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Finding New Sources of Resistances from Durum Wheat Landraces Against Leaf Rusts *(Puccinia triticina)* and Studying Environmental Factors for Disease Development

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Abstract: The use of genetic resistance is the key approach for rust management and ecological safety. Nowadays, the Puccinia triticina pathogens have virulent on most released durum wheat varities and break the resistance status of hosts through mutations and genetic recombination. To overcome the problems, mining of new resistances genes is inevitable. The aim of this study is searching new sources of resistance from durum wheat landraces to leaf rust and the influence of environmental factors for disease epidemiology. The 142 durum wheat landraces planted the simple lattice design with 12 blocks and 12 plots per replication and each plot size is 0.5 m X 1m. The disease spreader line planted at 1m intervals between blocks at the same sowing date. The natural occurrence of Puccinia triticina is highly epidemic at early stage and the data recorded started at the first symptom appear spreader lines. Totally 34 durum wheat landraces have been identified as adult plant resistance genes. Among them the seven durum wheat landraces (222428, 214348, 226860, 222705, 204391, 222454, 226882) have categorized the first group and the second twenty seven landraces (226893, 222389, 208189, 222680, 204586, 222552, 214527, 204363, 222435, 204521, 204463, 238132, 214606, 208191, 8063, 222764, 214264, 204432, 238131, 222553, 204555, 226889, 226965, 238128, 203968, 222560, 214312). These landraces considered as the high level of slow rusting and moderate level of partial resistance to reduce epidemics of leaf rust disease respectively. Utilizing these resistance sources for next leaf rust resistance breeding is crucial. The average weekly maximum temperature and relative air humidity is positively significant and negatively very highly significant ($P<0.001$) with leaf rust disease progress over time respectively. The AUDPC is very highly significant and negatively affect on days of heading, date of maturity and grain yield.

Keywords: AUDPC, Disease Progress, Partial Resistance, Puccinia Triticina

1. Introduction

The leaf rust is the most common cereal disease of Teff, Wheat, Maize, Sorghum and Barley in the world and even adapted wider environment [13]. The wheat leaf rust caused by *Puccinia triticina* is the most prevalent and high annual yield losses as global basis [11, 29]. In sub-Saharan Africa (SSA), Ethiopia is the largest producer of wheat with approximately 1.7 million ha of land under cultivation [8]. Wheat production faced many challenges in the country like poor knowledge of wheat production technologies, inadequate supply and use of agricultural inputs, poor extension support, low soil fertility, pests and diseases are the major ones [31]. Among the disease components leaf rust play the great role of wheat production constraint in Ethiopia [19]. The 3.62 t/ha average yield was obtained as world basis [1] which is higher than the national average yield 3.05 t/ha [6]. These data tells the wheat rust play higher yield reduction percentage as contrasting other disease like bacteria and viral disease [24]. In the country *Puccinia triticina* is one of the important diseases of wheat and yield loss due to this disease has reached up to 75% [7].

Leaf rust (Brown rust) only grow the living tissue of hosts and said to be obligate pathogens. The pathogen produce sexual (pycnial or aecial) and asexual (telial or uredinal) spores to complete its full life cycle on the hosts. The known primary hosts are bread wheat, durum wheat, cultivated and wild emmer wheat, Ae. speltoides, Ae. cylindrica and triticale; the secondary or alternate hosts are *Thalictrum speciosissimum* and *Isopyrum fumaroides* [5, 12]. Leaf rust attacks the leaf blades, leaf sheaths and glumes [11]. The disease development requires high moisture and warm weather conditions. To reduce leaf rust the wheat growers utilize resistant cultivars and pesticides. However, due to the high cost of fungicide these cannot be applied as resource poor farmers and therefore utilization of resistance sources is very important approach for minimizing yield loose caused by leaf rust in Ethiopia [30]. For wheat yield sustainability in the country evaluation of wheat landraces as adult stage or Adult Plant Resistance (APR) genes is interesting to slow down rust pressure at field level [16]. The identification of new resistance sources to leaf rust is significant for breeding durable rust resistant varities in combination with potential yielder and other important agronomic traits [4]. Therefore the objective of this study was to identify the new sources of adult plant resistance and effect of meteorology for leaf rust disease epidemiology.

2. Materials and Methods

The study was conducted during 2020 main cropping season in Debrezeit Agricultural research center nursery fields. Geographically the area is 08°46′N latitude and 39°00′ E longitude with an altitude of 1900 m. a. sl. The center receives 851 mm the mean annual rainfall, 28.3°C the mean maximum temperature and 61.3% mean annual relative humidity. The durum wheat nursery field has characterized as pellic-vertisol [3].

The one hundred fourthy two durum wheat landraces obtained from Ethiopian biodiversity institute and additionally two cultivaries (Morocco and Arendato) from Debrezeit research center. The simple lattice design was used has the size of plot is 0.5 m width and 1m length. The design laid out 12 blocks per replication and 12 plots per blocks. Each plot had 50 cm row length and 20cm width. Distance between blocks and plots were 15 cm and 10 cm, respectively. The spreader lines (Morocco & Arendato) were mixed equal ratio has planted at 50 cm interval between two blocks as the same sowing date for landraces. The twenty seeds are planted in the rows and only one row per plots are utilized data collection. The natural epidemics of *puccinia triticina* was show symptom on spreader lines earlier than the landraces. The agronomic practices like fertilizer application, cultivation and weeding are the practices of per recommendation of Debrezeit agricultural research center.

2.1. Disease Assesment and Data Collection

The spreader line is inspected for the presence or absence of leaf rust. The data was collected when the first symptom seen in susceptible cultivars and this was continued until disease severity reached 100% in the infector rows and were collected at one times in every week. The seven weekly data was entered excel for analysis of slow rust parameters. The severity of *puccinia triticana* estimated on the single plot as percentage of uridinia coverage on the leaf. The modified Cobb's scale was used for estimation [20] and this scale ranged from 0-9. Where, 0%=immune and 100%=completely susceptible. The response to infection was estimated based on the size of uredinia where; 0= no infection, R= necrotic areas with or without small pustules, MR= small pustules surrounded by necrotic areas, M= Pustules of variable size, some necrosis or chlorosis, MS= Medium sized pustules, no necrosis, but some chlorosis, S= large pustules no necrosis or chlorosis [22]. The Coefficient of infection was calculated by taking the product of percent disease severity and the value of host response i.e R=0.2, MR=0.4, M=0.6, MS=0.8 and S=1.0 [22].

The terminal rust severity (TRS) data was obtained when the susceptible cultivar reached the maximum percentage of the final data collection period [17]. The climatic data like mean minimum temperature, mean maximum temperature, mean relative humidity of air and mean rainfall from date of planting (August 4, 2020) up to date of harvesting (Dec 12, 2020) were obtained from near the center of meteorological station of Debrezeit.

The agronomic parameters like: 1) Days to heading (DH) is the number of days from planting until 50% of the plants produced spikes in each experimental plot.2) Days to maturity (DM): the number of days from planting to 75% of the plants in a plot reached maturity. 3) Total number of tillers (TT): the number of tillers recoded from twenty plants in each experimental unit at maturity stage. 4) Number of productive tillers per plant (NPT): the numbers of tillers per plant bearing productive heads were counted at the time of harvest and average was recorded from the twenty plants taken in the experimental unit were used for statistical analysis.5) Number of kernel per spike (NKPS): Number of grains recorded per main tiller from ten randomly selected plants tagged before commencement of tillering from each experimental plot at maturity stage. 6) 1,000-kernel weight (TKW): Weight of 1,000 kernels sampled from total grain harvest of each experimental plot and weighted in grams. 7) Grain yield (GY): Grain yield in gram/plot at 12.5% moisture content was recorded using sensitive balance and transformed into t/ha.

2.2. Data Analysis

The disease severity data were entered into Microsoft excel and computed for area under disease progress curve, coefficient of infection, terminal rust severity and rate of disease development. The R – package software library agricolae, lme4 and GGally are used. The rates of stem rust increase (r-value) as a function of time were estimated based on proportional measures of the extent of infection at different times by taking the coefficient of the slope of the regression line [26]. The AUDPC is computed for the seven week disease severity data [28]. The meteorological data and leaf rust disease severity were computed as linear regression and produced regression line using R package [21].

$$AUDPC = \sum_{i=1}^{n-1} \frac{(Y_{i+1}+Y_i)}{2}(t_{i+1}-t_i)$$

Where, Yi is the cumulative disease severity expressed as a proportion at the ith observation; ti is the time (days after planting) at the ith observation and n is total number of observations.

3. Results

The durum wheat landraces display diverse and variable results tested under field conditions based on slow rust parameters (Table 1). The analysis of variance tells as very highly significant ($p<0.001$) differences among durum wheat landraces for the reaction of naturally occurring *puccinia triticana* isolates in Debrezeit research center fields. This indicates the broad chance of selecting leaf rust resistance landraces next breeding activities.

Table 1. *Analysis of variance for slow rusting parameters.*

Slow rusting parameters	Sum.sq		Mean. sq		F-value	Pr (>F)
	Landraces	Residuals	Landraces	Residuals		
AUDPC	50361950.0	16293097.0	352181.0	123433.0	2.9	***
CI	126044.0	26477.0	881.4	200.6	4.4	***
TRS	102808.0	25500.0	718.9	193.2	3.7	***
Rate	62.9	14.8	0.4	0.1	3.9	***

Signif. Codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

3.1. The Leaf Rust Disease Parameters

The terminal rust severity (TRS) is the final data for recording rust severity during disease assesment from the fields. The maximum and minimum TRS value scored from variety Arendato and the minimum from accession number 222428 respectively (Table 2). These value ranges from 20 – 95%. The eight landraces (204363, 226882, 222454, 204391, 222705, 226860, 214348, 222428) have grouped 1-30% final record of leaf severity. These lines are considered as high level of partial slow leaf rust resistance genes and thirty nine lines grouped under final disease severity range 31-50% which are moderate level of slow rust resistance. The rests have >50% TRS values which has no slow rusting adult plant resistance. The two group of reaction are identified among these first group has the landraces possess with moderately susceptible (MS) and the second group with susceptible (S) for reaction. Therefore, majority percentages (70%) of landraces have susceptible (S) and 30% are moderately susceptible (MS) reaction for puccinia triticina Debrezeit nursery fields.

Table 2. *The reaction and mean separation of durum wheat landraces for puccinia triticana.*

Landraces	TRS	Response	CI	Rate	AUDPC Mean
Arendato	95	S	95	2.13	2633.80^{a}
213036	100	S	100	2.54	2208.50 ^{ab}
213037	80	S	80	1.88	2189.30 ^{abc}
Morocco	90	S	90	2.17	2145.50 ^{abcd}
208201	90	S	90	2.51	2086.00 $^{a-e}$
204560	90	S	90	2.13	1963.50 $^{a-f}$
208183	80	S	80	1.90	1963.50 $^{a-f}$
208128	85	S	85	2.15	1946.00 $^{a-g}$
226883	90	S	90	2.16	1891.80 $^{b-h}$
204409	85	S	85	2.13	1876.00 $^{b-i}$
238129	85	S	85	1.88	1874.30 $^{b-i}$
238125	85	S	85	2.24	1856.80 $^{b-j}$
204545	75	S	75	2.03	1788.50 $^{b-k}$
214495	50	S	50	2.05	1788.50 $^{b-k}$
226973	90	S	90	2.31	1736.00 $^{b-l}$
204453	85	S	85	2.00	1736.00 $^{b-l}$
222464	75	S	75	2.02	1722.00 $^{b-l}$
226858	90	S	90	2.33	1720.30 $^{b-l}$
214608	90	S	90	2.13	1718.50 $^{b-m}$
204444	85	S	85	2.00	1718.50 $^{b-m}$
204543	80	s	80	2.00	1718.50 $^{b-m}$
226885	90	S	90	2.15	1718.50 $^{b-m}$
226884	85	S	85	2.03	1716.80 $^{b-m}$
204589	80	S	80	2.10	1687.00 $^{b-n}$
216098	70	S	70	1.69	1683.50 $^{b-n}$
214467	70	S	70	1.93	1681.80 $^{b-n}$
238124	85	S	85	1.95	1666.00 $^{b-o}$
208200	80	S	80	1.87	1648.50 $^{b-p}$
226977	75	S	75	1.74	1631.00 $^{b-p}$
222433	65	S	65	1.72	1613.50 $^{b-p}$
238123	85	S	85	2.21	1613.50 $^{b-p}$
208476	70	S	70	1.62	1613.50 $^{b-p}$
214605	75	S	75	1.96	1611.80 $^{b-p}$
222451	70	S	70	1.85	1580.30 $^{b-p}$
212648	75	S	75	1.85	1576.80 $^{b-r}$
238127	80	S	80	1.96	1559.30 $^{b-s}$
222450	60	S	60	1.49	1545.30 $^{b-t}$
226869	70	S	70	1.80	1543.50 $^{b-t}$
222437	60	S	60	1.52	1543.50 $^{b-t}$
222449	80	S	80	2.00	1543.50 $^{b-t}$
204454	75	S	75	1.85	1541.80 $^{b-t}$
214589	75	S	75	1.93	1541.80 $^{b-t}$
238126	75	MS	60	1.59	1526.00 $^{b-u}$
204011	65	S	65	1.59	1526.00 $^{b-u}$
222505	70	S	70	1.90	1508.50 $^{c-u}$
222550	80	S	80	1.96	1506.80 $^{c-v}$
222474	90	S	90	2.22	1491.00 $^{d-w}$
226857	70	S	70	1.72	1491.00 $^{d-w}$
203992	85	S	85	2.19	1487.50 $^{d-x}$
222432	85	S	85	2.10	1475.30 $^{d-y}$
5250	60	MS	48	1.49	1475.30 $^{d-y}$
221740	70	S	70	1.86	1473.50 $^{d-y}$
222388	65	S	65	1.67	1473.50 $^{d-y}$
222422	65	S	65	1.68	1471.80 $^{d-z}$
238114	72.5	S	72.5	1.78	1464.80 $^{d-A}$
226978	65	S	65	1.59	1459.50 $^{d-A}$
212650	75	S	75	1.97	1459.50 $^{d-A}$
7974	70	S	70	1.82	1456.00 $^{d-A}$
208188	65	S	65	1.60	1454.30 $^{d-B}$

Landraces	TRS	Response	CI	Rate	AUDPC Mean
226867	75	S	75	1.57	1454.30 $^{d-B}$
238115	72.5	S	72.5	1.72	1447.30 $^{e-B}$
208785	80	S	80	2.08	1440.30 $^{e-B}$
214418	65	S	65	1.54	1438.50 $^{e-B}$
206627	65	S	65	1.65	1436.80 $^{e-B}$
238113	57.5	S	57.5	1.32	1429.80 $^{e-B}$
5204	60	S	60	1.54	1405.30 $^{e-C}$
238121	70	S	70	1.64	1403.50 $^{e-C}$
222482	70	S	70	1.81	1386.00 $^{f-D}$
222582	70	S	70	1.77	1386.00 $^{f-D}$
204509	60	S	60	1.49	1370.30 $^{f-D}$
226859	70	S	70	1.41	1368.50 $^{f-D}$
204522	55	MS	44	1.42	1366.80 $^{f-D}$
204476	65	MS	52	1.66	1366.80 $^{f-D}$
222488	55	S	55	1.42	1366.80 $^{f-D}$
204562	75	S	75	1.90	1352.80 $^{f-E}$
236986	65	S	65	1.54	1351.00 $^{f-E}$
236987	50	S	50	1.21	1351.00 $^{f-E}$
226876	60	S	60	1.52	1351.00 $^{f-E}$
208934	75	S	75	1.80	1351.00 $^{f-E}$
204428	60	S	60	1.44	1333.50 $^{f-F}$
226898	65	MS	52	1.78	1331.80 $^{f-F}$
222469	55	S	55	1.42	1314.30 $^{f-F}$
216069	60	S	60	1.41	1302.00 $^{f-G}$
204542	60	S	60	1.45	1296.80 $^{f-G}$
236988	62.5	MS	50	1.58	1289.80 $^{f-G}$
208197	65	MS	52	1.73	1279.30 $^{f-G}$
226886	65	S	65	1.74	1267.00 $^{f-G}$
222556	50	S	50	1.18	1263.50 $^{g-G}$
238120	70	S	70	1.57	1263.50 $^{g-G}$
222381	60	S	60	1.58	1247.80 $^{h-G}$
226866	55	S	55	1.42	1244.30 $^{h-G}$
222426	60	S	60	1.59	1230.30 $^{h-G}$
226821	55	S	55	1.36	1228.50 $^{h-G}$
222815	50	S	50	1.27	1226.80 $^{h-G}$
226971	65	S	65	1.55	1214.50 $^{h-G}$
222520	55	S	55	1.39	1212.80 $^{h-G}$
226880	55	S	55	1.36	1193.50 $^{i-G}$
222559	50	S	50	1.21	1176.00 $^{j-H}$
204566	45	MS	36	1.13	1176.00 $^{j-H}$
204506	60	S	60	1.63	1176.00 $^{j-H}$
222405	50	MS	40	1.27	1139.30 $^{k-H}$
211488	50	MS	40	1.26	1127.00 $^{k-H}$
204410	45	S	45	1.21	1109.50 $^{k-H}$
5071	45	MS	36	1.16	1106.00 $^{k-I}$
222439	45	S	45	1.19	1072.80 $^{l-I}$
232119	50	S	50	1.13	1071.00 $^{l-I}$
222494	55	S	55	1.36	1051.80 $^{l-I}$
208206	60	S	60	1.47	1022.00 $^{m-I}$
5180	45	MS	36	1.19	1016.80 $^{n-I}$
214312	45	MS	36	1.10	983.50 $^{o-J}$
208331	55	MS	44	1.34	964.30 $^{p-J}$
222560	35	MS	28	0.90	899.50 $^{q-K}$
203968	40	MS	32	0.99	880.30 $^{r-K}$
238128	40	MS	32	0.96	878.50 $^{s-K}$
226965	50	MS	40	1.16	878.50 $^{s-K}$
226889	40	S	40	0.99	876.80 $^{s-K}$
204555	35	MS	28	0.91	864.50 $^{s-K}$
222553	45	S	45	1.22	861.00 $^{t-K}$
238131	40	MS	32	1.02	857.50 $^{t-K}$
204432	35	MS	28	0.90	841.80 $^{u-K}$
214264	45	MS	36	1.11	841.80 $^{u-K}$
222764	35	MS	28	0.89	810.30 $^{v-K}$
8063	35	MS	28	0.91	794.50 $^{w-K}$
208191	35	MS	28	0.92	792.80 $^{x-K}$
214606	45	MS	36	1.09	789.30 $^{y-K}$
238132	50	S	40	1.12	775.30 $^{z-K}$
204463	35	MS	28	0.80	773.50 $^{A-K}$
204521	35	MS	28	0.94	770.00 $^{A-K}$
222435	35	MS	28	0.92	757.80 $^{B-K}$
204363	30	MS	24	0.82	724.50 $^{C-K}$
214527	35	MS	28	0.89	719.30 $^{C-K}$
222552	35	MS	28	0.89	717.50 $^{C-K}$
204586	45	MS	36	1.06	705.30 $^{D-K}$
222680	35	MS	28	0.89	701.80 $^{D-K}$
208189	35	MS	28	0.86	666.80 $^{E-K}$
222389	35	S	35	0.83	649.30 $^{F-K}$
226893	35	MS	28	0.82	614.30 $^{G-K}$
226882	25	MS	20	0.66	495.30 ^{HIJK}
222454	25	MS	20	0.66	491.80 ^{HIJK}
204391	25	MS	20	0.64	479.50 ^{HIJK}
222705	25	MS	20	0.66	479.50 ^{HIJK}
226860	25	MS	20	0.54	409.50 ^{IJK}
214348	20	MS	16	0.47	288.80 ^{JK}
222428	20	MS	16	0.40	236.30 ^{K}

The means followed with the same letters in the columns are not significantly different.

The very highly significant differences ($P<0.001$) among landraces for computed value of coefficient of infection (CI). The highest value from durum accession 213036 which has susceptible than even the check cultivars (Arendato & Morocco). The arrangement of landraces based on the coefficient of infection is necessary for the identication of field resistance having high, moderate and low level of resistance of tested accessions which have ability of slowing down the disease progress of leaf rust in the fields. Considering on these, seven accessions (222428, 214348, 226860, 222705, 204391, 222454 &226882) have low CI which has ranges 1-20% CI and the other thirty one durum wheat landraces (204363, 222560, 204555, 204432, 222764, 8063, 208191, 204463, 204521, 222435, 214527, 222552, 222680, 208189, 226893, 203968, 238128, 238131, 222389, 204566, 5071, 5180, 214312, 214264, 214606, 204586, 222405, 211488, 226965, 226889, 238132) have grouped under the CI values ranged between 21-40%. The remaining 104 durum wheat landraces above the 40% CI values (Table 2).

3.2. The Area Under Disease Progress Curve (AUDPC) and Disease Progress Rate (DPR)

The value of AUDPC showed the wide leaf rust resistant variations of landraces (Table 2). Depending on these results the maximum the mean AUDPC computed from Arendato (2633.80) and the lowest from accession number 222428 (236.30). The 38 groups of durum accessions identified on the significance group these indicates the field screening of durum wheat landraces have varying degree of resistance for reaction of leaf rusts. The AUDPC is the most effective ways of characterizing accessions for evaluating slow rust parameters for adult plant resistant.

Based on the mean ranges of AUDPC the durum landraces categorized into five groups. The first group has 100-500, the second group has 500-1000 AUDPC, the third group includes 1000-1500, The fourth and fifth group holds 1500-2000 and

2000-2500 and above respectively (Table 2). Depending on this range, the first group has seven accessions (222428, 214348, 226860, 222705, 204391, 222454 & 226882) with moderately susceptible (MS) reaction and the second group includes the twenty seven accessions (226893, 222389, 208189, 222680, 204586, 222552, 214527, 204363, 222435, 204521, 204463, 238132, 214606, 208191, 8063, 222764, 214264, 204432, 238131, 222553, 204555, 226889, 226965, 238128, 203968, 222560, 214312). The thirty four accessions (the sum of two groups) might be effective adult plant resistance genes for minimizing sporulation and leaf rust disease development.

The disease progression rate tells that how past the disease growth and development period from the first symptom up to the final stage. The range of disease progress lies between 0.40 and 2.54. The fast sporulation rate was seen on the susceptible accession N<u>o</u> 213036 and the long period of sporulation period needed on resistant accession N<u>o</u> 222428. The 26 accessions (18%) have ranges 0.4-0.99 disease progress rate and 91 accessions (63%) are less than two the mean disease progress rate. in the other hand, the 27 accessions (19%) considered to be two and above two the mean disease progress rate.

3.3. Environmental Components

The environmental studies are the most important factors for leaf rust disease development. Then the data were collected from meteorological station in Debrezeit similarly leaf rust disease severity data collection period (Table 3). The data concerns mean weekly minimum temperature (Min.tem), mean weekly maximum temperature (Max.tem), mean weekly relative humidity (RH) and mean weekly precipitation (RF). The table indicates that both Min.tem and RF have non significance effect on sporulation but the mean temperature and RH have positive and negative significance and very highly significance (P<0.001) differences among the 142 durum landraces respectively.

Table 3. *Variance components of meteorological parameters on leaf rust disease severity.*

Parameter	Estimate	Std.error	tvalue	Pr (>|t|)	Adjusted.R^2
Min.tem	-31.84	16.06	-1.98	0.1042	0.33
Max.tem	72.89	27.89	2.61	0.0475 *	0.49
RH	-4.57	0.57	-7.98	0.000498 ***	0.91
RF	-8.85	5.99	-1.48	0.1990	0.17

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The leaf rust disease increment per weekly interval is positively affected by average weekly maximum temperature and negatively affected with average weekly air relative humidity (figures 1 and 2).

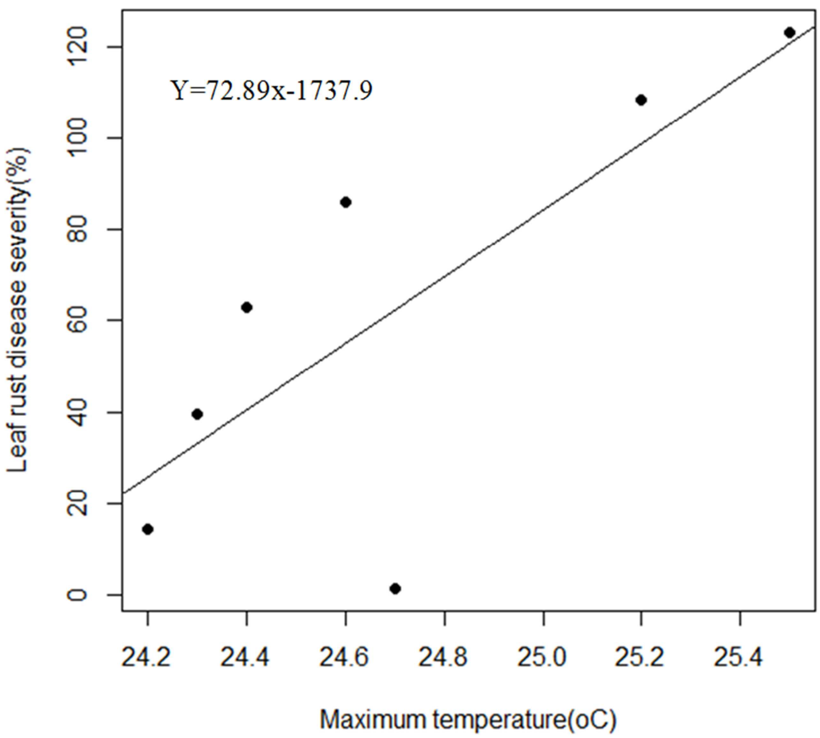

Figure 1. *The various ranges of maximum temperature on leaf rust severity.*

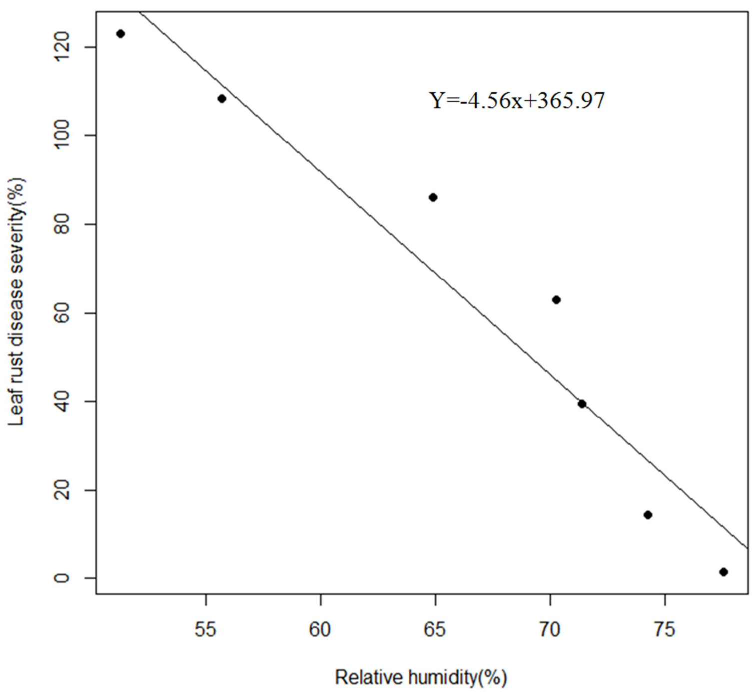

Figure 2. *The regression graph of leaf rust disease severity and average ranges of weekly air relative humidity (%).*

3.4. The Association of Yield and Yield Components with Disease Parameters

The date of heading, date of maturity and grain yield were negative and very high significant (P<0.001) associated with area under disease progress curve (figure 3). The thousand kernel weight, number of kernel per spikes are negatively but not significant with disease parameters and conversely productive tiller per square meters are positive and non-significant with area under disease progress curve. In the other hand, total tiller per meter square is positively and very highly significant related with AUDPC. In general speaking that the grain yield is integration of those mentioned yield parameters and the leaf rust disease is the significant negative influence grain yield in t/ha.

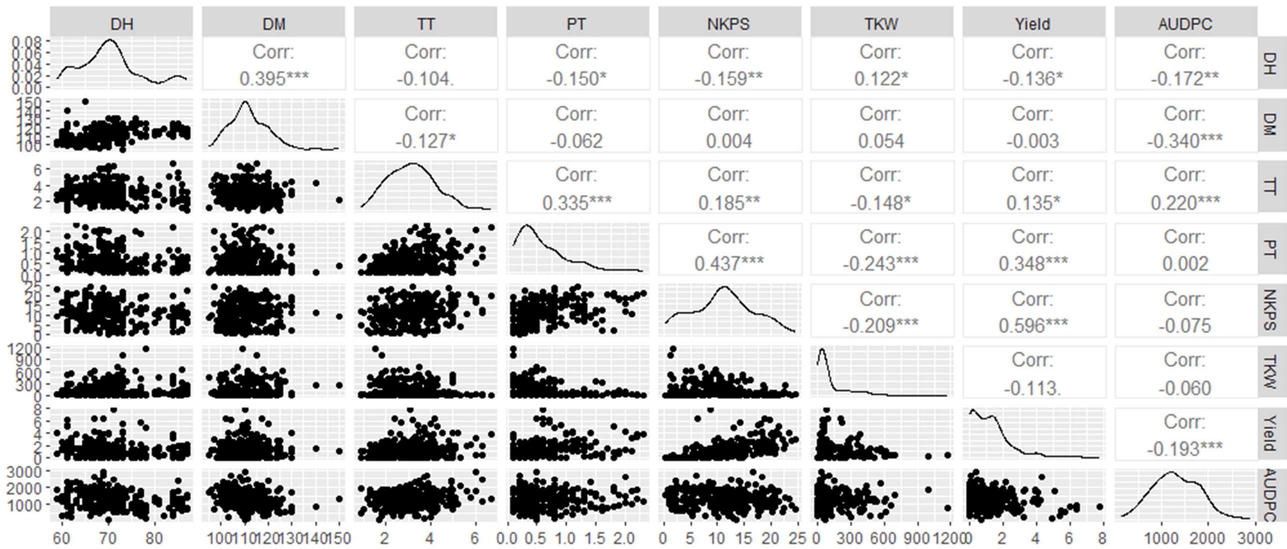

Figure 3. *The relationship between AUDPC and important agronomic traits.*

4. Discussion

4.1. Slow Rust Parameters

The screening of durum wheat landraces for different races of *puccinia triticina* shown the diversity of slow rusting resistance parameters like response to infection, terminal leaf rust severity, coefficient of infection, area under disease progress curve and leaf rust disease progress during the seven weekly collected data from Debrezeit research center. Based on the terminal rust resistance score; the first eight durum accessions have ranked high level of resistance and the second 39 durum landraces moderate slow resistance naturally occurring *Puccinia triticana.* These landraces have coefficient of infection ranges between 16-50% and considered to have adult plant resistance genes for leaf rust pathogens [16]. The 43 durum landraces (30%) were moderately susceptible (MS) reaction to the leaf rusts plus less than one mean disease progress rate during the seven week leaf rust collected data.

The 34 durum landraces have the AUDPC ranges between 200-1000 values. The AUDPC is the most important slow rusting parameters for evaluation of durum landraces either resistance or susceptible of leaf rusts [27]. The evaluation of accessions with TRS, DPR, CI, AUDPC the most criteria for utilization of horizontal resistance of leaf rusts. The first seven accessions (222428, 214348, 226860, 222705, 204391, 222454 & 226882) have 100-500 AUDPC with low TRS, CI and low DPR comparing with 27 durum landraces which have grouped 500-1000 AUDPC, TRS ranges 31-50% and CI has 20-40%. The grouping landraces with low AUDPC, TRS and CI is the most important approaches to identify slow rusting resistance landraces to utilize leaf rust management (Draz et al., 2015; Hei., 2016). In the other hand the genetic diversity of durum wheat accessions promote broad resistance to leaf rust races and selections for gene manipulations of next resistance breeding (Herrera et al., 2005).

4.2. The Effect of Environment for Leaf Rust Development

Environment plays significant role for successful infection and sporulation of susceptible hosts. The above table 3 indicates that both maximum temperature and relative humidity has significant for progress of leaf rust. At early time, maximum temperature range between 24.2°C -24.4°C the severity become low and no more rust development seen the 55-63 DAP (days after planting) while at 25.2°C -25.4°C the severity reaches 100-120 percentages and majority of landraces have susceptible and become high disease progress rate. The temperature and average severity is positively associated i e R=0.49 (figure 1). The *Puccinia triticina* in nature, require optimum temperature for reproduction, multiplication and expression of virulence proteins [11]. Therefore, temperature ranges of during studied period produces the changes of disease severity.

The air relative humidity were very highly significant and negative linear relationship with average leaf rust severity (figure 2). The increment of average percentage relative humidity i e from first day of symptom up to the final disease severity scoring /55-97 days / the severity becomes decreases from 120 – 20% and even zero with reversely changes of mean relative humidity from 55%- 75%. The relative humidity plays the most important role for the establishment of puccinia triticana on 142 durum landraces and the variation solely accounts 91% among accessions and even other unknown factors. The 55-63 DAP the mean range disease severity were 100-120% which becomes maximum with 55-60% RH. This indicate that most of genotypes susceptible with initial percentages of air relative humidity and at latter growth stage the plant develops resistance genes when the increment of mean weekly percentages of relative humidity. The fluctuation of air relative humidity with the earlier stage brings susceptibility and virulence of puccinia triticina and most of yield loss occur at this stage [11, 18]. The authors suggested that the 50% yield loss occurred during the early growth stage of plant with combination of favorable climatic conditions [2].

In the other terms the adult plant resistance gene(s) is more expressed on the variability of weather conditions. For instance, the unit change of the average weekly air relative humidity results the unit reduction of average weekly disease severity on durum wheat accessions. when the weather variability is miss match with the pathogenicity status of *P. triticana* even though, the host become susceptible the outcome might lower infection, smaller size of uridinia, the shorter period of sporulation and reduced level of spore density on the above part of leaves [14]. In the other hand, the unit incremental changes of average weekly maximum temperature produce the unit incremental changes of average disease severity on 142 durum accessions.

4.3. The Association of Yield and Yield Components with Disease Parameters

The leaf rust disease is negatively and very highly associated with grain yield per hectare (r=-0.19), date of maturity (r=-0.34) and date of heading (r=-0.17). The other agronomic parameters except total tiller were no significantly associated with leaf rust disease. Therefore, the objective of examining these studies was to see the effect of disease is positively associated or negatively related the final grain yield or not (Figure 3). The P. triticana competing with photosynthetic products, water absorption, nutrient translocation and reducing the area of leaf for capturing sunlight. The cumulative effect decline the final yield per hectare during harvesting time [25]. The progress of leaf rust disease on the susceptible hosts result reduced number of tiller, fewer number of productive tiller, small number of kernels per spike/empty kernels and underweight seeds with no grains [23].

5. Conclussion

Wheat production in the world is challenged by many biotic factors among them the rust disease is currently feared disease and results above 60% yield loss. The mining of resistance source is more appropriate in spite of using other management option of disease control like fungicides. The screening of durum wheat landraces for bulk *P. triticana* races is important for identification slow rusting /adult plant resistance genes. Under field level the eight and thirty nine durum accessions grouped high level and moderate level of slow rusting based on TRS 1-30% and TRS 31-50% respectively. The seven accessions (222428, 214348, 226860, 222705, 204391, 222454 &226882) first level slow rusting resistance with CI ranged from 1-20%.

The AUDPC is the most important of grouping accessions with their resistance category. Based on these the AUDPC mean ranged between 100-500 has seven accessions (222428, 214348, 226860, 222705, 204391, 222454 & 226882) and the other twenty seven accessions (226893, 222389, 208189, 222680, 204586, 222552, 214527, 204363, 222435, 204521, 204463, 238132, 214606, 208191, 8063, 222764, 214264, 204432, 238131, 222553, 204555, 226889, 226965, 238128, 203968, 222560, 214312) has holds the value of mean AUDPC ranges from 500-1000 and considered as resistance sources for leaf rusts. The air RH is very highly significant and negative influence on the leaf rust severity and the variation is accounted in 91% and the average weekly maximum temperature is significant and positive influence of disease development. The AUDC is very highly significant and negatively related for date of heading, date of maturity and grain yield per hectare.

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