4.3 Response of genotypes across three treated locations

4.3.1 Combined analysis of variance

The analysis of variance for all agronomic traits is displayed in table 22. The ANOVA uses the F test to determine whether there exists a significant difference among treatment means or interactions. In this sense it is a preliminary test that informs breeder if he or she should continue the investigation of the data at hand. The combined analysis of variance for 14 traits across three locations indicated that there was significant ($p<0.001$) variation among locations, genotypes and their interaction for days to heading (DH), day to maturity (DM), scald, scald disease incidence (SDI%), plant height (PH), grain yield (GY), spike length (SL), seed per spike (SPS), and thousand seed weight (TSW). Spray treatment (management) on the other hand has been significantly different for traits such as scald disease, scald disease incidence, net-blotch, biological yield, grain yield, harvest index (HI%) and AUDPC. However it was non-significant for days to heading (DH), days to maturity (DM), plant height (PH), tillering capacity (TC), spike length (SL), seed per spike (SPS), and thousand seed weight (TSW). Furthermore, location by spray treatment (management) interaction had shown non-significant variation for most of the traits with the exception of scald, scald disease incidence, AUDPC and thousand seed weight. The study also revealed that there was no significant variation among spray treatment and genotypes interaction for all of the traits. Likewise, the interaction between location, spray treatment and genotypes yielded no significant variation for many of the traits with the exception of scald and scald disease incidence. Descriptive statistics was further run using Minitab (MinitabInc, 2010), for the sprayed and non-sprayed blocks. The mean, standard error, minimum and maximum values for individual sites are displayed in table 23 & 24. Additionally, broad sense heritability (H) was calculated based on entry mean across environments and individual plot basis for each trait (Table 22). Consequently, PH, SL and SPS had high heritability ($H>=0.70$). Further, DH, DM, Scald, SDI%, AUDPC, HI, TC and TSW had relatively intermediate inheritance ($H = 0.5$-0.67). NB, BY and GY on the other hand had small heritability ($H<0.45$) that is large portion of the variation has come from environment (Table 22). In summation, the heritability of most of the traits was high, at least in part due to the diversified genetic background in the BCC collection. More specifically, the broad-sense heritability estimates of scald disease (0.23 on individual plot basis and 0.61 on entry mean across environment) indicate that resistance is influenced largely by the genotype. Likewise, the broad-sense heritability estimates of heading days (0.30 on individual plot basis and 0.67 on entry mean across environment) pointed out that earliness is strongly influenced by genotype. Considering grain yield, there was variation among genotypes for the sprayed and non-sprayed blocks. G1 had the highest yield from the sprayed (4.89 tha^{-1}) and non-sprayed (5.01 tha^{-1}) blocks at Korem site. In a similar manner this genotype was also best performer at Debre Birhan (8.17 tha^{-1}) from the sprayed blocks and (7.76 tha^{-1}) from the non-sprayed blocks. In Istayish however the best performer in the sprayed block was G30 which has got an average yields of 4.68 t/ha. In the non-sprayed block on the other hand the best performer was G28 with average yield of 4.51 tha^{-1}. An average of 0.14, 0.48 and 0.27 tha^{-1} yield difference was observed between the sprayed and non-sprayed plots at Korem, Debre-Birhan and Istayish sites, respectively. However, in Mekelle, yield loss could not be estimated due to absence of sprayed block resulted from small quantity seeds during planting. These results signify that leaf scald had major contribution in the reduction of grain yield. It can also be confirmed this circumstances from the combined analysis of variance that there was significant variation (P<0.001) between genotypes in grain yield for sprayed and non-sprayed blocks (managements) (Table 22). On the contrary, there was no significant variation among genotypes in days to heading between the sprayed and non-sprayed plots. Related result has been reported by (Leur and Gebre, 2003) evaluated 13 farmer varieties for simple agronomic traits, as well as for resistance to scald. In their report they have find out that early maturing landraces collected from the same region have shown differences in heading date even though they are all susceptible to scald disease. Besides they have also observed high diversity levels for each trait differed between varieties, e.g. ‘Magie’ was highly variable in its reaction to scald infection, but not for heading date, while the opposite was found for varieties ‘Semereta’ and ‘Tolose’. Likewise analysis of variance for individual site had also indicated that there was no significant interaction of genotypes with the spray treatment (management) (Appendix, XVI, XVII, & XVIII). Additionally results obtained from the regression analysis has also shown that the contribution of scald to the variation in days to heading (R^2) among the non-sprayed block in Mekelle, Korem, Debre-Birhan and Istayish sites were 19.5%, 0.1%, 14.1%, and 22.3% respectively (Appendix I, III, V & XIV). More importantly this study have revealed that there was raw number confounding effect; most of the two row type barley genotypes were generally shown earliness in heading as compared to six rowed barley genotypes. Similar observation has been reported by (Tsehaye, Bjørnstad *et al*., 2012).

Table 22: Basic cross-location ANOVA for a trial involving 36 genotypes evaluated at 3 locations (Korem, Debre-Birhan and Istayish)

Sources of variations	DF	Mean square													
		DH	**DM**	**Scald**	**SDI %**	**AUDPC**	**NB**	**PH**	**BY**	**GY**	**HI %**	**TC**	**SL**	**SPS**	**TSW**
Loc	2	34077.02***	76194.32***	57234.1***	75812.30***	555324.00*	26508.40***	31290.83***	148.34*	409.43***	26902.87***	1601.78***	125.22***	10710.28***	9845.92***
Mgt	1	9.22^{ns}	175.06^{ns}	113697.14***	150599.06***	1013457.46^{ns}	34008.11***	780.27^{ns}	229.93***	6.76***	14965.34***	13.77^{ns}	5.79^{ns}	111.71^{ns}	190.30^{ns}
Loc x Mgt	2	18.81^{ns}	141.18^{ns}	5322.90*	13027.60**	398999.00*	1139.30^{ns}	582.29^{ns}	2.23^{ns}	0.56^{ns}	346.50^{ns}	22.57^{ns}	3.20^{ns}	69.82^{ns}	317.16*
Rep/(Loc*Mgt)	6	125.57***	111.12**	500.20*	510.20^{ns}	66900.00***	730.40*	566.14***	20.25***	4.13***	184.11*	28.80***	3.97**	238.15***	30.49**
Blocks/Rep/(L*M)	60	34.26^{ns}	66.14***	166.50^{ns}	226.20^{ns}	9210.00^{ns}	358.30^{ns}	85.6***	3.03*	0.58^{ns}	80.94^{ns}	6.59*	0.86^{ns}	46.93^{ns}	10.98^{ns}
Genotype	35	398.18***	417.32***	2098.29***	1805.44***	14655.90***	2480.49^{ns}	445.25***	5.39^{ns}	4.09**	345.45***	25.99***	7.31***	1045.64***	129.96***
Loc * Genotype	70	130.98***	140.04***	826.10***	824.40***	5982.00^{ns}	1893.50***	133.71***	4.73***	2.25***	139.86**	5.69^{ns}	2.09***	190.81***	42.89***
Mgt * Gen.	35	26.72^{ns}	33.44^{ns}	606.09^{ns}	493.00^{ns}	8250.03^{ns}	341.90^{ns}	35.87^{ns}	1.94^{ns}	0.53^{ns}	47.77^{ns}	2.87^{ns}	0.83^{ns}	59.07^{ns}	7.80^{ns}
Loc * Mgt * Gen	70	19.94^{ns}	30.68^{ns}	442.40***	394.40*	8871.00^{ns}	341.90^{ns}	44.84^{ns}	2.28^{ns}	0.56^{ns}	77.04^{ns}	3.38^{ns}	0.79^{ns}	66.37^{ns}	7.5^{ns}
Residual	150	20.99	29.87	195.1	251.5	7268	294.6	39.65	2.04	0.5	82.35	4.5	1	58.93	10.33
LEE		24.49	29.64803	-	-	-	334.89	-	-	-	-	-	-	-	-
Total	431														
VC_G		22.27	23.11	106.02	81.75	722.83	48.92	25.96	0.05	0.15	17.13	0.38	0.44	71.24	7.26
H_{GME}		0.67	0.66	0.61	0.54	0.6	0.24	0.7	0.12	0.45	0.6	0.45	0.71	0.82	0.67
H_{ipb}		0.3	0.29	0.23	0.17	0.09	0.06	0.29	0.02	0.14	0.15	0.07	0.26	0.44	0.28

DF= degree freedom, ^{ns} = non-significant at p=0.05, *significant at p<0.05, **significant at p<0.01, ***significant at p<0.001

VC_G=genotypic variance component : $\sigma^2G = (Gms - \sigma^2e)/12$

H_{GME}=Heritability based on genotype mean across environments: $\delta^2_g/(\delta^2_g+(\delta^2_{GxE})/r+ (\delta^2e)/r*l*m) = \delta^2/(\delta^2+(\delta^2_{gxe})/3+ (\delta^2_e)/12)$

H_{ipb}=Heritability on individual plot basis: $\delta^2_g/(\delta^2_g+\delta^2_{GxE}+ \delta^2_e)$

Table 23: Performance of key agronomic parameters in barley genotypes tested at Mekelle and Korem locations in northern part of Ethiopia during 2012.

Variable	**Mekelle**				**Korem**							
	Non-sprayed				Sprayed				Non-sprayed			
	Mean	SE mean	Min	Max	Mean	SE mean	Min	Max	Mean	SE mean	Min.	Max.
DH	67.17	2.36	45.62	92.53	72.04	1.83	51.77	97.34	72.78	1.98	49.71	98.25
DM	98.81	1.20	88.80	117.57	104.92	2.10	85.21	135.47	105.36	2.22	82.34	130.43
Scald	9.88	2.77	-6.63	66.57	1.02	0.61	-0.10	15.50	22.36	2.86	-2.33	69.98
SDI %	6.86	2.29	-7.72	57.08	1.93	1.02	-2.92	22.46	29.28	2.74	-3.36	61.76
AUDPC	47.50	11.00	0.00	305.00	0.00	0.00	0.00	0.00	114.30	13.70	0.00	317.50
NB	27.10	2.26	-1.95	54.31	0.88	1.05	-6.76	30.75	24.15	2.13	-2.83	51.13
PH(cm)	73.48	1.41	53.78	90.80	83.02	1.39	65.24	96.24	88.21	1.46	68.39	104.56
BY (t/ha)	6.55	0.38	2.33	12.00	7.52	0.18	5.55	9.88	8.52	0.16	6.11	10.78
GY (t/ha)	1.46	0.11	0.36	2.63	3.49	0.12	2.23	4.93	3.36	0.13	1.84	4.74
HI %	22.01	0.94	9.65	32.38	47.98	1.42	28.99	68.64	39.10	1.07	24.27	49.23
TC	4.68	0.20	2.64	9.68	4.35	0.22	1.93	8.58	4.85	0.24	3.08	9.98
SL	6.47	0.19	3.65	9.08	5.37	0.14	4.10	7.24	5.88	0.14	4.64	7.73
SPS	35.55	1.94	14.94	57.46	31.20	1.54	16.05	50.11	31.01	1.30	16.78	42.50
TSW	42.52	1.26	27.20	56.81	52.06	0.79	38.00	63.01	51.66	0.90	37.31	65.12

Table 24: Performance of key agronomic parameters in barley genotypes tested at Debre-Birhan and Istayish locations in northern part of Ethiopia during 2012.

Variable	Debre-Birhan								Istayish							
	Sprayed				**Non-sprayed**				**Sprayed**				**Non-sprayed**			
	Mean	SEM	Min	Max	Mean	SEM	Min.	Max.	Mean	SEM	Min.	Max.	Mean	SEM	Min.	Max.
DH	80.60	0.43	76.50	86.04	81.36	0.58	76.92	89.77	102.48	1.01	95.07	119.53	102.24	0.94	93.89	117.52
DM	133.96	0.73	125.94	142.21	132.00	0.54	126.50	139.00	151.25	1.05	141.13	169.58	150.40	1.08	136.52	163.91
SDS%	26.59	3.99	-3.60	81.79	72.30	4.71	-0.95	94.45	4.09	0.73	-1.14	11.58	34.65	3.39	-0.62	71.86
SDI %	27.02	4.03	-8.36	79.96	86.41	4.75	-2.87	102.97	5.96	1.06	-2.14	27.50	31.30	3.18	3.09	68.78
AUDPC	77.80	11.20	0.00	242.00	272.10	17.00	12.40	445.00	20.96	4.14	0.00	80.50	143.50	11.20	30.00	305.00
NB	32.29	5.33	-5.51	83.45	43.79	6.82	-23.78	101.58	9.74	2.82	-6.34	61.18	29.79	3.84	0.06	78.17
PH	104.82	1.44	86.47	118.91	107.79	1.69	87.67	127.39	78.16	1.13	61.58	89.50	76.50	1.31	58.11	92.15
BY (t/ha)	9.28	0.25	6.31	12.62	10.90	0.31	6.66	14.87	8.17	0.21	5.91	11.50	9.73	0.17	7.51	12.29
GY (t/ha)	6.52	0.19	3.55	8.96	6.04	0.19	3.03	7.83	3.50	2.08	2.08	4.62	3.23	0.12	1.91	4.67
HI %	71.69	1.81	46.73	101.50	56.73	1.42	31.47	69.50	44.23	1.60	22.35	63.39	32.69	0.86	21.29	43.07
TC	11.47	0.51	5.16	18.66	11.03		6.60	16.57	7.03	0.30	3.87	11.10	8.00	0.37	4.67	13.14
SL	7.53	0.17	5.35	9.94	7.45	0.14	5.92	9.54	6.55	0.15	4.86	8.75	6.65	0.31	4.21	14.96
SPS	47.24	2.24	22.01	69.88	47.86	2.36	22.32	67.31	33.43	1.45	20.35	55.70	35.86	1.34	18.61	56.47
TSW	42.18	0.69	33.37	48.85	37.56	0.78	27.62	47.00	35.66	0.48	30.23	42.16	36.64	0.47	29.85	42.67

4.4 Response of genotypes in single-sites

4.4.1. Responses of genotypes to the non-sprayed fields at Mekelle site

In Mekell, genotypes were evaluated from the non-sprayed block only due to limited amount of seed during sowing. No spray was made in this location. Analysis of variance for this site revealed that genotypes were significantly ($p<0.001$) different for all traits measured except for scald, SDI%, AUDPC, net-blotch and biological yield (Appendix XV).

Days to heading

Considering mean performance of the genotypes, days to 50% heading ranged from 46 to 93 with average score of 69 days and standard error of 2.36 (Table 22). Genotype 36 displayed shortest days to heading (45 days) followed by G34 [50days] and G32 [52days]. On the contrary, G21 took longer days (93 days) to reach 50% heading followed by G4, G12 and G13 with 92 days. G4 was initially characterized as early in 2004 growing season at Debre-Birhan but it turned out to be late in the 2012 growing season. This could be associated with incorrect data recording. In general, thirty genotypes were found with days to heading less than 79 (Appendix XVIII). Based on regression analysis (Figure 16), the relationship between days to heading and scald disease was significant negative ($P<0.05$). Only G31 had a score greater than 60% which is considered as susceptible and the others were not. So it is difficult to compare performance difference among genotypes in this site due to little amount of disease severity.

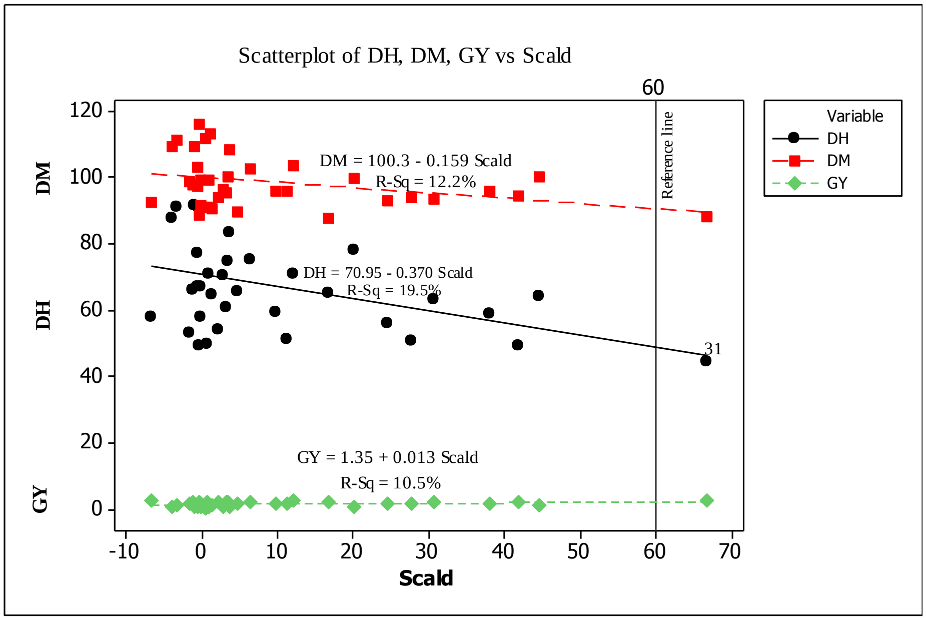

Figure 16: Scatterplot with regression for DH, DM and GY(t/ha) vs. Scald disease in the non-sprayed blocks in Mekelle

Days to maturity

Days to maturity ranged from 89 to 118 days with an average of 103 days and standard error of 1.2. Days to maturity had significant negative relationship (P=0.037) with scald disease (Figure 16). Although only one genotype was found to have severity percent greater than 60 (susceptible), considerable numbers of early maturing genotypes had higher severity percent on average than the later maturing ones. None of the ones maturing in more than 100 days had scald above 20, and none of the ones heading later than 70 days had scald above 20, clearly indicate that scald disease severity was higher on early heading and maturing genotypes than late ones.

Scald disease

The rate of scald disease severity level for Mekelle site was small as compared to Debre-Birhan and Istayish. It ranged from 0 to 66.6 with average score of 12.11. This location is characterized by hot and erratic rainfall distribution; secondary spread of the pathogen might have been influenced. Only genotype 31 was found to be highly susceptible in this site. Similarly, the area under disease progress curve (AUDPC) ranged from 0 to 150 with an average of 39.50 and net-blotch severity percent ranged from 0 to 54.31 with average of 27.2. Both scald and net-blotch had less infection than what is often seen at higher altitudes and cooler temperatures.

Grain yield

Grain yield performance, ranged between 0.36 to 2.63 tha^{-1} with an average of 1.46 tha^{-1} and twenty one of the genotypes had a score above the average. G6, G9, G25, G26, G28, G29 and G31 were however found to be high performers in Mekelle. All are early type; this clearly indicates that in shorter growing season (drought prone areas) early maturing genotype that cannot grow long enough to achieve its full yield potential can give better yield than late maturing genotype. Considering the national mean grain yield, this result revealed that the national barley collection can contribute a lot to the food and feed security in vulnerable areas. Regression analysis in this site revealed that grain yield had no significant relationship with scald disease in this site, possibly because disease severity was mild.

4.4.2. Response of genotypes to the sprayed and non-sprayed fields at Korem site

Analysis of variance for this site revealed that spray treatment (management) was significantly different among genotypes for scald, SDI%, and AUDPC at $P<0.01$ and for NB and SL at $p<0.05$ (Appendix XVI). Genotypes were highly significantly different ($p<0.001$) for all parameters except for net-blotch. Moreover, the interaction of genotypes and spray treatment were found to be significant ($p<0.001$) only for DH, scald disease severity and AUDPC (Appendix XVI).

Days to heading

Days to 50% heading (flowering) in this site ranged from 52 to 97 with an average of 72 days in the sprayed block and 50 to 98 days with an average of 73 days in the non-sprayed block (table 23). Though the average difference between sprayed and non-sprayed block was 1 day, from the analysis of variance it was not significant. In all, 28 genotypes were found to be early heading (<79 days).

Days to maturity

Days to maturity on the other hand ranged between 85 and 136 with average score of 105 in the sprayed block. In the non-sprayed block the range was between 82 and 130 with average score of 105. Accordingly, G2, G5, G9, G10, G17, G20, G22, G26, G27, G29, G32, G34 and G36 were found to be early maturing (<100 days) based only on the sprayed block only in order to avoid bias.

Scald disease

Scald disease severity level ranged from -0.10 to 15.5 percent with average score of 1.02 % in the sprayed block. In the non-sprayed block conversely the range was from -2.3 to 70.0 percent with average score of 22.4%. So in this site only G22 was found to be highly infected. Generally, the severity level in this site was mild due probably to lack of enough sources of inoculums in the area. Besides, regression analysis (Figure 17) revealed that the relationship between days to heading (DH) and scald in both the sprayed as well as the non-sprayed blocks were non-significant. Even though the relationships in all cases appeared to be negative (Figure 15), the amount of disease was very small to cause real differences in heading, maturation and other traits. This could be associated with little inoculums in the site and/or little stubble remained from previous cropping season. Additionally, the experimental site was bordered by a wheat trial, which is non-host for barley scald disease, might have hindered the movement of the pathogen.

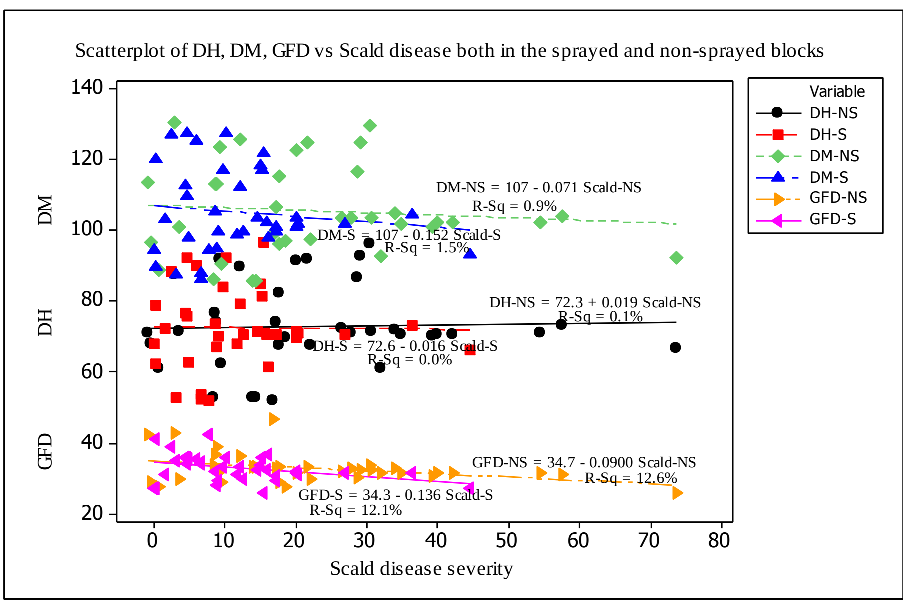

Figure 17: Scatterplot with regression for DH, DM and GFD vs. Scald disease both in the sprayed and non-sprayed blocks in Korem

Further, difference in days to heading between sprayed and non-sprayed (DHDiff) fields was also regressed against the difference in scald disease between sprayed and non-sprayed fields (NS-S). Consequently, the regression analysis has revealed that there was no significant relationship. On the other hand though the relationship appeared to be negative ($r = -0.27$, $P=0.14$), considering the difference in scald disease between sprayed and non-sprayed as predictor, there was no statistically significant relationship.

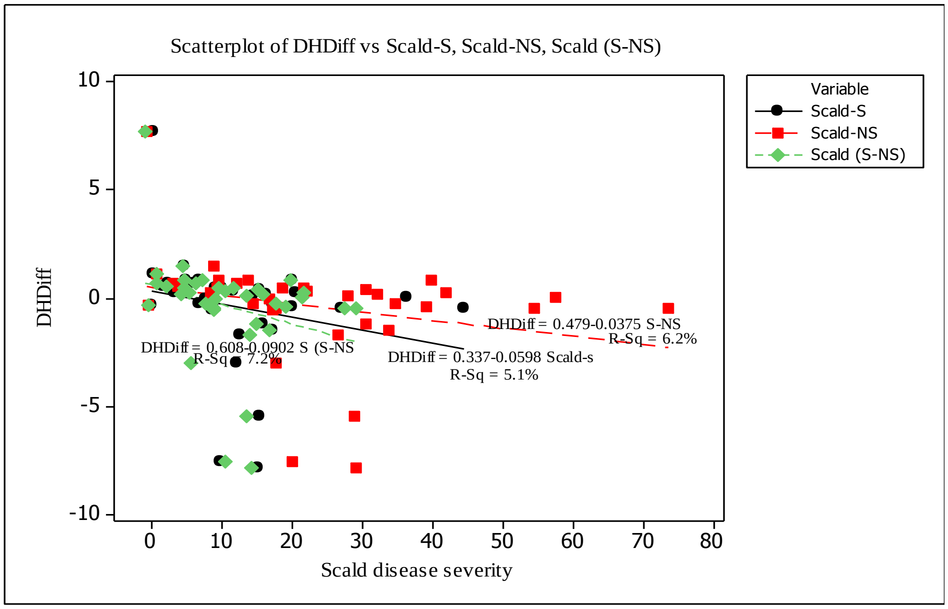

Figure 18: Scatterplot with regression for days to heading difference (DHDiff) in the spray treatment Vs. Scald disease from the sprayed and non-sprayed blocks in Korem

Note:

(Scald-S= Scald disease from sprayed block, Scald-NS= Scald disease from non-sprayed block, Scald (S-NS) = scald disease difference between sprayed and non-sprayed blocks)

Grain yield

The other important parameter was grain yield and it ranged between 2.23 and 4.93 tha^{-1} with average yield of 3.49 tha^{-1}in the sprayed block. In the non-sprayed block however the range was between 1.84 and 4.74 tha^{-1} with average yield of 3.36 tha^{-1} (Table 23). Therefore, 0.14 tha^{-1} grain yield difference have been observed between the sprayed and non-sprayed block. This location was third best performer in terms of grain yield next to Debre-Birhan and Istayish.

4.4.3. Response of genotypes to the sprayed and non-sprayed fields at Debre-Birhan site

Analysis of variance for this site revealed that, spray treatments (management) were significantly different for SDS%, SDI%, and AUDPC at p-value ($p<0.01$) and for HI% and TSW at p-value ($p<0.05$). Genotypes were significantly ($p<0.001$) different for all parameters except for AUDPC. The interaction between spray treatment and genotypes were also significantly ($p<0.05$) different for DH, DM and GYtha^{-1}. Furthermore, the interaction was significant for SDS% and SDI% at $p<0.001$ and $P<0.01$, respectively (Appendix XVII).

Days to heading

The mean performance of the genotypes of days to heading was between 77 and 86 days with an average score of 81 days in the sprayed block while 77 and 90 days for the non-sprayed block with an average score of 81days (table 6). G4, G5, G9, G11, G26, G29, G30, G33, G34 and G36 were found in this case early heading followed by G6, G7, G12, G14, G15 and G25.

Days to maturity

Days to maturity for the sprayed block ranged from 126 to 142 days with average score of 134 days. But for the non-sprayed block, the range was between 127 to 139 days with average score of 132 days. Moreover, regression analysis revealed that the relationship between days to maturity and scald disease severity was insignificant in both sprayed and non-sprayed blocks (APPENDIX X and XI). However, days to maturity in the sprayed field had weak negative relationship with scald disease and only 4.6% of the variation in days to maturity was caused by scald disease. In the non-sprayed block on the other hand very weak positive association was observed and as a result scald disease had no any contribution in the variability of days to maturity (Figure 19). Similarly grain filling duration had same pattern as days to heading. Exceptional to this was grain filling duration (GFD) and scald disease from the non-sprayed block had significant positive relationship (Figure 19). And 18.7% of the variation was caused by scald disease. So this result clearly shown that the effect of scald disease on maturity in general was minimal or none.

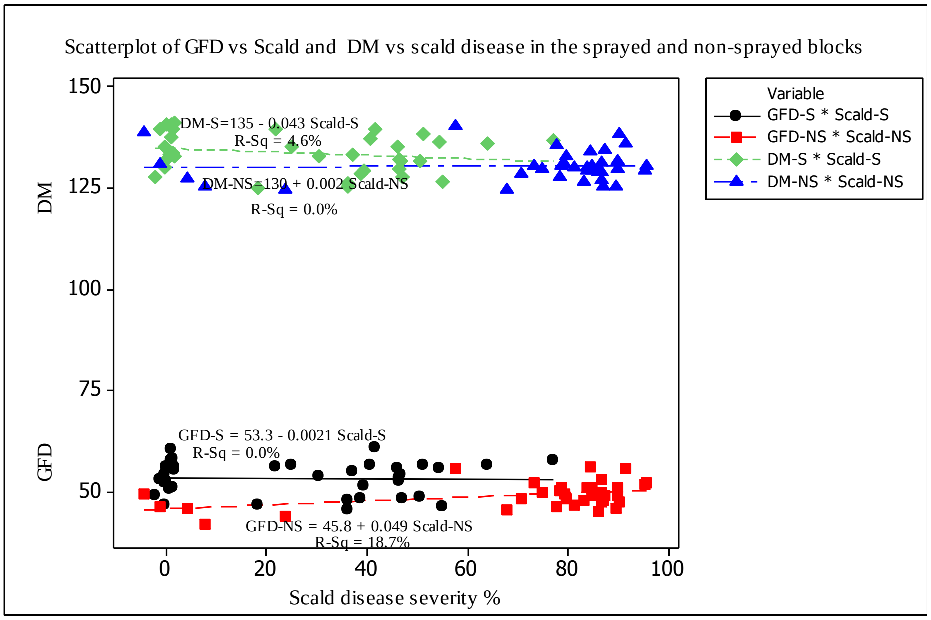

Figure 19: Scatterplot showing the relationship between DM and scald disease in the sprayed and non-sprayed blocks in Debre-birhan

Scald disease

Lattice adjusted scald disease severity value was ranged from -3.60 to 81.79% with average score of 26.59% from the sprayed block, and between -0.95 and 94.45% with average score of 72.3 from the non-sprayed block (Table 23). In sum, the amount of disease in this site was much higher as compared with the other sites probably due to presence of favorable environmental conditions and higher accumulation of disease spores than other locations because of repeated growing of barley at this site. Considering only the non-sprayed part, G1, G6, G7, G12, G14, G15 and G25 were found to be resistant and the remaining genotypes were all susceptible. From the preliminary screening of the barley core collection in 2004 at Debre-Birhan, G4, G5, G9 and G11 were among others selected as resistant. The genotypes had severity percentage of 51, 41, 0 and 31 respectively (Table 15). However, this study has revealed that the resistance capacity of these genotypes was not maintained; they had 87, 85, 84 and 78 severity percentage, respectively, possibly due to variability in the pathogen or genotypes interacting with the physical environment. Regression analysis was run to see if there was any significant association among scald diseases, days to heading and grain yield. Consequently, the analysis of variance revealed that there was significant ($P<0.05$) negative association between days to heading and scald disease severity in the sprayed and non-sprayed blocks. As a result, there was 14.1% variation in days to heading as well as in scald disease severity in the sprayed and non-sprayed blocks. The remaining 85.9% can be explained by other factors. The regression lines of figure 18A suggest that scald severity percent for the non-sprayed block are generally higher than those achieved with sprayed block across the range of days to heading. For the non-sprayed block, days to heading below about 85.5 were associated with scald disease severity percent greater than 60. In contrast, for the sprayed block, days to heading of any level were not associated with scald disease severity above 60. Besides from figure 20B, scald disease severity of both the sprayed and non-sprayed blocks were not associated with days to heading above 90.

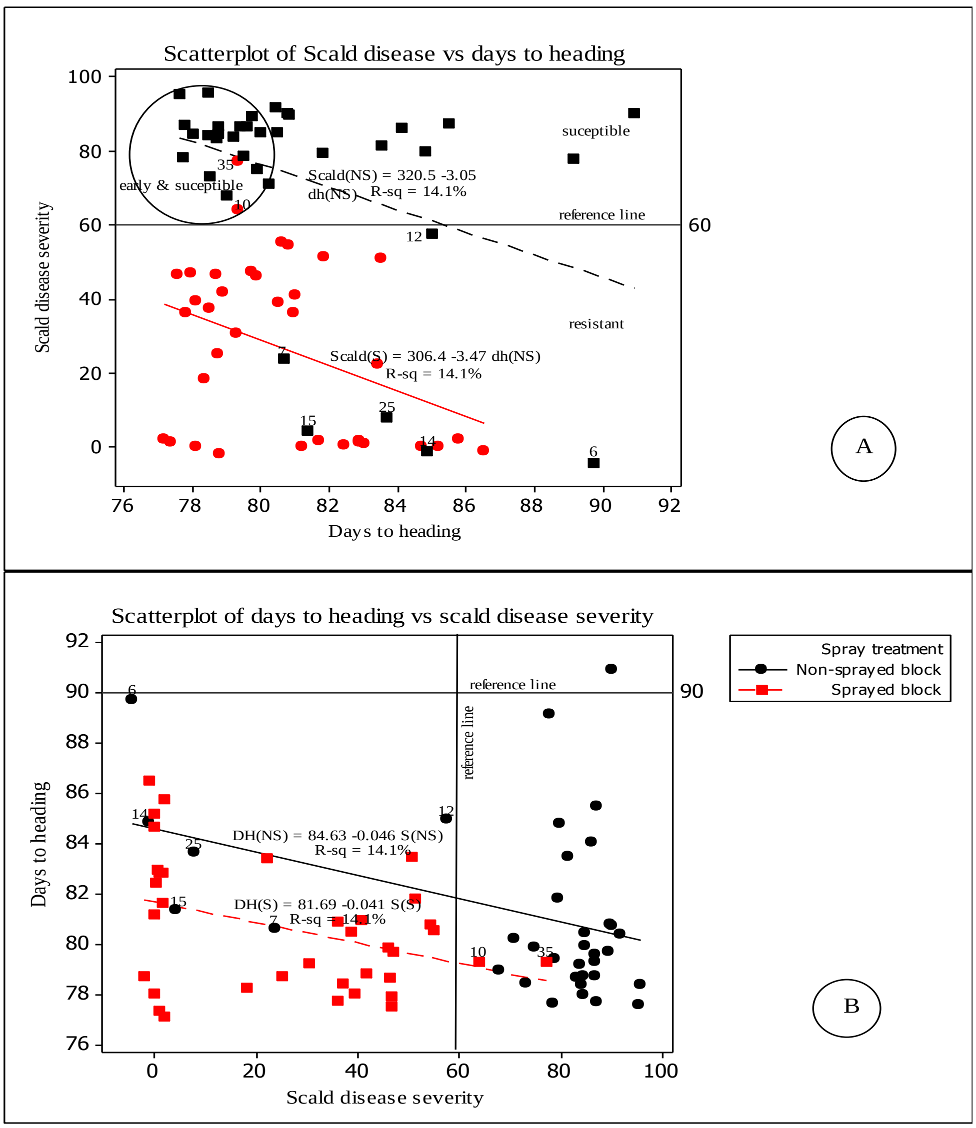

Figure 20: Relationship between scald disease and days to heading from the sprayed and non-sprayed blocks in Debre-birhan.

This result was confirmed through the application of linear model: $Y_i = \alpha_0 + \beta_1 X_i + (\beta_2 X_j)*1$ (sprayed) and $Y_i = \alpha_0 + \beta_1 X_i + (\beta_2 X_j)*0$ (non-sprayed).Where, Y is the dependent variable scald disease), α, is the intercept, β, is the slope, and X is the independent variable (days to heading). For Xj, 1 represents the sprayed treatment and 0 represents the non-sprayed treatment. Accordingly, the regression analysis revealed that spraying of the anti-fungus chemical had proven to reduce the severity level significantly by 47.8% (Scald disease = 332.34 - 3.20 DH - 47.8*S, with R^2 = 52.13%) (Figure 20A).

Furthermore, most of early maturing genotypes had shown susceptibility to the disease in both the sprayed as well as the non-sprayed blocks (Figure 20). This result is in agreement with the finding of Leur and Gebre (Leur and Gebre, 2003). However, G6, G7, G14, G15 and G25 which were moderately early from the non-sprayed block had low disease scores (Figure 20 and table 17). In sum, complete control of the disease could not achieved through four sprays in the control block. So complete control may require an increase in the number of sprays, but this would only be practical for research activities, not for farmers.

Grain yield

The other important trait of this study was grain yield. Hence in the sprayed block, grain yield ranged from 3.55 to 8.96 tha^{-1} and the average was 6.52 tha^{-1}. In the non-sprayed block on the other hand the range was between 3.03 and 7.83 tha^{-1} with average score of 6.04 tha^{-1}. On average, 0.48 tha^{-1} grain yield difference was observed between the sprayed and non-sprayed blocks in this site. And so G1, G11, G13, G17, G20, G23, G26 and G30 were found to be best yielder followed by G8, G15, G16 and G31 in the sprayed block. In contrast, G25 was relatively poor yielder. However, from the non-sprayed block G6, G7, G14 and G15 had moderately high yield with very low disease severity. Their performance in heading days against scald disease in the non-sprayed block was also very good. The relationship between grain yield in the sprayed and non-sprayed blocks was further explained by regression analysis. Consequently, there was no significant relationship between grain yield and scald disease both in the sprayed and non-sprayed blocks. Though the relationship between grain yield in the sprayed and non-sprayed appeared to be weak positive, substantial yield differences have been observed between the sprayed and non-sprayed blocks (Figure 19). So based on linear regression equation (GY-S=5.90

+ 0.003 Scald S + 0.51*S) obtained from the analysis, 0.51 tha^{-1} yield was retained due to spray of chemical (X_j).

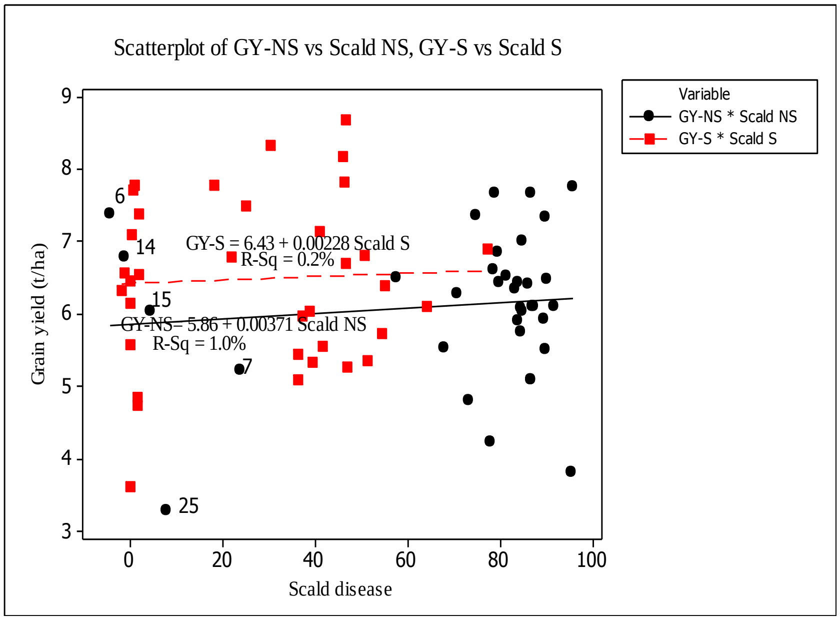

Figure 21: Scatterplot showing the relationship between grain yield and scald disease in both the sprayed and non-sprayed blocks in Debre-birhan

Additionally, grain yield was regressed against days to heading. As a result grain yield from the sprayed block had negative but non-significant relationship with days to heading. Obviously grain yield tended to reduce by 0.09 tha^{-1} for unit increase in days to heading from the sprayed block (Figure 21). Contrary, grain yield from the non-sprayed block had positive but non-significant relationship with days to heading (Figure 21).

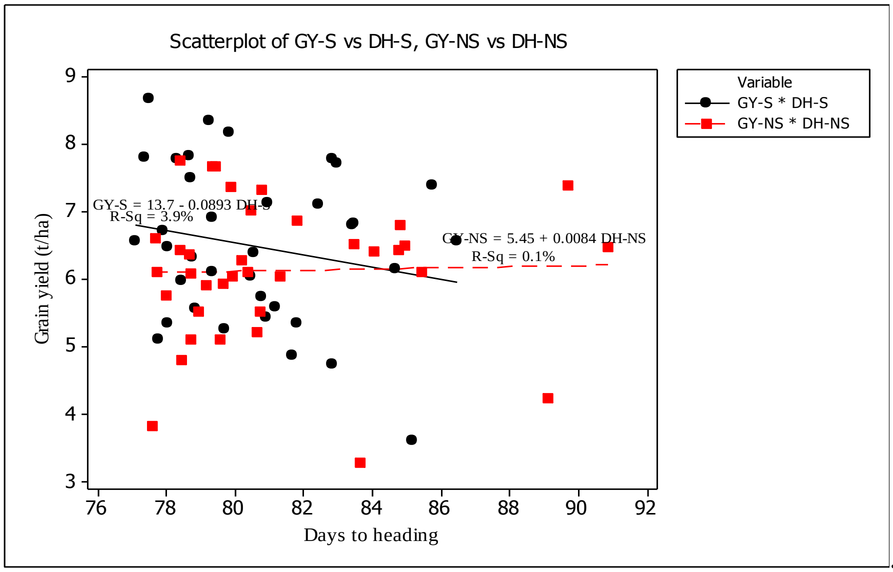

Figure 22: Scatterplot showing the relationship between grain yield and days to heading in both the sprayed and non-sprayed blocks in Debre-birhan

Furthermore, difference in days to heading between the sprayed and non-sprayed block was regressed against scald disease severity from both blocks and as a result no significant relationship was detected (Figure 23). But still G6, G7, G14, G15 and G25 from the non-sprayed block had shown very good performance.

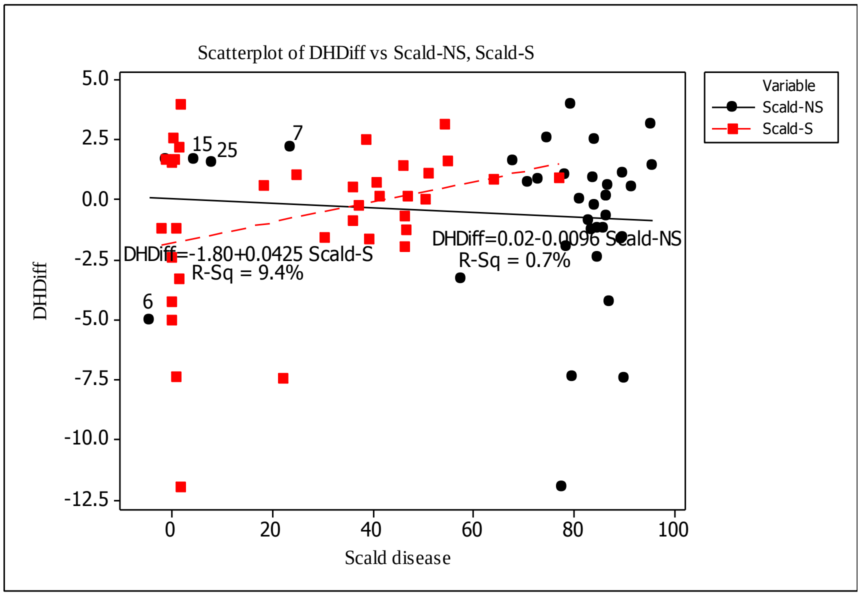

Figure 23: Scatterplot showing the relationship between difference in days to heading (DHDiff) and scald disease in both the sprayed and non-sprayed blocks in Debre-birhan

4.4.4. Response of genotypes to the sprayed and non-sprayed fields at Istayish site

The output of analysis of variance for this site revealed that, spray treatment was significant ($p<0.05$) for SDS%, SDI% and HI% only (APPENDIX XVIII). The remaining parameters were non-significant. Besides, genotypes were significant for DH, DM, NB, PH, GY tha^{-1} and SL. Nevertheless the interaction of spray treatment and genotypes were not significant for all parameters.

Days to heading

Mean performance evaluation of 50% days to heading was ranged from 95.07 to 119.5 for the sprayed block with an average of 102.48 days and from 94 to118 days for the non-sprayed blocks with average of 102.24 days (Table 23). The most prominent result of this study was genotypes that usually headed early in the low and middle altitude areas, had shown higher phenotypic elasticity with a character of lateness (higher altitude). This can clearly show us that these genotypes can grow in wide agro-ecology. Usually in this area genotypes headed 3-31/2 months are considered as early to moderately early maturing genotypes. As a result, 28 genotypes were found to be early (Appendix XXII). Typically in this experimental site; the association between days to heading and barley scald was not significant for the sprayed block. However, there was significant ($p<0.01$) relationship between days to heading and scald disease in the non-sprayed blocks (Appendix XIV). From the regression equation, $Y=106-0.124X$, on the other hand, days to heading declined on average by 0.12 day for every unit increase in scald disease in the non-sprayed block (Figure 24). Besides, the output from this analysis showed that the model here accounts for only 22.3% of the variance in days to heading and 3 days reduction has been observed in the sprayed block (DH-S = 106 - 0.124 Scald-S - 3.16 S). This could again be due to the phytotoxicity of the antifungal chemical. Even though the amount of disease severity was high and had significant negative association with days to heading in the non-sprayed blocks, its impact on earliness characteristics was negligible.

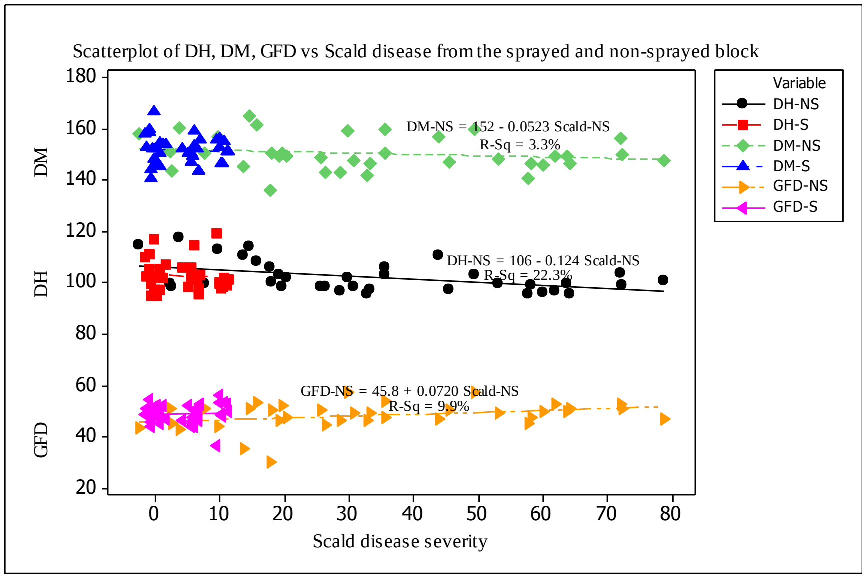

Figure 24: Relationship between GFD, DH and DM vs. scald disease severity in Istayish

Difference in days to heading (DHDiff) was also regressed against scald disease from both sprayed and non-sprayed blocks. Consequently, no significant relationship was existed. However, there was weak negative and positive relationship between DHDiff and scald disease in both sprayed and non-sprayed blocks respectively.

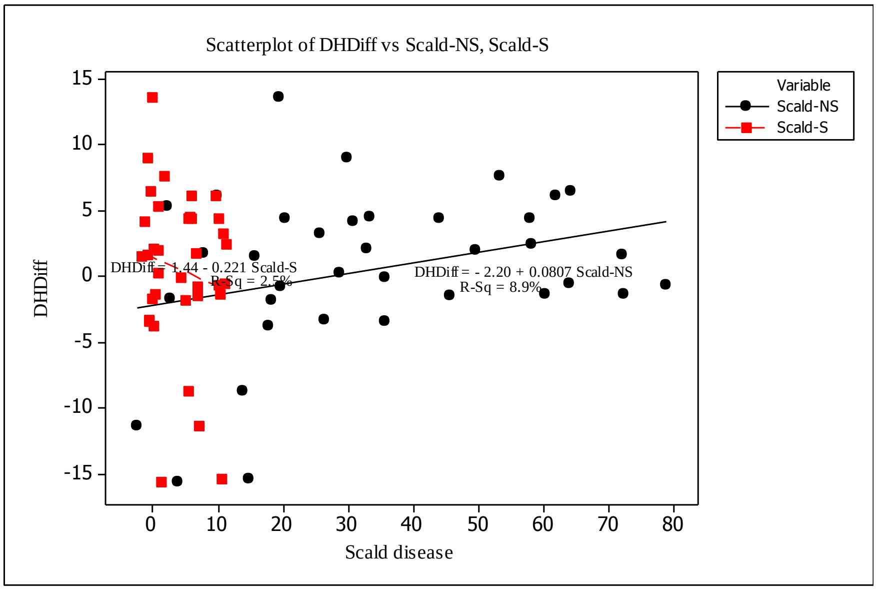

Figure 25: Relationship between differences in days to heading (DHDiff) vs. scald disease severity% in Istayish

Days to maturity

Maturity days in the sprayed block were ranged from 141.13 to 169.58 with average score of 151.25. Likewise in the non-sprayed block the range was between 136.52 and 163.91 with average score of 150.4. Regression analysis for days to maturity has also revealed that, there was no significant association between days to maturity and scald disease in both sprayed and non-sprayed blocks (Figure 24). Likewise grain filling duration (GFD) though had positive association with scald disease; it was not significant (Figure 24).

Scald disease

Scald disease severity level in the sprayed block was ranged from -1.14 to 11.58 percent with average score of 4.09 (Table 23), indicating that spraying at this site protected the plants very effectively. In the non-sprayed block on the other hand the range was between -0.62 and 71.86 percent with average score of 34.65. Even though this site is considered as hotspot for scald disease formation, making evaluation was a little bit hard due to small amount of disease occurrence possibly because of unfavorable environmental conditions in this season. Nevertheless, G10, G11, G20, G22, G23 and G35 were found to be susceptible.

Grain yield

Grain yield in the sprayed block in this site was ranged from 2.08 to 4.62 tha^{-1} with average score of 3.5 tha^{-1}. But in the non-sprayed block, the average was ranged between 1.91 and 4.67 tha^{-1} with average score of 3.23 tha^{-1}. Consequently, 0.27 tha^{-1} grain yield difference was observed between sprayed and non-sprayed block in this site. To see the relationship it was regressed against scald disease both from the sprayed and non-sprayed blocks. As a result, there was no significant relationship between grain yield and scald disease both in the sprayed and non-sprayed blocks. However, 0.44 tha^{-1} yield was saved due to spray (GY-S = 3.03 + 0.00569 Scald-S + 0.44*S). Further grain yield from the sprayed block had weak negative relationship with scald disease. However, in the non-sprayed block though the amount of disease was very little as compared to Debre-Birhan, the relationship appeared to be positive and it yielded fairly well.

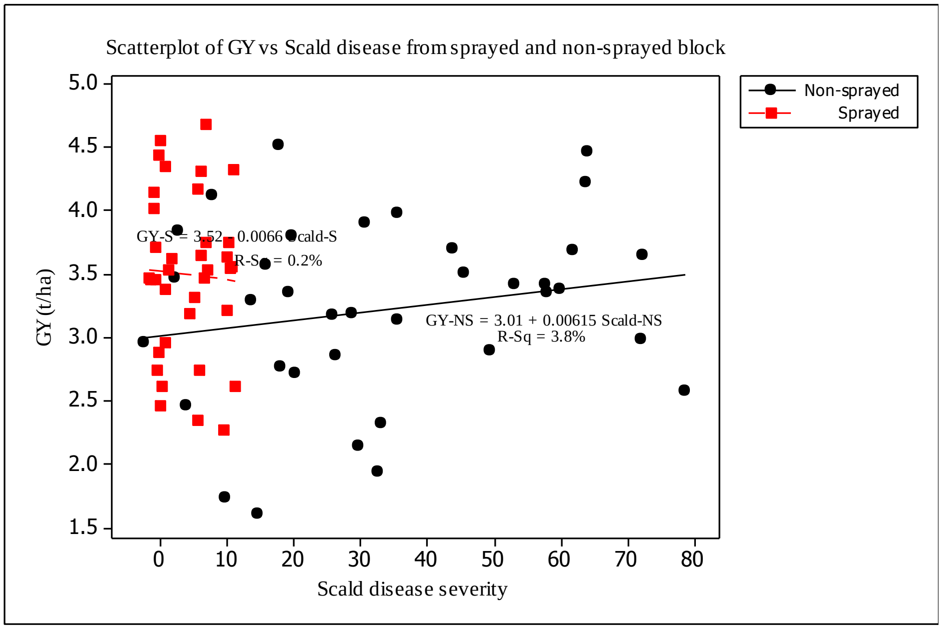

Figure 26: Scatterplot showing the relationship between Grain yield and scald disease in both the sprayed and non-sprayed blocks in Istayish