.1	65.1	35.9	58.1
EBW222062	52.5	96	60	21	23	63.1	2.76	18.1	11.9	61.5	43.5	75
EBW222063	51	98	75	27	28	62.3	3.05	15.2	12	65	34.5	57.6
EBW222064	51.5	94	72.5	30	29	63	2.36	15.3	12.1	65.5	35.3	57.8
EBW222065	51.5	96	70	45	26	62.1	2.22	14.5	12	65.7	32.7	48.9
EBW222066	51.5	98	75	27	30	64.2	2.88	15.2	12.2	66.3	34.9	56.1
EBW222067	53	96	72.5	40	29	61.2	3.95	15.1	12.3	65.6	35.4	56.3
EBW222068	54.5	95	75	31	21	56.2	3.62	17.2	11.7	62.3	40	69.2
EBW222069	54	99.5	72.5	16	29	60.4	3.28	16.4	12	65.8	38.2	68.1
EBW222070	51	96	82.5	17	28	66.4	4.64	14.8	12.2	67.1	35.7	57.4
EBW222071	51.5	96.5	72.5	40	25	60.1	2.37	15.7	12.2	65.2	36.8	62
EBW222072	53	95	72.5	45	22	60.9	2.98	15	12.1	66.2	34.8	58.6
EBW222073	52	95	65	30	26	62	2.16	16.8	12.3	63.1	39.5	68.2
EBW222074	54	94	65	21	28	61.3	3.03	16.3	12.4	65.1	39.2	67.1
EBW222075	55	95	62.5	40	23	58.6	2.67	16.8	12.2	63.3	39.3	68.8
EBW222076	55	94	72.5	50	24	58.1	2.78	15.9	12.2	63.3	35.1	63.1
EBW222077	53.5	94	80	50	21	59.7	1.98	16.2	12.1	63	37.2	63.9
EBW222078	53	98	77.5	17	29	65.6	5.27	15.3	12.3	67.3	36.5	61.9
EBW222079	52	96	77.5	30	33	59.6	3.4	15.6	12.2	64.9	35.7	61.7

EBW222080	51	95	67.5	21	30	65.6	2.67	17.2	12.4	64.3	42.8	72.1
EBW222081	53	95	65	30	29	64.6	2.34	16	12.2	65.1	38	63.7
EBW222082	52.5	95	70	31	27	61.5	1.67	15.8	12.2	65.3	37.3	63
EBW222083	52.5	97	70	21	27	61	3.49	15.6	12.3	64.4	35.7	61.3
EBW222084	52.5	95	65	50	24	66.3	2.77	15.5	12.4	65.7	37.5	62
EBW222085	54	95	77.5	27	29	63.1	2.78	15.1	12.2	66	35.1	58.5
EBW222086	52.5	96	75	50	29	62.6	1.82	15.5	12.3	66.3	36	59.9
EBW222087	52.5	95	62.5	55	25	61.8	2.5	14.5	12.2	66.8	33.7	51.4
EBW222088	52	95	80	8	31	64.9	4.33	16.3	12.1	64.2	37.9	65.8
EBW222089	51	97	75	29	28	66.1	3.5	17	11.8	63.5	41	70.4
EBW222090	51.5	96	85	35	30	62	4.09	14.5	11.9	67.1	33.1	54
EBW222091	52.5	94	67.5	40	27	65.1	2.91	15.8	12.1	64.9	37.1	62.3
EBW222092	54	99	80	8	25	63.6	2.64	15.5	12	66.5	36.2	63.6
EBW222093	52	95	72.5	35	26	61.5	3	16.9	11.8	62.1	36.2	64.1
EBW222094	53	94	67.5	45	21	61.5	2.39	16.4	11.8	63.3	40	67.2
EBW222095	52.5	102	70	6	28	66.9	2.48	15.9	12.2	64.8	37.2	63.1
EBW222096	51	94	70	31	29	61.5	2.72	15.4	11.9	65.3	36	58.2
EBW222097	51	94	70	30	30	62.1	3.29	16	12	64.5	37.5	63.8
EBW222098	54	96	75	45	23	58.2	3.84	16.4	12	64.9	38.4	66.1
Mean	52.5	95.8	71.3	32	26.5	62.2	2.82	15.8	12.1	64.8	37.1	62.5
LSD	1.46	2.26	6.99	13	4.06	3.37	1.16	1.05	0.21	1.91	3.07	6.84
CV	1.65	1.41	10.3	53.7	10	3.02	26.9	3.91	1.46	1.85	4.81	6.54

Source: DTH=Days to heading; DTM=Days to maturity; PHT=Plat height in centimeter ; TKW=Thousand kernel weight in gram; HLW= Hectoliter weight in kilogram per hectoliter weight; GYLD= grain yield in tone per hectare; GPC = grain protein content in percent; MCT=Moisture content in percent SC = starch content in percent; WG = wet gluten content in percent; ZSV = Zeleny sedimentation value in milliliter.

Table 3: Average score on important quality and agronomic traits of 20th High Temperature Wheat yield Trial (20HTWYT) tested at Melkasa.

Genotypic Correlation between Stem Rust and Quality Traits

Genotypic correlation between traits measures the genetic factors that the traits shared in common [26]. Result from the study revealed that grain yield had non-significant positive genotypic correlation with Days to Maturity r=0.313 and Hectoliter weight=0.249. Besides, grain yield shown highly Positive significant correlation with plant height, r=0.798***and thousand kernel weight, r=0.531*** at (P<0.001) (Table 4). This means most of the gens that govern the traits co-inherited. The same result on plant height and thousand kernel weight reported by Simane B, et al. [27,28]. Non-significant negative correlation, r=-0.178 at obtained between grain yield and days to maturity. This shows the inverse relationship between early type genotypes and the grain yield. Earliness is an important trait for drought prone stress areas and terminal moisture areas. So, selection for early maturing type has a penalty in yield.

In associations with quality traits, grain yield exerted non-significant and weak positive genotypic correlation with starch, r=0.097, with zeleny r=0.086.In contrast, highly negative strong correlation, r= -0.863*** at (p<0.001) exhibited between grain yield and moisture. Also, grain yield shown negative non-significant week correlations with protein, r=-0.131 and gluten, r= -0.036 at (Table 4). Similar negative association among the above traits testified except with moisture by Meles B, et al. [29,30]. Protein is often negatively associated with grain yield in cereal, wheat.

Stem rust disease affects grain yield and quality of wheat. Medium positive highly significant genotypic correlation r=0.402*** (Table 4) obtained between stem rust coefficient of infection and days to heading. This is probably due to that, late flowering enables the genotypes to escape the disease. In opposite, strong negative highly significant genotypic correlation r=-0.999***gained between grain yield and days to maturity. This showed that, early maturity group had a potential to escape the diseases effect. Generally, in the presence of stem rust disease, genotypes with late anthesis and early maturity group that is short grain filling period had capable of escaping the disease and deliver better grain yield.

Stem rust coefficient of infection had negative genotypic correlation with thousand kernel weight r=-0.811***, hectoliter weight r=-0.999***, and grain yield r= -0.957*** (Table 4). Besides, the associations were highly significant and very strong. These showed that the extent of the stem rust disease effect on the traits [31]. Highly susceptible genotypes delivered very low grain yield with very shriveled seed of poor quality, thousand kernel weights, and hectoliter weight.

The association of stem rust disease with quality parameters delivered the following results. Negative non-significant, r= -0.195 seen between grain yield and protein. The association was very week. Thus, the diseases didn't affect the protein content of the grain. Likely, week but significant negative genotypic correlation r=-0.346* obtained between grain yield and wet gluten content at (P<0.05) (Table 4).

The stem rust coefficient of infection had highly significant genotypic correlation with moisture r=-0.999***, starch content -0.468***, and Zeleny sedimentation value r=-0.568*** at (P<0.001). The association was very strong with starch content, medium with zeleny sedimentation value, and weak with starch content. In general, the stem rust coefficient of infection showed negatives genotypic correlations with all quality parameters (Table 4). Thus, wheat stem rust diseases affect the qualities of wheat grain.

Traits	DTH	DTM	PHT	SRCI	TKW	HLW	GYLD	GPC	MCT	SC	WG
DTM	-0.153ns										
PHT	0.402***	0.503***									
SR	0.447**	-0.999***	-0.447**								
TKW	-0.604***	0.279ns	0.330*	-0.811***							
HLW	-0.552***	0.633***	-0.205ns	-0.999***	0.224ns						
GYLD	-0.178ns	0.313ns	0.798***	-0.957***	0.531***	0.249ns					
Protein	0.340*	-0.274ns	-0.421**	-0.195ns	0.012ns	-0.167ns	-0.131ns				
Moisture	0.058ns	0.357*	0.016ns	-0.999***	0.959***	0.432**	-0.863***	-0.597***			
Starch	-0.251ns	0.607***	0.37	-0.468***	0.449**	0.307*	0.097ns	-0.832***	0.529***		
Gluten	0.233ns	-0.245ns	-0.443**	-0.346*	0.089ns	0.129ns	-0.036ns	0.943***	-0.166ns	-0.729***	
Zeleny	0.465***	-0.188ns	-0.258ns	-0.568***	0.084ns	0.014ns	0.086ns	0.944***	-0.316*	-0.679***	0.952***

Table 4: Genotypic correlation among Yield, stem rust diseases score, quality traits, and other agronomic traits of fifty bread wheat genotypes tested at Melksa, in2022.

DTH= Days to heading; DTM= Days to maturity; PHT= Plant height; SRCI= Stem rust coefficient of infection; TKW= Thousand kernel weight; HLW= Hectoliter Weight; GYLD= Grain yield; GPC = grain protein content; WG = wet gluten content; ZSV = Zeleny sedimentation value and SC = starch content; MCT=Moisture content

Phenotypic Correlation between Stem Rust Diseases and Quality Traits

Phenotypic correlations depend both on the correlation of additive genetic and on the correlation of environmental effects. Usually, most environmental effect act in the same direction and through the same pathways as genetic effects [32]. Grain yield had negative non-significant phenotypic correlation r= -0.00 with days to heading. Although, the correlation was week, earliness has inverse relationship with grain yield. Grain yield showed weak non-significant positive phenotypic correlation with days to maturity r=0.209 and hectoliter weight r=0.261 (Table 5).

Grain yield had positive highly significant phenotypic correlation with plant height r=0.489*** at (P<0.001) and significant phenotypic correlation with thousand kernel weight r=0. 0.348* at (P<0.05) (Table 5). Similar results reported by Dabi A, et al. [33,34].

The association grain yield had with that of quality traits revealed different results. Non-significant weak positive phenotypic correlation, r= 0.276 showed between grain yield and starch content (Table 4). Grain yield had non-significant negative correlation with grain protein content r=-0.147, moisture content r=-0.020, wet gluten content r= -0.104 (Table 5). The relation was inverse but it was weak. It was probably due to environmental effect.

Stem rust disease had highly significant negative phenotypic correlations with days to maturity r=-0.619*** and hectoliter weight r=-0.524*** at (P<0.001); Also, had significant phenotypic correlations with thousand kernel weight r= -0.292* and grain yield r= -0.282* (Table 5). These showed that the rust inversely affect the traits in different levels.

In related to quality traits, stem rust had negative non-significant correlations with grain protein content r= -0.208, moisture content r=-0.222, starch r=-0.175, gluten r=-0.111, and Zeleny sedimentation value r=-0.168 (Table 5). The associations were inverse. These indicated that, the stem rust diseases association with quality traits were more of genetic than environment.

Traits	DTH	DTM	PHT	SR	TKW	HLW	GYLD	Protin	Moisture	Starch	Glutin
DTM	-0.076ns										
PHT	-0.045ns	0.152ns									
SR	0.135ns	-0.619***	-0.034ns								
TKW	-0.396**	0.167ns	0.301*	-0.292*							
HLW	-0.422**	0.427**	0.029ns	-0.524***	0.347*						
GYLD	-0.100ns	0.209ns	0.489***	-0.282*	0.348*	0.261ns					
Protein	0.171ns	-0.206ns	-0.356*	-0.049ns	-0.208ns	-0.213ns	-0.147ns				
Moisture	-0.008ns	0.221ns	-0.149ns	-0.222ns	0.143ns	0.344*	-0.020ns	-0.339*			
Starch	-0.163ns	0.350ns	0.292*	-0.175ns	0.404**	0.381**	0.276ns	-0.824***	0.423**		
Gluten	0.110ns	-0.177ns	-0.407**	-0.111ns	-0.165ns	-0.004ns	-0.104ns	0.913***	-0.189ns	-0.637***	
Zeleny	0.233ns	-0.125ns	-0.308*	-0.168ns	-0.183ns	-0.117ns	-0.053ns	0.946***	-0.235ns	-0.683***	0.935***

Table 5: Phenotypic correlation among Yield, stem rust diseases score, quality traits, and other agronomic traits of fifty bread wheat genotypes tested at Melksa, in2022.

DTH= Days to heading; DTM= Days to maturity; PHT= Plant height; SRCI= Stem rust coefficient of infection; TKW= Thousand kernel weight; HLW= Hectoliter Weight; GYLD= Grain yield; GPC = grain protein content; WG = wet gluten content; ZSV = Zeleny sedimentation value and SC = starch content; MCT=Moisture content

Conclusion

The genotypic correlation of the quality traits with the stem rust diseases was negative, highly significant and medium to strong in strength except for protein, whereas, the phenotypic correlation was week, negative, and non-significant. Thus, the association between stem rust diseases and quality traits were more of genotypic effect than the environmental effect. Moreover, most of the genes that govern the traits were linked with that of stem rust susceptible genes [35-39].

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