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Assessment of Several Generations of Wheat Populations for Yield and Desirable Traits under Organic Agriculture

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Abstract

Composite crossed population is one of the strategies that can be suitable under organic agriculture conditions to buffer against fluctuating environments, hence these composites have inherent genetic variability. The objective of the study was - to assess several generations of compositely crossed populations of wheat for grain yield, yellow rust and important traits in organic farming. The ANOVA revealed that no significant difference was observed among several generations of composite wheat population for yield, whereas there was a significant (p = 0.002) difference for a thousand kernel weight. The composite population of I had high thousand kernel weight (43.22 g) and the lowest recorded for pure line (37.42 g). A highly significant difference (P<0.05) was observed among the composite crossed population for strip rust incidence and severity across phenological growths. The highest yellow rust incidence (92.0%) was recorded for the pure line, followed by two old populations at the milk stage. Even though diversity within composite populations limited the spread of disease expansion, several generations of composite populations exhibited similar grain yield as pure line. Therefore, further study is required using the diversity of wheat and variant alleles to combine and develop resilience cultivars to optimize yield, resistance to disease and nutrient use efficiency under organic conditions in their ecological farming system.

Keywords: Composite Populations; Resilance; Yield; Organic Farming; Wheat

Introduction

Organic farming is the integration of crop and livestock production systems that strive for sustainability. It has been emerging and growing worldwide since the 1990s. Organic agricultural land is slowly increasing in Europe, with the highest per capita consumption located in this continent, while it is stable in Africa [1]. Africa is also producing agricultural products, but destine for export. For example, Ethiopia is producing organic coffee, sesame and other products.

Organic farming is a systematic re-evaluation of natural agriculture that relies on biological fertilizer input. The aim of organic agriculture is to produce healthy food that is environmentally friendly by closing the nutrient cycle in ecosystems with low inputs of synthetic fertilizers and avoiding the use of chemicals and genetically modified organisms [2]. Otherwise, organic agriculture is an advantage in terms of increasing diversity (at farm level, crop type, improved variety, soil biota) [3]. Organic farmers require a variety that is suitable for organic conditions and a low-input system. Since this enables them to provide them with assurance and resilience to stresses rather than the application of chemicals [4]. Breeding for organic agriculture looks for stable yield, good quality, seed health, a better root system, and the ability to interact with beneficial soil microorganisms and suppress weeds [5-7].

Pure line wheat is a genetically uniform variety that improved through a pedigree approach, and it's a dominantly improved seed when using high inputs application and provides potential yield at the right environmental conditions [8]. Though, these improved varieties cannot often adapt well at marginal agricultural environments for low-input systems and under organic conditions. Besides, due to the inhabited application of synthetic chemicals under organic conditions, diseases are more likely to affect yield crops [9]. For instance, the wheat yield loss due to yellow rust disease was 40–80% [10]. Therefore, the development of vigorous and or resilience variety from diverse population and evaluation their generation can be a strategy for plant breeding under organic and followed, selection for resistance to disease, optimize yield, resilience to fluctuation of environment in their ecology under organic farming system.

Furthermore, exploring and broadening the genetic germplasm pool is also an approach for crop o breeding under organic conditions. This helps to select desired traits and population variety development that is suitable to their ecological farming [11]. For instance; composite crossed population of wheat developed through possible varietal crosses and selection at each generation cycle that can enhance genetic diversity within the composite population and enable resilience to unpredicted biotic and abiotic stresses. In this study, we set up to test several generations of varietal composite crossed populations of winter wheat for grain yield, yellow rust and important traits under organic farming. In addition, we hypothesized that a varietal composite crossed population would be expected to perform better yield and buffering against fluctuation of environment than a pure line of commercial check.

Materials and Methods

Composite varietal crossed populations made from all possible cross combinations developed at Elm Farm in the UK. Several generations cycles were further evaluated for yield, quality and other agronomic traits with university partnerships in some parts of Northern West Europe. Sven generation composite crop population and pure line as check were carried out at the organic farm of Wageningen University and Research Center, the Netherlands, in 2013/2014. The genotypes were randomized with a complete block design and replicated triple in the plot size 6 m x 7.5 m = 45 m^2. All wheat genotype seeds were treated with organic mustard powder, whereas synthetic chemicals were not applied during trial tested.

Collected Data

Forty plants were tagged from each plot randomly, and yellow rust disease incidence and severity for each plot was assessed at flag leaf sheath p (39), flowering (61) and milk growth stage (83).

$$Disease\ incidence\ (\%)\ = (\frac{Number\ of\ infected\ plant\ units}{total\ number\ of\ plant\ units\ assesed}*100)$$

$$\%incidence = (\frac{Number\ of\ infected\ leave}{total\ number\ leave}) = average\ infected\ leaves * 100$$

Yellow rust disease severity: Visual scales ranged from 1; few isolated lesions) to 9 = very severe symptoms score). In addition, disease severity was evaluated in percentage at these growth stages based on BBCH; Base, Bayer, Ciba-Geigy and Hoechst [12].

Yield and agronomic traits data

i) The distance between spikelet's

40 plants per plot were tagged and measured or scored for spike length, plant height and the distance from flag leaf to spik. The number of spikelets per spike was calculated using the following formula.

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

ii) Plant height: Plant height was measured in cm from these sampled plants, and their average was taken

iii) The distance from flag leaf to spike: The distance from flag leaf to spike was measured in cm from these sampled plants and their average taken.

iv) Grain yield and a thousand kernel weight: genotype was harvested and grain yield per plot as well as a thousand kernel weight weighted and recorded for each plot.

Statistical Analysis

Statistical analysis was carried out using GenStat 16th edition software. Genotype was considered as fixed effect, whereas replication was considered as random effect. The significance of the genotypes tested, and mean separation was done using the least significant difference (LSD) at 0.05. The correlation between agronomic traits and disease was analyzed by using SPSS software.

Results

Significant differences (*P* <0.01) were observed among the composite crossed wheat population for yellow rust incidence at different growth stages (Table 1). The yellow rust incidence rapidly increased across the growth stages (Figure 1). For example, the highest yellow rust incidence (92%) was observed on the commercial check (pure line), followed by the old generation of composite crossed populations; A (43.56 %) and B 30.17 %) at the milk growth stage respectively.

Table 1: Mean for the yellow rust incidence (%) at different growth stages for wheat population trial

Genotype	Mean for yellow rust incidence of tagged samples		
	YR_IncFL	YR_IncFW	YR_Inc MS
commercial check/pure line)	54.40	81.85	92.00
B (HU-08-UK composite, OP)	33.70	41.70	43.55
A (OP, HU-08-YQMS)	10.80	27.32	30.10
G (OP, HU-09-YQMS)	11.00	17.53	18.30
D (MG, HU-10-YQMS)	9.28	17.10	18.01
E (MG, HU-11-YQMS)	7.90	17.13	23.04
H (NG, HU-12-YQMS)	7.00	17.42	27.50
I (NG, HU-13-YQMS)	9.70	12.42	24.15
CV (%)	15.00	20.70	22.50
LSD at 0.05	4.84	20.21	16.30

Notice: YR_ IncFL= Yellow Rust Incidence at flag leave, YR_IncFW= Yellow Rust Incidence at flowering, YR_Inc MS= Yellow Rust Incidence at milk growth stage., Op= Old population, MG= Middle generation and NG= New generation.

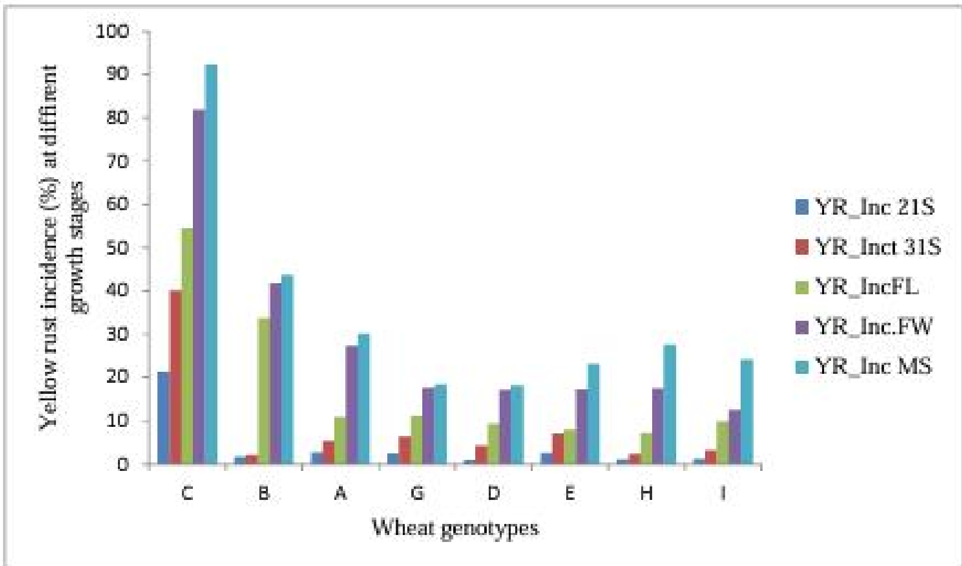

Figure 1: Trend of yellow rust incidence (%) expansion for each genotype across growth stages YRIncS21= yellow rust incidence at 21 growth stage, YRIncS31= yellow rust incidence at 31 growth stage, YRIncFL=yellow rust incidence at flag leaf appeared growth stage, YRIncFW=yellow rust incidence at flowering growth stage, YRIncMS= yellow rust incidence at milk stage

Significant differences (P <0.001) were revealed among the wheat population for strip rust severity (0-100% scaling rate) on the first and the penultimate leaves at flowering and milk growth stages (Table 2). The highest yellow rust severity (60.65%) was observed at the penultimate leaf at milk stage for the pure line), followed by old populations A and B (15.45 and 15.50%), respectively

Table 2: Comparison of mean for strip rust severity based on 0-9 scale and 0-100 % scoring rate at varied growth stages

Genotypes	Mean for Yellow rust severity based on (0-100 % scale)			
	YSV1sfLF	YSV2ndfLF	YSV1sfLM	YSV2nfLM
pure line	16.63	30.49	35.76	60.65
OP(B)	11.93	17.91	11.63	15.45
OP (A)	3.59	5.45	10.44	15.50
MG (G)	1.15	2.03	1.88	3.25
MG(D)	1.70	3.37	3.12	3.50
NG (E)	2.43	3.67	3.25	4.88
H (NG)	2.12	3.63	2.62	4.13
NG(I)	2.36	2.42	3.75	7.13
CV (%)	24.50	19.00	19.80	18.40
LSD, 0.05	5.27	6.21	8.52	9.62

YSV1sfLF (0-100 %) =Yellow Rust severity on the 1st flag leaf at flowering stage, YSV2ndfLF (0-100 % scaling) = Yellow Rust severity on penultimate leaf at flowering stage, YSV1sfLM (0-100 % scaling) = Yellow Rust severity on 1st flag leaf at milk stage, YSV2dfLM (0-100 % scaling rate) = Yellow Rust severity on penultimate leaf at milk growth.

Yield and Thousands Kernal weight

The ANOVA showed no significant difference (p > 0.05) among several generations of the wheat population for yield performance. Otherwise, significant differences ($P = 0.002$) were found among wheat population for a thousand kernel weight. The highest thousand kernel weight was recorded for the new generation of wheat population I (43.23 g), whereas the pure line revealed the lowest thousand kernel weight (37.43 g) (Table 3).

Significant differences observed among all wheat genotypes for; plant height (P<0.03), number of spikelets (P<0.014) and the distance from flag leaf to spike (P<0.007) (Table 3). The longest genotype was recorded for middle generation, E with an average length of 91.22 cm, while, population new population H had the shortest recorded average length of 76.28 cm indicating decreasing in height.

Table 3: Mean of grain yield (t/ha) and other traits for wheat genotypes

Genotype	Grain yield (t/ha)	TKW (g)	FT/ m^2	PT (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

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 spikelets, UFS = number of unfertile spikelets, TS =total number of spikelets / spikes, DS= the distance between spikelets

Correlation Among Traits

Yield displayed a significant positive association with a thousand kernel weight (r = 0.76), plant height (r = 0.64), and a non-significant negative association with strip rust incidence and severity. Likewise, plant height showed a significant positive correlation with spike length (r = 0.65), flag leave to spike (r= 0.70), fertile spikelet (r= 0.52), distance between spikelet (r = 0.65) and non-significant with yellow rust. Also, spike length showed significant positive correlation with fertile spikelet's (r= 0.90) and the distance between spikelet (r= 0.61) (Table 4). However, several of agronomic traits showed non-significant negative association with strip rust incidence and severity. This might be due to the broadened genetic base of the composite population, which enhances resistance to strip rust disease pressure under organic conditions.

Table 4: Assocation among agronomic triats and yellow rust disease in wheat population tested under organic conditions

	Y	TKW	plht	SL	FL	FS	UnfS	dS	YRIN	YRSV
GY	1									
TKW	0.75^{**}	1								
plht	0.65^{**}	0.54^{*}	1							
SL	0.21^{ns}	0.02^{ns}	0.65^{**}	1						
FL	0.45^{ns}	0.42^{ns}	0.70^{**}	0.25^{ns}	1					
FS	0.24^{ns}	-0.09^{ns}	0.52^{*}	0.90^{**}	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^{*}	0.65^{**}	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

Y= 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 spikelets, Unfs = number of unfertile spikelets, ds= the distance between spikelets, YRIN= yellow rust incidence, YRSV= Yellow rust severity, ns= non-significant

Discussion

Composite crossed population for yellow rust disease reaction and yield performance

Due to prohibited application of synthetic chemicals under organic condition, diseases pressure was likely observed on wheat genotypes. In this experiment, yellow rust incidence and severity exhibited on pure line than several generations of crossed population of wheat under organic condition. This might be due to pure line was narrow genetic based combination during derived line development via pedigree selection when compared to varietal composite population. Also, weak resistance of pure lines can explain due to low tillering capacity.

At seedling stage, the yellow rust symptoms and frequency was quite low for composite population. This statement was agreed with Chen [10]. Moreover, severity of strip rust was more observed on the old Composite population of A and B; however, it was not likely economic important due to low severity. This might be the diversity within composite crossed population enhanced the resilience of composite population to limit the spread of disease expansion across growth stages than the pure line under organic farming. This in line with Finckh and Mundt, Zhu et al. and Mundt, 2002) [13-15] who reported that varieties and multiline mixtures provide functional diversity of composite population that limits disease expansion. This may be due to the diversity based inter-varietal parents' combination the resistance genes were integrosed into the composite that build resistant to strip rust and cause different barriers to restrict the spread and expansion of the disease. Furthermore, we only tested the hypothesis of genetically diverse composite population would outperform a resiliance to disease than pure line. Furthermore, we only tested the hypothesis of genetically diverse composite population would outperform a resiliance to disease than pure line.

The genetic potential of several generation of wheat composite population did not display yield difference under organic farming, this showed that it did not support our hypothesis. The yield of wheat population was low, this might be due to slow-release nutrients under organic condition. on other hand, the new generation of composite crossed population had the highest thousand kernel weight with a comparable performance in yield, disease resistance and it likely more resilience population under organic condition. Murphy et al. [16] showed that the differences wheat genotypes for yield and genotype × system interaction under different growing conditions, indicating that further study require on diverse wheat genotypes under organic farming system

Plant height was the longest for the middle population; on E, whereas medium in height recorded for old population A and B. In contrast the shortest observed for the new generation population H. This study in contrary with Hensleigh et al. [17] who reported that the plant height of barley increased over years of generations.

Our study revealed that spike length positively associated with the distance between spikelets and employed positive effect on other traits. Akram et al (2008) stated that spike length had positive association with number of spikelets per spike. Increased in spike length was directly associated with increase in spikelet per spike, grain number per spike and contribute for final yield per plant. Therefore, plant height, spike length, grain per spike and thousand kernel weights can be considered for selection under organic conditions because these traits are directly contributing to final grain yield.

Conclusion

Our results highlighted that the diversity within varietal crossed population can improve the resilience of composite population under organic farming and suppress the spread of pathogens compared to the pure line. Several generations of composite populations exhibited similar grain yield potential as pure line. Threfore, further study is required using diversity of wheat and vareint alleles may be combined to develop a resilience cultivar to optimaize yield, resitance to disease and nutrient use efficiency under organic conditions in their ecological farming system.

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