academicresearchJournals

Vol. 6(3), pp. 193-201, April 2018
DOI: 10.14662/ARJASR2018.009

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Full Length Research

Performance of Composite Crosse Populations of Wheat for Yield, Resistance to Yellow Rust and other important traits under Organic Farming

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Accepted 14 March 2018

Organic agriculture requires robust variety such as composite crossed population (CCP) is one of strategy that suitable under low input and organic conditions to buffer against fluctuation environments due to their genetic diversity.The objective of the study was to evaluate the performance of eight composite crossed population of wheat along with check for grain yield, agronomic traits and resistance to yellow rust disease under organic condition in a randomized complete block design with three replications. Result of analysis variance showed no significant difference among wheat genotypes for grain yield (p= 0.45), whereas a highly significant (p=0.002) difference for TKW. CCP of HU-13-YQMS showed the highest TKW (43.23 g) and the lowest recorded for the check (37.43 g). The genetic potential of all wheat composite crossed population showed low yield performance under organic farming, this might be due to slow released of nutrient under organic condition. A highly significant difference (P<0.001) was observed among wheat genotypes for the yellow rust incidence and severity across growth stages. The highest yellow rust severity (6.01) and incidence (92.27 %) was recorded on the check (pure line) and followed by the population HU-08-UK comp and HU-08-YQMS at milk stage. CCP of HU-13-YQMS showed comparable grain yield, very low disease incidence and severity, indicating that genetic diversity within CCP increased the resilience of the population to limit the spread of disease expansion across growth stages than check under organic condition.Furthermore, exploitation of additional source of genetic diversity of wheat will be required and beneficial traits may be combined to develop stable and resiliencecultivar to buffer against fluctuating of environments under low input and organic conditions in their ecological farming system.

Key words: Organic condition, composite cross populations, resilience, grain yield, yellow rust

Cite this article as: Garoma B, Lammerts E, Nuijten E (2018).Performance of Composite Crosse Populations of Wheat for Yield, Resistance to Yellow Rust and other important traits under Organic Farming. Acad. Res. J. Agri. Sci. Res. 6(3): 193-201

INTRODUCTION

Wheat (*Triticumaestvum L.*) is a staple food in large part of the world and grown on 220 million of hectare worldwide in 2014 (http://faostat.fao.org/default.aspx. It feeds about 40% of the world population and occupies a central position in maintaining world food security (Asif*et al*., 2014). In last five decades, the production of wheat increased with the use of modern cultivar, high inputs, agronomic practices and managements. However, these modern cultivars cannot often perform under low inputs and organic conditions since synthetic fertilizers and agro-chemicals were widely applied during development of modern cultivars.

Organic agriculture become emerging worldwide with the objective to produce healthy and environmental friendly food by closing the nutrient cycle and low external inputs like fertilizer application, avoiding the use of pesticides, herbicides and genetic modified organism (Bulluck *et al.,* 2002). On other hand, organic farming benefit in terms of enhancing biodiversity (at the farm, crop, soil biota), maintenance of soil fertility and wide crop rotation (Mader *et al*., 2002).

Furthermore, organic farming integrates agro-diversity, resilience /or robust variety and agronomic practices in their ecological farming system. Because this can provide them insurance with respect to the impact of biotic and abiotic stress factors rather than application of synthetic chemicals (Finckh, 2008). The fact that organic farmers need cultivars that adapted to organic and low input systems. Breeding for the organic sector requires the desired traits such as stable yield, quality, resistant to disease, weed suppression and nutrient use efficiency (Lammerts van Bueren *et al*., 2001; Löschenberger *et al*., 2008).

Genetically uniform varieties that are developed via pedigree methods are the dominant commercial breeding method to acquire high yielding and wide adaptability when high application of inputs and favorable environment conditions are available (Phillips and Wolfe, 2005).However, these varieties cannot always perform well in marginal agriculture environments with low external inputs applied and under organic condition. Besides, due to prohibited application of synthetic chemicals under organic condition, foliar disease such as yellow rust, leaf rust and others diseases are more incurred yield limits under organic farming (Huber and Buerstmayr, 2006). For instance, the yield loss due to yellow rust was 40-80% throughout the world (Mcintosh *et al*., 1995). Yield loses due to yellow rust is varied at potential growing region of wheat in Ethiopia (Dereje and Chemeda., 2007). During the disease outbreak, yellow rust has recorded a yield loss as high as 50-60% in Europe (Moldenhaur *et al*., 2006). Therefore, development of robust variety from broadened population that resistance to disease, optimize yield, to be integrated with agro-diversity and practices in their ecology farming system is as one approach for organic farming.

Exploitation and broadening genetic variability in the gene pool population is one strategy of breeding for organic agriculture. This enables to select for important traits and the process to develop population variety that is adapted to ecological farming system (Lammerts van Bueren*et al*., 2005; Wolfe &Döring, 2010). The broadened genetic population is enriched by a number of crosses involving varieties particularly suited for organic agriculture and low input conditions (Löschenberger *et al*., 2008).Furthermore, the development of the composite cross population approach can be one option to increase genetic diversity within cultivars to promote better adaptation towards unpredicted biotic and abiotic stress factors. For instance, composite cross populations are heterogeneous crop that can show superior performance under unpredicted stress conditions (Phillips and Wolfe 2005). Therefore, the objective of this study was to evaluate the performance of composite cross populations of winter wheat for grain yield, resistance to yellow rust and important agronomic traits under organic condition.

MATERIALS AND METHODS

The experiment was conducted at the organic farm trial of Wageningen University and Research Center, the Netherlands during 2014. Seven composite cross populations and one pure line as check, totally eight wheat genotypes were used as treatment in a randomized complete block design (RCBD) with three replications. The plot size for each genotype was 6 m x 7.5 m of area 45 m^2. The experimental seed was treated with Tillecur (based on organic mustard powder) whereas synthetic fertilizer and pesticides were not applied during experiment conducted.

Collected data

Yellow rust disease incidence assessment at 21 and 31 growth stages

50 cm ruler length was thrown randomly four times in a diagonally way to count disease incidence for each plot of treatment at main shoot with two up to three tillers (21) and pseudo-stem erection with fist node detectable (31) growth stages, respectively. Accordingly, total number of leaves and infected leaves was counted for incidence observation at 21 and 31 growth stages.

According to Cooke (2006) disease incidence (%) =

$$\left(\frac{Numberofinfectedplantunits}{totalnumberofplantunitsassesed} * 100\right)$$

% incidence = $\left(\frac{Numberofinfectedleave}{totalnumberleave}\right)$ = average infected leaves * 100

Yellow rust incidence assessment at 39, 61 and 83 growth stages

40 plants were tagged from each plot randomly. Yellow

rust disease incidence for each plot was assessed at flag leaf sheath extending up (39), flowering (61) and milk stage (83). From each tagged plant, number of leaves and infected leaves was counted for disease incidence at these growth stages.

Yellow rust disease severity evaluation at 39, 61 and 83 growth stages

Visual scales range from no symptoms score, 0 and or 1 as few isolated lesion, very severe symptoms score 9 and other categories in various disease symptoms at corresponding fallen number was scored. Severity of disease was scored visually per tagged plant and its average taken.This data taken aaccording to (Cook, 2006) for wheat and barley disease severity evaluation. In addition, disease severity in percentage evaluated at these growth stages based on BBCH; Base, Bayer, Ciba-Geigy and Hoechst (Lancashire *et al.,* 1991).

Yield and other agronomic traits data

a) The distance between spikelet's

40 plants per plot were taken from tagged plants. Spike length was measured from these sampled plants. The number of spikelet per spike was calculated based on the following formula.

$$\text{Distance between spikelets (cm)} = \frac{Length of spike}{number of spiklets per spike}$$

b) Plant height: 40 plants per plot were taken from tagged samples. Plant height was measured in cm from these sampled plants and their average was considered as plant height.

c) The distance from flag leaf to spike: 40 plants per plot were taken from tagged samples. The distance from flag leaf to spike was measured in cm from these sampled plants and their average was taken.

d) Grain yield: after physiological maturation, each genotype was harvested and grain yield per plot weighted and recorded.

e) Thousand kernel weight (TKW): TKW weighted for each plot.

Statistical analysis

Statistical analysis was conducted by using Genstat 16th edition software. Analysis of variance through REML program was performed to test the significant of genotypes. We used criterion for declaring significant P< 0.05 and mean separation comparison significant for treatments separated by Fisher protected LSD-test at 5%.

The association within morphological traits, between agronomic traits and disease was analyzed by using SPSS software correlation coefficient.

RESULTS

Analysis of variance showed highly significant differences (*P*<0.001) among winter wheat genotypes for yellow rust incidence (%) at 21, 31, flag leave, flowering and milk growth stages (Table 1). However, there were no significant differences among composite cross populations for yellow rust incidence (%) at 21 and 31 growth stages. For flag leave, flowering and milk growth stages significant differences were observed among composite crossed population for yellow rust incidence. The yellow rust incidence increases across the growth stages from 21 to milk stages (Table 1). At milk stage, the highest yellow rust incidence (92.27%) was observed on the pure line (check), followed by composite cross populations B and A (43.56 %) and (30.17 %).

There were significant differences (*P*<0.001) among winter wheat genotypes for yellow rust severity (0-9 scale method) at flag leaf sheath extended stage, flowering stage and milk stages (Table 2). Also significant difference was observed among composite crossed population for yellow rust severity (0-9 scale) at these stages. At milk stage, the highest severity was recorded on C (pure line) (6.01), followed by CCP B and A (3.10 and 2.32) respectively.

Highly significant differences (*P*<0.001) were observed among all involved winter wheat genotypes for yellow rust severity (0-100% scaling methods) on the first flag leaf and the penultimate leaf at flowering and milk stages (Table 2). Also, significant differences were found among composite crossed population for yellow rust severity at these stages. The highest yellow rust severity (60.64%) was observed at the penultimate leaf at milk stage for the C (pure line), followed by populations A and B (15.44 and 15.50%), respectively.

Yield and other agronomic traits

Grain yield and 1000 kernel weight

There was no significant difference (*P*=0.45) among wheat genotypes for grain yield. For some genotypes lower yields were observed, like for the C (2.86 t/ha) and population B (2.65 t/ha) (Table 3), respectively. Highly significant differences (*P*=0.002) were found among all wheat genotypes for thousand kernel weight (TKW). Also,

Table 1. Comparison of mean for the yellow rust incidence (%) at different growth stages for the winter wheat trial in 2014 under organic experimental farm, Wageningen University.

	Mean for yellow rust incidence per 50 cm sample		Mean for yellow rust incidence of tagged samples		
Genotype	YR_Inc 21	YR_Inc 31	YR_IncFL	YR_IncFW	YR_Inc MS
C (check/pure line)	21.31	40.05	54.41	81.85	92.27
B (HU-08-UK composite)	1.67	2.03	33.73	41.68	43.56
A (HU-08-YQMS)	2.62	5.25	10.83	27.33	30.17
G (HU-09-YQMS)	2.32	6.33	11.08	17.53	18.33
D (HU-10-YQMS)	0.81	4.20	9.28	17.10	18.04
E (HU-11-YQMS)	2.46	6.90	7.91	17.13	23.04
H (HU-12-YQMS)	0.98	2.23	7.08	17.42	27.5
I (HU-13-YQMS)	1.17	3.20	9.72	12.43	24.17
CV (%)	25.70	24.40	14.60	20.70	22.50
LSD at 0.05	4.22	5.57	4.86	20.20	16.34

Genotypes having the same letter did not show a significant difference (P=0.05), CV%= coefficient of variation.
YR_Inc 21= Yellow Rust Incidence at 21 growth stage, YR_Inc 31= Yellow Rust Incidence at 31 growth stage, YR_IncFL= Yellow Rust Incidence at flag leave appeared stage, YR_IncFW= Yellow Rust Incidence at flowering stage, YR_Inc MS= Yellow Rust Incidence at milk stage.

Table 2. Comparison of mean for the yellow rust severity based on 0-9 scale and 0-100 % scoring methods at different growth stages for the wheat trial in 2014 under organic experimental farm, Wageningen University, the Netherlands

	Mean for Yellow rust severity based on (0-9 scale)			Mean for Yellow rust severity based on (0-100 % scale)			
Genotype	YSVFL	YSVF	YSVM	YSV1sfLF	YSV2ndfLF	YSV1sfLM	YSV2nfLM
C	4.25	4.10	6.10	16.63	30.49	35.76	60.64
B	2.70	2.78	3.10	11.93	17.91	11.63	15.44
A	1.67	1.77	2.32	3.59	5.45	10.44	15.50
G	1.28	1.36	1.68	1.15	2.03	1.88	3.25
D	1.25	1.52	1.67	1.70	3.37	3.12	3.50
E	1.14	1.64	1.89	2.43	3.67	3.25	4.88
H	1.22	1.42	1.92	2.12	3.63	2.62	4.13
I	1.29	1.37	1.93	2.36	2.42	3.75	7.13
CV (%)	11.8	17.50	20.10	24.50	19.00	19.80	18.40
LSD, 0.05	0.41	0.64	0.95	5.27	6.21	8.52	9.62

Genotypes having the same letter did not show significant difference (P=0.05) in per column, YSVFL (0-9 scale method)= Yellow Rust severity at flag leaf appeared stage, YSVF (0-9 scale method)= Yellow Rust severity at flowering growth stage , YSVM (0-9 scale methods)= Yellow Rust severity at milk stage, YSV1sfLF (0-100 % scaling)=Yellow Rust severity on the 1st flag leaf at flowering growth stage, YSV2ndfLF (0-100 % scaling)= Yellow Rust severity on penultimate leaf flowering growth stage, YSV1sfLM (0-100 % scaling)= Yellow Rust severity on 1st flag leaf at milk stage, YSV2dfLM (0-100 % scaling method)= Yellow Rust severity on penultimate leaf at milk stage.

Table 3. Comparison of mean grain yield (t/ha) and other agronomic traits for wheat genotypes under organic experimental farm during 2014, Wageningen, The Netherlands.

Genotype	Grain yield (t/ha)	TKW (g)	FT/ m^2	PLHT (cm)	SL(cm)	FL(cm)	FS	UFS	TS	DS
C	2.86	37.43	421.4	80.75	8.86	14.99	16.63	4.27	20.90	0.41
B	2.65	41.35	326.33	83.07	7.48	15.90	13.79	3.92	17.71	0.42
A	3.18	41.43	444.33	82.89	8.16	15.53	15.70	3.56	19.27	0.43
G	3.26	40.96	453.33	79.11	7.93	17.19	14.87	3.66	18.53	0.43
D	3.17	42.58	500.90	82.94	7.99	16.55	14.74	3.28	18.02	0.44
E	3.39	41.88	440.40	91.42	8.65	20.47	15.94	3.83	19.32	0.45
H	3.15	39.80	450.33	76.28	7.66	14.08	14.71	3.91	18.62	0.41
I	3.39	43.23	465.00	82.54	8.00	17.11	14.44	3.57	18.41	0.44
CV (%)	13.90	2.90	13.85	4.60	5.70	8.20	5.60	13.85	4.10	3.52
LSD, 0.05	NS	2.12	NS	7.03	NS	2.48	1.56	NS	1.42	NS

Genotypes having the same letter did not show significant difference (P=0.05), NS= No significant difference.
TKW (g) = Thousand kernel weight, FT per m^2= number of fertile tillers m^{-2}, PLHT= plant height (cm), SL= spike length in cm, FL= the distance between Flag leaf and spike in cm, FS= number of fertile spikelet, UFS = number of unfertile spikelets, TS =total number of spikelets / spike, DS= the distance between spikelets

a significant difference was observed among CCPs for TKW. The highest TKW was recorded for the population I (43.23 g) whereas the C showed the lowest TKW (37.43 g) (Table 3).

Other agronomic traits

The ANOVA showed significant differences among all involved wheat genotypes for some agronomic traits; plant height (P<0.03), total number of spikelets (P<0.014) and the distance from flag leaf to spike (P<0.007) (Table 3). Also, significant differences were observed among CCPs for these traits. The longest genotype was the population E with an average length of 91.42 cm, while, population H had the shortest recorded average length of 76.28 cm.

Correlation analysis

Good estimation of phenotypic and other traits correlation coefficient was observed within several traits. Grain yield showed a significant positive association with TKW (r= 0.76), plant height (r= 0.64) and non- significant negative correlation with yellow rust incidence and severity. Similarly, plant height revealed a significant positive association with spike length (r= 0.66), flag leave to spike (r= 0.69), fertile spikelet (r= 0.52), distance between spikelet (r= 0.64) and non-significant with disease pressure. Also, spike length showed significant positive correlation with fertile spikelet's (r= 0.89) and the distance between spikelet (r= 0.62) (Table 4). However, majority of agronomic triats showed non-significant negative assocation with yellow rust incideance and seveirty. This might be due to the braoden genetic base of population increase resilance to yellow rust disease pressure under organic farming.

The trend of trait distribution over scatter plot

Scatter graphs showed the trend of traits distribution over the plot. Data of morphological traits were collected from individual plant samples per populations. Spike length showed the best correlation with the distance between

Table 4. Pearson correlation among agronomic triats and disease parameters in wheat genotypes tested under organic conditions

	GY	TKW	plht	SL	FL	FS	UnfS	dS	YRIN	YRSV
GY	1									
TKW	0.76^{**}	1								
plht	0.64^{**}	0.54^{*}	1							
SL	0.21^{ns}	0.02^{ns}	0.66^{**}	1						
FL	0.45^{ns}	0.42^{ns}	0.69^{**}	0.25^{ns}	1					
FS	0.24^{ns}	-0.09^{ns}	0.52^{*}	0.89^{**}	0.09^{ns}	1				
UnfS	-0.69^{ns}	-0.67^{ns}	-0.54^{ns}	-0.32^{ns}	-0.40^{ns}	-0.25^{ns}	1			
dS	0.44^{ns}	0.57^{*}	0.64^{**}	0.62^{*}	0.48^{ns}	0.19^{ns}	-0.78^{ns}	1		
INFW	-0.21^{ns}	-0.56^{ns}	-0.01^{ns}	0.45^{ns}	-0.31^{ns}	0.51^{ns}	0.19^{ns}	-0.18^{ns}	1	
YRSV	-0.26^{ns}	-0.59^{ns}	0.02^{ns}	0.47^{ns}	-0.24^{ns}	0.50^{ns}	0.32^{ns}	-0.22^{ns}	0.95^{**}	1

GY= grain yield, TKW = Thousand kernel weight,Plht= plant height (cm), SL= spike length in cm, FL= the distance between Flag leaf to spike in cm, FS= number of fertile spikelet, Unfs = number of unfertile spikelets, ds= the distance between spikelets, YRIN= yellow rust incidence, YRSV= Yellow rust severity, ns= non-significant

spikelets on the plot. The two traits association showed evenly distributed over scatter plot for almost wheat genotypes (Figure 1). On the other hand, plant height did not show an association with the distance from flag leaf to spike on the scatter plot (Figure 2). The trait distribution showed no variation and was more condensed at the centre area, implies that as plant height increased not necessarily often an increment of the distance from flag leaf to spike.

DISCUSSION

Yellow rust disease

The current study was carried out to evaluate the performance of winter wheat composite crossed population along check for grain yield, yellow rust resistance and other morphological traits. Difference among wheat genotypes as well as among CCPs was observed for yellow rust disease pressure across growth stages. The yellow rust disease expanded over growth stages but varied in severity among CCPs. At seedling stage, the yellow rust symptoms and frequency was quit low for CCPs. Strip line yellow rust formation was not observed at early seedling stage during experiment conducted. This statement was agreed with (Chen, 2005) reported that stripes of uredia were not formed on seedling leaves whereas narrow stripes on the leaves were only formed after stem elongation.

In the present study, the yellow rust incidence and severity was observed to a higher extent on pure line (check) than on the CCPs under organic farming. This could be because the pure line wasgenetically uniform, narrow genetic based combination during line development compared to CCPsand the resistant of the pure line seems too weak. Also, its resistance too weak can explain the low tillering rate of the pure line. The fact that the pure line leave were more severely infected by yellow rust likely had resulted in decreased photosynthesis and more cost energy for others activities during vegetative growth stages. According to Owera *et al.,* (1981) reported that barley plant infected with brown rust reduced the net photosynthesis and increased photo-respirations.

Even though the incidence and severity of yellow rust was more observed on the old CCPs (A and B), it seems not economically important due to low severity observed. One may conclude that the diversity within a population increased the resilience of the population restricted the spread of disease expansion across growth stages more than the pure line under organic farming. This observation tends to agree with Finckh and Mundt (1992); Dübin and Wolfe (1994), Zhu *et al*. (2000) and Mundt, 2002) who argue that variety and multiline mixtures can provide functional diversity that limits pathogen and pest expansion. It is likely that due to the diversity inter-parents used to develop the population different combinations of resistance genes have been incorporated into the composite cross population and cause different barriers to restrict the spread and expansion of the pathogen.

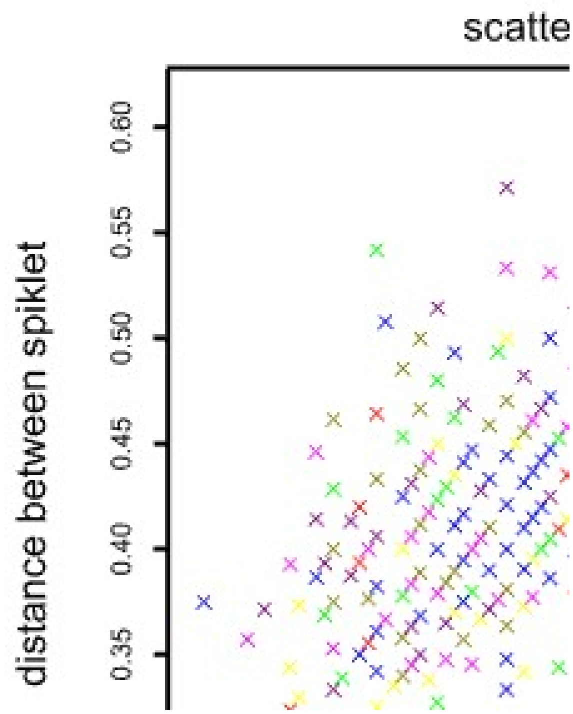

Figure 1. Spike length with correlation to distance between spikelet on scatter plot

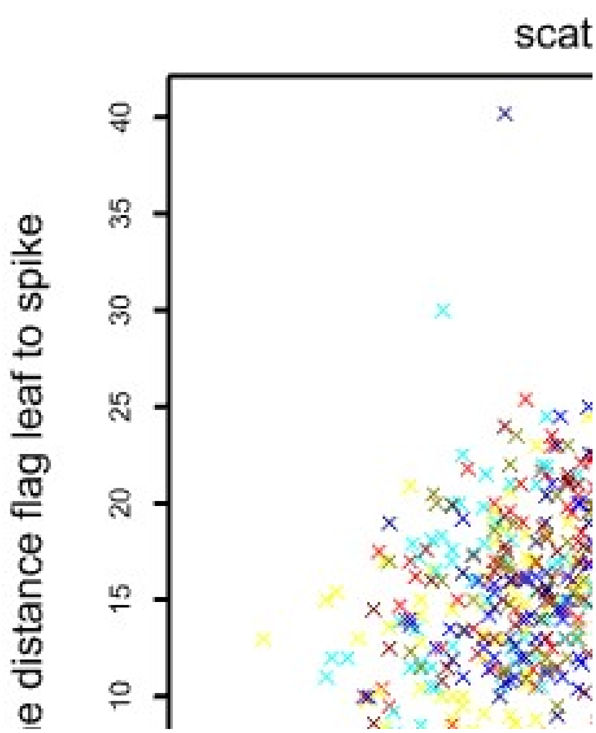

Figure 2. Plant height with association to distance from flag leaf to spike on scatter plot

Grain yield and thousand kernel weight

Grain yield, quality and other desired traits are mainly considered for wheat improvement. Grain yield is a very complex trait and governed by several genes, physiological and biochemical plant processes (Mohammadi *et al*., 2012). Differences in genetic potential of wheat for targeted traits, environmental conditions and their interactions were useful to interpret the results.

The genetic potential of all wheat composite crossed population showed low yield performance under organic farming. This might be due to slow released nutrient under organic condition. However, the magnitude ofHU-13-YQMSpopulation with the highest TKW showed a comparable performance in grain yield, yellow rust resistance and likely resilience population under organic condition.Several studies conducted on wheat genotypes under organic and conventional conditions. Murphy *et al*., (2007) reported that the differences among 35 winter wheat genotypes for grain yield and genotype × system interaction under different growing conditions (organic and conventional condition). In close agreement to this statement and in line with present study, I suggested that further research should be advisable on genetic variability of CCPs for yield potential selection under low input and organic conditions.

Other agronomic traits

Morphological traits such as plant height, the distance from flag leaf to spike and others showed difference among winter wheat genotypes. The longest plant height was observed for the population E, medium in height recorded for the old population (population A and B) and the shortest observed for the population H. Whereas the results of the pure line was in between the old and mid populations. In present study the old and the newly introduced population showed similar in plant height. This observation was in contrary with Hensleigh *et al.* (1992) who argues that the plant height of barley increased over the years of reproduction.

Significant positive as well negative association observed among agronomic traits and disease parameters. Yield and morphological trait showed non-significant negative association with yellow rust, implies that the diversity within population strengthening the resilience of population against disease pressure. Our result indicated that spike length was positively correlated with the distance between spikelets and exerted positive effect through other traits like plant height because plant height also showed significant positive correlation with spike length. Akram *et al* (2008) reported that spike length had positive relationship with number of spikelet per spike. Increase in spike length is directly associated with increase in spikelet per spike as well as grain number per spike and contribute for the grain yield per plant. Therefore, plant height, spike length, grain per spike and thousand kernel weights should be considered for selection under organic conditions because these traits are directly contributing to grain yield.

CONCLUSION

Yellow rust incidence and severity pressure expanded from young seedling to milk stages. Our results suggest that the diversity within the CCPs can improve the resilience of the population under organic farming condition to suppress the spread of pathogens compared to the pure line. The composite crossed populations (CCPs) showed similar grain yield potential as check during evaluated cropping season. The result did not support the hypothesis that the CCPs would show significant difference for grain yield under organic conditions. Threfore, exploitation on source of genetic diversity of wheat will be required for further study and beneficial traits may be combined to develop a resilience cultivar to optimaize yield, resitance to disease and nutrient use efficiency under low input and organic conditions in their ecological farming system.

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