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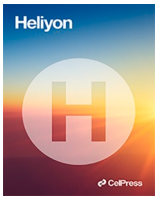

Research article

Adult-plant resistance to leaf scald and net form net blotch in food barley genotypes at a hot spot location in Ethiopia

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ABSTRACT

Globally, the fungal pathogens *Rhynchosporium graminicola* and *Pyrenophora teres* f. *teres* produce foliar diseases that significantly reduce barley yield. These diseases are known as leaf scald and net form net blotch, respectively. One hundred food barley genotypes in reaction to the diseases were assessed in Ethiopia's natural environment. Since Ethiopia is a secondary center of genetic diversity in barley and consequently its pathogens, this assessment is certainly of interest in identifying new sources of resistance and using the identified genotypes in breeding. In addition, effect of the diseases on yield and yield components of food barley and the association between the parameters were studied. A simple lattice design was used for the field testing. Ten center rows (5 m^2) were assessed for grain yield, and the results were converted to t ha^{-1}. Eyal classes and Eyal and Brown reaction types were used to evaluate the reactions of barley genotypes in one year breeding scheme. The association between the independent and dependent variables was examined using Pearson correlation in ellipses predictor. The Logistic and Gompertz models were employed to analyses disease rates. The maximum grain yield (6.7 t ha^{-1}) and lowest grain yield (1.7 t ha^{-1}) were recorded by genotypes HB#P356 and SARC#P42, respectively. Among evaluated genotypes, 21 % were susceptible, 44 % were moderately susceptible, 20 % were moderately resistant, and 15 % were resistant to leaf scald disease. Genotypes like HB#P1235, HB#P1244, HB#P1251, HB#P386 and the other 11 demonstrated resistance reactions to leaf scald disease. In reverse, the 17 genotypes, including HB#P394, SARC#P5, SARC#P29, and SARC#P12, were susceptible to scald disease. The reactions of genotypes to net form net blotch disease were as follows: 12 % were susceptible, 77 % were moderately susceptible, 8 % were moderately resistant, and 3 % were resistant. A few genotypes, including HB#P340, SARC#P10, and SARC#P14, were susceptible to net form net blotch. Genotypes, HB#P1319, HB#P825, and HB#P830, showed resistance to net form net blotch disease. Consequently, in later breeding schemes, these genotypes, which are resistant to leaf scald and net form net blotch, can be utilized as a parental genotype for crossing and variety development. Moreover, these genotypes can also be important as a genetic resource for future breeding and genetic research. Plant height and the severity of both diseases showed an adverse association ($r = -0.1$), suggesting that barley breeders should take these two factors into account when designing targeted their breeding program.

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1. Introduction

Two Hordeum subspecies can be distinguished from one another based on the shape of the spikes and the number of viable spikelets at each rachis node. In two-row barley (*Hordeum vulgare* subsp. *distichum*), only the central spikelet is fertile, while three viable spikelets are present in six-row barley (*Hordeum vulgare* subsp. vulgare, also known as *Hordeum hexastichum*) [1,2]. The hulled and naked forms within these two subspecies are distinguished by the adherence or lack of the protective membranes of the caryopses. These days, naked barley is grown less frequently and is mostly used as food for humans [3].

The world's leading barley producer is Russia. Russia produced 23. 4 million tons of barley as of 2022, or 15.10 % of the total amount produced. Australia accounts for 9.28 % of global barley production, making it the second-largest producer in the world with 14.4 million tons. The top three countries are France, Germany, and Canada, with 11.3 million tons, 11.2 million tons, and 10 million tons, respectively [4]. Global barley output was greater than 154.1 million tons on a cultivated area of 55.3 million hectares that remained mostly stable from 2000 to 2008. Recently, global barley production and productivity have exceeded 3.0 t ha^{-1} [5]. This suggests that average yields have increased, rather than arable land being extended. Among the principal grains, barley ranks fifth next to sorghum in Ethiopia in terms of area covered and production [6]. In Ethiopia's highlands, barley is a major crop, of which 2.1 million metric tons were obtained from 0.95 ha cultivated with a 2.2 t ha^{-1} yield recorded [7]. One of Ethiopia's most important barley-producing regions is Oromia, which has 0.5 million hectares under cultivation and a total yield of 2.4 t ha^{-1} [7].

Due to the fact that the world's population has more than doubled since 1961 and is predicted to triple to nine billion people by 2050 [8], the average amount of barley produced worldwide has increased from 2.4 to 3.1 t ha^{-1} over the past 20 years (Supplementary Fig. 1). This indicates that the annual growth rate of barley output worldwide is less than 1 % [9]. Therefore, the international market would not have been able to meet demand over the previous 20 years. Moreover, the FAO estimates that over 800 million people globally suffer from malnutrition [8], indicating that hunger is still a major problem. While Gilland [10] anticipated that the average yield of major cereals in 2050 must be better than 5t ha^{-1} in order to ensure existing world food security, but the yields in the country and Oromia region, are lower than the global averages of 3.16 t ha^{-1} [8]. Therefore, in order to boost global food production, the gap between farmer yield and feasible yield needs to be narrowed as soon as possible. The best approach to accomplishing this goal is currently believed to be the development of cultivars with higher resistance to biotic and abiotic stress in conjunction with improved management approaches [9]. The most significant biotic stresses are foliar diseases. Out of the forty barley diseases found in Ethiopia, the most common and extensive ones are leaf scald (*Rhynchosporium graminicola* Heinsen ex A.B. Frank) [11] and net form net blotch (*Pyrenophora. teres* f. *teres*) [12]. Several investigations have indicated that *R. graminicola* and *P. teres* f. *teres* persists as mycelium in barley waste from season to season [13]. Then, *R. graminicola* and *P. teres* f. *teres* attributes in yield losses ranging from 10 % to 45 % [14] and 10–44 %, respectively. On susceptible barley cultivars, losses of almost 100 % are possible due to *R. graminicola* [15]. Moreover, economic yield is reduced as a result of poor grain quality for products like malting barley globally. *R. graminicola* infects millions of hectares of barley in the Far East, Yemen, Central Asia, West Asia, North Africa, and Andean countries (Peru, Colombia, Bolivia, and Ecuador) [16]. Both diseases are observed in Ethiopia during the cropping season in the highlands due to excessive precipitation and cold temperatures [17]. Thus, in a leaf scald-favorable season and on a susceptible cultivar, yield loss of up to 67 % has been seen; likewise, yield loss of up to 34 % has been reported due to net form net blotch.

This magnitude of yield loss demonstrates the significance of both diseases. Numerous studies showed that both diseases populations are becoming more diverse [18,19], which has a major effect on the barley production. Currently, control techniques are being employed to restrict the outbreaks of barley foliar diseases. These include genetic resistance through breeding, timing of fungicide application, dates of sowing, amount of N fertilizer, seed treatments, and crop rotations [20]. Knowing how host resistance selection affects pathogen population structure is essential for managing diseases through resistant cultivars and offers valuable insights into the dynamics of host-parasite co-evolution processes [14,21,22]. Scholars from several countries have examined the relationship between host resistance variability and pathogen variation in various diseases [23–26]. Resistant genotypes are particularly essential in terms of ecological and cost considerations in management practice. Subsequent research indicates that barley genotypes exhibit resistance to pathogens. Crop development programs must include the breeding of disease resistance. Because of this, breeders' main concerns are figuring out how to introduce new genetic variation and comprehend the genetic diversity that already exists in breeding populations. Then, resistance locus pyramiding, marker-aided back crossing, and marker assisted selection all depend on an understanding of quantitative trait loci (QTLs). There were QTLs, or marker trait correlations, indicating leaf scald resistance in every barley chromosome, except for of 5H [27–29]. According to research, barley possesses at least 11 genes that protect it from leaf scald [30]. Similarly, QTLs were found across all barley chromosomes for net form net blotch (NFNB) [31–33] and spot form net blotch (SFNB) [31,34]. Because they offer a steady supply of traits desired by breeders, such as genes for resistance or tolerances to significant abiotic and biotic stresses, genetic resources stored in gene banks, such as barley landraces and wild barley accessions, are therefore essential to genetic improvement efforts [35].

Ethiopian landrace groups have been frequently cited as a source of resistant genes for leaf scald and net blotch [33,36–38]. Arabi et al. [39] reported that net blotch partial resistance is also present in the Ethiopian line CI5791 and the Dutch cultivar "Banteng'' out of 180 landrace populations. They were retained as bulks and acquired from the Plant Genetic Resources Centre/Ethiopia PGRC/E [39]. Samples of these landrace were taken from the administrative regions of Shewa, Arsi, Bale, Gojjam, and Gonder, correspondingly, representing 70, 80, 17, 10, and 3 landrace populations. The populations with the highest resistance to leaf scald were 2(3285), 10 (3291), 20(1671), and 23 (3336). Additionally, Manninen et al. [33] discovered that Ethiopian line CI 9819 was resistant to spot form net blotch and net form net blotch. Daba et al. [38] assessed 234 barley genotypes during the seedling growth stage and 184 barley genotypes during the field screening phase for both diseases. They found that Ethiopian genotypes were immune to net blotch, 86 % of

landraces and 87 % of breeding genotypes were resistant to leaf scald. Bjørnstad et al. [40] found that two QTL at the chromosomes 3H and 7H controlled resistance to scald in the "Steudelli" and one QTL at 3H in the "Jet". Jalata et al. [41] found that HB#P1307 and HB#P42 had the highest combining ability for leaf scald and net blotch. Zeleke [42], reported that HB#P52 and HB#P533 showed the lowest net blotch severity. IBON 174/03 was resistant for net blotch, and HB#P120 resistant for leaf scald disease [43]. Cultivars Sabini, Grace, Bahati, HB#P120 showed the highest initial and final disease severity [44]. Houda et al. [45] found that the Focused Identification of Germplasm Strategy (FIGS) and Generation Challenge Program (GCP) subsets were able to identify sources of leaf scald resistance at both plant growth stages. Anil et al. [46] evaluated the barley collection and suggested 2.6 %, 29.5 %, 62.2 %, and 5.7 % genotypes were assigned to the resistant reaction class, moderately resistant reaction class, moderately susceptible reaction class, and susceptible reaction class, respectively.

A number of barley genotypes have been crossed and screened at the Holetta Agricultural Research Center, Ethiopia, in an effort to improve the morpho-agronomic and grain quality characteristics. In barley variety development, various breeding schemes are undertaken, starting from parental evaluation, selection for crossing, and segregating population evaluation. Based on parental performance assessment, crossing is designed to generate the first filial generation (F_1) of specific parental combinations and advance to the second filial generation (F_2) in the same season. Likewise, the F2 population is advanced into the F_3 generation and planted to multi-environments, subjecting the population to various stress factors. With mild negative selection, the F_3 population are advanced to F_4 generation where single plant selected to constitute F4:5L recombinant genotypes and evaluated as Preliminary Observation Nursery (PON). Thus, the best genotypes selected under PON will be advanced to Preliminary Variety Trail (PVT) and the best genotypes selected in PVT will be advanced to National Variety Trail (NVT) for multi-environment adaptation and stability test. Again, it is not much known about the reaction of commercial cultivars and released varieties. Once more, despite the efforts made and the barley genotypes that are currently present in the center a hot spot area it is unclear how they will respond to leaf scald and net blotch. Therefore, in the current investigation, the reaction of one hundred genotypes were assessed using Eyal classes and Eyal and Brown reaction types over the course of a year at a Preliminary Variety Trial.

2. Material and methods

2.1. Description of the study area

The current research was done at the Holetta Agricultural Research Center. It is located 38 km west of Addis Ababa, the capital city of Ethiopia. The Center is located at a latitude of $9^0$00'N and a longitude of $38^0$30'E, with an altitude of 2400m.a.s.l. The temperature at this location varies between 6^0C - 22^0C, with an annual average rainfall of 1144 mm. The soil type is classified as Eutric Nitisol with a pH of 4.92 (http://www.eiar.gov.et/holetta/).

Table 1
Lists of genotypes used for the study.

Genotypes	Genotypes	Genotypes	Genotypes
HB#P1002	HB#P1319	HB#P370	HB#P356
HB#P1006	HB#P1321	HB#P371	HB#P357
HB#P1016	HB#P1322	HB#P375	HB#P358
HB#P1138	HB#P1323	HB#P376	HB#P359
HB#P114	HB#P1325	HB#P377	HB#P382
HB#P115	HB#P1326	HB#P386	HB#P790
HB#P1174	HB#P1333	HB#P387	HB1966
HB#P1225	HB#P1334	HB#P394	SARC#P10
HB#P1226	HB#P1340	HB#P441	SARC#P11
HB#P1235	HB#P1341	HB#P643	SARC#P12
HB#P1243	HB#P1349	HB#P797	SARC#P14
HB#P1244	HB#P135	HB#P801	SARC#P15
HB#P1251	HB#P1355	HB#P802	SARC#P20
HB#P1265	HB#P1389	HB#P818	SARC#P24
HB#P1268	HB#P141	HB#P820	SARC#P28
HB#P1273	HB#P148	HB#P822	SARC#P29
HB#P1289	HB#P203	HB#P825	SARC#P31
HB#P1293	HB#P309	HB#P830	SARC#P32
HB#P1307	HB#P314	HB#P848	SARC#P4
HB#P1308	HB#P336	HB#P860	SARC#P42
HB#P1309	HB#P340	HB#P865	SARC#P5
HB#P131	HB#P344	HB#P866	SARC#P6
HB#P1316	HB#P345	HB#P868	SARC#P8
HB#P1317	HB#P357	HB#P870	SARC#P9
HB#P1318	HB#P359	HB#P338	Walashe

HB#P1318: HB= Holetta breed; P1318 = Plot number 1318. SARC#P9: SARC = Sinana Agricultural Research Center; P9=Plot number 9, Walashe = cultivar name. The names of some lines are similar, but they are different on their pedigree.

2.2. Plant materials

The current investigation used a set of 100 food barley genotypes. In the selection breeding scheme for the 2021 production year, they had completed segregation at their filial generation four. They were assessed at the PON breeding scheme throughout the 2022 production year. In the 2023 production year, they advanced from the PON breeding scheme to the NVT breeding scheme. The panel included check varieties and food barley genotypes (Table 1). The susceptible genotype HB#P1307 and the resistant cultivar Walashe were used as a control.

2.3. Experimental design

A simple lattice design was used to assess the reaction of one hundred genotypes. Ten blocks were used to accommodate these genotypes, and ten genotypes were grouped within each block. In a 2m plot length, the barley seed was planted in 12 rows, 0.2m apart. Plots were separated by 1m, and blocks were separated by 1.5m. In each 5 m^2 plot, 37.5g was sown and planting was carried out by hand drilling. Planting took place in the second week of June, during the course of the year trial. About 60.5 and 25.0 kg ha^{-1} for NPS and urea, respectively, were used to fertilize the plots. Plots were hand-weeded and treatments applied similarly to other agronomic procedures.

2.4. Data collection

Based on diseases on set, the assessments for leaf scald and net form net blotch were started. In order to study the diseases' progression, the diseases were scored five times over the course of ten days. Since it is difficult to assess disease from dead leaves, the disease was assessed from the top four leaves during the soft to mid-dough growth stages to examine the representative of barley genotypes [47]. This growth stage was the third data scoring season in our experiment, and it occurred 85 days after planting. For this investigation, the disease severity was measured as the percentage of leaf area covered by necrosis [48]. Ten plants per plot were used to measure the plant height and the heigh to which disease occurs in order to calculate the leaf Scald Progress Coefficient (SPC) or Net form net blotch Progress Coefficient (NFNBPC).

2.5. Data analysis

The Eyal et al. [49] created the Septoria Progress Coefficient (SPC) and Percent Coverage of Disease (PCD) for wheat genotype's reaction determination. We substituted "Scald" or "Net blotch" for "Septoria" in the current research. Prior to determining the genotypes' reaction, the Scald Progress Coefficient (SPC) or Net Form Net Blotch Progress Coefficient (NFNBPC) was calculated using the following formula: SPC or NFNBPC equal to Plant Height (cm)/Disease Height (cm). Thus, using the Eyal et al. [49] classes and the Eyal and Brown [50] reaction types, the genotype reactions were established with few modifications.

R - PCD less than 15 %, SPC or (NFNBPC) less than 0.40.

MR - PCD less than 15 %, SPC or (NFNBPC) = 0.40 to 0.65.

MS - PCD = 15–40 %, SPC or (NFNBPC) = 0.40 to 0.70.

S - PCD greater than 40 %, SPC or (NFNBPC) greater than 0.70.

Two models were used to determine the disease rate and to linearize the disease severity: the ln(y/(1-y) Logistic model was used to linearize the disease severity, and the -ln[-ln(y)] Gompertez model was also used to linearize the disease severity, where y represents the disease in ratio. Excel was used to create the graph and determine the slope of the disease increase using the linearized data. Using SAS statistical software version 9.3, the data were examined using parametric Pearson correlation analysis to verify the association between the dependent and independent variables. The significance threshold within the dependent and independent variables was examined using the 95 % and 99 % prediction ellipses. The area under the disease progress curve was also calculated using AUDPC = $\sum_{i=1}^{n-1} \frac{(y_i+y_i+1)}{2}*(t_i+1-t_i)$ formula. Where y_i is an assessment of disease at the *i* th observatuion, t_i is time at the *i* th observatuion, and *n* is the total number of observatuion.

3. Results

3.1. Reaction of the food barley genotypes to leaf scald and net form net blotch

The majority of food barley genotypes exhibited a moderate susceptible reaction to leaf scald and net form net blotch diseases. In terms of genotype resistance to leaf scald disease, out of 100, 21 % were susceptible, 44 % were moderately susceptible, 20 % were moderately resistant, and 15 % were resistant. Leaf scald disease resistance was demonstrated by genotypes like HB#P1235, HB#P1244, HB#P1251, and HB#P386 in addition to the other 11. Table 2 shows that 17 more individuals, including SARC#P5, SARC#P29, SARC#P12, and HB#P394, were susceptible to leaf scald disease. Additionally, 12 % genotypes were susceptible, 77 % genotypes were moderately susceptible, 8 % genotypes were moderately resistance, and 3 % genotypes were resistance reaction to net form net blotch disease and several genotypes, including HB#P1319, HB#P825, and HB#P830, were resistant to net form net blotch disease. Table 2 shows that certain genotypes, including SARC#P10, SARC#P14, and HB#P340, were susceptible to net form net blotch.

Table 2
Severity, reaction and (Mean ± Std) yield of barley genotypes.

Genotypes	SPCD (%)	SPC	RSD	NFNB PCD (%)	NFNBPC	RNFNBD	YLD (t ha^{-1})	Genotypes	SPCD (%)	SPC	RSD	NFNB PCD (%)	NFNBPC	RNFNBD	YLD (t ha^{-1})
HB#P1002	13.5	0.4	MR	30	0.61	MS	3.7 ± 0.7	HB#P370	13.5	0.43	MR	20.5	0.40	MS	3.5 ± 1.4
HB#P1006	21.5	0.44	MS	23.5	0.46	MS	2.7 ± 0.2	HB#P371	14.5	0.42	MR	20.5	0.43	MS	4.6 ± 0.8
HB#P1016	19	0.53	MS	26.5	0.67	MS	4.7 ± 0.1	HB#P375	14	0.19	R	24.5	0.56	MS	3.7 ± 0.5
HB#P1138	38.5	0.6	MS	32.5	0.60	MS	2.9 ± 0.1	HB#P376	13.5	0.48	MR	21	0.49	MS	5.1 ± 1.7
HB#P114	43.5	0.75	S	20	0.68	MS	2 ± 0	HB#P377	14	0.17	R	20	0.39	MS	3.5 ± 0.6
HB#P115	31	0.56	MS	20	0.56	MS	5.4 ± 1.5	HB#P386	12	0.24	R	18	0.41	MS	3.9 ± 1.4
HB#P1174	52.5	0.78	S	20.5	0.56	MS	4.2 ± 0.4	HB#P387	14.5	0.41	MR	42	0.71	S	2.9 ± 2.4
HB#P1225	14	0.21	R	23.5	0.55	MS	3.8 ± 0.7	HB#P394	70	0.81	S	12.5	0.41	MR	4.5 ± 1.7
HB#P1226	13	0.41	MR	20	0.42	MS	4.5 ± 0.4	HB#P441	20.5	0.49	MS	20.5	0.49	MS	4.3 ± 0.1
HB#P1235	14	0.22	R	17	0.33	MR	3.4 ± 1	HB#P643	17	0.44	MS	41	0.73	S	4.9 ± 0
HB#P1243	14	0.41	MR	29	0.62	MS	3.6 ± 0.2	HB#P797	42.5	0.71	S	20	0.43	MS	5.6 ± 0.1
HB#P1244	13.5	0.21	R	17	0.31	MR	3.5 ± 0.2	HB#P801	44.5	0.77	S	14	0.41	MR	5 ± 0.4
HB#P1251	14	0.19	R	19	0.42	MS	3.7 ± 0.1	HB#P802	21	0.46	MS	21	0.44	MS	4.5 ± 0
HB#P1265	35	0.61	MS	25	0.57	MS	4.4 ± 1.5	HB#P818	26	0.55	MS	21.5	0.47	MS	4.6 ± 0.1
HB#P1268	26	0.52	MS	41.5	0.76	S	4.2 ± 1	HB#P820	21.5	0.52	MS	17.5	0.42	MS	5.2 ± 1.4
HB#P1273	50	0.74	S	23	0.41	MS	3.5 ± 2.5	HB#P822	26	0.65	MS	20	0.51	MS	5.1 ± 0.5
HB#P1289	51.5	0.72	S	21	0.59	MS	4.8 ± 0.4	HB#P825	37	0.57	MS	13.5	0.32	R	4.3 ± 0.6
HB#P1293	28.5	0.52	MS	20	0.46	MS	5.6 ± 0.1	HB#P830	14.5	0.24	R	14	0.26	R	4.1 ± 1
HB#P1307	35	0.77	S	19	0.48	MS	5.5 ± 0.8	HB#P848	31	0.56	MS	20.5	0.42	MS	4.4 ± 0.5
HB#P1308	23	0.42	MS	22	0.42	MS	3.2 ± 1.3	HB#P860	27.5	0.50	MS	20.5	0.45	MS	3.8 ± 0.2
HB#P1309	42.5	0.46	MS	20	0.46	MS	3.6 ± 0.3	HB#P865	21.5	0.61	MS	14	0.41	MR	4.4 ± 0.4
HB#P131	26.5	0.56	MS	19.5	0.47	MS	4 ± 1	HB#P866	19.5	0.52	MS	19.5	0.52	MS	3.9 ± 0.4
HB#P1316	13.5	0.41	MR	19.5	0.52	MS	5.2 ± 0.6	HB#P868	28	0.59	MS	22	0.41	MS	3.8 ± 0
HB#P1317	13.5	0.24	R	23.5	0.55	MS	4.7 ± 1.2	HB#P870	44	0.72	S	19	0.41	MS	5.2 ± 0.6
HB#P1318	24.5	0.58	MS	30	0.61	MS	5.4 ± 0.1	HB#P338	13.5	0.41	MR	32	0.61	MS	4 ± 0.4
HB#P1319	24	0.48	MS	14.5	0.20	R	4.3 ± 1.3	HB#P356	14	0.19	R	19	0.43	MS	6.7 ± 0.2
HB#P1321	20.5	0.42	MS	20.5	0.42	MS	3.9 ± 1.3	HB#P357	13	0.24	R	21	0.53	MS	4.2 ± 0.6
HB#P1322	27.5	0.66	MS	19	0.45	MS	4.5 ± 0.5	HB#P358	13.5	0.2	R	24	0.49	MS	4.7 ± 0.2
HB#P1323	26	0.41	MS	20.5	0.41	MS	3.9 ± 0.7	HB#P359	14	0.42	MR	18.5	0.41	MS	4.3 ± 1.3
HB#P1325	14	0.41	MR	23	0.51	MS	2.8 ± 0	HB#P382	13.5	0.23	R	20.5	0.51	MS	2.8 ± 0.4
HB#P1326	40	0.52	MS	14.5	0.38	S	5.7 ± 1	HB#P790	25	0.65	MS	17.5	0.48	MS	4.1 ± 0.9
HB#P1333	14	0.41	MR	24	0.44	MS	4.5 ± 0.2	HB1966	23.5	0.56	MS	21.5	0.56	MS	3.7 ± 0.7
HB#P1334	28.5	0.43	MS	26	0.47	MS	3.5 ± 1	SARC#P10	22.5	0.62	MS	42.5	0.84	S	2.5 ± 0.8
HB#P1340	14.5	0.41	MR	14.5	0.41	MR	3.2 ± 0.1	SARC#P11	42.5	0.77	S	24	0.49	MS	2.9 ± 1.2
HB#P1341	17.5	0.4	MR	28.5	0.51	MS	5 ± 0.7	SARC#P12	60	0.81	S	41.5	0.85	S	3.6 ± 0.4
HB#P1349	21.5	0.58	MS	18.5	0.43	MS	3.1 ± 1.3	SARC#P14	46.5	0.81	S	40.5	0.86	S	2.7 ± 0.3
HB#P135	33.5	0.57	MS	22.5	0.48	MS	5 ± 0.5	SARC#P15	16.5	0.41	MR	18.5	0.41	MS	4.4 ± 0.3
HB#P1355	21	0.57	MS	21.5	0.57	MS	3.6 ± 0.4	SARC#P20	28.5	0.62	MS	26	0.62	MS	2.7 ± 0.1
HB#P1389	17.5	0.43	MS	42	0.62	MS	3.7 ± 1.4	SARC#P24	50	0.80	S	19	0.69	MS	2 ± 0.3

(*continued on next page*)

Table 2 (*continued*)

Genotypes	SPCD (%)	SPC	RSD	NFNB PCD (%)	NFNBPC	RNFNBD	YLD (t ha^{-1})	Genotypes	SPCD (%)	SPC	RSD	NFNB PCD (%)	NFNBPC	RNFNBD	YLD (t ha^{-1})
HB#P141	39	0.59	MS	24.5	0.55	MS	2.5 ± 0.2	SARC#P28	20	0.44	MS	20.5	0.41	MS	2.8 ± 0.5
HB#P148	50	0.72	S	17	0.37	MS	2 ± 0.5	SARC#P29	76	0.84	S	16	0.42	MS	2.9 ± 0.9
HB#P203	19.5	0.47	MS	24.5	0.49	MS	3.7 ± 0.1	SARC#P31	65	0.73	S	18	0.59	MS	3 ± 0.6
HB#P309	33	0.61	MS	22	0.61	MS	3.6 ± 0.5	SARC#P32	17.5	0.49	MS	22.5	0.51	MS	2.7 ± 0.7
HB#P314	62.5	0.89	S	41	0.76	S	3.9 ± 0.5	SARC#P4	90	0.85	S	12	0.44	MR	2.3 ± 0.7
HB#P336	14	0.24	R	21	0.45	MS	2.9 ± 1.3	SARC#P42	24	0.54	MS	31.5	0.54	MS	1.7 ± 0.4
HB#P340	14.5	0.41	MR	42	0.81	S	4 ± 0.6	SARC#P5	82.5	0.86	S	40.5	0.79	S	2.5 ± 0.9
HB#P344	21	0.59	MS	21	0.53	MS	3.4 ± 1	SARC#P6	14.5	0.41	MR	24	0.44	S	4.8 ± 0.7
HB#P345	12	0.24	R	21.5	0.55	MS	4.3 ± 1	SARC#P8	56.5	0.73	S	14	0.44	MR	2.9 ± 0.2
HB#P357	14.5	0.42	MR	22	0.41	MS	4.8 ± 0.3	SARC#P9	52.5	0.84	S	41	0.80	S	3.1 ± 0.1
HB#P359	14.5	0.42	MR	20.5	0.44	MS	4.7 ± 0.9	Walashe	15.5	0.41	MR	20	0.42	MS	3.3 ± 2.4

SPC = Leaf scald Progress Coefficient, SPCD = Leaf scald percent coverage of disease, RSD = Reaction to leaf scald disease, NFNBPCD=Net form net blotch percent coverage of disease, NFNBPC=Net form net blotch Progress Coefficient, RNFNB= Reaction to Net form net blotch, YLD (t ha^{-1}) = Yield in tons per hectare.

3.2. Area under disease progress curve (AUDPC) of food barley genotypes

The lowest leaf scald disease, AUDPC was scored on some genotypes in the current study. Among the evaluated 100 genotypes, the highly resistant genotype HB#P386 had the lowest (443) AUDPC value, followed by the (448) AUDPC value recorded from the genotype HB#P1244 (Table 3). In contrast, the highly susceptible genotype SARC#P5 had the highest (2651) AUDPC value, followed by 2585 and 2565, respectively, from the genotype SARC#P29 and HB#P394 (Table 3). Also, the lowest net form net blotch disease AUDPC was scored on some genotypes. The genotype HB#P1334, which is considered moderately susceptible, had the lowest (221) AUDPC. Once more, the moderately resistant genotype SARC#P4 had score (425) AUDPC. The other resistant genotype HB#P1319, had the AUDPC score of 493. On the susceptible genotype SARC#P10, the maximum (1438) AUDPC was recorded. Once more, on the susceptible genotype SARC#P14, (1341) AUDPC was scored. Additionally, on the moderately susceptible genotype HB#P1389, (1294) AUDPC was scored (Table 3).

Table 3
(Mean ± Std) of area under disease progress curve, and disease rate in Logistic and Gombertez models of food barley genotypes.

Genotypes	AS	RL	RG	ANFNB	RL	RG	Genotypes	AS	RL	RG	ANFNB	RL	RG
HB#P1002	608 ± 27	0.92	0.91	855 ± 37	0.52	0.51	HB#P370	513 ± 20	0.9	0.9	698 ± 14	0.8	0.8
HB#P1006	1280 ± 44	0.9	0.9	727 ± 35	0.8	0.82	HB#P371	554 ± 21	0.9	0.9	711 ± 18	0.2	0.2
HB#P1016	799 ± 22	0.4	0.4	889 ± 16	0.2	0.2	HB#P375	547 ± 19	0.9	0.9	754 ± 13	0.2	0.15
HB#P1138	1168 ± 68	0.8	0.83	1139 ± 25	0.9	0.9	HB#P376	630 ± 54	0.93	0.9	713 ± 26	0.55	0.55
HB#P114	1647 ± 97	0.96	0.96	635 ± 27	0.74	0.75	HB#P377	459 ± 13	0.8	0.8	684 ± 27	0.8	0.8
HB#P115	1310 ± 74	0.37	0.38	702 ± 11	0.62	0.62	HB#P386	443 ± 15	0.85	0.84	603 ± 22	0.9	0.9
HB#P1174	2070 ± 77	0.84	0.86	731 ± 8	0.55	0.55	HB#P387	536 ± 20	0.9	0.9	1019 ± 17	0.25	0.25
HB#P1225	529 ± 15	0.8	0.8	713 ± 14	0.36	0.35	HB#P394	2565 ± 98	0.94	0.94	470 ± 14	0.95	0.95
HB#P1226	504 ± 21	0.8	0.8	644 ± 25	0.7	0.7	HB#P441	662 ± 25	0.8	0.8	772 ± 11	0.65	0.64
HB#P1235	468 ± 11	0.8	0.8	666 ± 9	0.25	0.25	HB#P643	581 ± 16	0.85	0.9	1082 ± 43	0.35	0.36
HB#P1243	647 ± 26	0.9	0.9	1035 ± 19	0.84	0.83	HB#P797	1400 ± 96	0.99	0.99	682 ± 17	0.92	0.92
HB#P1244	448 ± 11	0.8	0.8	572 ± 18	0.84	0.83	HB#P801	1600 ± 107	0.97	0.99	736 ± 30	0.6	0.6
HB#P1251	449 ± 12	0.9	0.9	659 ± 7	0.65	0.65	HB#P802	657 ± 34	0.82	0.82	725 ± 9	0.92	0.92
HB#P1265	1139 ± 57	0.92	0.93	734 ± 29	0.7	0.7	HB#P818	947 ± 56	0.82	0.8	738 ± 16	0.6	0.6
HB#P1268	983 ± 13	0.6	0.6	1295 ± 33	0.8	0.8	HB#P820	641 ± 34	0.7	0.7	601 ± 14	0.55	0.56
HB#P1273	1665 ± 84	0.93	0.93	815 ± 28	0.99	0.99	HB#P822	1073 ± 73	0.94	0.92	709 ± 8	0.1	0.1
HB#P1289	1926 ± 81	0.93	0.93	758 ± 43	0.9	0.9	HB#P825	1433 ± 114	0.9	0.9	648 ± 2	0.23	0.23
HB#P1293	839 ± 60	0.8	0.75	716 ± 6	0.5	0.5	HB#P830	522 ± 9	0.8	0.8	560 ± 6	0.5	0.5
HB#P1307	1159 ± 53	0.63	0.61	653 ± 18	0.9	0.9	HB#P848	1143 ± 70	0.94	0.97	810 ± 16	0.5	0.5
HB#P1308	797 ± 53	0.8	0.8	763 ± 29	0.65	0.63	HB#P860	968 ± 68	0.98	0.99	711 ± 18	0.7	0.72
HB#P1309	1465 ± 77	0.92	0.94	686 ± 21	0.96	0.96	HB#P865	835 ± 62	0.9	0.83	628 ± 12	0.05	0.05
HB#P131	1037 ± 75	0.8	0.73	592 ± 21	0.57	0.56	HB#P866	686 ± 53	0.98	0.97	713 ± 7	0.8	0.8
HB#P1316	475 ± 12	0.9	0.9	747 ± 20	0.34	0.36	HB#P868	941 ± 58	0.9	0.9	812 ± 6	0.12	0.12
HB#P1317	511 ± 13	0.9	0.93	1031 ± 26	0.03	0.03	HB#P870	1402 ± 53	0.96	0.95	704 ± 6	0.12	0.12
HB#P1318	869 ± 27	0.54	0.56	1078 ± 49	0.6	0.6	HB#P338	509 ± 4	0.44	0.44	1028 ± 22	0.75	0.75
HB#P1319	839 ± 51	0.82	0.8	493 ± 14	0.9	0.9	HB#P356	502 ± 21	0.92	0.92	686 ± 16	0.99	0.99
HB#P1321	760 ± 40	0.92	0.92	729 ± 12	0.9	0.9	HB#P357	479 ± 15	0.9	0.9	756 ± 8	0.36	0.37
HB#P1322	844 ± 76	0.9	0.9	644 ± 17	0.8	0.82	HB#P358	500 ± 11	0.84	0.84	749 ± 18	0.3	0.3
HB#P1323	959 ± 77	0.9	0.93	770 ± 8	0.65	0.65	HB#P359	560 ± 25.1	0.96	0.97	574 ± 18	0.6	0.6
HB#P1325	698 ± 30	0.9	0.9	713 ± 14	0.4	0.4	HB#P382	504 ± 26	0.93	0.9	632 ± 13	0.56	0.55
HB#P1326	1134 ± 90	0.85	0.85	569 ± 17	0.8	0.8	HB#P790	797 ± 49	0.85	0.86	684 ± 6	0	0
HB#P1333	578 ± 23	0.8	0.8	830 ± 24	0.96	0.96	HB1966	896 ± 77	0.9	0.9	860 ± 24	0.1	0.12
HB#P1334	1144 ± 74	0.99	0.99	221 ± 43	0.9	0.92	SARC#P10	828 ± 15	0	0	1438 ± 16	0.5	0.5
HB#P1340	592 ± 32	0.96	0.97	639 ± 12	0.9	0.9	SARC#P11	1510 ± 80	0.93	0.9	839 ± 11	0.4	0.4
HB#P1341	569 ± 23	0.9	0.9	956 ± 20	0.3	0.3	SARC#P12	2529 ± 110	0.83	0.83	1073 ± 36	0	0
HB#P1349	666 ± 44	0.84	0.85	628 ± 23	0.8	0.83	SARC#P14	1899 ± 139	0.97	0.95	1341 ± 26	0.26	0.24
HB#P135	1222 ± 63	0.97	0.96	680 ± 35	0.8	0.8	SARC#P15	540 ± 26	0.7	0.7	655 ± 10	0.13	0.13
HB#P1355	646 ± 32	0.83	0.84	729 ± 368	0.6	0.6	SARC#P20	990 ± 50	0.97	0.98	986 ± 7	0.14	0.12
HB#P1389	765 ± 12	0.9	0.9	1294 ± 35	0.57	0.57	SARC#P24	1958 ± 147	0.93	0.92	596 ± 18.1	0.2	0.2
HB#P141	1429 ± 73	0.94	0.93	761 ± 36	0.74	0.76	SARC#P28	673 ± 31	0.85	0.83	594 ± 27	0.8	0.8
HB#P148	1800 ± 102	0.9	0.84	578 ± 24	0.9	0.9	SARC#P29	2585 ± 82	0.93	0.94	569 ± 3	0.25	0.24
HB#P203	594 ± 34	0.85	0.85	734 ± 37	0.73	0.74	SARC#P31	2315 ± 151	0.94	0.93	635 ± 11	0.6	0.6
HB#P309	1163 ± 36	0.8	0.8	801 ± 12	0.54	0.54	SARC#P32	789 ± 86	0.8	0.7	860 ± 13	0.7	0.7
HB#P314	2435 ± 78	0.9	0.9	673 ± 18	0.7	0.7	SARC#P4	3173 ± 23	0.7	0.7	425 ± 6	0.82	0.83
HB#P336	504 ± 16	0.94	0.9.5	657 ± 9	0	0	SARC#P42	848 ± 43	0.4	0.44	1082 ± 97	0.96	0.97
HB#P340	549 ± 3	0.8	0.8	1136 ± 35	0	0	SARC#P5	2651 ± 134	0.7	0.73	846 ± 55	0.9	0.9
HB#P344	659 ± 24	0.73	0.72	565 ± 24	0.7	0.7	SARC#P6	1991 ± 57	0.8	0.74	1060 ± 34	0.8	0.8
HB#P345	488 ± 12	0.9	0.9	720 ± 13	0.63	0.63	SARC#P8	547 ± 23	0.9	0.9	749 ± 35	0.8	0.8
HB#P357	565 ± 31	0.9	0.9	747 ± 13	0.5	0.5	SARC#P9	572 ± 25.1	0.93	0.93	736 ± 21	0.8	0.8
HB#P359	578 ± 31	0.92	0.93	583 ± 29	0.7	0.7	Walashe	1962 ± 32	0.52	0.52	481 ± 12.1	0.9	0.9

AS = AUDPC for leaf scald, ANFNB = AUDPC for net form net blotch, R = square in Logistic model, R = square in Gombertez model.

3.3. Disease rate

The data gathered over a period of ten days were used to generate the disease progress curve. Based on the values of the Logistic and Gombertez models, a graph's linear form was created (Table 3). The resistant genotype showed the leaf scald severity fluctuation. The graph's sigmoidal form showed that the leaf scald growths either similarly or did not expand on resistant genotype HB#P1235. The graph's linear form demonstrated that when the number of days grew by 9 intervals, the scale rose by 0.02 values. After planting, from 81 days to 90 days, the leaf scald severity increases smoothly on the resistant genotype HB#P1244; however, following this time, it declined slowly (Fig. 1A). As the number of days rose by 9 intervals, the leaf scald severity increased by 0.1 values. The sigmoidal form of the graph indicated that, on the susceptible genotype SARC#P5, the leaf scald reduced after 71–80 days of planting, but it significantly rose after 80 days. Beginning 80 days after planting, the leaf scald was quite aggressive (Fig. 1D). On the highly susceptible genotype SARC#P5, the leaf scald severity increased by 0.5 as time increased by a 9-day interval. The susceptible genotype SARC#P29 had the highest leaf scald severity at the beginning and continued to increase up to 90 days after planting (Fig. 1C). On the susceptible genotype SARC#P29, the leaf scald severity increased by 0.3 as time increased by a 9-day interval.

The sigmoidal form of the graph indicated that the net form net blotch severity was increase in smooth manner start from 72 up to 90 days of planting on resistant genotype such as HB#P1319. The graph's linear form revealed that when the days rose by 9 intervals, the net form net blotch increased by 0.05 values (Fig. 2A). On the susceptible genotype SARC#P10, net form net blotch severity increased significantly between 72 and 81 days of planting, but it decreased significantly between 81 and 90 days of planting. As the number of days rose by 9 intervals, the disease rate increased by 0.1 (Fig. 2B). The susceptible genotype SARC#P14 had the highest net form net blotch severity for the first 72–81 days after planting, according to a sigmoidal graph (Fig. 2C). Once more, the net form net blotch severity significantly reduced between 81 and 90 days after planting. The net form net blotch severity increased by 0.14 rate as time increased by 9-day intervals.

3.4. Effect of leaf scald and net form net blotch diseases on yield and yield components of food barley and the association between the variables

Genotype HB#P356 had the best yield (6.7 t ha^{-1}), and it was resistant to leaf scald disease but moderately susceptible to net form net blotch. The moderately susceptible genotype to both diseases, HB#P1293, also had the second highest (5.6 t ha^{-1}) grain yield. Amazingly, the susceptible genotype to leaf scald, HB#P1307, had the highest yield output (5.5 t ha^{-1}). The genotype SARC#P42, which is moderately susceptible to both diseases, had the lowest grain production (1.7 t ha^{-1}) (Table 2). Days to maturity (Fig. 3B) and days to heading (Fig. 3A) showed a weakly negative correlation (−0.4) with leaf scald severity. Table 4 indicates a strong and

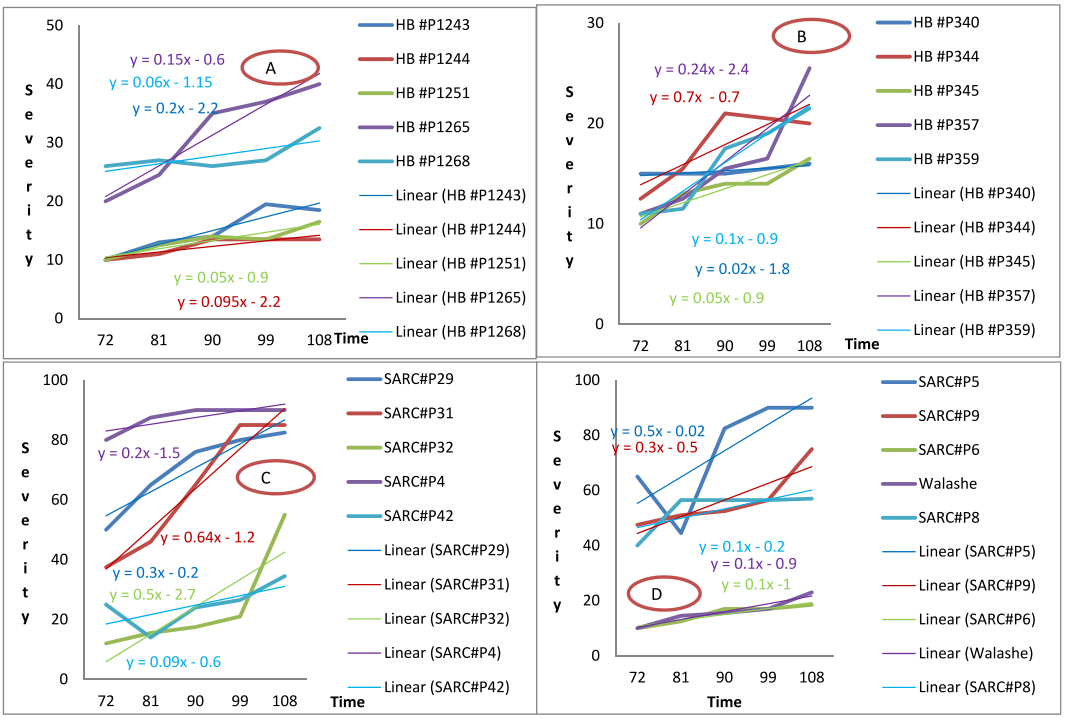

Fig. 1. Sigmodal and Linear forms of the leaf scald disease by using the Logistic and Gombertez models: the sigmodal graph and linear question designated by the same color are the same. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

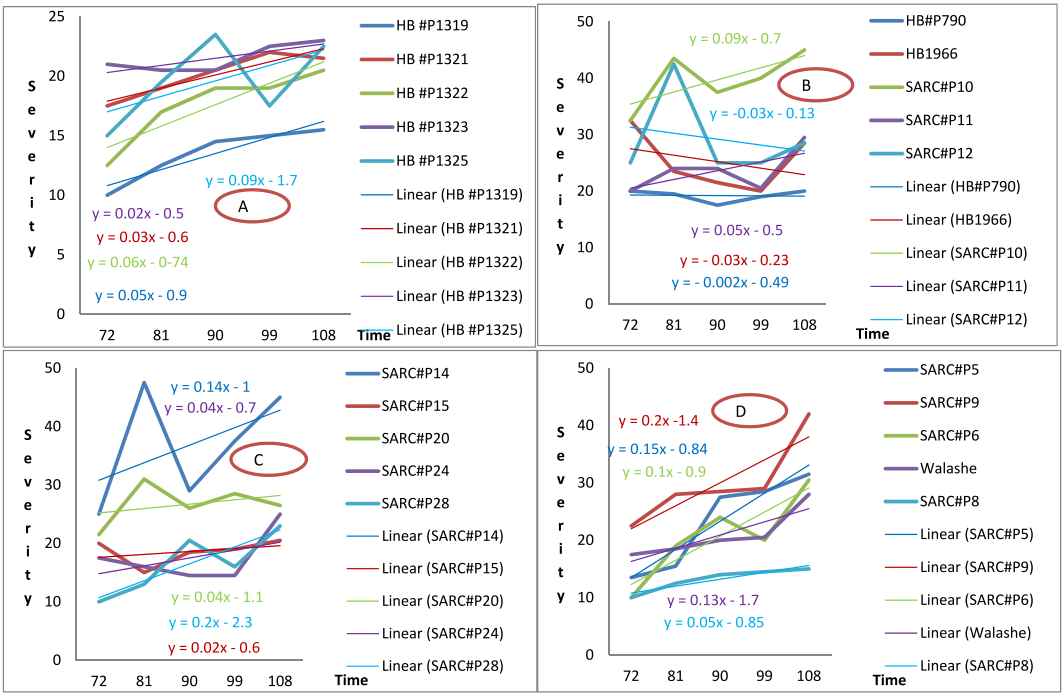

Fig. 2. Sigmodal and Linear forms of the net form net blotch disease by using the Logistic and Gombertez models: the sigmodal graph and linear question designated by the same color are the same. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

significant ($p < 0.001$) positive correlation (0.8) between the severity of leaf scald disease and disease height (upward movement) (Table 4). There was a significant ($p < 0.01$) association between the severity of net form net blotch disease and the days to heading and net form net blotch disease height (Table 4) (Fig. 4).

4. Discussion

Global barley crop is impacted by two major diseases: leaf scald [20] and net blotch. Therefore, one of the most important tactics for controlling and reducing the effects of these diseases is the development of resistant barley cultivars. However, the methods used for the determination of barley genotype reactions at the adult-growth stage are inadequate, with various methods being performed by several researchers [51–53]. Once more, it is unknown how to determine the varieties' reaction at the PVT stage in Ethiopia; yet, it is crucial to obtain several resistant varieties at this stage.

Eyal and Ziv [54] suggested that the genotypes reaction types can be affected by cultivars, plant stature, and maturity, so they should be adjusted. Therefore, they employed the Septoria Progress Coefficient (SPC) along with an assessment of disease severity to get around some of the challenges related to plant development habits (maturity and height) and the appearance of symptoms. The reaction class they proposed was based on SPC and PCD. Using the Eyal and Ziv [54] class method is crucial since it can minimize numerous components that impact barleys' reaction. However, these classes' types can't represent reaction categories. As a result, four reaction types were used in current investigation, which were based on the classes and reaction types proposed by Eyal et al. [49] and Eyal and Brown [50].

According to the Eyal and Brown [50] and Eyal et al. [49] classifications, genotype having PCD and SPC values greater than 40 % and 0.7, respectively, should be regarded as susceptible. Therefore, the reaction of genotype HB #P114 was categorized as susceptible because it had 43.5 % (SPCD) and 0.75 (SPC) values. The susceptible genotype SARC#P4 received a SPCD of 90 % and an SPC of 0.85, in which it had the maximum (3173) AUDPC score. The susceptible check HB#P1307 had 35 % (SPCD) and 0.77 (SPC). Jalata et al. [41] found that HB#P1307 had the highest combining ability for leaf scald and net blotch. In the current study, genotype HB#P1016 had 19 % (SPCD) and 0.53 % (SPC), and determined as a moderately susceptible, but it had medium (799) AUDPC. Eyal and Brown [50] and Eyal et al. [49] indicated that genotype has PCD less than 15 %, SPC = 0.40 to 0.65 is considered as a moderately resistant. In this study, the reaction category of cultivar Walashe was moderately resistant because it had a SPCD of 15 % and an SPC of 0.30, and lower (736) AUDPC. The genotype has PCD less than 15 %, SPC less than 0.40 is considered as a resistant [49,50]. The resistant genotype, such as HB#P345, had 14 % (SPCD) and 0.24 (SPC) values. Moreover, the genotype had a (488) AUDPC score. Additionally, the reaction of some genotypes to a net form net blotch was proposed. Genotype HB#P1438 reaction was classified as susceptible due to it had 42.5 % NFNBPCD and 0.84 NFNBPC values. It had a (828) AUDPC value. The genotype HB#P1319 had a (493) AUDPC score, in addition to 14.5 % (NFNBPCD) and 0.2 (NFNBPC) values. Few genotypes in the current study were resistant at the PVT, but most of

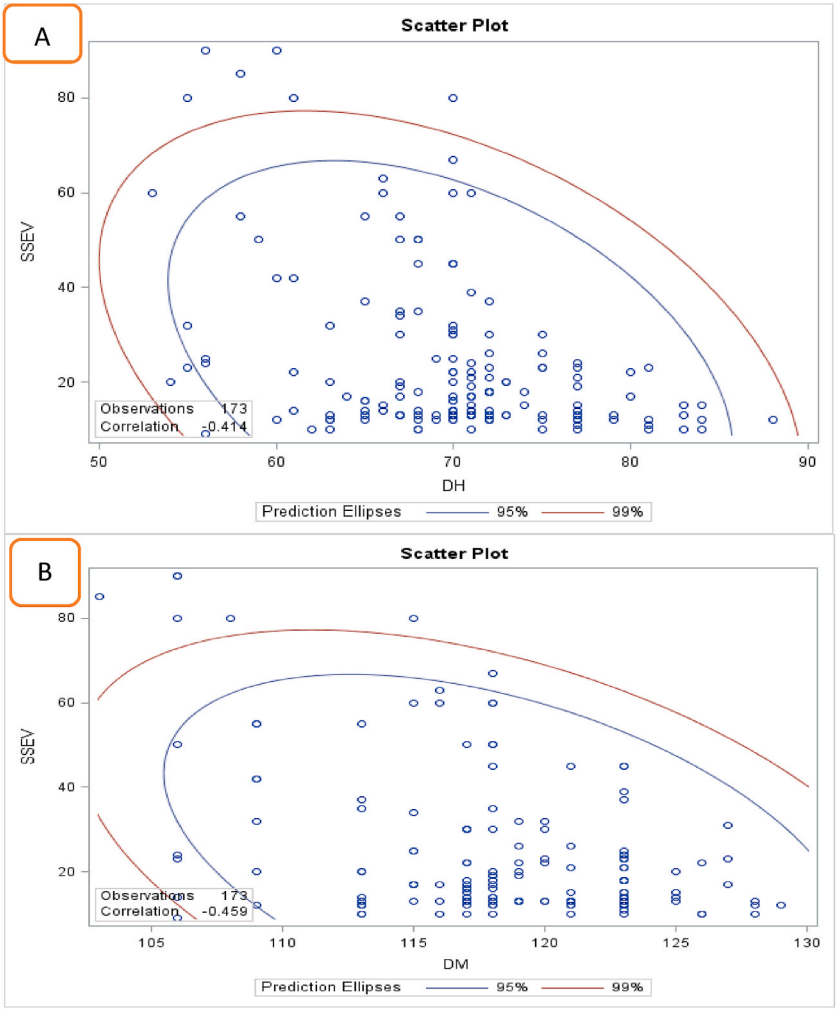

Fig. 3. Correlation of leaf scald disease severity with barley agronomic traits. Ssev = Leaf scald severity; DM = days to maturity; DH = days to heading.

Table 4
Correlation between the diseases and different agronomic traits during the 2023 production year.

	YLD	DH	DM	PH	SDH	SSEV	NFNBDH	NBS
Gyd	1	0.015Ns	−0.02Ns	0.7***	0.1Ns	−0.01Ns	0.015Ns	−0.1Ns
DH	0.015Ns	1	0.73***	0.03Ns	−0.2*	−0.4***	−0.02Ns	−0.3***
DM	−0.02Ns	0.73***	1	−0.04Ns	−0.2Ns	−0.4***	0.06Ns	−0.14Ns
PH	0.7***	0.03Ns	−0.04Ns	1	−0.1Ns	−0.11NS	−0.15Ns	−0.1Ns
SDH	0.1Ns	−0.2*	−0.2NS	−0.07Ns	1	0.8***	0.5***	−0.04Ns
SSEV	−0.01Ns	−0.4***	−0.4***	−0.11NS	0.8***	1	0.24*	−0.02Ns
NFNBDH	0.02Ns	−0.02Ns	0.06Ns	−0.15Ns	0.5***	0.24*	1	0.4***
NFNBS	−0.1Ns	−0.33***	−0.14Ns	−0.1Ns	−0.04Ns	−0.02Ns	0.4***	1

YLD = Grain yield; DH = Day to heading; DM = Day to maturity; PH= Plant Height; SDH = Leaf scald disease height; SSEV = Leaf Scald severity; NFNBDH=Net form net blotch disease height; NFNBS= Net form net blotch severity.

them were susceptible or moderately susceptible to both diseases.

In Ethiopia, the reaction of barley genotypes has been proposed in a number of reports [20]. Bjørnstad et al. [40] used quantitative trait loci to identify the chromosome number where resistant allele found for leaf scald disease. Therefore, they found that two QTL found at the 3H and 7H on the "Steudelli" and 3H on the "Jet". Jalata et al. [41] found that HB#P42 had the highest combining ability for leaf scald and net blotch. Zeleke [42], reported that HB#P52 and HB#P533 showed the lowest net blotch severity. IBON 174/03 was resistant for net blotch, and HB#P120 resistant for leaf scald disease [43]. Wondimu et al. [44] reported that Ibon, EH-1847,

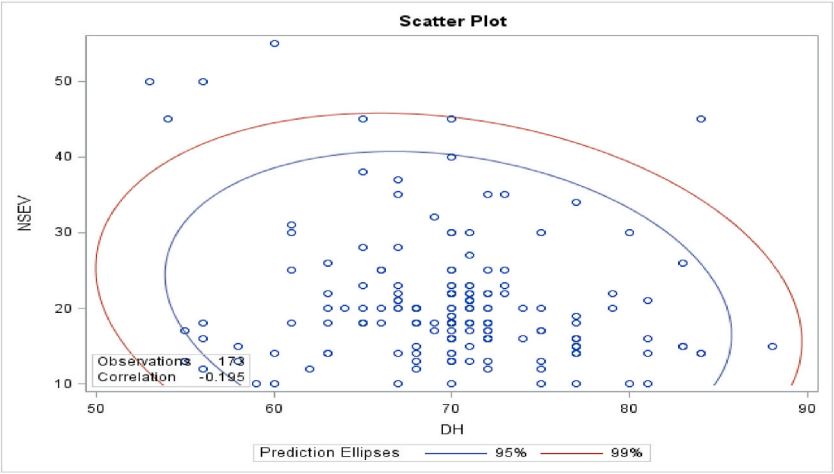

Fig. 4. Correlation of net form net blotch with barley agronomic traits. NFNBSev = net form net blotch severity; DH = days to heading.

Miscal-21, and Traveler had the lowest initial and final disease severity index. Houda et al. [45] also identified the reaction of two specific barley genetic resources subsets. In Ethiopia, Anil et al. [46] evaluated the barley collection and suggested 2.6 %, 29.5 %, 62.2 %, and 5.7 % genotypes were assigned to the resistant reaction class, moderately resistant reaction class, moderately susceptible reaction class, susceptible reaction class, respectively.

For this study, the Logistic regression model was selected over the Gombertez model due to its higher prediction. In other words, the Logistic or the Gombertez model that produced greatest r square value was selected. The linear form on the genotype SARC#P6, the Logistic and Gombertez models, had 0.8 and 0.74 r square value, respectively. Therefore, the Logistic model was selected for the genotype SARC#P6 to construct the linear form of the graph. The linear form and sigmoidal form of this genotype are indicated in Fig. 2D. The sigmoidal graph shows that the disease fluctuation was observed on the genotype SARC#P6. The graph shows that the disease increased from 72 to 90 days, decrease after 90–99 days, and again rose after 99 days of planting, whereas the linear form of the graph shows that the disease increased by 0.1 as time increased by 10 days.

The genotype HB#P345 was resistant, and the flow of the disease was very flexible. The linear form of the graph shows that the disease increased by 0.05 as time increased by 10 days (Fig. 1B). The up-and-down progress of the disease on the genotype HB#P345 was due to the reverse proportion of disease severity and plant height (Fig. 1B). As plant height increased, disease severity decreased. The disease's upward migration (first digit) is higher towards the top of the plant, while the disease severity (second digit) is lower [55]. The disease progress of HB#P345 was very high start from 72 to 90 days and similar after 99 and again increased after 99days (Fig. 1B).

Plant height/Disease height (Ph/Dh) is one of the complicated criteria that is often associated with field disease evaluation, along with wheat leaf blotch [56], spot blotch [57], glume blotch [58], and tan spot [59]. The current study concludes that there is a negative correlation between leaf scald and Ph/Dh is consistent with the overall tendency of late and tall genotypes to prevent infection. The present study found a negative link between plant height and the severity of both diseases. Moreover, the severity of both diseases was significantly lower at the bottom of plant height. The same with the result of current study, the inverse relationship between plant height and disease severity has been reported by several scholars. The correlation analysis, which revealed substantial negative relationships between the plant height and disease severity, found that only a little amount of height helped to lowering wheat leaf blotch infections [60]. Furthermore, Ben M'Barek et al. [53] proposed that the relationship between leaf scald disease and barley height is inverse.

Grain output is another difference between barley genotypes. The assessed genotypes' grain yields in the current study varied from 1.7 t ha^{-1} to 6.7 t ha^{-1}. The average grain yield for each variety varied from the lowest at 1.6 t ha^{-1} to the highest at 3.4 t ha^{-1}, as reported by Assefa et al. [61]. Strong negative correlations between wheat leaf blotch infection and yield may also be explained by the possibility that infection of the flag and second leaves during the grain-filing stage has a significant effect on photosynthesis and could reduce grain yield [62,63]. However, the current investigation was unable to identify a correlation between yield and the diseases severity. With the exception of a few genotypes, the disease severity was relatively low for the resistant genotypes at flag growth stages. Scholars showed that resistance in the adult stage was significantly impacted negatively by plant height [53,60].

The first three to four growing leaves are evenly spaced on both short and tall cultivars; on tall varieties, however, the distance between each leaf increases as it gets closer to the flag leaf. The gap of 70–90 cm between the upper and lower leaves of dwarf cultivars permits pycnidiospores to splash onto newly emerging leaves [64,65]. Research on wheat leaf blotch disease revealed that dwarf cultivars with higher plant parts are more prone to the disease than taller barley because they are closer to sources of inoculum. This facilitates the spread of disease from infected lower leaves. As a result, pycnidia appear earlier on the higher plant portions of dwarf cultivars than they do on the leaves of taller cultivars. Therefore, resistance and morphology-related genetic traits affect the severity and spread of wheat leaf blotch disease [65].

5. Conclusion

A significant foliar disease that impacts barley productivity globally are leaf scald and net blotch. It is very important to select the right method of disease reaction evaluation. It is possible to employ genotypes like HB#P1235, HB#P1244, HB#P1251, and HB#P386 for additional crossing because they demonstrated resistant reaction to scald disease. A barley breeder seeking net form net blotch resistant genotypes and higher yield variety can cross HB#P1319, HB#P825, and HB#P830. To control the severity of leaf scald, barley breeders should take plant height into consideration in addition to yield and yield-rated characteristics. According to recent studies, breeders may choose to use the most resistant and moderately resistant genotypes in their future breeding schemes.

CRediT authorship contribution statement

Girma Ababa: Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Wami Hailu:** Writing – review & editing, Writing – original draft. **Tigist Shiferaw:** Writing – review & editing, Writing – original draft. **Wondimu Fekadu:** Writing – review & editing, Writing – original draft. **Sentayehu Alamerew:** Writing – review & editing, Writing – original draft.

Data Availability

The data that support the findings of this study are available on request from the corresponding author.

Ethical statement

This study did not engage in any human or animal testing.

Source of fund

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e40529.

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