Comparisons of Several Generations of Winter Wheat Composite Cross Populations with a Modern Cultivar under Organic Farming

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Major thesis for Master of Science in Plant Sciences

(Specialization Plant Breeding and Genetic Resources)

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February 2013

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Acknowledgements

Abbreviations

^0C degree Celsius

CCP-s   composite cross populations

cm   centimetre

DUS   distinct, uniform and stable

FHB   Fusarium head blight

gm   Gram

K cal   kilocalorie

lsd   Least Significant Difference

PAR   Photo-synthetically Active Radiation

SD   standard deviation

t/ha   Metric ton per hectare

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ABSTRACT

The study was conducted in the organic trial field of Wageningen University and Research Centre with the objective of assessing the potentials of composite cross populations of winter wheat with the pure line cultivars. Four different aged composite cross population, one CCP-extra population and one pure line winter wheat cultivar were evaluated using a randomized complete block design with three replications. There were much more observed differences between the genotypes at the vegetative stage and not for the grain yield. Genotypes have shown comparable grain yield performance in the experiments tested 2011/12 growing period, significant (p = 0.009) difference for the thousand kernel weight. The pure line cultivar Naturastar show the lowest thousand kernel weight of 34.3 gm. and the highest kernel weight was genotypes CCP-1 (39.5 gm). For the traits related to ground shading capacity genotypes show significant difference plant height (P = 0.0010), PAR at early stage (P = 0.001), area of the leaf next to the first node (P = 0.002) and ground shading at early development stage (P = 0.002). The longest genotype was CCP-1 with the length of 95.87 cm and Naturastar was the shortest one with the length of 90.4 cm. Less PAR was measured in the pure line cultivar Naturastar (199.3 μmolm-2s-1) and next to this the newly introduced population CCP-1 (322.7 μmolm-2s-1) also show significantly less PAR. Genotypes also show significant difference in percent of heads infested by Aphid (0.001) and spike compactness (0.001). The pure line cultivar was the highest in the percent of heads infested by aphid 28.63 % of heads were infested and the most compacted genotype 0.4179 cm between the spikelets and the lowest infestation was observed in CCP-extra population 13.11% and also the less compacted 0.4805 cm between the spikelets. Estimation of phenotypic correlation coefficient among traits indicated that there was significant correlation between grain yield with number of spikelets per spike (r = 0.397) and with PAR 1 (r = -0.513). Plant height with flag leaf spike distance (r = 0.803). Flag leaf spike distance with number of spikelets per spike with spike compactness (r = -0.62). Significant differences were observed for the traits plant height, flag leaf spike length and width of the leaf next to the first leaf. For plant height and flag leaf spike spike length, all CCPs have higher values for the diversity index. There were no significant differences between the CCPs in values for the Shannon-Weaver diversity index, H'. Genotypes showed highly significant differences for the SD within plots for the traits plant height (P<0.001), flag leaf spike distance (P<0.001), width of the 1st next to the 1st node (P<0.008) and width of the flag leaf (P<0.001).

Key words: winter wheat, composite cross population, organic, low-input

1. Introduction

1.1. Background information

Wheat is a cereal grass of the Graminae (*poaceae*) family and of the genus *Triticum* is the world's largest cereal crop. It has been described as the 'king of cereals' due to the area covered by wheat, high productivity and the prominent position it holds in the international food grain trade. Wheat (*Triticum spp*.) was domesticated 8000 years ago; it is one of the first cultivated cereal crops in all over the world. South-western Asia is believed as the origin of wheat (Acquaah 2007). It can be used as food and feed (Acquaah 2007; Hildermann, Thommen et al. 2009; Prohens, Nuez et al. 2009). Wheat starch can also be chemically modified and used as the manufacture of paper, adhesives, plastic films, sweeteners, thickeners cosmetic powder and cream (Prohens, Nuez et al. 2009). Not only the wheat grain has economic advantage but the straw also has importance for making different materials. The straw of wheat is rich in fibrous materials and used as production of structural composites, moulded products and packaging materials (Prohens, Nuez et al. 2009).

Wheat compares well with other cereals in nutritive value. Wheat flour of whole grain has a good nutrition profile with 13.7 percent protein, 1.87 percent fat, 72.57 percent total carbohydrates 12.2 percent fibre (Norwitz 2011)[1] 1.8 percent ash, 2.0 percent reducing sugars, 6.7 percent pentosans, 59.2 percent starch, and provides 314 K cal/100g of food. It is also a good source of minerals and vitamins viz., calcium (37 mg/100g), iron (4.1 mg/100g), thiamine (0.45mg/100g), riboflavin (0.13mg/100g) and nicotinic acid (5.4mg/100mg).

According to international grain council (2012)[2], in the 2010/11 cropping season 653 million tons of wheat were produced and 695 million ton estimated for 2011/12 in the world. The crop can grow on wider range of environment; it can grow best with optimum temperature of 25 ^{0}C but the crop can also grow 3-4^{0}C of minimum and 30-36^{0}C of maximum temperature (Briggle 1980; Prohens, Nuez et al. 2009). According to Acquaah (2007) the crop is best adapted to cool temperate climates where the rainfall is not greater than 400-600mm per year.

Based on the season of production there are two types of wheat i.e. winter wheat and spring wheat. Winter wheat is sown in the fall and it can have some growth before the onset of the weather in winter. Growth then ceases and the plants remain dormant through winter, where after the growth

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[1] http://www.immuneweb.org/lowcarb/food/grains.html verified November 07, 2012
[2] http://www.igc.int/downloads/gmrsummary/gmrsumme.pdf verified October 19, 2012

resumes in spring and harvest will be in the summer. Winter wheat needs vernalisation during the winter to induce flowering. This is not the case with spring wheat and can therefore be sown after the winter and can grow in a shorter period.

Wheat is a monoecious plant and has perfect flower. It reproduce sexually as self-pollinated and limited up to 3% cross pollination is possible (Prohens, Nuez et al. 2009); due to these aspects seed recovery needs little effort.

Breeding for organic agriculture system requires traits like weed competition, nutrient-use efficiency, nutritional value and end use for local artisan markets in addition to main traits of interest for conventional agriculture like yield, disease resistance and mass market end-use quality (Löschenberger, Fleck et al. 2008; Lammerts van Bueren 2012).

Plant breeding is a practice which is the outcome of the interaction between plant genetic material, selection environment and the persons carrying out the activity. According to Löschenberger et al. (2008) the first organic variety trial in Austria was conducted in 1995, and as a result the specific organic value for cultivation and use test was establihed for winter wheat and spring barley in 2001 and 2002, respectively.

1.2.   Statement of the problem

According to Willer (2012) in the year 2010 about 37 million hectares of land was cultivated in organic agriculture from 160 countries. Out of the 37 million hectare of land 10 million hectare were from Europe. The organic agriculture covers about 0.9% of the agricultural land in the world, 4.7% of the European Union cultivated land was organic (Willer 2011). The report show the growth of organic agriculture in Europe is strong, the area increases by 0.8 million hectares which is about 9% incensement at the end of 2009 compared with the previous years.

Half of the world's food produced by the resource-poor farmers, 1.4 billion peoples in the world rely on crops grown in low-input systems as the primary source of agricultural production (Murphy, Lammer et al. 2005; Fess, Kotcon et al. 2011). Due to the fact that cultivars developed under modern plant breeding programs do not perform will under the low-input condition resource poor farmers did not benefit from modern cultivars (Fess, Kotcon et al. 2011).

Cultivar development for organic agriculture needs also special attention to fulfil the requirements of the organic production system. Organic crop production is not allowed to use chemical fertilizers, herbicides, insecticides and the like to make favourable conditions for the crop (Lammerts van Bueren 2002; Lammerts van Bueren, Wilbois et al. 2007). As the result the productivity potential of organic farms is on average 20-30% lower than conventional farming systems (Mäder, Fliessbach et al. 2002; Mason, Navabi et al. 2007; de Ponti, Rijk et al. 2012). The organic farmers apply different soil fertility managements, (wide crop rotation, addition of green manures, fallowing, use of organic, non-chemical fertilizers, etc.). They look for cultivars with a good buffering capacity and good competitive ability rather than using chemicals to protect their crops (Mason, Navabi et al. 2007). Due to this, cultivars adapted to organic growing conditions need additional traits compared to those adapted to high external input systems (Lammerts van Bueren, Wilbois et al. 2007). Studies conducted in Washington State to see the performance of wheat cultivars in conventional and organic fields show that those genotypes that are top yielding in the conventional system do not always perform as good in the organic fields, due to genotype $\times$ system interaction so that varieties should be selected under organic condition for the organic production systems (Dawson, Murphy et al. 2006).

As organic cultivars are lacking, currently most of the organic and low-input farms use cultivars developed for the conventional agriculture (Lammerts van Bueren 2002; Lammerts van Bueren, Struik et al. 2002; Murphy, Lammer et al. 2005; Lammerts van Bueren, Jones et al. 2011). Those cultivars for the conventional agriculture were developed under high input conditions, making the environment favourable to the crop by adding fast releasing synthetic fertilizer and other chemical crop protections to improve the growing environment. Modern cultivars developed for conventional agriculture are genetically homogeneous (pure line) to comply to the legal requirement of the DUS testing (distinct, uniform and stable) criteria to register officially and release the cultivar (Dawson and Goldringer 2012). Genetic uniformity of the cultivar leads to decrease of biodiversity (Fasoula and Tokatlidis 2012). However, for the improvement of sustainability of agricultural systems biodiversity at all levels is crucial (Dawson and Goldringer 2012).

The organic and low-input farms may not have similar soil nutrient conditions like conventional agriculture. Disease, pest and weed pressure also become high due to the fact that chemical protection is not allowed in organic farming and resource limitation in the low-input farms; as the result

those cultivars developed under favourable condition may not be efficient under organic and low-input condition. In organic farming condition it is not easy to fit the environment to the crop, like at conventional farms, so the cultivars should be fit to the environment (Dawson and Goldringer 2012). The selection environment should be similar to the production environment, which means for low-input condition cultivars should be developed under low-input environment and vice-versa (Ceccarelli 1996; González, Slafer et al. 2005). Therefore organic farmers need cultivars adapted to organic, low-input farming systems. This means emphasis on traits such as nutrient efficiency in uptake and use, good weed competition ability and disease resistance (Wolfe, Baresel et al. 2008).

To increase sustainability and competitive ability of the cultivar by increasing the genetic diversity, the Organic Research Centre, Elm Farm in the United Kingdom developed composite cross populations (CCP) of wheat from 20 parents. The composite cross population had three foundations; the first one developed from crosses of parents having good baking quality, the second from crosses of parents having a good yielding potential and the third develop from parents of both good quality and yield potential (YQ). To evaluate the potential of those composite populations across different environment the cycling CCP-YQ population project designed over ten European countries. Wageningen University and Research Centre is one of the trial sites for the cycling project. Starting from the 2008/09 cropping season Wageningen University and Research Centre received seeds of the composite population from Hungary annually and carried out the trial under organic trial field conditions including a pure line bred for organic farming systems for comparison and re-sowing the harvested CCPs yearly.

1.3. Objective

General objective of the study: What are the potentials of the composite cross population compared with the pure line cultivars?

Specific objective

1) To compare the yield of winter wheat pure line cultivar with the composite cross populations under the organic/low-input agriculture. Relevant questions to be answered:
   - ➢ Does the yield of the pure line significantly differ from the CCPs?
   - ➢ Which cultivar/population shows better performance under organic/low-input condition?
2) To study the yield performance of the CCPs over the year. Relevant questions to be answered:
   - ➢ Do the CCPs show more yield stability over the years compared to the pure line?
      - ➔ at the level of overall means
      - ➔ at the plot level
3) To evaluate the ground shading capacity of the cultivars.
   - ➢ Do the CCPs differ in shading ability among each other compared to pure line?
4) How does the diversity with the CCPs evolve over the years? Which traits show most diversification?

2. Material and Methods

2.1. Composite cross and parental materials

Twenty parents were selected based on their high yielding potential (nine parents) and baking quality (12 parents) including four male sterile lines and 190 possible cross combinations were done by hand in UK-Elm Farm Organic Centre in 2001 (Fig.1).
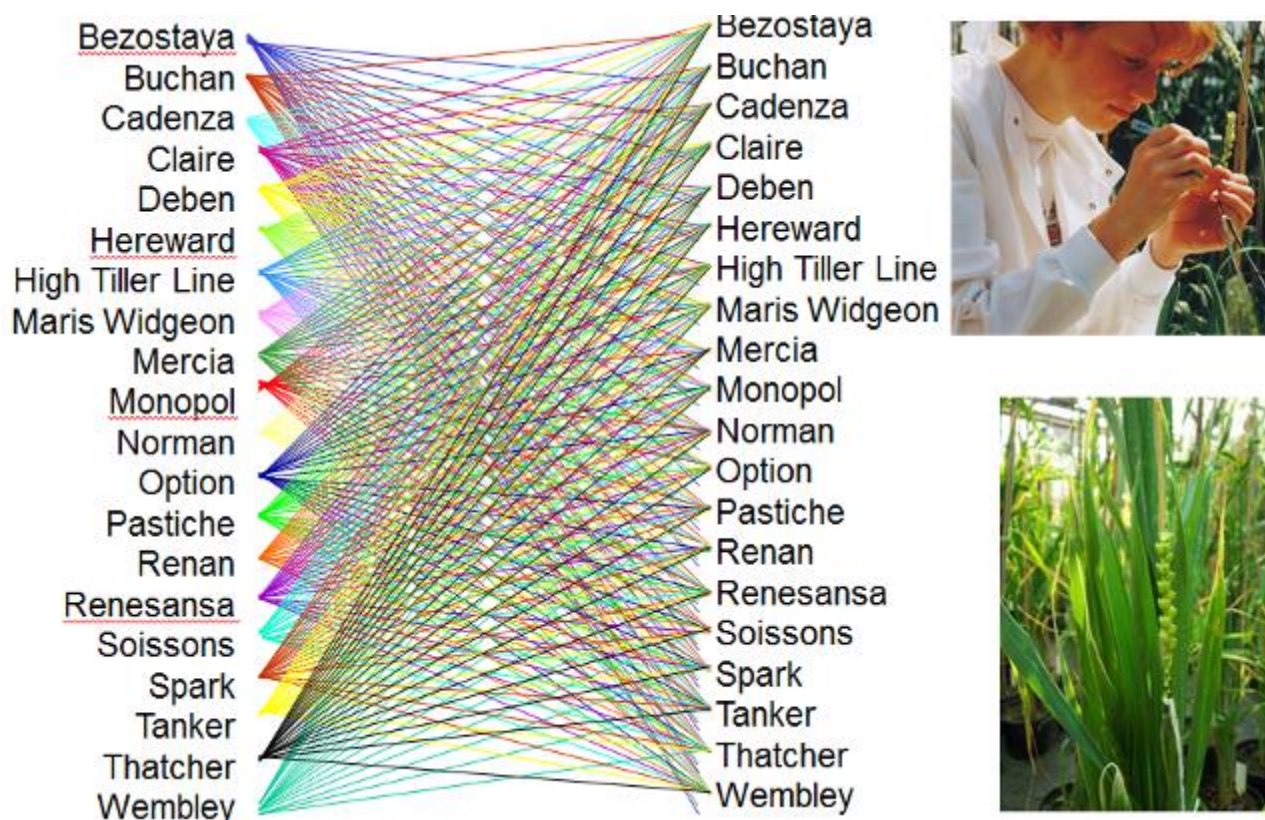
Figure 1. Parental lines and 190 possible cross combinations done by hand in the UK-Elm Farm Organic Centre. © The Organic Research Centre- UK

The composite cross populations were grouped according to the potentials of their parents into three groups see Fig 2: 1) "Yield (Y)" being those offspring's from the best "yielding" parents, 2) "Quality (Q)" those being offspring's from of the best "quality" parents and 3) "Yield and Quality (YQ)" being those offspring's from the combined "quality" and "yield" parents. In our trial only offspring's from the combined parents YQ, including 93 cross combinations were used. The seeds were bulking up over the year by sowing and re-sowing without selection.

	Bezostaya	Cadenza	Hereward	Maris Widgeon	Mercia	Monopol	Pastiche	Renan	Renesansa	Soissons	Spark	Thatcher	Buchan	Claire	Deben	HTL	Norman	Option	Tanker	Wembely
Bezostaya		YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	Y	Y	Y	Y	Y	Y	Y	Y
Wembley	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	Y	Y	Y	Y	Y	Y	Y	
Tanker	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	Y	Y	Y	Y	Y	Y		
Option	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	Y	Y	Y	Y	Y			
Norman	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	Y	Y	Y	Y				
HTL	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	Y	Y	Y					
Deben	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	Y	Y						
Claire	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	Y							
Buchan	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ	YQ								
Thatcher	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q									
Spark	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q										
Soissons	Q	Q	Q	Q	Q	Q	Q	Q	Q											
Renesansa	Q	Q	Q	Q	Q	Q	Q	Q												
Renan	Q	Q	Q	Q	Q	Q	Q													
Pastiche	Q	Q	Q	Q	Q	Q														
Monopol	Q	Q	Q	Q	Q															
Mercia	Q	Q	Q	Q																
Maris Widgeon	Q	Q	Q																	
Hereward	Q	Q																		
Cadenza	Q																			

Y - 33 crosses; Q – 63 crosses; YQ –93 crosses

Figure 2. Parental lines and possible combination of the good yield and quality crosses (Y= only yield, Q= quality and YQ=both yield and quality © The Organic Research Centre- UK

In some CCP populations naturally derived male sterile (MS) genotypes were included to stimulate cross fertilisation: indicated e.g. as YQMS. The YQMS composite cross population were distributed every year to different European countries for the cycling project. Wageningen University and Research Centre's organic trial farm Droevendaal received the composite cross population seed every year from cycling partner Hungary and sent harvested seeds to the next cycling partner in Witzenhausen, Germany (Kassel University). The cycling of composite cross population for yield and quality started in 2008.

2.2. Experimental set-up

The field experiment was conducted at the organic trial farm Droevendaal (Fig. 3) of Wageningen University and Research Centre the Netherlands during the seasons: 2008/2009, 2009/10, 2010/11

and 2011/12. The experimental design was a randomized complete block design (RCBD) and had three replications (Appendix Figure 1). Number of plots was different each year as the number of genotypes differed each year. The plot size of 6 m x 7.5 m (45m^2) were used except in 2011/12 the plot size of one genotype (CCP-1) was 4.5 m x 7.5 m = 33.75 m^2 due to seed shortage. Further field management details are indicated in Table 3. Each plot consisted of four beds of 1.5 m X 7.5 m with a small path between the beds. The soil is sandy.

Table 1. Description of the tested composite cross populations and the number of seasons grown in Wageningen, and their genotype code for this report.

Code of the genotype	Description	Year of harvest	
		HU	WUR
CCP-1	YQMS[1] CCP newly introduced and grown for one season	2011	2012
CCP-2	YQMS CCP grown for the second season	2010	2011
CCP-3	YQMS CCP grown for the third season	2009	2010
CCP-4	YQMS CCP grown for the fourth season	2008	2009
CCP-extra [3]	This population had a different history than CCP-4, but also grown for the fourth season	2008	2009

[1] YQMS CCP = the composite cross population based on crosses from parents with good yield and good quality, HU = Hungary, WUR = Wageningen University and Research Centre

The number and type of genotypes tested in each cropping season were not the same. The genotypes tested in each year are listed in Table 2. During 2008/09 cropping season only three genotypes were tested. In 2009/10 and 2011/12 cropping season the number of genotypes tested were six and in the 2010/11 cropping season the number of genotypes were five. The composite cross populations harvested in the previous season were replanted in the next season.

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[3] This population (CCP-extra) has the same parental background as the other composite population but it was grown for several years in Hungary and experienced harsh environmental conditions (severe winter which almost destroyed the whole yield and the remaining genotypes could have caused a shift in the population) .

Table 2 Genotypes tested in each cropping season

2008/09	2009/10	2010/11	2011/12
Perineo[1]	Naturastar[1]	Naturastar	Naturastar
CCP-4	CCP-3	CCP-2	CCP-1
CCP-extra	CCP-4	CCP-3	CCP-2
	CCP-extra	CCP-4	CCP-3
	Rouge de Bordeaux[3]	CCP-extra	CCP-4
	Zeeuwse Witte[4]		CCP-extra

[1] *pure line cultivar,* [2] *composite cross populations,* [3] *old land race from France,* [4] *old Dutch landrace*
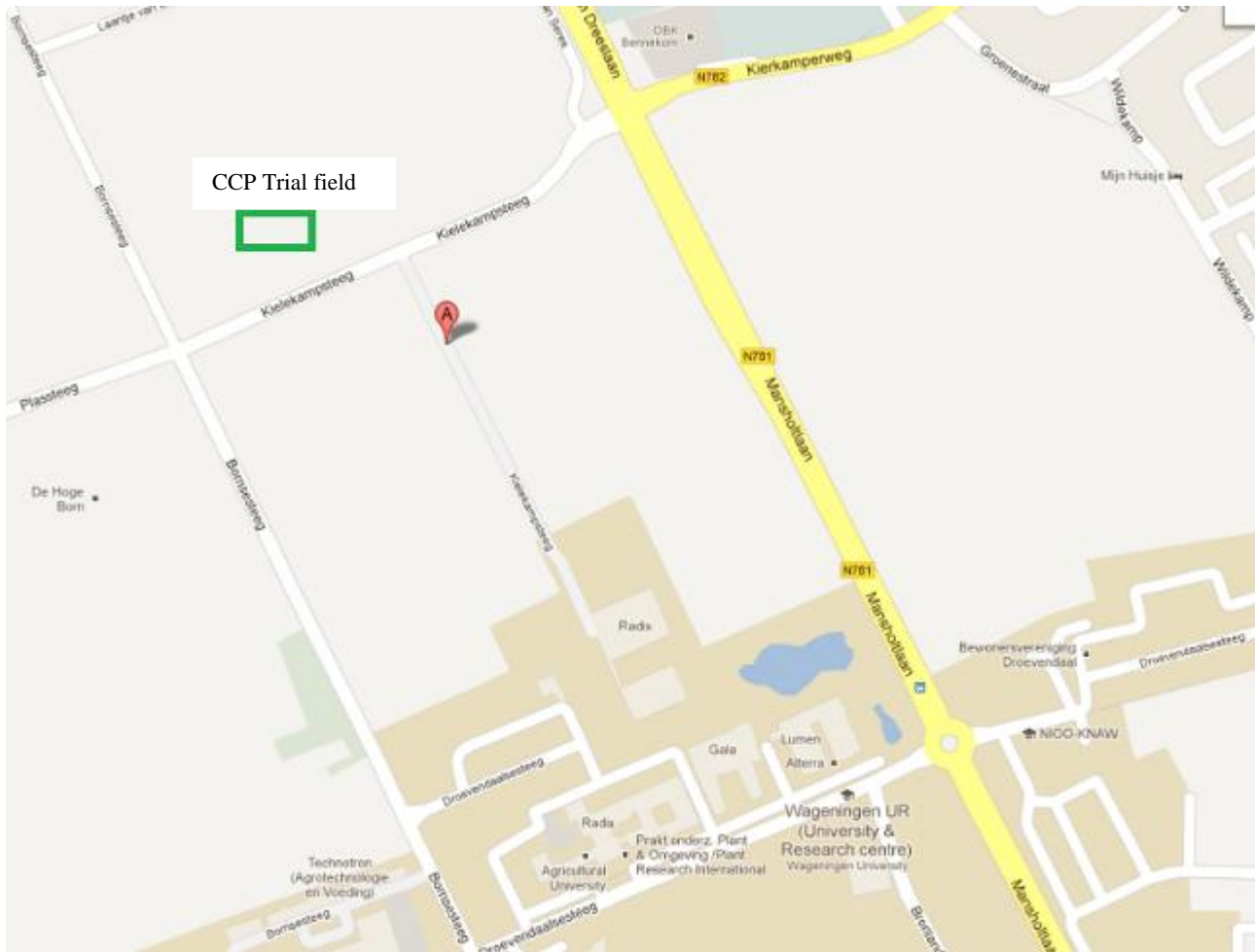
Figure 3. Map of Wageningen with location of the organic trial of composite cross population (CCP) in 2012. *(A=farm building of Droevendaal)*

Table 3. Major agronomic practices of the organically managed field trials 2008-2012, Droevendaal-Wageningen, The Netherlands

Growing period	Sowing date	Harvesting date	Pre crop	seaweed pellets (kg N/ha)	Seed treatment	Sowing density (Seeds/m^2)	Remark
2008-09	7/11/ 2008	29/07/ 2009	Peas	60	Tillecur[1]	200	
2009-10	21/10/2009	13/08/ 2010	Faba bean	60	Tillecur	500	Very cold spring and very hot summer
2010-11	28/10/2010	05/08/ 2011	Spring wheat	60	Tillecur	500	Water lodging during winter and high weed infestation (Camomilla)
2011-12	24/10/2011	14/08/2012	Spring barley	90	Tillecur	500	

[1]*Tillecur mustard powder and organic flours wetting and adhesive agents to treat seeds before sowing to protect the pathogen of wheat bunt (Tilletia tritici)*

2.3. Data collection

From the experiments conducted in 2008/09, 2009/10 and 2010/11 only the grain yield and thousand kernel weight data were collected. For the experiment conducted in 2011/12 data were collected from individual plants such as plant height, number of fertile spikelet's per spike, flag leaf area, length of spike etc. 40 plants per plot were randomly selected for the measurement. The plant growth stage was evaluated using the extended BBCH growth scale-for cereals (Monograph and Meier 2001).

➢ **Number plants per m^2**

Number of plants per m^2 data was taken at the stem elongation stage (growth stage 31) by using 0.5 m X 0.5 m = 0.25 m^2 quadrant. The number of plants in the quadrant was counted; the data were taken four times in each plot randomly.

➢ **Ground cover**

The ground cover data was taken when the crop was at the growth stage of 30-31, the data were taken by estimating the value using scales of 1 to 9, where 9 was the value for 100% ground cover.

➢ **Erectness of the plant**

The erectness of the plant data was taken when the crop was at the growth stage of 30-31, The data was taken by estimated value using scales of 1 to 9 where 9 for planophyle and 1 for erect plant architecture.

➢ **Light interception**

The light interception data was taken by using SS1− Sun-Scan Canopy Analysis System which measures Photo-synthetically Active Radiation (PAR). The data was taken at two different growth stages of the crop. In each stage the reading was taken six times at each plot and mean of the readings was used for the analysis.

➢ **Length and width of leaf**

The length and width of the leaf next to the first node, next to the second node and flag leaf data were taken from the mean of 40 randomly selected plants per plot recorded in cm.

➢ **Leaf area**

Measurements for the leaf area were taken in the field and the results were taken to calculate the leaf area as indicated below (BILGI, 2006):

$$Leaf\ area = L\ X\ W\ X\ F$$

Where L = Maximum length (cm)

W = Maximum width (cm)

F = factor (0.707 for wheat (BILGI 2006)

➢ **Date to 50% flowering**

Dates to flowering data were taken when 50% of the plants in each plot were flowering by checking every 2-3 days during flowering time.

➢ **Number of spikelets per ear**

Numbers of spikelets per spike were counted from the mean of 40 randomly selected plants from each plot.

➢ **Number of fertile an unfertile spikelets**

The number of spikelets with grains was counted as fertile spikelets and the empty spikelets counted as unfertile spikelets; the data were taken from the mean of 40 plants per plot at the growth stage of 90.

➢ **Spike length (cm)**

The mean spike length of 40 plants per plot was taken. The spike length (cm) was measured from the base of the spike to the top of the last spikelet, excluding the awns.

➢ **Distance between the flag leaf and the spike**

The length of the distance between the flag leaf and the spike were measured in cm. The mean length was taken from 40 plants per plot.

➢ **The distance between spikelets**

The data of 40 plants per plot were recorded by exploiting the data of spike length and number of spikelet per spike.

$$Distance\ between\ spikelet's\ (cm) = \frac{Lenth\ of\ spike\ (cm)}{Number\ of\ spikelet's\ per\ spike}$$

➢ **Plant height**

The mean height of 40 plants per plot was randomly measured. The plant height was taken from the base of the plant to the last spikelet excluding the awns recorded in cm.

➢ **Percent of Aphid infestation**

Of all plants in a quadrant of 0.5 m x 0.5 m (0.25 m^2) the head was assessed by eye and the number of heads infested by aphids counted (Fig 4).
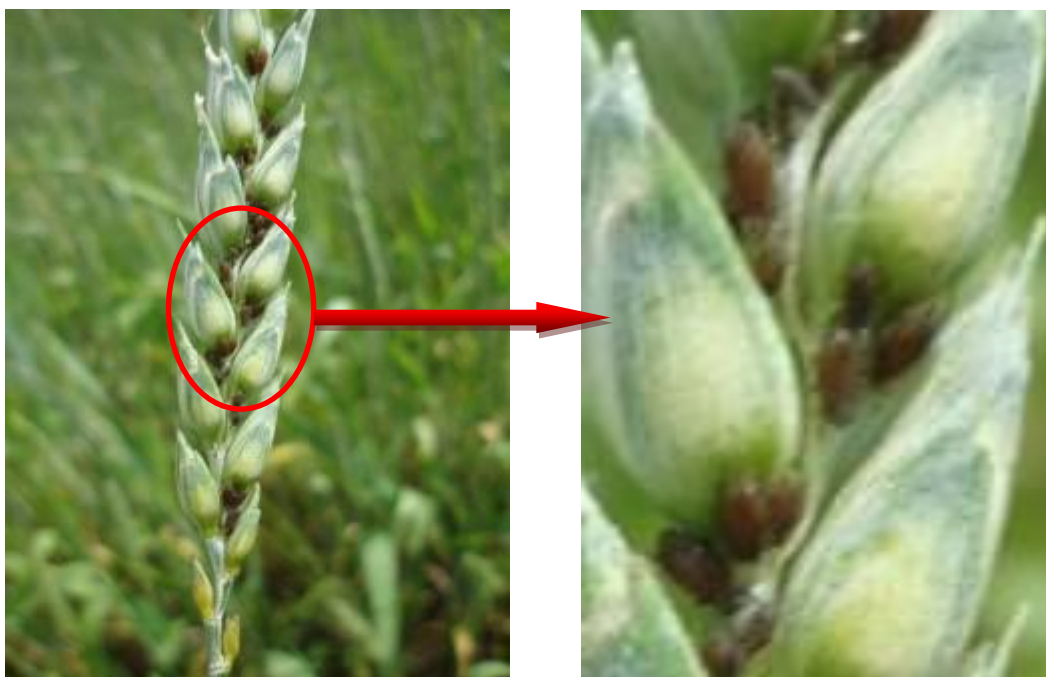
Figure 4. Wheat head infested by aphid showing aphid populations between the spikelets

The % of aphid infestation calculated as

$$\% \ of \ aphid \ infested = \frac{Number \ of \ heads \ infested \ by \ aphid}{total \ number \ of \ heads \ in \ the \ quadrant} * 100$$

Six samples were taken randomly in each plot.

2.4.   Environmental conditions

The rainfall temperature data and other environmental data of the experimental area were recorded in the Meteostation Haarweg- Wageningen[4]. The summary of rainfall and minimum and maximum temperature data are presented in Appendix Table 34-45.

2.5.   Statistical analysis

The statistical software Genstat 15th edition was used for the statistical analyses. For the analysis of variance a general treatment structure in randomized blocks was carried using a threshold p value < 0.05 to declare differences significant. To check the assumptions of

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[4] http://www.met.wau.nl/haarwegdata/dayfiles/ verified October 27, 2012

ANOVA (normality and homogeneity of variance) were not violated the residual plots were run (Appendices Figure). When the difference was significant ($P < 0.05$) the fishers protected least significant (LSD) test ($\alpha = 0.05$) was used to study which means differed significantly. The output of the ANOVA analysis can be found in Appendix Table 1 - 20.

> *Analysis of the genotypic variance*

The genotype and phenotypic variance components and coefficient of phenotypic and genotypic variability were estimated as:

$$\text{Genotypic variance } (\sigma 2g) = \frac{MSg - MSe}{r}$$

Where MSg = Mean square due to genotype

MSe = Environmental variation (error mean square)

r = the number of replication

Environmental variance ($\sigma^2 e$) = error mean square

Phenotypic variance ($\sigma^2 p$) = $\sigma^2 g + \sigma^2 e$

Heritability in the broad sense is the ratio of the total genetic variance to the phenotypic variance (Dudley and Moll 1969). This is calculated as:

$$\textit{Broad sense Heritability } (H^2) = \frac{\sigma^2 g}{\sigma^2 p}$$

Where H^2= Broad sense heritability

$\sigma^2 e$= Environmental variance

$\sigma^2 p$= Phenotypic variance

$\sigma^2 g$=Genotypic variance

> *Analysis population Diversity*

To study the diversity in performance of the genotypes the phenotypic traits were converted to different discrete classes: plant height to five classes, but other traits were converted to three classes as low, intermediate and high. The proportions of each class for each genotype were calculated (Appendix Table 33).

The phenotypic frequency data of the traits were analyzed by the Shannon-Weaver diversity index, H'. This diversity index is widely used in studies of germplasm collections (Bechere, Belay et al. 1996). This is calculated as:

$$H' = \sum_{i=1}^{n} pi \, logpi$$

Where n is the number of phenotypic classes for the trait and pi is the proportion of the total number of entries in the ith class. H' was calculated for each genotype and phenotypic traits. To keep the H' value between the range of 0 −1 each value of H' were divided by log (n). For the analysis variance of diversity of each trait the normalized value of H' was used.

3. Literature Review

3.1. Cytogenetics of wheat

The gene pool of wheat is large and it is known by its diversity among the cereal crops (Prohens, Nuez et al. 2009). The species of *Triticum* are grouped into three ploidy classes, which are diploid (2n=2x=14), tetraploid (2n=2x=28) and hexaploid (2n=6x=42). Common wheat (*T. aestivum*) is an allohexaploid of genomic formula AABBDD (Prohens, Nuez et al. 2009). The two main commercial type of wheat are durum (*Triticum durum* L., 2n = 4x=28) and common wheat (*Triticum aestivum* L., 2n=6x=42). In hexaploid wheat the 21 chromosomes are divided into seven homologous groups identified with numbers from 1 to 7. Homoeologous chromosomes are similar both in structure and gen content.

The three chromosomes within the ABD homologous group usually share some loci in common for specific trait. Tetraploid and hexaploid wheat reproduce naturally as diploid. The gene ph1 (pairing homoeologous) which is present on the long arm of 5 B chromosome makes the reproductive mechanism possible which enables diploid pairing to occur (Acquaah 2007; Prohens, Nuez et al. 2009). The common wheat *Triticum aestivum* L. is the more widely grown wheat.

3.2. Genetic Variation

The difference between individuals due to their genetic makeup or the influence of environmental factor in which they are grown is known as variation. If two individuals grow in the exactly similar environment and show differences in their characters such variation is genetic variation. The information, the type and the magnitude of genetic variability has great importance for the formulation of a plant breeding program (Khodadadi, Fotokian et al. 2011).

Genetic variability is the primary interest of the plant breeder since the highest genetic distance between parents will result in higher heterosis in the progeny (Khodadadi, Fotokian et al. 2011). Phenotypic variation is the result of both the genetic and the environmental factors. Genetic distance estimation could be one of the essential tools for selection of parents in wheat hybridization program.

3.3. Desirable traits for organic breeding program

Organic agriculture is not only focussed the product of a certain cultivar (e.g. traits related to productivity) but it is also a production controlled system (Lammerts van Bueren, Struik et al. 2002). Organic farming systems shares priority on traits like yield and end-use quality with the conventional breeding, but in addition aim at traits such as good competition with weeds, resistance to seed-borne diseases and nitrogen use efficiency (Acquaah 2007; Löschenberger, Fleck et al. 2008; Lammerts van Bueren, Jones et al. 2011; Lammerts van Bueren 2012). Most organic farms depend on mechanical weed control. Mechanical harrowing machines may cause damage to the plant during harrowing; the ability of genotypes to tolerate the mechanical damage or to recover rapidly from the damage are good traits which are important for organic farming systems (Donner and Osman 2006).

3.3.1. Weed suppression ability of cereals

According to Mason, Navabi et al. (2007) weed competition is the main factor for the reduction of crop yield in organic farming. Poor weed management practice is one of the yield limiting factors in organic agriculture (Bond and Grundy 2001). As the result of poor weed management the weed seed number in the soil increases through time. The weed diversity of weed species is also high in organic farming system (Bond and Grundy 2001; Mason, Navabi et al. 2007; Reid, Yang et al. 2009). Scientific studies confirm that there is genetic variation between wheat cultivars in weed competitive ability (Lammerts van Bueren, Jones et al. 2011; Lammerts van Bueren 2012). Some studies show that cultivars with the highest grain yield under weed free condition did not keep their rank under weedy condition which tells us there is difference in weed competitiveness between cultivars (Dawson, Murphy et al. 2006).

Effective weed management practice is essential for sustainable organic agriculture; cultivars having a high competitive ability against weeds will have an importance as cultural control to decrease the damage of weeds in organic agriculture (Hoad, Bertholdsson et al. 2011). In organic agriculture complete weed control is not advisable. Low weed population in the organic farm is encouraged because weeds may serve as shelter and food for the beneficial organisms (Bond and Grundy 2001; Hoad, Bertholdsson et al. 2011). Whereas if the weed population level is above the critical threshold level weed control is crucial (Hoad, Topp et al. 2008).

Competitive ability of the genotype against important weeds is not the function of single trait rather it is the result of the interaction of various desirable characters (Donner and Osman 2006; Hoad, Topp et al. 2008). Scientific studies approve that crop competitive ability in many of cereals reduce the growth of weeds (Hoad, Topp et al. 2008). Agronomic factors like seed rate and spacing between and within rows also affect the competitiveness of the crop against the weed. Different crop cultivars have different competitive ability. Modern semi-dwarf wheat cultivars are less competitive than older standard long-straw types (Lemerle, Gill et al. 2001; Didon 2002). The growth and development of the root also affects the weed competitive ability of the crop but it is not clearly understood because it is not easy to study (Wilson 1988). Weed competitive ability should be integrated with other important characteristics during cultivar selection for organic agriculture (Hoad, Bertholdsson et al. 2011).

3.3.2. Important traits for weed suppression in cereals

Crop ground cover, leaf canopy size and light interception are some of the important characteristics of cultivars for weed suppression (Hoad, Bertholdsson et al. 2011). The relative plant height of the competing crop can influence the competition for light of the crop against weeds which means that tall wheat cultivars can be better competitors than short cultivars due to shading ability (Lemerle, Gill et al. 2001). With respect to the environmental conditions, weed type and density will influence the competitive ability of wheat cultivars (Lemerle, Gill et al. 2001). According to Donner and Osman (2006) crop ground cover, growth habit of the crop, tillering capacity, rapid early growth to stem extention and plant height are important physiological and morphological traits for the crop's weed competitivenss.

➔ *Crop ground cover*

The crop ground cover is related to the light interception of the crop, as the crop ground cover increases when the weed population decreases. This is due to the fact that the shading effect of the crop will suppress the growth of the weed (Donner and Osman 2006). Studies show that, the ground cover at the early stage of the crop is strongly correlated with weed suppression. The width of the leaves is also indicating the ground cover potential (Hoad, Bertholdsson et al. 2011). Selection of cultivars for weed competitive ability should consider the early ground cover ability.

➔ *Growth habit of the crop*

The leaf inclination is the main contributing factor of the growth habit of the crop (Hoad, Bertholdsson et al. 2011). The growth habit of the crop at early stage has impact on the weed competitive ability of the crop; for example, if the crop at early stage has planophile growth habit it can cover the ground and the fractional light interception will increase and as a result the weed suppression of the crop increases (Donner and Osman 2006; Hoad, Bertholdsson et al. 2011). The competitive ability of planophile genotypes in a later growth stage is related to large flag leaves (Köpke 2005; Hoad, Bertholdsson et al. 2011). Cereals varieties which have erect leaves are poor in their weed competitive ability (Donald 1968).

➔ *Tillering capacity*

Shoot population density is measured as the number of shoots per given area. This is the result of plant population density and the capability of the plant to produce tillers (Donner and Osman 2006). Cultivars differ in their establishment; some cultivars have a good establishment and have a higher shoot population and others have poor. Some cultivars may have both: a good tillering and good establishment (Donner and Osman 2006). If the plant density is low then high tillering capacity is important. Due to the fact that in organic agriculture it is not allowed to use chemical seed treatment for diseases and pests the crop establishment can be affected. High tillering ability will compensate poor crop establishment (Hoad, Bertholdsson et al. 2011).

➔ *Rapid early growth*

The rapid growth of the crop at the early stage will help the crop to take the essential nutrients faster than the weed; as a result the shading capacity over the newly emerging weeds will increase (Donner and Osman 2006). The weed competitive ability is associated to the crop vigour. According to Hoad et al. (2011) traits like seed size, seedling growth rate, coleoptile tiller development and seed embryo size contributes to early crop vigour.

➔ *Plant height*

Plant height is a very important trait for weed competition; tall plants have a good competitive ability at good crop density (Donner and Osman 2006; Hoad, Bertholdsson et al. 2011). Early stem elongation of the crop is more important than tall stem at maturity (Donner and Osman 2006). For erectophile leaf habit plant height can compensate weed shading ability

(Donner and Osman 2006). Plant height should be considered as one of the shading abilities of the crop to suppress weed growth. According to Donner and Osman (2006):

> "The effect of crop height is not consistant, most likely because changing in height is associated with changing in other characterstics such as plant growth habit. Plant height does appear to compensate for low value in other characteristics such as low plant or shoot density."

Plant height has also associated with Fusarium head blight (FHB) disease resistance, which is a serious wheat disease all over the world. The gene which is responsible for the dwarf growth characteristics of the wheat (Rht1 and Rht2) increases the sensitivity of the wheat crop to FHB (Fess, Kotcon et al. 2011). QTL studies conducted to know the relation between plant height with FHB confirm that plant height and FHB disease resistance have a positive relation (Piepho 1998).

→ Allelopathy

Weed control in conventional agriculture depends on the use of herbicides, which has various ecological and environmental impacts, Allelopathy is one of the biological safe weed control measure (González, Slafer et al. 2005). However, biological weed control methods are the least exploited areas in weed management (Wu, Pratley et al. 2000). Plants produce phytotoxins and this phytotoxins interfere the growth of other plants; this is called allelopathy (Wu, Pratley et al. 2000). Acording to Donner and Osman, (2006) cultivars of barley, oat and wheat (González, Slafer et al. 2005) show allelopathic properties with different propertions, but to exploit the allelopatic effect in breeding more work needs to be done. Different wheat cultivares have a different allelopatic potential against weeds (Murphy, Lammer et al. 2005). Studies conducted to see the allelopatic effect of wheat accession on the root growth of ryegrass show that there was a significant difference between the genotpes tested on the inhibition of the root length of rye grass (Wu, Pratley et al. 2000). In this study Wu et al. (2000) concluded that wheat accessions with vigorous growth parameters do not have a correlation with strong allelopathic activity and vice versa. According to the review of Zuo et al. (2005) and Wu et al. (2001) different autors found different chemicals which are responsible for the allelopatic effect in wheat, such as:

> phinolic acids (*p*- hydroxybenzoic acid, vanillic acid and syringic acid) and hydroxamic acids (2, 4-dihydroxy -7-methoxy-1, 4-benzoxazin-3-one) are recognized as phtotoxic allelochemicals. The chemicals can affect the nitrogen absorption, bio-

membrene permebility, protein synthesis, photosynthesis, respiration enzyme activity, balance of plant hormones and water potential in affected plants.

The allelopathic chemicals in wheat are water soluble chemicals and which can be distributed to the soil and affect the germination of weed seeds (Wu, Haig et al. 2001). Using crop varieties that have allelopathic potential can reduce the need of using synthetic herbicides to early season application (Wu, Pratley et al. 2000) which can also be advantageous for the organic farms.

3.3.3. Yield stability

According to Lammerts van Bueren et al. (2002) the management of the organic farming is not only aiming at high yield under low-input condition but also at yield stability. The buffering capacity of the population is higher than the pure lines in the fluctuation of the growing environment, due to the fact that populations have a diverse genetic pool to buffer adverse conditions compared to the pure line cultivars[5]. To evaluate the performance of the genotypes, selection in a breeding program needs many years and location. This makes selection for yield stability difficult (Tester and Langridge 2010). Infection of cultivars by fungal diseases is one of the causes for the reduction of the yield in the areas of humid and temperate climate areas like the Netherlands (Lammerts van Bueren, Struik et al. 2002).

3.4.   Selection strategies

To improve yields under organic/low-input agricultural system selection of genotypes should be conducted under the organic/low-input conditions (Fess, Kotcon et al. 2011). Studies confirm that cultivars selected under a high input environment mostly did not show their potential in a low-input environment (González, Slafer et al. 2005; Fess, Kotcon et al. 2011). Acording to Ceccarelli et al. (1998) selection of cultivars in the target (low-input) environment is more efficient than indirect selection.

Cultivar selection for weed competitive ability can be conducted in both directly with the presence of weeds and indirectely by looking for traits that are associated with weed competitive ability (Hoad, Bertholdsson et al. 2011). Traits for indirect selection like plant height and development rate are relatively easy to quantify whereas some crop characteristics

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[5] http://www.efrc.com/ manage/ authincludes/ article uploads/Research/Plant%20breeding/ TAG%20Bulletin%2022%20Elm%20Farm.pdf verified November 23, 2012

like shading ability are a combination of several traits and thus not easy to quantify (Hoad, Bertholdsson et al. 2011). So selection for weed competitivenss needs great attention by taking different traits and crop characters into consideration.

3.5. Evolutionary breeding

Evolutionary breeding is the use of mass selection method to improve the crop through evolution, which is used by the farmer for more than 10,000 years (Murphy, Lammer et al. 2005). Evolutionary breeding creates populations that are not uniform or stable, whereas those populations are genetically diverse and the genetic constitution changes over time (Döring, Knapp et al. 2011). Evolutionary crop breeding is most effective in a population that has a broad genetic heterogeneity. Genotypes that have superior response to abiotic and biotic stresses naturally will form a population (Lammerts van Bueren 2012), no artificial selection is under take the natural selection in the population will select the high yielding genotypes (Murphy, Lammer et al. 2005). Individuals which have a heritable trait that can give more offspring than other individuals will change the population through time (Phillips and Wolfe 2005). As the result the core of evolution is heritable variation (Phillips and Wolfe 2005). Evolutionary plant breeding has four stages. The principle of first stage is similar to conventional plant breeding, which is creating of genetic variability by making hand crosses (for a composite cross population) or mixing of different cultivars (for a variety mixture). Composite cross populations are populations of segregating individuals derived from inter-crossing a number of parents and it is a way of making crop communities with a high degree of heterogeneity (Phillips and Wolfe 2004). Cycles of multiplication of the seeds of the cross separately will be undertaken in the second stage. To produce the first composite cross population seeds of each cross will be mixed equally. The populations created by crossing of different genotypes are called composite cross population. In the third stage, the plant population number increases and with no active selection of individual plants part of the harvested seed will be saved for sowing again. The fourth stage will be the result of evolutionary breeding; the yield can be used as food or feed. It can also be used as the starting material for a further plant breeding program by selecting single plants which have desirable traits (Döring, Knapp et al. 2011).

Genetic diversity has an important role in plant breeding either to exploit heterosis or to generate productive recombination. The first most important step in a plant breeding process is parental selection (Khodadadi, Fotokian et al. 2011). Modern cultivars, breeding lines and cultivars adapted to specific environment are the major sources for parental selection

(Murphy, Lammer et al. 2005). According to Murphy et al. (2005) to start evolutionary breeding for inbred grain crops various type of breeding may be used. Among those

1) A simple cross with two carefully selected parents

2) A top cross consisting of three parents

3) Cross of 4 – 10 parents that are successively bulked and

4) A composite cross consisting of more than 11 parents.

Crossing schemes have drawbacks and advantages but more parents will result in more genetic diversity and the greater the longer lasting genetic diversity of the population. But potential dilution of good parents and long and more complex will be the crossing schemes; this is the drawback of using large numbers of parents. As indicated in Figure 5 which is the suggested evolutionary breeding scheme, the basic methods of evolutionary breeding are similar for all crossing schemes. After the initial crosses the F1 plants will grow in the green house, the F2 plants can be sown in the breeder's field and the F3 plants can grow in a wider area in the target environment or farmer's field. Hand rouging of the disseised and deformed plants (negative mass selection) will be made in the field and blowing or screening of the small seeds during harvesting will be done but the natural selection is the dominant. After F 3 – F 4 generation they will have 94% homogeneity in self-pollinating species. After this one can choose to expand the breeding practice further than the bulking population by selecting plants that show best adaptation and have a good quality to fulfil the market demand. The populations become better adapted as they grow over more years in a given environment (Murphy, Lammer et al. 2005). The populations developed through bulking of evolutionary breeding can be considered as modern landraces.

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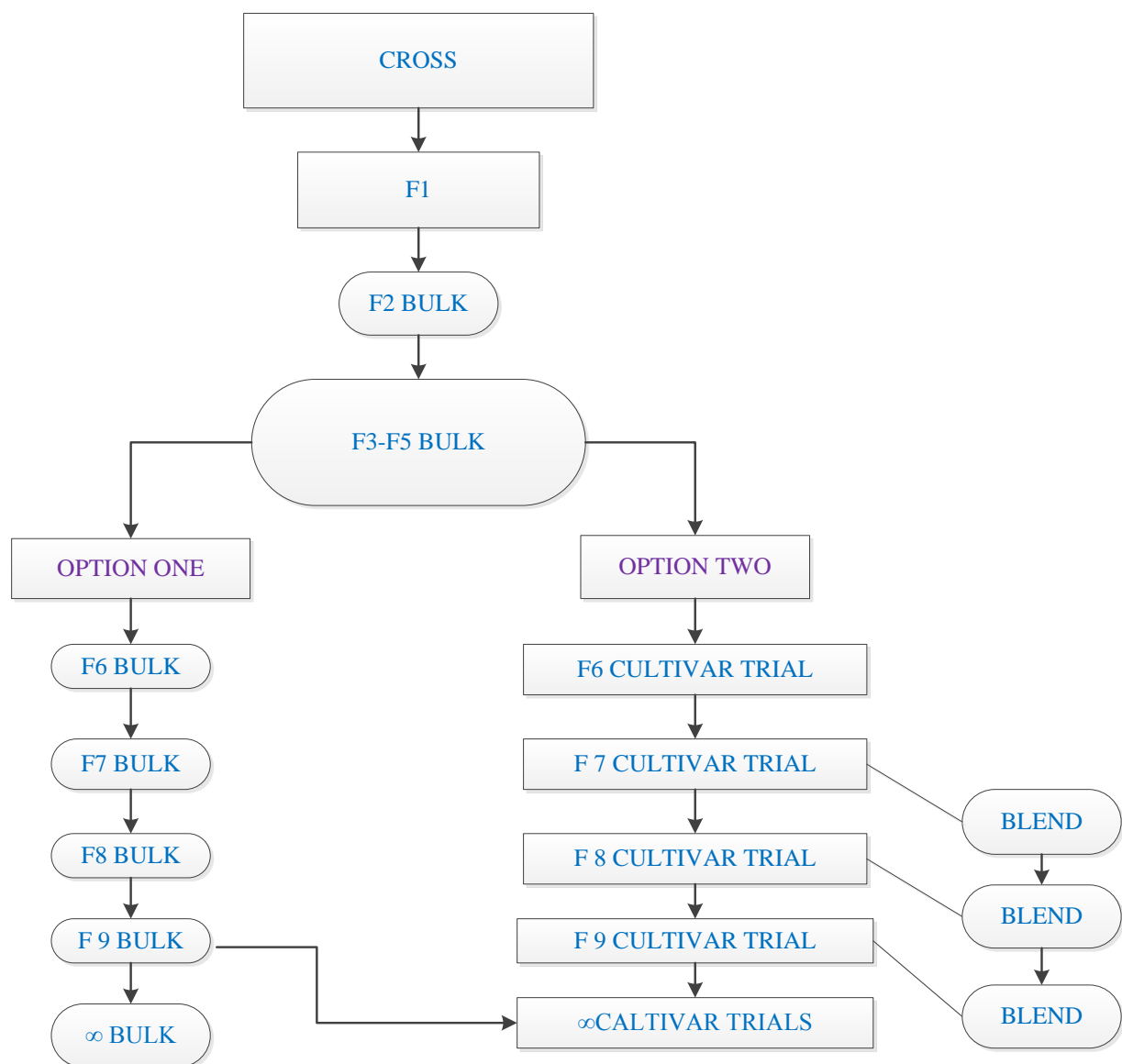
Fig 5. Scheme of evolutionary breeding method (source: Murphy et al., 2005).

The main requirement for evolutionary breeding is genetic diversity. The advantages of genetic diversity on crops are complementation, cooperation, compensation and capacity (Döring, Knapp et al. 2011). When crops grow together with diverse genotype have different resource need they will complement each other in the uptake of limiting resource (Busch, Janke et al. 1974). For example, if crops with different rooting patterns grow together or crops with different light interception strategy they will not compete each other for the same resource. Some genotypes produce volatiles which have a repellent or toxic effect for insect pests and if those genotypes grow together with other genotypes they can help to protect those genotypes from pest attack. These type of effects termed as cooperation. In many cases, when one grows a pure line cultivar he can harvest a good yield only in good growing environment.

If the growing environment varies the harvest will decline; whereas if the cultivar is mixed with genotypes which can withstand different environmental conditions it is possible to compensate each other. The average yield over different growing seasons will be higher with mixed genotypes than with pure lines under high variable environmental condition due to compensation (Döring, Knapp et al. 2011). The population including various genotypes have the capacity to have more characters than the pure line.

Whereas genetic diversity also has some limitations; like competition of genotypes in populations for the same resources (e.g. plants compete for light and water). In diverse population plants may cost much of the energy for competition rather than grain yield, for instance if plants compete for light and plants that have good competitive ability for light but are poor in grain yield grow with those plants which have poor competitive ability with good grain yield, plant which have good competition for light will dominate and finally the productivity of the crop will be low (Döring, Knapp et al. 2011). In genetically diverse population maximized grain yield is not stable through evolution the population can be dominated by high competitiveness but low grain yield ability genotypes (Zhang, Sun et al. 1999).

Murphy et al. (2005) argue that the organic growers and low-input farmers have diverse mechanisms for maintaining the soil fertility and pest management. This diversity is a challenge for the breeder to develop a cultivar for diverse agro-climatic zones. It is not economically feasible having test plots of different practice in the breeding station. Whereas the evolutionary breeding is a cost effective method to select specific traits in large number of plants having various populations growing on different farms.

In evolutionary breeding parental selection and progeny yield prediction is an important tool for the breeder to take in consideration before starting the breeding program; because yield is the major component of the breeding activity. Studies are conducted to evaluate the performance of the offspring of spring wheat parents having different yielding potential parents; high yielding parents (high $\times$ high) , high $\times$ low and low yielding parents (low $\times$ low) offspring from high yielding parents give the highest yield and the lowest yield was observed from offspring come from low yielding parents (Busch, Janke et al. 1974). This study indicates that parental means can be applied in predicting the usefulness of their crosses. This is different for yield quality, as this is not affected by natural selection. So it is important to include high quality parents in evolutionary breeding programs (Murphy, Lammer et al. 2005).

4. Results and Discussion

4.1. Analysis of variances of 2011/12 experiment

Introduction

There was no significant difference (*p=0.37*) among the genotypes for the grain yield, PAR at the flowering stage and area of the second leaf next to the second node (Table 4). Whereas very highly significant differences were observed among the genotypes for the thousand kernel weight, number of spikelets per ear, number of unfertile spikelets, number of productive tillers m^{-2}, plant height, area of the 1st leaf, percent of aphid infested heads, length between the flag and spike and spike compactness (Table 4). Area of the flag leaf and spike length also exhibited significant and highly significant difference respectively.

Table 4. Analysis of variance of traits measured in the winter wheat trial 2011/12, Droevendaal, Wageningen, The Netherlands

Traits	MSr	MSg	MSe	CV%	H^2	F pr
Grain yield metric ton ha^{-1}	0.734	0.098	0.080	7.1	0.07	0.370^{ns}
Thousand kernel weight	0.201	11.336	1.947	3.7	0.62	0.009***
Number of productive tiller m^{-2}	131.1	1214.7	186.8	3.5	0.65	0.006***
Number of spikelets per ear	23.693	192.79	4.514	11.7	0.93	0.001***
Percent of fertile spikelets per ear	1149.92	207.35	66.880	10.3	0.41	0.009***
Plant height	19.17	618.81	99.880	10.7	0.63	0.001***
PAR 1	9381	3569	2245	34.4	0.83	0.001***
PAR 2	7182	4731	9381	26.0	0.19	0.772^{ns}
Area of the 1st leaf ^{1}(Next to 1st node)	2.175	16.706	4.298	22.0	0.49	0.002***
Area of the 2nd leaf (Next to 2nd lode)	8.383	7.467	5.860	17.2	0.08	0.273^{ns}
Area of the flag leaf	79.97	85.74	32.130	25.0	0.36	0.021*
Ground cover	1.722	2.889	0.322	9.3	0.72	0.002***
Leaf orientation	0.222	3.156	0.756	17.8	0.51	0.026*
Flag leaf spike distance	17.52	93.29	27.46	28.7	0.44	0.005***
Ear compactness	0.007	0.063	0.004	13.4	0.84	0.001***
Days to flowering	0.056	4.456	0.056	0.1	0.96	0.001***
Spike length	16.481	5.672	1.901	16.4	0.40	0.011**
Percent of Aphid infested heads	294.1	638.16	29.690	32.8	0.87	0.001***

MSr= Mean square due to replication, MSg= Mean square due to genotype, MSe= Mean square due to error, CV%= coefficient of variation, *** there is very highly significant difference, ^{ns} no significant difference

There were much more observed differences between the genotypes at the vegetative stage and not for the grain yield.

4.2. Comparison of mean performance of yield and yield components of 2011/12 experiment

Grain yield is the main target that can be considered through its yield components. It is very complex trait governed by several physiological and biochemical plant processes (MOHAMMADI, SHARIFI et al. 2012).

4.2.1. Grain yield

Genotypes have shown comparable grain yield performance in the experiments tested 2011/12 growing period. The highest mean grain yield in metric ton ha^{-1} (t/ha) was recorded in the pure line genotype Naturastar (4.22 t/ha) and the lowest was 3.78 t/ha in genotype grow for the fourth time in the area CCP-4 (Table 5) but no significant difference observed among the genotypes (appendix ANOVA table 1). Naturastar show significant difference for traits have positive relation to yield like number of spikelets per spike and number of fertile tillers. Whereas it also had significant difference in percent of fertile spikelets per ear and significantly lower than other genotypes for the thousand kernel weight.

Table 5. Mean comparison of grain yield and yield related traits of genotypes tested in 2011/12 growing season

No	Treatment	GYTha	TKWg	NFT	NSLt	PFS
1	Naturastar	4.22	34.30 a	434.40 b	20.65 d	78.26 a
2	CCP-1	4.16	39.50 b	380.00 a	18.43 c	80.77 bc
3	CCP-2	3.89	39.40 b	394.00 a	17.41 ab	79.12 ab
4	CCP-3	4.10	38.10 b	392.00 a	17.80 b	80.30 abc
5	CCP-4	3.78	39.00 b	381.00 a	17.90 bc	81.60 c
6	CCP-extra	3.88	38.03 b	390.00 a	17.15 a	78.63 a
	Lsd (5%)	ns	2.538	24.863	0.539	2.073
	F probability	0.37	0.009***	0.006***	.001***	0.009***
	CV	7.1	3.7	3.5	11.7	10.3

[1] *Genotypes having the same letter did not show significant difference (p=0.05), GYTha= grain yield ton per hectare, TKWg=thousand kernel weight gram, NFT= number of fertile tiller per m^2, NSLt= number of spikelet per spike, PFS=percent of fertile spikelet's per ear*
*** there is very highly significant different between the genotypes ns=no significant difference observed*

From these results we can see that the pure line cultivar Naturastar and the CCPs have different strategy to keep their productivity; the pure line cultivar use high number of spikelets per ear and high number of productive tillers, whereas the CCPs keeps its productivity by increasing the kernel weight.

The grain yield result shows that genotypes have equal performance in grain yield productivity but the heritability in broad sense was very low (0.07) this shows as the possibility to repeat this result is very low.

4.2.2. Thousand kernel weight

Genotypes tested in 2011/12 growing period show significant ($p = 0.009$) difference for the thousand kernel weight. The pure line cultivar Naturastar show the lowest thousand kernel weight of 34.3 gm. and the highest kernel weight was genotypes CCP-1 (39.5 gm). It is from the newly introduced from Hungary (Table 5); thousand kernel weights of other genotypes were in between. But no significant difference was observed with the composite cross populations and between the CCP-extra and all the composite populations. Thousand kernel weights of the Naturastar were significantly lower than all genotypes tested, maybe due to the high number of tillers, see below.

Studies argue that wheat spikes affected by *Fusarium* head blight have reduced kernel weight (Wong, Tekauz et al. 1992). Due to that, it is likely to guess genotypes with low kernel weight are susceptible for the Fusarium head blight. Sieving out the infected seeds (smaller than 2-2.5mm) is advisable for organic and low-input cereal production systems; because *Fusarium* head blight is one of the yield reduction factor for those production systems as well as the conventional crop production system.

The broad sense heritability for the thousand kernel weight in this experiment was high (0.62), which indicates that the repeatability of the result is high. Thousand kernel weights can be used as best trait for selection of genotypes.

4.2.3. Number of fertile tillers

The number of fertile tillers has significant difference among genotypes. The number of fertile tillers of pure line cultivar Naturastar was significantly different from the CCPs whereas no significant difference was observed between the CCPs.

4.2.4. Number of spikelets per spike

Genotypes were show significant difference in the number of spikelets per spike. Naturastar was with highest number of spikelet's per spike and CCP-extra was the least and others were in between the two (Table 5). The newly introduced genotype from Hungary CCP-1 performed significantly different from other cycling composite cross populations except for CCP-4, but no significant different was observed between other composite cross populations.

Number of spikelets per spike with number of tillers will determine the number of grains produced per plant. The number of spikelets is one of the determinant traits for the productivity of the genotype. In this experiment number of spikelets per spike had high heritability (0.93). This heritability indicates that the repeatability of the trait is high and we can use it as one of the selection criteria.

4.2.5. Percent of fertile spikelets per ear

Not all spikelets in the ear were fertile; some of the spikelets did not contain grains. Studies showed that not all genotypes have the gene which governs the number of spikelets per spike and the number of fertile florets (González, Slafer et al. 2005). The loci basically determines the photoperiod response of the crop and the loci is found in the group of 2 chromosome (González, Slafer et al. 2005).

In this experiment genotypes show significant difference in the percent of fertile spikelets (Appendix ANOVA Table 6). Naturastar and CCP-extra were with lowest percent of fertile spikelets 78.26 and 78.63 percent respectively. CCP-4 had the highest percent of fertile spikelets per ear (81.60 %) other genotypes were in between (Table 5). This difference may be due to the genetic makeup of the cultivars or it may be due to the infestation of the heads with aphids, since the pure line cultivar Naturastar also had high number of heads infested by aphid. The trait has 0.77 coefficient of heritability.

4.3.   Traits related to shading capacity of the crop

Ground shading ability of the genotypes will help to suppress the weed growth through restricted penetration of light to the ground under the canopy. As a result management of the crop production improves with no additional cost and it is a more environmental friendly practice (Drews, Neuhoff et al. 2009). Genotypes had different shading capacities at different

growth stages, some genotypes have good shading ability at the initial crop development stage and others have at the late stage. Due to this, selection of genotypes may depend on the growing environment for instance if there is extended rain (moisture) in the late growing period the one may choose those genotypes having good shading ability at the late growing stage. Selection of genotypes based on their ground shading ability may have great importance in the organic and low-input agricultural systems. Ground shading ability of the crop is not determined by the single trait, rather it is a combination of various agronomic traits (Hoad, Neuhoff et al. 2005).

4.3.1. Leaf area

➢ *First leaf*

There was a significant difference among the genotypes for the area of the leaf next to the first node. The largest leaf area was observed CCP-2 which was 9.719 cm^2 and the smallest leaf area was CCP-4 while the other genotypes were in the middle. However, only the oldest population (CCP-4) differed significantly from all other genotypes, but no significant difference was found between the other genotypes (Table 6).

Faster leaf area development at the early stage of the crop increase the water use efficiency of the crop by increasing the ground shading capacity of the crop as the result evaporation decrease. The ground shading capacity also increase the weed competition ability of the crop as the light interception decrease (Rebetzke, Botwright et al. 2004). Selection of genotypes having large leaf area at the early development stage of the crop is advantageous to suppress the development of weeds at early stage; however. the trait had a medium heritability (0.49) in our experiment.

➢ *Second leaf*

In the leaf area of the leaf next to second node no significant difference was observed. The largest leaf area was observed in the population which grows for the third time (CCP-3) which was 14.31 cm^2 and the smallest was CCP-4 (13.69 cm^2) but the difference was not significant and the heritability of this trait also low (0.08).

Table 6. Comparison of mean of traits related to shading capacity of the crop

No Treatment	Area of the 1st leaf	Area of the second leaf	Area of the flag leaf	Plant height	PAR1	PAR2	Ground cover	Leaf orientation
Naturastar	9.64 b	14.23	24.09 c	90.40 a	199.30 a	364.10	6.33 bc	4.33 ab
CCP-1	9.41 b	13.79	23.08 bc	95.87 c	322.70 b	357.40	6.67 c	6.00 c
CCP-2	9.72 b	14.18	21.61 a	95.66 c	517.50 c	400.40	6.33 bc	6.00 c
CCP-3	9.42 b	14.31	22.49 ab	91.65 a	514.50 c	381.80	5.33 b	4.67 abc
CCP-4	8.72 a	13.69	22.39 ab	92.50 ab	523.60 c	362.10	4.00 a	3.33 a
CCP-extra	9.69 b	14.07	22.29 ab	94.71 bc	534.90 c	365.60	6.00 bc	5.00 bc
Lsd (5%)	0.535	Ns	1.437	2.534	99.1	Ns	1.033	1.58
F probability	0.002 ***	0.614	0.021 *	0.001 ***	0.001 ***	0.772	0.002 ***	0.026 *
CV	22	17.2	25	10.7	34.5	26	9.3	17.8

[1] *Genotypes having the same letter did not show significant difference (p=0.05), ns=no significant difference, *** there is very highly significant different between the genotypes PAR1=the photo- synthetically active radiation at the stem extension of the crop, PAR2=the photo-synthetically active radiation at the flowering stage*

➢ *Flag leaf*

Significant difference was observed in the flag leaf area. The largest leaf area was observed in the pure line genotype Naturastar which was 24.09 cm^2 and the smallest flag leaf area was registered in oldest population (CCP-4) other populations were in the middle. A significant difference was observed between CCP-2 and CCP-1 and Naturastar. No significant difference was observed between (CCP-1) and the Naturastar as well as between CCP-2, CCP-3, CCP-4 and CCP-extra. CCP-1 was not also significantly different from other CCP populations except with CCP-2. The flag leaf area did not show consistent pattern (increasing or decreasing trained) for different generations.

4.3.2. Plant height

Genotypes tested in the 2011/2012 growing season showed significant differences in their height. The longest genotype was CCP-1 with the length of 95.87 cm and Naturastar was the shortest one with the length of 90.4 cm others were in between; however both are still fairly tall compared to short-straw cultivars. The significant difference was observed between gen-

otypes Naturastar and CCP-3 with CCP-extra, CCP-2 and CCP-1; CCP-4 with CCP-2 and CCP-1 (Table 6).

The plant height of the CCPs show a decreasing trained through generations; the oldest population become shorter than the newly introduced populations. This result is in contrary with the result of (Hensleigh, Blake et al. 1992) the plant height of barley increased as the later generation. Our experiment result was also different with the results of (Allard 1988) in barley composite cross experiment, mean height change was not high until generation F_{25} and the mean height increase stranded about 5% by the generation F_{53}.

Plant height with other traits can be used as a criterion to select genotypes for weed competition abilities. Genotypes that are short and erectophile with the smallest narrow leaves are poor in weed suppression (Hoad, Neuhoff et al. 2005). Studies also show that plant height and Fusarium ear disease severity have negative correlation, which means short genotypes are severely infested with Fusarium ear disease of wheat compared with taller cultivars (Hilton, Jenkinson et al. 1999; Spanic, Lemmens et al. 2005).

Despite the above advantages of long plants, it has also disadvantages on the productivity of the crop. As the plant height increase the crop become susceptible to lodging as the soil fertilizer level increase (Law, Snape et al. 1978). But lodging is less of a problem in the organic and low-input agricultural systems, since the fertility level of the soil is low. Even if the difference between genotypes in our trial had statistically significant, the difference is not so much big, the highest genotype had 95.87 cm and the lowest was 90.4.

4.3.3. Photo-synthetically active radiation (PAR)

At the stem extension stage (Growth stage 31-32) of the crop significant difference was observed between the genotypes in PAR under the canopy of the crop. Less PAR was measured in the pure line cultivar Naturastar (199.3 $\mu molm^{-2}s^{-1}$) and next to this the newly introduced population CCP-1 (322.7 $\mu molm^{-2}s^{-1}$) also show significantly less PAR than other populations but the other populations did not show significant difference between them.

According to Köpke (2005), the weed mass produced is influenced by the available PAR, as when the amount of PAR decreases the weed mass production also decreases. The pure line

cultivar show good shading capacity at early stage of crop development than other populations.

At flowering stage all of the genotypes had equal shading capacity for the light interception. The lowest PAR was observed in the newly introduced population CCP-1 (357.4 $\mu molm^{-2}s^{-1}$) and the highest PAR was observed in CCP-2 (400.4 $\mu molm^{-2}s^{-1}$) but no significant difference was observed between the genotypes.

4.3.4. Crop ground cover and leaf orientation

Genotypes showed significant differences for the ground cover and leaf orientation at the early development stage. The newly introduced composite cross population had good ground shading (6.67) followed by the pure line cultivar Naturastar (6.33); but no significant difference was observed between the pure line cultivar and the newly introduced composite cross population. However, a significant difference was observed between CCP-1 with CCP-3 and CCP-4. In this trial the oldest composite cross population CCP-4 showed a poor ground cover, maybe due to its small leaf area. The ground cover potential therefore showed a decrease through time.

Like the ground shading ability the newly introduced composite cross population CCP-1 showed the highest scale for the leaf orientation, the two recently introduced CCP-1 and CCP-2 had a more planophile leaf orientation than other genotypes. The oldest composite cross population CCP-4 had erect leaf orientation, other genotypes were in between.

4.4. Pest and disease related traits

Pest and disease are economically important yield limiting factors in organic and low-input agricultural production systems. Having the knowledge of such traits is advantageous to select the genotype.

4.4.1. Percent of Aphid infested heads

There was significant difference observed between genotypes tested in percentage of aphid infested heads. Also in a study of Akhtar, Hussain et al. (2010) genotypic differences in aphid infestation were found among cereals. The highest percent of infestation was observed in the pure line cultivar Naturastar with 28.63% of heads were infested by aphid and the lowest in-

festation was observed in CCP-extra only 13.11 % of the heads infected other genotypes were in between (Table 7). No significant difference was observed between the composite populations but all the composite populations significantly differ from the pure line cultivar Naturastar.

Aphids can cause a significant damage on the productivity of wheat. According to Rabbinge, Drees et al. (1981) aphids affect directly by sapping the assimilates and indirectly by covering the photosynthesis area of the plant by the honeydew. In our experiment the pure line cultivar Naturastar had high numbers of heads infested by aphids. The composite populations with less percent of heads infested with aphid are good for the organic and low-input agriculture production systems than the pure line cultivar which is highly susceptible for aphid damage.

Table 7. Comparison of mean of traits related to pest and disease related traits

No	Treatment	PAIH (%)	FLSD (cm)	SCs (mm)
1	Naturastar	28.63 b[1]	17.25 a	4.18 a
2	CCP-1	15.48 a	18.61 bc	4.62 b
3	CCP-2	13.18 a	19.66 c	4.63 b
4	CCP-3	14.59 a	17.44 ab	4.74 bc
5	CCP-4	14.75 a	18.07 ab	4.76 bc
6	CCP-extra	13.11 a	18.55 abc	4.81 c
	Lsd (5%)	3.603	1.328	0.016
	F probability	0.001***	0.005***	0.001***
	CV	32.8	28.7	13.4

[1] *Genotypes having the same letter did not show significant difference (p=0.05), ns=no significant difference*
PAIH= percent of aphid infested heads, FLSD= flag leaf spike distance, SCs= spike compactness
*** there is very highly significant different between the genotypes

4.4.2. Flag leaf spike distance

Genotypes tested in 2011/12 growing period show significant difference in the flag leaf spike distance (Appendix ANOVA table 3). Genotype CCP-2 has longest flag leaf spike distance whereas Naturastar was the lowest and other genotypes were in between (Table 7). There was significant difference between genotype Naturastar and CCP-2. The difference between the genotype Naturastar with genotype CCP-3, CCP-4 and CCP-extra and also genotype CCP-extra CCP-1 and CCP-2 doesn't show significant difference.

There is an assumption that cultivars with short distance between the flag leaf and the spike are more susceptible for head diseases. As the distance between the flag leaf and the spike decrease the air movement between the flag leaf and head decrease and this makes the microclimate favourable for disease development (Hilton, Jenkinson et al. 1999). The pure line cultivar Naturastar had shown less distance between the spike and the flag leaf, according to this assumption the pure line will be favourable for head disease development. For the organic and low-input agriculture production systems, genotypes with long flag leaf spike distance will be advisable.

4.4.3. Spike compactness

The distance between the spikelets is a measure for the compactness of the spike. As the distance between the spikelets decreases the spike will be compacted. Genotypes show significant difference in the spikes compactness. Naturastar was the most compacted genotype with the spikelet distance of 0.4179 cm and genotype CCP-extra population was less compacted with distance between the spikelet's of 0.4805 cm others were in between the two (Table 7).

Even though Fusarium head blight (FHB) resistance is polygenic control (Hilton, Jenkinson et al. 1999; Bai and Shaner 2004) studies confirm that the compactness and looseness of the spike can be used as a criterion for the selection of genotypes for FHB resistance[6]. This is due to the fact that in compact heads the air movement between the spikelets decreases and the head stays moist for a longer time and it makes a more favourable environment for the development of the disease. Our experiment result shows that the most compacted genotype is Naturastar; this genotype could risk to be more susceptible to FHB compared to other tested genotypes with less compacted heads. However, no FHB was observed.

4.5. Grain yield of all year experiment

The field trial started in the 2008/09 growing season, the grain yield and thousand kernel weight data was collected each year. The yield performance of the experiments conducted in the cropping seasons of 2008/09, 2009/10 and 2010/11 were lower than the yield of 2011/12 (Table 8).

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[6] http://cd.planetdiversity.org/fileadmin /files/ planet diversity/Programme/Plenary_ Season/14_05/Lammerts_14_5_Europe_Organic_ppt_en.pdf verified November 19, 2012

In 2008/09 growing season trial, no significant grain yield difference was observed between the genotypes tested. The pure line cultivar Pirineo had the highest grain yield (2.09 t/ha) and the CCP-4 was the lowest (1.95 t/ha) but the difference was not statistically significant (Table 8).

The CCP-extra tended to be the highest grain yielding genotype in 2009/10 cropping period with 1.817 t/ha but no significant difference was observed between the genotypes. All of genotypes showed poor grain yield performance which was below 2 t/ha (Table 8). The lowest grain yield was observed in the French landrace Rouge de Bordeaux which was 0.81 t/ha. This cropping season had very cold spring and very hot summer (appendix table 43-45), according to (FERRIS, Ellis et al. 1998) in wheat temperature for more than four days around anthesis can decrease the rate of grain filling and reduce the grain number. The poor grain yield performance of the genotypes in this cropping period may be due to the environmental factor.

In the experiment conducted in 2010/11 no significant grain yield was observed. The highest grain yield was observed in the pure line cultivar Naturastar (1.41 t/ha) and the lowest grain yield was the composite cross population which introduced in the area in 2009/2010 growing period CCP-3 (0.84 t/ha). The grain yield productivity of the genotypes tested was below 2 t/ha which is very poor (Table 8).

Table 8. Grain yield (t/ha) of all trials during four growing seasons between 2008/2009-2011/2012, at Droevendaal, Wageningen, The Netherlands.

Genotypes	2008/09	2009/10	2010/11	2011/12
Perineo	2.09	-	-	-
Naturastar	-	1.16	1.41	4.22
CCP-1	-	-	-	4.16
CCP-2	-	-	1.23	3.89
CCP-3	-	0.96	0.84	4.10
CCP-4	1.95	0.94	1.14	3.78
CCP-extra	2.06	1.82	1.02	3.88
Rouge de Bordeaux	-	0.81	-	-
Zeeuwse Witte	-	1.43	-	-
Cv%	6.4	18.4	26	7.1
F pr.	0.439^{ns}	0.245^{ns}	0.262^{ns}	0.37^{ns}

ns=No significant yield difference observed between genotypes in all growing seasons

All the tested genotypes showed a poor performance in the first three growing periods which was by far lower than the grain yield obtained in 2011/12 growing period. The highest grain yield in the previous trials was 2.09 (Perineo) metric tons per hectare in 2008/09 which was approximately doubled less than the lowest yield obtained in 2011/12 trial.

The experimental field of this trial was water lodged in the winter and early spring and highly infested by (Camomilla) weed (personal communication with the organic farm manager Andries Siepel). According to scientific studies, weed infestation on wheat can have a significant grain yield reduction (Das and Yaduraju 1999). The water lodging and weed infestation problem in this growing period may be the cause for the lower grain yield.

4.6. Thousand Kernel weight of all year experiment

In 2008/09 cropping season significant difference was observed between the genotypes in their thousand kernel weight (Table 9). The highest kernel weight was observed in the pure line cultivar Pirineo (47.87 gm.) and the lowest was the composite cross population CCP-4 (44.4 gm).

Table 9. Thousands kernel weight of all trials during four growing seasons between 2008/2009-2011/2012, at Droevendaal, Wageningen, The Netherlands.

Genotypes	2008/2009	2009/2010	2010/2011	2011/2012
Perineo	47.87 c	-	-	-
Naturastar	-	28.93 a	38.34 a	34.30 a
CCP-1	-	-	-	39.50 b
CCP-2	-	-	43.32 c	39.40 b
CCP-3	-	31.43 ab	39.31 a	38.10 b
CCP-4	44.40 a	32.30 ab	39.80 ab	39.00 b
CCP-extra	45.87 b	34.03 b	42.31 bc	38.03 b
Rouge de Bordeaux	-	34.27 b	-	-
Zeeuwse Witte	-	28.97 a	-	-
Cv%	1.3	7.1	3.8	3.7
Lsd	1.317	4.11	2.493	
F Pr.	0.005***	0.05*	0.021*	0.009***

*** very highly significant difference, *significant difference , Genotypes with the same letter did not show significant difference (p=0.05)*

Thousand kernel weight of the genotype tested in 2009/10 cropping season had significant difference. Rouge de Bordeaux (34.27 gm.) was significantly higher than Naturastar and Zeeuwse Witte (28.93 gm.) the Dutch landrace (28.97 gm.). But it was not significantly different from other genotypes. The lowest thousand kernel weight was observed in Naturastar (Table 9). All the cultivars have performed poorly for their thousand kernel weight which was less than 35 gm in 2010. This low performance in the thousand kernel weight may be due to the hot summer in 2010 which can affect the grain filling.

In the trial conducted in the period of 2010/11, there was significant difference among the genotypes in their thousand kernel weight. The newly introduced composite cross population (CCP-2) has the highest thousand kernel weight (43.32 gm.) and the Naturastar was the lowest (38.34 gm.). No significant difference was observed between Naturastar, CCP-3 and CCP-4 genotypes. No significant difference was also observed between CCP-2 and CCP- extra populations.

4.7. Correlation of yield and yield related traits

Grain yield is a complex trait which is governed by various genes and number of related traits and influenced by the environmental conditions. To select the best yielding genotype it is important to know the direct and indirect interrelationship among various traits.

Grain yield shows very highly significant negative correlation with PAR 1 (r = -0.513) and positive correlation with the number of spikelets per spike (Table 10). Plant height had very highly significant positive correlation with the flag leaf spike distance (r = 0.803). Flag leaf spike distance had very highly significant negative correlation with number of spikelet per spike (r = -0.62). Number of spikelet's per spike had very highly significant negative correlation with spike compactness r =-0.616 and PAR1 (r = -.0587), very highly significant positive correlation with days to flowering (r = 0.507). Spike compactness had negative correlation with day to flowering (r = -0.748).

The correlation of traits showed as the PAR at the developmental stage had negative influence on the grain yield and as the number of spikelets per spike increased the yield also increased. The negative correlation between the flag leaf spike distance and the number of spikelets per spike tells as the genotypes has high distance between the flag leaf and spike the

number of spikelets decrease this may be due to the plant costs large energy of the distance between the spike and the flag leaf as the result the number of spikelets will decrease.

Table 10. Correlation coefficient for yield and yield related traits of winter wheat trial 2011/12

Yield ton per ha	1	1	2	3	4	5	6	7
Thousand kernel weight (gm.)	2	0.010						
Plant height	3	0.077	0.460*					
Flag leaf Spike distance	4	-0.224	0.364*	0.803***				
Length of spike	5	0.063	0.195	0.159	-0.084			
Number of spikelet per spike	6	0.397*	-0.149	-0.441*	-0.620 ***	0.158		
Spike compactness	7	-0.482*	0.005	0.309	0.349*	0.096	-0.616***	
Area FL	8	0.005	-0.408*	-0.046	-0.076	0.178	0.327*	0.088
AREA_1st_L	9	0.232	-0.098	0.216	-0.056	0.181	0.020	-0.238
area_2nd_L	10	0.036	-0.091	-0.065	-0.243	0.243	0.057	-0.218
PAR_1	11	-0.513***	0.385*	0.102	0.328*	-0.043	-0.587***	0.393*
PAR_2	12	0.296	0.113	0.189	0.252	-0.027	-0.197	0.152
Ground cover	13	0.264	-0.170	0.215	0.252	-0.323*	-0.104	-0.441*
Leaf orientation	14	0.056	0.160	0.428	0.418	-0.253	-0.301	-0.195
Days to flowering	15	0.303	-0.272	0.001	-0.090	-0.020	0.507***	-0.748***

		8	9	10	11	12	13	14
AREA 1st_L[1]	9	-0.288						
Area 2nd_L	10	-0.360*	0.849					
PAR 1	11	-0.284	-0.096	0.174				
PAR 2	12	-0.046	-0.222	-0.352*	0.055			
Ground cover	13	-0.102	0.273	-0.025	-0.251	0.131		
Leaf orientation	14	-0.159	1.173	0.089	0.100	0.214	0.769	
Days to flowering	15	0.259	0.35*	0.112	-0.553***	-0.203	0.672***	0.418

[1]the area of the leaf next to the 1st node ; [2] area of the leaf next to the 2nd node
***= very highly significant difference **= is highly significant at $p<0.01$, * is significant at $p<0.05$

4.8. Estimation of diversity index

4.8.1. Shannon-Weaver diversity index

The relative values of the traits for Shannon-Weaver diversity index, H' were different. The diversity index was small for all the traits (Table 11). Significant differences were observed for the traits plant height, flag leaf spike length and width of the leaf next to the first leaf. For plant height and flag leaf spike spike length, all CCPs have higher values for the diversity index than the pure line cultivar Naturastar (Table 11).

For traits for which no significant differences were found between genotypes: the pure line cultivar often showed the lowest the Shannon-Weaver diversity index, H' such as for spike length and length of the leaf next to the first node (0.165). These results are plausible, as we expect lower diversity index from the pure line cultivar. However, the pure line cultivar had a high H' value for the number of spikelets per spike (0.186) which could be due to the fact that this cultivar had high tillering and the younger tillers were smaller than the earlier formed ones. There was no significant difference in number of spikelets per spike, however.

There were no significant differences between the CCPs in values for the Shannon-Weaver diversity index, H', for the traits shown in Table 11 except for width of the leaf next to the first node. For the trait width of the leaf next to the first node this population showed a low H' index value (0.135) which is surprising as we expect a high diversity index value for the newly introduced population due to the fact that this population comes from a different environment and is likely less adapted.

The lowest diversity index was observed in width of the flag leaf with the highest value of CCP-1 (0.122) and the lowest of CCP-2 (0.066); however, no significant different was observed between the genotypes tested. This traits may be less appropriate to assess the diversity of the genotypes, since the values for the Shannon-Weaver diversity index, H' were very different.

Table 11 Mean diversity index of each phenotypic characters of genotype (Shannon-Weaver diversity index, H') applied to the results of the trial 2001/2012, Droevendaal, Wageningen , The Netherlands.

Genotypes	Plant height	Spike length	Number of spikelets	Flag leaf spike length	Length of leaf next to 1st node	Width of leaf next to the 1st node	Length of flag leaf	Width of flag leaf
Naturastar	0.161 a[1]	0.219	0.186	0.048 a	0.165	0.173 ab	0.222	0.071
CCP-1	0.216 b	0.258	0.171	0.222 b	0.196	0.135 a	0.224	0.122
CCP-2	0.208 b	0.253	0.099	0.238 b	0.206	0.217 b	0.226	0.066
CCP-3	0.204 b	0.242	0.119	0.224 b	0.215	0.213 b	0.213	0.076
CCP-4	0.201 b	0.265	0.151	0.244 b	0.206	0.213 b	0.211	0.106
CCP-extra	0.208 b	0.231	0.121	0.259 b	0.165	0.193 b	0.213	0.076
CV%	5.4	8	23.1	12.2	19.9	13.1	12.7	40
lsd.	0.019	0.036	0.059	0.046	0.069	0.046	0.050	0.063
F. Pr	0.001***	0.108^{ns}	0.054^{ns}	0.001***	0.472^{ns}	0.017**	0.967^{ns}	0.354^{ns}

[1] *Genotypes with the same letter did not show significant difference (p=0.05), ***very highly significant difference, ** highly significant difference, ^{ns} no significant difference was observed between genotypes*

4.8.2. Standard deviation within plots

The tested genotypes showed difference in their standard deviation (SD) within the plots. No significant difference was observed for the SD of the grain yield t/ha. The highest SD was observed in the CCP-4 (0.73) and the lowest SD was in the CCP-1 (0.39). Low SD in grain yield suggests a good level of stability..

Table 12 Mean comparison of standard deviations within plots genotypes tested in the 2011/12 growing season at Droevendaal, Wageningen.

No	Treatment	GYTha	PH	Spike length	PFS	FLSD (cm)	L1L	W1L	LFL	WFL
1	Naturastar	0.70	5.01 a	1.28	7.93	2.35 a	1.42	0.12 ab	3.15	0.16 a
2	CCP-1	0.39	11.76 b	1.39	7.28	5.63 b	1.56	0.11 a	3.23	0.21 b
3	CCP-2	0.61	10.20 b	1.33	8.19	5.37 b	1.68	0.14 bc	3.27	0.19 b
4	CCP-3	0.56	10.00 b	1.37	8.33	5.68 b	1.69	0.15 c	3.04	0.20 b
5	CCP-4	0.73	10.68 b	1.44	8.22	5.62 b	1.63	0.14 bc	3.04	0.24 a
6	CCP-extra	0.56	10.00 b	1.33	8.65	5.87 b	1.45	0.14 bc	2.73	0.19 b
	Lsd (5%)	ns	2.25	ns	ns	1.10	ns	0.02	ns	0.025
	F probability	0.458	0.001***	0.764	0.654	0.001***	0.643	0.008***	0.573	0.001***
	CV	35.6	12.9	9.9	12.1	11.9	15.5	8.1	12.2	6.9

[1] *Genotypes having the same letter did not show significant difference (p=0.05), GYTha= grain yield ton per FLSD= flag leaf spike distance, PFS= percent of fertile spikelet's per ear, W1L=width of the first leaf next to the 1st node L1L= length of the first leaf next to the 1st node, WFL= width of the flag leaf, LFL= length of the flag leaf *** there is very highly significant different between the genotypes ns=no significant difference observed*

Genotypes showed highly significant differences for the SD within plots for the traits plant height ($P<0.001$), flag leaf spike distance ($P<0.001$), width of the 1st next to the 1st node ($P<0.008$) and width of the flag leaf ($P<0.001$). Other traits did not show significant difference for the SD. These results are similar to the outcomes of the Shannon-Weaver diversity index (Table 11), except for the trait width of the flag leaf. For these traits, the genotype with high SD is more diverse than with lower SD.

For plant height, a significant difference was observed between the pure line cultivar and the CCP-populations and no significant difference was observed between the CCP-populations. Also for the flag leaf spike distances no significant difference was observed between the CCP-populations. The only difference was observed between the CCP-populations and the pure line cultivar Naturastar. For the width of the 1st leaf next to the 1st node the CCP-1 is

significantly different from other CCP-populations and the Naturastar. The CCP-1 is not significantly different from the pure line cultivar. This result also had a similar pattern with the Shannon-weaver diversity index values.

However, for the width of the flag leaf the highest SD was observed in the CCP-4 which was significantly different form other CCP-populations and the pure line cultivar. The pure line cultivar had the lowest values and was significantly lower than all other genotypes. This result is different from the Shannon-weaver diversity index values that were not significantly different. This difference in resuls suggests that it is good to use different methods.

The pure line cultivar generally had lower values for both the Shannon-weaver diversity index and the SD within plots than the CCPs. This confirms our expectations since the CCPs have a higher level of diversity and we expect more variation from those populations. The differences in values between the CCPs, including the CCP-extra, are not significant for most of the traits measured and this shows that the CCPs maintain diversity within population for more than four generations.

5. Conclusions

The nitrogen availability in the organic agriculture farming system is lower which makes it a challenge to find genotypes with good grain yield and the baking quality potential under organic farming system compared to the conventional farming system. When the pure line cultivar Naturastar was registered the baking quality was below the standard for the conventional condition but above the others under organic condition (Legzdina and Skrabule 2005). The composite cross populations are derived from crosses between parents with good quality and parents with a good yield, so we can expect that the composite populations will have better baking quality[7].

The CCPs showed similar yield potential as the pure line cultivar (bred for organic farming) in all experimental years. The pure line had a lower thousand kernel weight compared to the CCPs, but its tillering capacity was higher which suggests different pathways for producing yield. The composite cross populations showed significant, lower number of spikes infested by aphids lower number of spikelets per spike and lower spike compactness which also likely influences yield. There was no significant difference observed between different advanced generations of composite cross populations (the composite cross population introduced in the area before four year and the newly introduced) in the grain yield potential and yield components.

For traits related to ground shading ability and tolerance to ear disease, many differences were found. The pure line variety Naturastar seems to have better ground shading ability than the CCPs, based on the measurements PAR 1, area of the flag leaf and number of productive tillers, despite its erect leaves and shorter plant height. The CCPs seem to decrease in ground shading capacity over the four generations, resulting in shorter plant height, higher PAR 1, lower ground cover and more erect leaves. Based on these results we cannot state that the composite cross populations will be the best cultivars for the organic and low-input agricultural systems.

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[7] http://www.sustainweb.org/resources/files/other_docs/ORC _bulletin_109 _bread_article.pdf verified December 11, 2012

In terms of yield, the potential of the composite cross populations seems not to decline through time. This property of the composite cross population is good for the resource poor farmer's. Therefore, farmers can use the previous year harvest as seed for the coming year and will not need every year new seed from the seed companies.

The finding in this study is based on the single location during four growing periods and only one pure line cultivar was compared with the composite cross populations. The information provided by the comparison over four seasons is limited because the productivity of the geno-types was influenced in the previous years by various environmental reasons. Thus further studies using multi-location trials including quality tests is required to generate more reliable information about the potentials of the composite cross populations.

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APPENDICES

CC Populations - experimental design 2011-2012 Organic Experimental Farm Droevendaal in Wageningen

N

51 m

3.23	3.24	3.25	3.26	3.27	3.28	3.29	3.30	3.31	3.32	3.33
A	F	C	F	D	F	B	F	E	F	G

6m

2.22	2.21	2.20	2.19	2.18	2.17	2.16	2.15	2.14	2.13	2.12
E	F	A	F	G	F	B	F	D	F	C

34.5m

1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11
C	F	E	F	B	F	A	F	D	F	G

7.5m

6m   3m

Varieties:

A HU08-NL09-NL10-NL11, YQMS cycling experiment (harvest Droevendaal 2011)

B HU08-NL09-NL10-NL11, UK composite organic 5yrs HU (Harvest Droevendaal 2011)

C Naturastar (pure line variety, via Agrifirm)

D HU10-NL11, YQMS cycling experiment (harvest Droevendaal 2011)

F intercrop (rye)

G HU09-NL10-NL11, YQMS cycling experiment (harvest Droevendaal 2011)

E HU11, YQMS cycling experiment (new from Hungary)

Seed treated with Tillecur

Sowing date: 24-10-2011

Sowing rate: 500 seeds/m²
Rye plots: 3m x 7.5m
Wheat plot size: 6m x 7,5m = 45 m²
Ras E: 4.5m x 7,5m = 33.75 m²   vanwege zaad te kort en aangevuld met winterrogge

Fertilisation: 90 kg N/ha from see weed pellets (applied in March 2012)

Precrop :spring barley

Farm path

Information on origin of the seed:	Number of years multiplied/grown at Droevendaal farm:
A HU08-NL09-NL10-NL11, YQMS cycling experiment (harvest Droevendaal 2011)	2012 is 4th season
B HU08-NL09-NL10-NL11, UK composite organic 5yrs HU (Harvest Droevendaal 2011)	2012 is 4th season
C Naturastar (pure line, via Agrifirm)	2012 is 1st season
D HU10-NL11, YQMS cycling experiment (harvest Droevendaal 2011)	2012 is 2nd season
F intercrop (rye)	not relevant
G HU09-NL10-NL11, YQMS cycling experiment (harvest Droevendaal 2011)	2012 is 3rd season
E HU11, YQMS cycling experiment (new from Hungary)	2012 is 1rst season

Appendix Figure 1 Field plan of the trial conducted in 2011/12 growing period
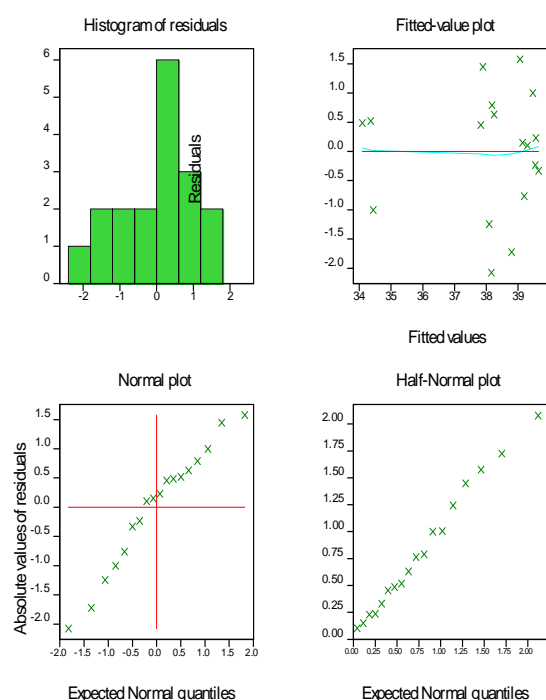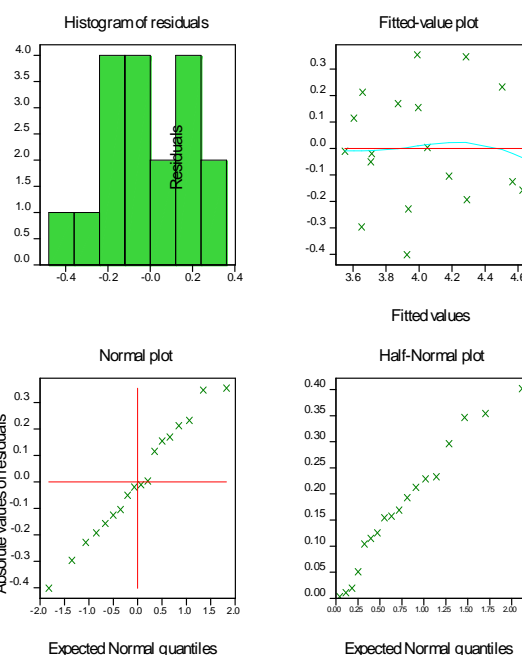
Appendix Figure 2. Residual plots for thousand kernel weight (Fig A) and Residual plots for yields Metric ton ha^{-1}(Fig. B) of the experiments conducted in 2011/12
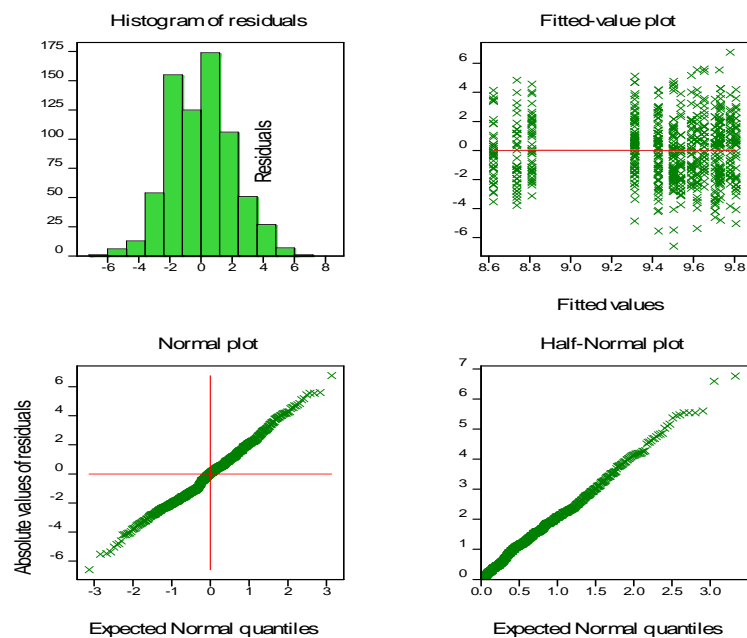
Appendix Figure 3. Residual plots for the area of the leaf next to the first node for the area of the leaf next to the first node

area_2nd_leaf
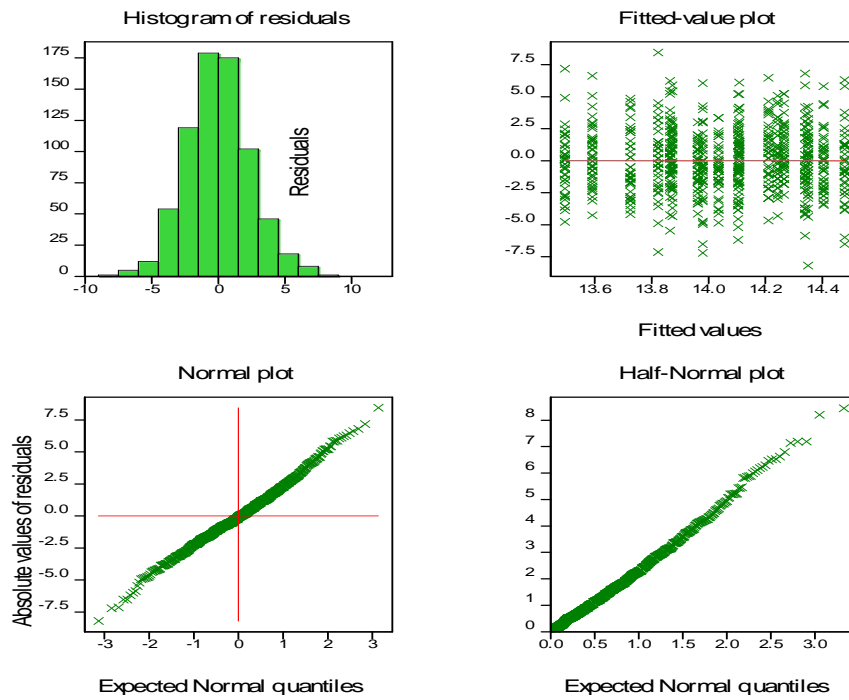
Appendix Figure 4. Residual plots for the area of the leaf next to the second node for the area of the leaf next to the first node

area_F_leaf
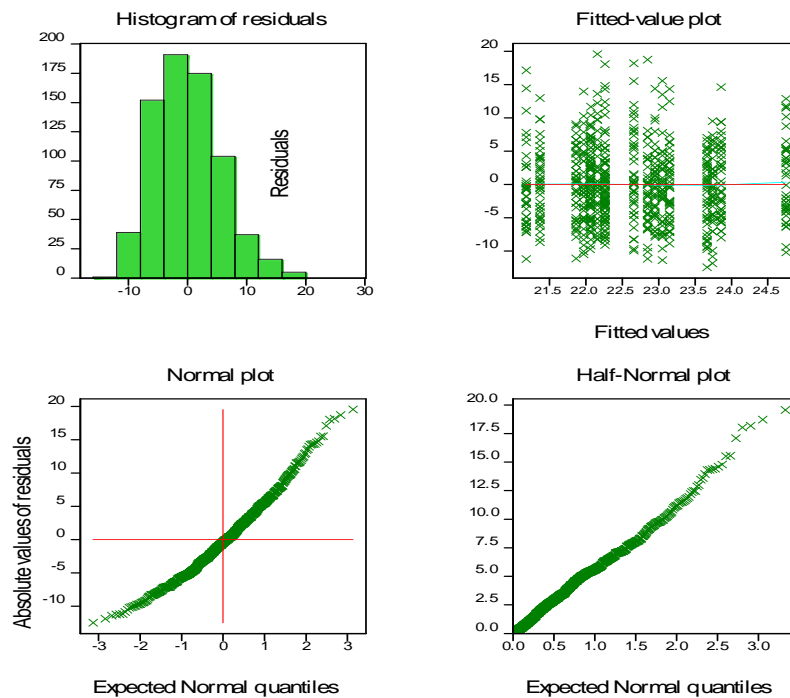
Appendix Figure 5. Residual plots for the area of the leaf next to the second node for the area of the flag leaf

Appendix: Tables

ANOVA tables of 2011/12 Experiment

Appendix Table 1. Analysis of variance of Yield Metric ton ha-1 experiments conducted in 2011/12

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	1.4674	0.7337	9.13	
Treatment	5	0.4884	0.09768	1.22	0.37^{ns}
Residual	10	0.80394	0.08039		
Total	17	2.75974			

^{ns} no significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square   F pr.= F probability

Appendix Table 2. Analysis of variance of thousand kernel weight gm.

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	0.401	0.201	0.1	
Treatment	5	56.678	11.336	5.82	0.009***
Residual	10	19.466	1.947		
Total	17	76.544			

***There was very highly significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square   F pr.= F probability

Appendix Table 3. Analysis of variance of length between the flag leaf and the spike

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	35.03	17.52	0.64	
Treatment	5	466.44	93.29	3.40	0.005***
Residual	712	19549.08	27.46		
Total	719	20050.55			

***There was very highly significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square   F pr.= F probability cv=28.7; lsd=1.328

Appendix Table 4. Analysis of variance of plant height

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	38.34	19.17	0.19	
Treatment	5	3094.07	618.81	6.19	<.001***
Residual	712	71186.30	99.98		
Total	719	74318.71			

***There was very highly significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square   F pr.= F probability cv=10.7; lsd=2.534

Appendix Table 5. Analysis of variance of distance between spikelets

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	0.01434	0.00717	1.87	
Treatment	5	0.315765	0.063153	16.5	<.001***
Residual	712	2.724803	0.003827		
Total	719	3.054909			

***There was very highly significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square   F pr.= F probability cv=13.4; lsd=0.0157

Appendix Table 6. Analysis of variance of percent of fertile spikelets

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	2299.83	1149.92	17.19	
Treatment	5	1036.74	207.35	3.10	0.009***
Residual	712	47619.17	66.88		
Total	719	50955.75			

***There was very highly significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square   F pr.= F probability cv=10.3; lsd=2.073

Appendix Table 7. Analysis of variance of leaf area(cm^2) next to the first node

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	4.35	2.175	0.51	
Treatment	5	83.528	16.706	3.89	0.002***
Residual	712	3059.972	4.298		
Total	719	3147.851			

*** *There is very highly significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square   F pr.= F probability*

Appendix Table 8. Analysis of variance of leaf area(cm^2) next to the second node

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	16.766	8.383	1.43	
Treatment	5	37.335	7.467	1.27	0.273[ns]
Residual	712	4172.149	5.86		
Total	719	4226.251			

[ns] *no significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square   F pr.= F probability*

Appendix Table 9. Analysis of variance of area(cm^2) of the flag leaf

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	159.93	79.97	2.49	
Treatment	5	428.72	85.74	2.67	0.021*
Residual	712	22877.86	32.13		
Total	719	23466.52			

*There *is significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square   F pr.= F probability*

Appendix Table 10. Analysis of variance of PAR at crop development stage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	1876264	938132	41.78	
TRETMENT	5	1784286	356857	15.89	<.001***
Residual	100	2245441	22454		
Total	107	5905991			

*** there is very highly significant difference between the genotypes CV = 34.4

Appendix Table 11. Analysis of variance of PAR at flowering stage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	143639	71820	7.66	
TRETMENT	5	23657	4731	0.5	0.772[ns]
Residual	100	938071	9381		
Total	107	1105367			

[ns] No significant difference between the genotypes CV = 26

Appendix Table 12. Analysis of variance Ground cover at crop development stage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	3.4444	1.7222	5.34	
TRT	5	14.4444	2.8889	8.97	0.002***
Residual	10	3.2222	0.3222		
Total	17	21.1111			

CV= 9.3 lsd=1.033

Appendix Table 13 Analysis of variance leaf orientation at development stage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.4444	0.2222	0.29	
TRT	5	15.7778	3.1556	4.18	0.026*
Residual	10	7.5556	0.7556		
Total	17	23.7778			

CV= 17.8 lsd=1.581

Appendix Table 14. Analysis of variance days to flowering

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.11111	0.05556	1	
tretment	5	22.27778	4.45556	80.2	<.001
Residual	10	0.55556	0.05556		
Total	17	22.94444			

CV= 0.1 lsd=0.4238

ANOVA tables of 2008/09 experiments

Appendix Table 15. Analysis of variance of Yield Metric ton ha^{-1} experiments conducted in 2008/09

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	0.00242	0.00121	0.07	
Treatment	2	0.03429	0.01714	1.02	0.439[ns]
Residual	4	0.06724	0.01681		
Total	8	0.10396			

[ns]*no significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square   F pr.= F probability*

Appendix Table 16. Analysis of variance of thousand kernel weight gm. [1] experiments conducted in 2008/09

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	1.7422	0.8711	2.58	
Treatment	2	18.1689	9.0844	26.89	0.005***
Residual	4	1.3511	0.3378		
Total	8	21.2622			

****There was very highly significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square   F pr.= F probability*

ANOVA tables of 2009/10 experiments

Appendix Table 17. Analysis of variance of Yield Metric ton ha^{-1} experiments conducted in 2009/10

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	0.5734	0.2867	1.05	
Treatment	5	2.1324	0.4265	1.57	0.254[ns]
Residual	10	2.718	0.2718		
Total	17	5.4238			

[ns] no significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square   F pr.= F probability

Appendix Table 18. Analysis of variance of thousand kernel weight gm. ^{1} experiments conducted in 2009/10

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	172.968	86.484	16.94	
Treatment	5	82.731	16.546	3.24	0.05*
Residual	10	51.046	5.105		
Total	17	306.744			

*There was significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square   F pr.= F probability

ANOVA tables of 2010/11 experiments

Appendix Table 19. Analysis of variance of Yield Metric ton ha^{-1} experiments conducted in 2010/11

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	0.12802	0.06401	0.75	
Treatment	4	0.55384	0.13846	1.61	0.262[ns]
Residual	8	0.68679	0.08585		
Total	14	1.36865			

[ns] no significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square F pr.= F probability

Appendix Table 20. Analysis of variance of thousand kernel weight gm. ^{1} experiments conducted in 2010/11

Source of variation	DF	SS	MS	v.r	F pr.
Block stratum	2	1.028	0.514	0.21	
Treatment	4	53.137	13.284	5.44	0.021*
Residual	8	19.544	2.443		
Total	14	73.708			

*There was significant difference between the genotypes. DF= degree of freedom, ss=sum of square, MS =means of square   F pr.= F probability

Appendix tables 21. Of summery statistics for the experiment conducted in 2011/12

Treatments	Mean	Median	Minimum	Maximum	Sd[1]	Variance
CCP-4	92.5	92.25	59	114.5	11.02	121.4
CCP-extra	94.71	93.5	74	116.5	10.03	100.5
Naturastar	90.4	91	73	103	5.13	26.34
CCP-2	95.66	92	75	121	10.25	105.1
CCP-1	95.87	93.25	68	124	11.82	139.7
CCP-3	91.65	91	65	128.5	10.27	105.6

Appendix Table 22. Summery statistics for Number spikelets per spike

Treatments	mean	Median	Minimum	maximum	Sd[1]	Variance
CCP-4	17.9	18	12	24	2.23	4.97
CCP-extra	17	18	12	24	2.07	6.12
Naturastar	20.65	20	10	26	2.2	4.85
CCP-2	17.41	18	10	22	1.98	3.92
CCP-1	18.43	18	14	22	2.26	5.12
CCP-3	17.8	18	12	22	2.07	4.26

Appendix Table 23. Summery statistics for distance between spikelet's

Treatments	mean	Median	Minimum	maximum	Sd[1]	Variance
CCP-4	0.48	0.47	0.32	0.66	0.0595	
CCP-extra	0.48	0.47	.33	0.68	0.0657	
Naturastar	0.418	0.41	0.33	0.8	0.054	
CCP-2	0.5	0.456	0.361	0.7	0.0662	
CCP-1	0.46	0.46	0.31	0.64	0.0604	
CCP-3	0.47	0.47	0.36	0.66	0.0549	

Appendix Table 24. Summery statistics for distance from the flag leaf to spike

Treatments	mean	Median	Minimum	maximum	Sd[1]	Variance
CCP-4	18.07	18	5.5	31	5.78	
CCP-extra	18.55	18	5.5	36.1	5.85	
Naturastar	17.25	17.5	8	22	2.38	
CCP-2	19.66	19.5	4	31	5.38	
CCP-1	18.61	18.5	3.7	31	5.63	
CCP-3	17.44	17.5	2.5	33.2	5.54	

Appendix Table 25. Summery statistics for   unfertile spikelet

Treatments	mean	Median	Minimum	maximum	Sd[1]	Variance
CCP-4	3.23	3	2	6	1.375	
CCP-extra	3.62	4	1	14	1.524	
Naturastar	4.34	4	2	8	1.369	
CCP-2	3.57	3.5	1	7	1.308	
CCP-1	3.45	3	2	7	1.236	
CCP-3	3.45	3	2	7	1.353	

Appendix Table 26. Summery statistics for Spike length

Treatments	mean	Median	Minimum	maximum	Sd[1]	Variance
CCP-4	8.52	8.5	5.5	12	1.453	
CCP-extra	8.214	8.25	5.2	12.3	1.337	
Naturastar	8.627	8.5	6	12	1.408	
CCP-2	8.042	8	5.5	11	1.33	
CCP-1	8.5	8.5	5.5	12	1.472	
CCP-3	8.408	8.5	5.5	11.5	1.354	

Appendix Table 27. Summery statistics for leaf area (cm^2) next to the first node

Treatments	mean	Median	Minimum	maximum	Sd[1]	Variance
CCP-4	8.723	8.498	4.949	13.57	2.065	2.463
CCP-extra	9.692	9.88	5.090	16.54	2.077	4.314
Naturastar	9.639	9.544	5.79	15.27	1.949	3.799
CCP-2	9.719	10.22	4.242	15.17	2.314	5.352
CCP-1	9.413	9.544	14	8.109	1.704	2.904
CCP-3	9.416	9.290	2.906	14.42	2.262	5.119

Appendix Table 28. Summery statistics for leaf area (cm^2) next to the second node

Treatments	mean	Median	Minimum	maximum	Sd[1]	Variance
CCP-4	13.69	13.61	8.399	20.68	2.494	6.222
CCP-extra	14.07	13.74	7.918	19.76	2.404	5.779
Naturastar	14.23	14	9.191	20.22	2.133	4.551
CCP-2	14.18	14.39	6.151	20.68	2.607	6.795
CCP-1	13.79	13.68	6.681	22.27	2.296	5.274
CCP-3	14.31	14	7.954	21.14	2.565	6.58

Appendix Table 29. Summery statistics for leaf area (cm^2) of the flag leaf

Treatments	mean	Median	Minimum	maximum	Sd[1]	Variance
CCP-4	22.39	21.80	11.45	41.72	6.118	37.43
CCP-extra	22.29	22.28	10.73	37.33	4.922	24.23
Naturastar	24.09	23.60	11.20	38.46	5.805	33.69
CCP-2	21.61	20.89	9.955	40.30	5.807	33.72
CCP-1	23.08	22.79	11.67	41.57	6.009	36.10
CCP-3	22.49	22.38	12.87	37.47	5.33	28.41

Appendix Table 30. Summery statistics for PAR at crop development stage

Treatments	mean	Median	Minimum	maximum	Sd[1]	Variance
Naturastar	199.3	179.9	133.4	324	47.5	2256
CCP-1	322.7	277	156.5	593.6	121	14632
CCP-2	517.5	489.1	169.9	978.6	239.4	57299
CCP-3	514.5	528.3	251.3	851.1	189.1	35776
CCP-4	523	521.9	279.9	876.7	193.9	37610
CCP-extra	534.9	398.4	157.1	1000	308	94880

Appendix Table 31. Summery statistics for PAR at late crop development stage

Treatments	mean	Median	Minimum	maximum	Sd[1]	Variance
Naturastar	364.1	345.7	170.8	680.1	137.3	18848
CCP-1	357.4	359.5	259.5	455.6	53.42	2854
CCP-2	400.4	337.2	248.4	855.3	145.3	21125
CCP-3	381.8	354.9	190.7	557.9	82.66	6833
CCP-4	362.1	328.3	268.6	513.1	77.16	5953
CCP-extra	365.6	362.6	197.7	567.4	89.54	8017

Appendix Table 32. Summery statistics for ground cover at the Early crop development stage

Treatments	Mean	Median	Minimum	Maximum	Sd[1]	Variance
CCP-4	4	4	4	4	0	0
CCP-3	5.33	5	5	6	.577	.333
CCP-2	6.33	6	6	7	.577	.333
CCP-1	6.667	7	6	7	.577	.33
Naturastar	6.33	7	5	7	1.155	1.333
CCP-extra	6	6	5	7	1	1

Appendix Table 33. Summery statistics for leaf orientation at the Early crop development stage

Treatments	Mean	Median	Minimum	Maximum	Sd[1]	Variance
CCP-4	3.33	3	3	4	0.577	0.333
CCP-3	4.667	5	4	5	0.577	0.33
CCP-2	6	6	6	6	0	0
CCP-1	6	6	6	6	0	0
Naturastar	4.333	4	3	6	1.528	2.333
CCP-extra	5	5	4	6	1	1

Appendix Table 34 phenotypic characteristics of genotypes

Character Range	Natu-rastar	HU-08-YQMS	HU-09-YQMS	HU-10-YQMS	HU-11-YQMS	UK-COMPOSITE
Plant height						
Dwarf (<74 cm)	2	3	4	0	3	2
Small (74-88 cm)	36	42	51	35	30	35
Medium (88-101 cm)	81	49	41	49	46	49
Long (101-113 cm)	1	25	23	29	33	30
Very long (>113 cm)	0	1	1	7	8	4
Spike length						
Short (<7.05 cm)	17	28	24	37	25	27
Medium (7.05-9.95 cm)	77	66	76	68	68	79
Long (>9.95 cm)	26	26	20	15	27	14
Number of spikelets						
Low (<15)	2	12	8	11	8	13
Medium (15-21)	65	100	105	107	93	104
High (>21)	53	8	7	2	19	3
Flag leaf spike length						
Short (<13 cm)	6	20	21	14	14	19
Medium (13-22.99 cm)	114	72	81	74	81	67
Long (>22.99cm)	0	28	18	32	25	34
Length of leaf next to 1st node						
Short (<13cm)	13	19	12	6	14	2
Medium (13-16.49 cm)	95	87	84	77	90	85
Long (>16.49 cm)	12	14	24	37	16	33
Width of leaf next to the 1st node						
Narrow (<0.75 cm)	8	32	22	22	9	22
Medium (0.75-1.05)	91	80	85	83	103	87
Wide (>1.05)	21	8	13	15	8	11
Length of flag leaf						
Short (<16.5 cm)	11	19	13	23	16	16
Medium (16.5-22.8 cm)	75	86	84	82	81	85
Long (>22.8)	34	15	23	15	23	19
Width of flag leaf						
Narrow (<1 cm)	0	0	0	0	0	0
Medium (1-1.8 cm)	109	103	110	112	100	110
Wide (>1.18 cm)	11	17	10	8	20	10

Appendix: 35 Tables of Environmental data

Appendix Table 25 Minimum daily temperature (^{0}c) of 2011/12growing period

Day	October	November	December	January	February	March	April	May	June
1	5.8	7.8	3.5	10.1	-8.6	7.7	-6.5	5.8	1.0
2	7.0	8.3	1.8	3.0	-11.1	2.0	-2.4	4.9	0.1
3	5.9	10.4	4.1	3.4	-12.2	1.1	-0.7	11.1	6.9
4	10.5	11.1	4.1	4.3	-18.8	-0.8	2.7	1.9	1.6
5	14.4	4.8	1.8	3.2	-11.6	4.2	1.8	4.5	0.8
6	6.6	6.3	0.4	3.0	-17.7	-0.3	-0.4	-0.9	9.8
7	5.7	9.1	2.9	4.7	-17.4	-1.3	-1.5	-2.8	9.4
8	3.6	5.0	0.5	4.8	-12.3	-1.1	-0.8	7.6	8.3
9	0.9	2.9	1.5	5.2	-13.3	0.5	6.5	12.1	6.6
10	16.2	3.0	-0.9	-0.5	-11.6	5.9	6.7	14.4	6.2
11	13.0	2.9	-0.4	6.1	-13.5	0.5	1.7	5.9	12.3
12	9.8	1.6	3.5	2.1	-13.2	0.1	-1.0	1.8	9.6
13	1.5	1.5	4.2	2.0	-1.4	6.2	-1.3	0.7	2.9
14	0.7	-4.2	2.2	-1.6	0.7	-0.9	-1.6	2.2	1.7
15	3.1	-4.5	3.9	-2.9	1.7	-1.9	-3.7	4.6	12.3
16	0.8	-0.8	1.1	-7.1	0.0	-0.5	-4.4	-0.9	9.0
17	2.5	-1.7	-1.0	-7.6	1.2	1.9	-5.3	-1.3	7.6
18	6.2	-1.0	-1.0	-6.2	1.9	1.9	2.8	9.0	5.3
19	1.5	-2.8	-2.0	3.2	-3.0	-1.4	1.1	9.3	4.2
20	1.0	-3.5	0.3	-0.6	-6.2	-0.5	1.3	9.1	11.7
21	-1.3	-0.2	2.9	0.9	1.1	-0.2	2.5	9.4	12.4
22	0.1	-0.8	5.8	3.0	2.6	0.7	2.7	13.1	9.6
23	2.0	0.7	7.5	-0.4	5.4	1.2	4.2	11.0	8.0
24	3.0	2.3	3.7	-2.3	-1.4	0.6	2.0	14.8	8.8
25	8.0	5.0	5.8	1.0	-1.6	0.7	2.9	12.2	5.7
26	5.3	1.3	9.8	2.8	2.5	-0.7	8.5	10.1	3.7
27	5.2	2.4	6.9	0.1	0.1	-0.5	8.6	9.7	13.9
28	4.4	-2.1	4.4	-1.8	7.2	-1.6	9.9	8.1	11.7
29	7.0	4.6	3.0	-1.3	7.4	-1.8	3.7	4.4	11.6
30	6.2	2.8	1.6	-2.1		3.0	1.9	4.3	11.5
31	9.2		3.4	-7.4		-5.5		7.3	

Source : Haarweg weather station data (Wageningen)

Appendix Table 36 Maximum daily temperature (^{0}c) of 2011/2012 growing period

Day	October	November	December	January	February	March	April	May	June
1	31.1	18.9	12.7	12.5	0.4	10.0	15.8	25.5	23.3
2	29.6	17.0	11.8	10.1	-0.9	15.5	19.1	24.5	22.6
3	26.5	16.6	10.2	10.2	-1.6	13.2	22.1	20.8	11.2
4	22.2	19.9	8.3	8.2	-2.7	14.1	11.7	17.9	14.5
5	19.4	19.6	8.0	9.1	-2.8	8.2	14.9	14.6	22.0
6	17.0	12.4	8.2	9.2	-2.5	14.4	16.3	13.6	23.2
7	16.8	10.8	8.3	8.7	-3.1	6.2	13.4	21.6	25.1
8	17.0	13.2	10.5	8.2	1.2	12.0	17.1	20.0	23.6
9	16.3	15.4	7.7	9.6	0.8	14.2	13.4	24.3	19.4
10	19.2	8.4	7.2	9.4	0.4	12.9	12.6	23.6	26.6
11	16.7	10.8	5.6	9.2	1.2	19.0	17.9	18.7	24.7
12	13.6	13.5	9.4	9.7	0.7	16.9	18.9	20.1	25.7
13	18.9	6.0	11.6	8.7	5.9	11.2	19.2	23.1	22.2
14	17.4	11.3	5.9	10.6	7.5	10.0	19.0	22.5	24.8
15	15.4	7.8	6.9	10.4	7.5	18.9	14.1	17.3	21.8
16	18.5	8.9	5.1	5.6	8.5	15.6	17.0	18.2	23.8
17	16.7	8.0	8.4	7.2	9.6	16.2	14.5	21.3	24.4
18	13.5	12.8	6.3	5.6	9.5	14.4	18.4	23.4	25.4
19	16.8	12.5	5.6	8.3	8.2	16.4	18.5	27.1	26.5
20	13.6	4.4	9.4	8.6	7.2	17.8	18.1	30.4	25.5
21	13.9	5.4	6.5	10.2	9.0	20.2	16.3	29.9	24.9
22	13.2	8.9	10.5	8.7	10.9	21.8	17.9	32.5	21.8
23	16.0	10.4	10.8	8.9	13.8	23.1	19.2	33.9	25.0
24	14.4	12.1	9.1	5.6	10.0	22.0	20.6	30.2	18.3
25	11.9	9.2	10.3	5.5	13.3	21.2	18.3	27.0	24.0
26	16.1	11.1	11.9	5.4	12.6	21.4	19.3	27.3	27.7
27	17.5	14.3	9.9	9.3	13.3	23.0	20.7	30.4	24.4
28	23.2	11.4	7.1	6.9	10.2	23.4	19.8	29.7	32.0
29	17.8	11.1	7.7	0.7	11.5	16.4	26.5	26.0	26.9
30	15.9	12.0	9.5	-0.8		15.4	26.8	27.5	28.8
31	19.7		10.5	0.2		13.6		21.6	

Source : Haarweg weather station data (Wageningen)

Appendix Table 37 Rain fall data of 2011/12 growing period

Day	October	November	December	January	February	March	April	May	June	July
1	0.0	18.5	8.9	11.1	0.0	0.0	0.0	2.0	0.0	0.6
2	0.0	0.1	4.2	4.2	0.0	0.0	0.0	8.0	0.0	0.0
3	0.0	0.0	11.8	10.6	2.5	0.0	0.0	0.0	12.4	0.0
4	0.0	0.9	0.5	8.1	0.0	4.6	2.7	0.0	10.3	0.0
5	0.8	0.0	3.1	15.4	0.0	4.9	0.0	1.5	0.0	0.3
6	3.6	0.0	2.2	0.1	0.0	0.0	1.0	0.0	8.6	0.3
7	10.8	0.0	5.6	5.9	0.0	8.7	2.0	0.0	3.0	0.2
8	3.5	0.0	7.4	0.4	0.0	0.7	1.2	1.3	0.9	12.3
9	5.7	0.0	1.7	0.7	0.0	0.0	9.6	19.5	0.1	1.4
10	0.6	0.0	0.0	0.0	0.0	1.3	8.3	21.3	0.0	0.4
11	4.6	0.0	0.0	0.2	0.0	0.0	3.4	0.0	6.3	
12	18.4	0.0	2.7	0.2	0.1	0.0	1.9	0.0	0.0	
13	0.0	0.0	8.5	2.0	2.1	0.0	0.2	0.0	0.0	
14	0.0	0.0	13.6	0.0	3.4	0.0	0.0	0.0	0.0	
15	0.0	0.0	8.4	0.0	1.8	0.0	0.1	10.4	8.4	
16	0.0	0.0	14.3	0.0	0.1	0.0	0.0	0.1	0.7	
17	0.0	0.0	3.6	0.0	0.2	0.0	1.9	0.0	0.0	
18	6.1	0.0	6.8	3.3	6.8	0.1	4.2	0.0	9.0	
19	3.2	0.0	2.3	12.9	0.6	0.0	0.1	0.1	0.0	
20	0.7	0.0	7.0	5.2	0.1	0.0	1.6	7.7	0.0	
21	0.0	0.0	0.2	7.0	0.0	0.0	4.3	0.0	14.2	
22	0.0	0.0	4.0	4.6	1.1	0.0	0.2	0.0	1.8	
23	0.0	0.1	2.9	4.6	1.3	0.0	0.9	5.4	0.0	
24	0.0	0.0	2.6	0.1	0.4	0.0	0.4	1.6	10.1	
25	1.8	0.8	0.9	0.1	0.0	0.0	2.2	0.0	0.0	
26	0.4	0.0	0.4	4.6	0.1	0.0	4.8	0.0	0.0	
27	0.0	2.4	0.0	0.0	0.0	0.0	1.4	0.0	0.1	
28	0.0	0.0	0.2	1.4	0.1	0.0	4.5	0.0	0.3	
29	0.0	0.5	9.5	0.1	0.0	0.0	0.0	0.0	0.0	
30	0.0	0.0	1.9	0.8		0.0	0.0	0.0	0.0	
31	0.0		8.0	0.0		0.0		6.8		

Source : Haarweg weather station data (Wageningen)

Appendix Table38: Daily Minimum temperature data of 2008/2009 growing period

Day	November	December	January	February	March	April	May	June	July
1	4.3	0.9	-4.0	-3.6	-3.7	0.0	3.3	6.5	12.5
2	1.5	-1.2	-10.8	-2.4	-3.4	6.0	1.2	3.6	13.8
3	2.2	-1.2	-12.4	0.4	-3.2	1.6	-0.2	5.3	12.5
4	2.6	0.4	0.3	0.0	3.8	6.1	-1.4	4.2	10.8
5	7.7	1.0	-7.2	-0.2	-0.6	4.3	8.6	2.6	9.5
6	6.0	0.7	-14.4	0.5	-1.3	0.7	9.5	2.5	12.2
7	4.4	-2.3	-10.6	-4.6	-5.1	7.7	6.0	5.2	11.8
8	3.4	-2.6	-9.5	-3.8	2.1	3.3	3.4	4.2	12.1
9	7.2	-2.2	-12.7	-1.2	1.1	2.6	1.9	10.9	9.5
10	9.4	-4.8	-12.9	0.6	3.4	10.5	2.2	10.3	11.4
11	6.1	-0.2	-7.1	-3.5	-2.7	8.8	5.3	6.2	8.9
12	5.4	-1.5	-2.5	-3.8	3.5	7.3	5.0	2.7	10.2
13	1.0	-3.0	3.4	-1.4	-0.8	4.3	10.9	2.1	8.6
14	7.5	-0.9	-3.1	-6.7	5.9	3.7	13.1	8.9	7.8
15	9.1	-1.6	-0.6	-7.4	5.4	4.3	7.9	5.5	11.6
16	-0.6	-0.5	-0.4	3.8	1.6	4.6	6.4	3.3	6.2
17	-1.3	-3.1	2.8	-0.6	-4.9	7.5	5.9	2.2	9.0
18	2.5	-2.7	0.7	-4.7	-5.3	3.5	5.2	12.7	10.3
19	3.1	0.0	1.3	-2.3	0.7	2.1	2.9	6.4	10.8
20	6.1	2.9	1.0	3.9	-6.4	0.1	1.9	6.7	8.0
21	0.5	6.4	-1.4	3.4	-5.2	-0.4	1.6	2.0	6.0
22	-0.7	-1.5	-0.2	5.1	-2.7	-0.9	0.8	0.5	15.4
23	-0.9	3.1	2.7	4.5	1.7	-0.7	5.2	2.7	11.8
24	-4.5	-0.7	-1.5	-1.7	-2.3	-0.9	5.2	7.3	12.9
25	-3.9	-1.3	-0.9	1.2	2.8	9.5	7.9	14.1	6.5
26	-4.8	-3.4	-2.1	3.9	2.1	10.5	6.7	10.6	6.8
27	4.4	-5.4	-6.6	6.1	2.5	6.9	3.9	16.7	10.5
28	2.2	-6.5	-6.8	-2.6	3.2	0.2	3.9	12.5	9.7
29	-3.5	-6.9	-6.8		1.8	-0.6	1.5	12.2	13.1
30	-4.3	-10.2	-2.4		-0.9	-0.6	7.8	13.1	4.1
31		-11.1	-3.0		-1.8		7.3		3.7

Source : Haarweg weather station data (Wageningen)

Appendix Table 39: Daily Maximum temperature data of 2008/2009 growing period

Day	November	December	January	February	March	April	May	June	July
1	8.8	8.9	0.2	2.4	14.1	18.3	25.8	31.4	32.0
2	15.1	5.2	3.7	4.1	11.6	20.8	22.8	27.7	34.2
3	10.0	6.5	0.5	6.0	9.4	24.9	18.3	22.3	33.4
4	10.1	5.0	2.8	1.8	11.5	15.1	19.3	23.6	30.0
5	10.6	8.2	1.0	8.6	8.1	21.5	14.9	21.6	32.3
6	15.5	11.6	1.5	12.4	7.1	21.0	18.5	21.3	27.9
7	14.2	10.6	1.5	6.9	12.6	17.3	21.8	23.1	22.0
8	13.9	4.3	-2.0	6.9	14.5	14.1	20.3	24.7	22.5
9	11.6	3.8	4.3	4.7	9.3	20.4	21.4	23.5	21.5
10	14.9	7.4	-1.9	8.6	8.0	25.5	26.1	25.0	20.4
11	12.3	4.0	1.3	8.0	14.7	25.0	21.0	25.4	25.0
12	12.8	4.5	5.6	7.8	10.3	21.4	20.9	25.6	24.3
13	14.1	2.8	5.3	6.7	14.0	23.3	23.7	29.9	27.4
14	10.9	8.1	7.7	8.4	16.3	23.7	25.0	24.0	29.0
15	12.0	3.7	7.6	3.9	12.8	25.2	21.0	24.0	28.0
16	11.8	2.2	3.7	10.4	12.7	22.2	19.9	24.2	30.3
17	11.2	4.6	7.4	7.0	18.4	19.6	20.8	26.8	26.5
18	9.2	7.7	7.7	7.1	18.6	21.0	22.3	26.4	20.4
19	11.7	10.2	9.3	4.0	15.5	21.2	24.1	23.1	23.3
20	11.8	10.4	8.5	7.1	14.7	23.1	25.3	26.1	24.1
21	8.2	9.7	7.2	8.6	15.9	24.0	24.0	25.4	30.2
22	6.2	12.5	5.8	10.3	15.1	19.9	22.6	27.0	28.5
23	1.7	6.6	7.8	10.8	10.6	19.9	26.3	27.9	24.1
24	4.6	7.7	8.0	7.1	13.2	21.8	28.4	29.0	24.7
25	9.1	6.5	6.9	8.5	11.5	23.9	29.3	30.0	24.5
26	6.4	4.2	7.5	10.7	9.1	23.8	24.2	28.4	26.9
27	6.8	2.9	5.6	9.5	12.5	20.1	18.9	30.8	29.4
28	4.5	2.2	3.0	10.5	12.9	14.9	25.5	29.9	25.2
29	4.4	3.0	3.7		13.6	21.1	25.8	32.4	29.8
30	3.6	5.2	5.0		15.2	24.6	26.4	32.7	24.3
31		1.5	5.1		17.6		27.2		26.0

Source : Haarweg weather station data (Wageningen)

Appendix Table 40: Daily rainfall data of 2008/2009 growing period

Day	November	December	January	February	March	April	May	June	July
1	0.0	18.5	8.9	11.1	0.0	0.0	0.0	2.0	0.0
2	0.0	0.1	4.2	4.2	0.0	0.0	0.0	8.0	0.0
3	0.0	0.0	11.8	10.6	2.5	0.0	0.0	0.0	12.4
4	0.0	0.9	0.5	8.1	0.0	4.6	2.7	0.0	10.3
5	0.8	0.0	3.1	15.4	0.0	4.9	0.0	1.5	0.0
6	3.6	0.0	2.2	0.1	0.0	0.0	1.0	0.0	8.6
7	10.8	0.0	5.6	5.9	0.0	8.7	2.0	0.0	3.0
8	3.5	0.0	7.4	0.4	0.0	0.7	1.2	1.3	0.9
9	5.7	0.0	1.7	0.7	0.0	0.0	9.6	19.5	0.1
10	0.6	0.0	0.0	0.0	0.0	1.3	8.3	21.3	0.0
11	4.6	0.0	0.0	0.2	0.0	0.0	3.4	0.0	6.3
12	18.4	0.0	2.7	0.2	0.1	0.0	1.9	0.0	0.0
13	0.0	0.0	8.5	2.0	2.1	0.0	0.2	0.0	0.0
14	0.0	0.0	13.6	0.0	3.4	0.0	0.0	0.0	0.0
15	0.0	0.0	8.4	0.0	1.8	0.0	0.1	10.4	8.4
16	0.0	0.0	14.3	0.0	0.1	0.0	0.0	0.1	0.7
17	0.0	0.0	3.6	0.0	0.2	0.0	1.9	0.0	0.0
18	6.1	0.0	6.8	3.3	6.8	0.1	4.2	0.0	9.0
19	3.2	0.0	2.3	12.9	0.6	0.0	0.1	0.1	0.0
20	0.7	0.0	7.0	5.2	0.1	0.0	1.6	7.7	0.0
21	0.0	0.0	0.2	7.0	0.0	0.0	4.3	0.0	14.2
22	0.0	0.0	4.0	4.6	1.1	0.0	0.2	0.0	1.8
23	0.0	0.1	2.9	4.6	1.3	0.0	0.9	5.4	0.0
24	0.0	0.0	2.6	0.1	0.4	0.0	0.4	1.6	10.1
25	1.8	0.8	0.9	0.1	0.0	0.0	2.2	0.0	0.0
26	0.4	0.0	0.4	4.6	0.1	0.0	4.8	0.0	0.0
27	0.0	2.4	0.0	0.0	0.0	0.0	1.4	0.0	0.1
28	0.0	0.0	0.2	1.4	0.1	0.0	4.5	0.0	0.3
29	0.0	0.5	9.5	0.1	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	1.9	0.8		0.0	0.0	0.0	0.0
31	0.0		8.0	0.0		0.0		6.8	

Source : Haarweg weather station data (Wageningen)

Appendix Table 41: Daily Minimum temperature data of 2009/2010 growing period

Day	October	Novemb.	December	January	February	March	April	May	June	July
1	1.1	10.2	-4.1	-9.4	-7.7	-2.1	-0.6	1.2	2.9	11.2
2	2.7	1.1	0.3	-10.0	-3.3	-3.4	-0.3	5.4	4.1	18.4
3	9.2	0.3	4.2	-10.6	-2.3	-4.3	4.7	3.7	2.3	13.9
4	-0.4	4.4	1.9	-6.8	1.2	-5.0	1.1	-2.0	3.3	9.8
5	3.4	4.7	3.6	-6.2	1.3	-8.1	0.5	-3.6	3.2	8.3
6	12.0	2.5	5.5	-9.0	1.3	-3.4	3.3	2.9	8.1	4.5
7	11.9	0.7	4.0	-12.0	0.3	-5.6	5.7	5.0	8.7	3.7
8	-0.4	0.4	-0.6	-12.7	-3.5	-6.8	-2.4	7.1	11.1	12.8
9	-1.6	4.9	2.2	-4.2	-7.8	-6.5	-2.6	3.7	14.0	11.5
10	7.8	2.7	8.0	-1.6	-10.7	-5.9	-2.6	0.9	16.1	14.4
11	6.3	3.1	-0.5	-0.9	-9.5	-1.1	-3.9	-1.5	7.1	17.3
12	1.9	1.5	-1.4	-4.2	-11.3	0.8	-4.0	4.7	4.0	12.2
13	-3.5	8.8	-2.9	-4.6	-3.0	1.6	1.2	5.7	1.2	9.4
14	-5.5	10.2	-8.4	-1.4	-3.8	3.2	-3.4	-0.5	2.4	14.2
15	-7.2	5.3	-10.9	0.4	-6.6	2.3	-2.0	-0.6	6.9	13.0
16	3.1	4.4	-10.6	0.4	-4.0	0.3	-3.4	6.0	4.5	9.3
17	-3.8	7.3	-4.6	0.5	-4.9	-0.9	-5.4	0.0	6.6	6.1
18	-3.5	7.7	-11.6	-1.4	0.7	-2.0	-3.6	-1.5	9.7	4.8
19	1.0	7.8	-17.6	2.5	-0.1	8.5	-1.2	-0.9	8.2	6.9
20	3.2	4.2	-7.2	2.0	-5.4	11.4	-2.3	-1.3	9.2	8.9
21	6.3	3.0	-4.7	1.6	-8.2	-0.4	-3.4	1.9	2.5	16.1
22	1.1	5.1	-2.2	0.6	0.7	-0.2	-5.0	3.5	-0.1	7.6
23	-0.1	8.0	-4.0	-0.3	1.8	3.5	-4.9	3.9	3.0	6.4
24	3.2	8.3	-4.1	-0.3	1.8	6.9	-3.2	6.0	6.9	5.8
25	9.0	7.5	0.4	-8.0	7.2	8.8	-1.3	3.2	6.1	5.6
26	10.0	4.8	0.1	-12.2	4.3	5.9	1.8	3.5	5.1	11.5
27	7.1	4.8	1.5	-13.0	2.6	5.0	1.2	3.4	10.6	10.5
28	2.6	1.9	-4.0	-0.1	3.3	5.8	4.0	0.0	7.7	12.9
29	5.7	6.2	-0.8	-2.6		7.2	8.2	0.0	6.3	10.7
30	2.7	-1.2	0.0	-1.9		4.0	-0.2	8.2	9.8	6.5
31	7.1		-0.3	-2.3		3.5		3.8		13.9

Source : Haarweg weather station data (Wageningen)

Appendix Table 42: Daily Maximum temperature data of 2009/2010 growing period

Day	October	November	December	January	February	March	April	May	June	July
1	18.0	15.0	10.3	1.7	1.2	10.5	11.5	18.6	23.0	34.6
2	16.5	14.0	7.4	1.0	4.1	10.1	16.4	11.3	25.9	37.9
3	16.8	12.0	10.3	2.0	6.3	10.4	16.0	10.3	27.0	36.8
4	19.3	12.8	6.1	0.1	8.6	9.0	16.0	17.5	28.7	32.1
5	13.8	11.1	9.3	1.8	6.3	8.1	14.0	17.7	31.0	32.2
6	18.4	11.0	11.8	-0.3	7.0	5.8	19.2	20.2	32.7	30.9
7	22.7	14.1	10.1	-0.8	3.2	5.9	22.3	11.6	25.0	31.8
8	21.0	13.7	10.8	-1.9	0.3	7.0	18.5	14.4	29.4	36.0
9	17.1	9.5	9.3	-0.4	1.2	8.3	21.0	16.7	21.5	39.5
10	21.0	9.6	10.6	0.5	1.3	8.3	18.0	19.6	25.4	38.7
11	16.9	11.7	9.9	0.1	-0.4	9.8	15.0	11.2	26.3	35.4
12	18.8	13.8	6.7	-0.5	2.8	8.2	18.6	10.3	25.1	29.3
13	17.6	16.9	5.3	-0.6	0.3	12.0	20.0	13.8	20.9	31.9
14	14.1	14.9	0.0	4.0	-1.2	11.5	19.5	17.5	27.6	34.3
15	17.5	13.9	3.7	1.7	-0.7	11.3	19.6	19.0	24.5	26.8
16	16.6	15.2	-0.4	1.7	3.1	14.8	17.1	20.7	26.5	30.8
17	17.1	13.3	-0.3	6.4	2.2	16.8	24.4	20.1	28.7	26.4
18	17.7	13.2	0.3	5.2	8.5	21.1	22.9	20.3	22.0	29.2
19	12.0	12.8	-2.7	7.4	7.3	17.7	19.0	21.8	21.8	32.8
20	14.1	16.3	-0.4	6.7	6.7	19.5	16.8	24.4	18.7	33.8
21	17.4	18.0	0.2	4.5	4.2	16.0	15.5	25.9	26.8	31.1
22	12.2	14.3	1.7	5.9	8.3	15.3	17.9	24.9	27.2	29.2
23	18.1	12.3	1.2	2.9	7.3	18.2	20.0	28.8	31.4	29.3
24	14.1	14.1	1.2	0.6	13.5	20.7	22.1	26.9	32.1	27.4
25	17.8	12.7	2.5	-0.1	13.3	23.6	27.4	24.5	31.1	25.3
26	16.3	9.7	7.2	0.6	12.8	14.7	22.5	14.0	32.5	24.8
27	18.4	9.8	5.1	3.4	10.6	17.3	23.3	20.6	33.0	27.5
28	18.6	9.2	11.1	7.7	11.7	16.8	25.7	22.4	35.5	27.0
29	17.5	11.0	2.2	4.5		18.3	29.5	25.6	32.4	24.6
30	15.6	9.9	1.6	0.7		18.5	17.3	21.5	32.8	27.2
31	15.6		0.5	0.7		13.9		20.1		27.5

Source : Haarweg weather station data (Wageningen)

Appendix Table 43: Rain fall data of 2009/2010 growing period

Day	October	Novemb.	Decemb,	January	February	March	April	May	June	July
1	0.6	15.6	0.0	0.0	1.0	2.5	6.8	5.6	0.0	0.0
2	0.5	1.3	1.3	0.7	18.9	0.0	1.0	7.8	0.0	0.0
3	3.7	6.5	6.5	0.1	0.4	0.0	7.0	2.9	0.2	0.0
4	0.2	6.8	6.1	0.0	1.9	0.0	5.9	0.0	0.0	0.0
5	2.6	6.1	8.1	0.1	2.8	7.0	0.0	0.0	0.0	0.0
6	5.9	0.4	5.6	0.0	0.2	1.5	0.0	0.0	0.0	1.9
7	21.9	4.3	0.4	0.0	0.0	0.0	0.2	2.7	0.0	0.0
8	15.4	0.0	3.1	0.0	0.0	1.3	0.6	0.7	0.0	7.7
9	7.2	0.0	3.5	1.3	0.0	0.0	0.0	0.0	0.0	2.4
10	2.5	0.7	9.8	0.6	1.2	0.0	0.0	0.0	29.3	1.1
11	12.7	0.2	0.1	0.1	0.3	0.0	0.0	18.4	0.0	0.0
12	1.7	3.3	0.0	0.1	0.0	0.0	0.0	9.4	12.2	0.0
13	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	2.0	0.0	0.3	1.1	0.0	0.0	0.1	14.4	0.0
15	0.0	1.8	0.0	0.0	0.0	7.0	0.0	0.0	3.6	0.0
16	1.5	0.5	0.0	5.4	0.0	0.6	0.0	0.0	0.0	0.0
17	2.0	0.0	3.5	2.8	0.6	0.0	0.0	3.0	0.6	0.0
18	0.0	0.7	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.3	1.9	2.3	0.0	0.0	0.0	0.3
20	0.0	1.0	5.2	0.1	0.0	15.0	0.0	0.0	0.0	0.0
21	0.0	1.0	2.0	0.2	0.0	1.9	0.2	0.0	0.1	0.0
22	1.4	7.9	4.6	0.0	11.5	0.0	0.0	0.0	0.0	0.0
23	0.0	16.5	0.0	0.0	1.0	0.0	0.0	0.0	1.9	0.0
24	5.4	0.8	0.8	1.1	1.6	0.0	0.0	0.0	0.0	0.0
25	0.5	1.7	14.4	0.0	5.9	1.4	0.9	0.0	0.5	0.0
26	2.1	7.8	0.0	0.0	3.2	0.5	0.0	2.5	9.1	0.0
27	0.0	2.9	3.1	2.0	1.0	1.7	0.0	0.1	2.5	0.0
28	0.0	21.4	0.1	0.9	18.6	1.8	0.0	0.0	9.4	0.0
29	0.0	0.3	6.1	11.1		3.7	0.1	2.7	0.7	0.0
30	0.0	0.0	4.2	3.7		1.4	5.1	10.8	0.0	0.0
31	0.1		0.1	1.8		2.4		0.3	1.3	

Source : Haarweg weather station data (Wageningen)

Appendix Table 44: Maximum Temperature data of 2010/11 growing period

Day	October	November	Decembe	Januar	February	March	April	May	June	July
1	20.1	9.6	-3.7	0.4	1.3	6.4	16.5	22.2	27.7	24.1
2	18.1	12.2	-5.3	0.4	3.5	8.9	24.5	18.7	29.7	24.7
3	23.8	16.0	-0.7	0.4	7.9	8.6	17.8	19.6	30.7	25.8
4	23.5	16.4	0.2	0.4	9.8	9.2	18.7	22.5	34.3	26.5
5	22.7	14.9	2.0	0.4	11.3	7.6	13.4	22.8	28.3	29.4
6	20.1	12.4	1.8	5.9	10.8	9.9	23.1	26.8	32.0	28.0
7	18.7	9.2	-0.6	7.9	12.1	10.0	19.6	30.5	25.4	27.4
8	17.1	8.8	-0.2	11.9	11.0	13.2	20.0	31.9	23.6	25.7
9	21.3	7.7	3.4	6.8	10.9	12.2	19.8	24.8	24.9	24.4
10	20.9	8.1	5.6	4.9	13.8	9.4	23.5	29.1	24.6	27.6
11	18.9	9.4	7.3	5.7	11.4	13.6	24.2	26.0	22.2	30.1
12	16.0	12.5	6.8	8.7	8.1	15.8	15.0	24.6	24.8	30.8
13	17.3	11.6	1.2	10.5	10.4	16.3	16.8	26.0	25.3	15.4
14	13.9	12.5	0.0	10.9	7.9	19.1	18.6	23.2	27.8	14.7
15	14.4	11.9	5.5	9.7	9.5	18.7	22.0	21.3	27.6	26.0
16	11.8	6.3	3.2	12.9	12.9	14.2	21.2	17.7	24.0	25.8
17	14.2	5.8	0.4	9.9	11.7	10.5	22.8	19.5	22.2	24.0
18	14.7	9.8	0.1	6.2	1.9	13.9	22.4	22.0	22.0	21.2
19	15.7	9.5	-0.1	9.0	5.8	14.9	27.4	20.9	19.5	25.6
20	12.0	9.3	-1.0	5.4	3.9	18.3	27.3	27.3	24.5	26.3
21	12.0	9.2	0.3	2.8	3.7	18.0	28.7	28.6	25.7	25.3
22	14.6	8.0	0.3	6.3	4.7	19.8	28.4	25.0	20.8	25.1
23	8.3	8.5	0.3	6.5	3.9	19.9	29.1	26.1	24.2	23.1
24	13.8	8.8	0.4	7.6	5.8	21.5	28.4	22.3	23.0	14.4
25	13.5	5.2	-0.5	8.1	8.2	19.7	27.3	27.0	17.1	25.2
26	10.6	5.7	0.2	4.4	11.4	10.9	26.0	23.0	29.1	20.4
27	11.3	1.8	0.4	2.8	6.1	18.8	19.2	22.1	34.3	28.2
28	13.2	2.2	0.3	2.1	5.6	17.3	23.2	22.6	36.0	29.5
29	13.1	-0.6	0.3	2.6		19.0	25.3	27.2	24.9	23.1
30	13.5	-0.4	0.1	1.1		20.5	24.3	33.3	25.7	19.0
31	13.5		0.4	-0.2		13.6		21.3		21.9

Source : Haarweg weather station data (Wageningen)

Appendix Table 45: Minimum Temperature data of 2010/11 growing period

Day	October	November	December	January	February	March	April	May	June	July
1	3.7	6.8	-7.7	-1.8	-3.4	0.8	9.4	5.8	-0.2	3.9
2	12.1	8.2	-8.5	-3.6	0.9	-1.3	8.1	4.2	-0.7	5.1
3	14.0	10.8	-13.2	-4.2	-0.2	-2.4	7.7	-2.6	10.6	4.1
4	12.7	14.2	-9.7	-1.3	4.6	-3.2	5.2	-4.3	14.2	3.0
5	12.6	10.3	-4.2	-2.0	9.5	-2.9	2.7	-2.5	13.1	3.8
6	11.0	5.7	-8.2	0.3	7.2	-4.5	7.2	4.7	12.3	11.7
7	7.6	0.7	-2.7	0.0	5.2	-4.5	1.2	13.2	11.9	8.8
8	10.3	0.9	-8.5	5.6	-2.9	-2.7	1.0	13.1	7.6	10.5
9	8.3	4.7	-6.5	-1.0	-5.0	1.6	0.9	11.0	2.7	5.2
10	3.8	1.4	-3.7	-2.6	1.4	2.8	0.4	8.9	2.2	3.3
11	0.6	1.8	4.7	-1.1	5.0	-1.4	1.6	5.1	1.5	5.8
12	0.2	7.7	-4.1	0.9	3.0	0.1	0.8	3.0	0.0	10.9
13	-0.2	8.9	-6.8	8.0	4.6	8.4	0.2	2.0	11.3	12.5
14	-0.6	7.8	-7.9	7.3	4.0	8.0	0.0	0.0	6.0	12.0
15	7.2	0.8	-7.5	7.4	0.7	7.3	-0.3	1.0	7.4	11.6
16	0.9	-0.5	-4.5	5.5	-0.4	4.8	-0.5	9.5	7.5	11.0
17	-1.7	-0.3	-4.4	4.7	-1.7	4.7	1.5	4.1	10.2	13.4
18	-3.0	4.4	-6.6	2.3	0.4	4.5	-0.3	3.5	11.9	13.2
19	6.0	4.7	-2.6	-0.6	0.8	-3.0	2.8	4.9	10.3	8.7
20	1.8	3.6	-3.6	-2.5	-1.9	-3.3	0.5	0.9	9.9	11.1
21	2.7	0.2	-2.6	-1.1	-4.5	-3.7	1.4	0.1	10.5	8.1
22	5.3	-1.1	-0.6	0.9	-6.2	-1.9	11.1	6.3	8.8	8.3
23	2.7	0.5	-0.6	1.2	-3.7	-0.4	6.1	7.3	10.5	8.4
24	-0.4	-0.4	-1.2	2.9	0.7	-0.8	3.8	1.7	6.4	10.4
25	-1.0	-0.2	-3.2	0.1	4.0	0.6	1.7	0.5	10.6	4.9
26	-0.9	-2.2	-0.9	-2.1	6.1	-1.0	0.6	8.5	11.8	12.7
27	6.5	-3.4	-0.2	-3.2	0.7	-1.2	6.2	3.4	16.9	10.7
28	7.0	-5.4	-0.1	-4.8	0.7	-3.3	6.8	3.1	18.5	13.3
29	4.4	-3.7	-1.5	-7.4		-3.1	9.8	6.2	6.6	9.5
30	3.9	-3.7	-3.7	-7.2		-0.9	9.1	4.6	5.1	12.8
31	5.1		0.1	-2.7		9.4		1.3		6.0

Source : Haarweg weather station data (Wageningen)

Appendix Table 46: Rain fall data of 2010/11 growing period

Day	October	Novembe	Decembe	January	February	March	April	May	June	July
1	2.9	0.0	0.0	0.7	0.6	0.0	0.0	0.0	0.0	1.1
2	7.9	0.9	0.4	0.1	0.2	0.0	0.0	0.0	0.0	0.0
3	0.0	7.0	0.0	0.1	4.2	0.0	3.2	0.0	0.0	0.0
4	0.0	0.3	6.2	0.0	0.9	0.0	0.0	0.0	0.0	0.0
5	0.0	17.3	9.7	0.0	0.0	0.0	0.0	0.0	10.1	0.0
6	0.1	12.8	0.0	17.0	0.0	0.0	0.0	0.0	22.3	1.6
7	0.1	0.1	0.0	3.3	0.0	0.0	0.0	0.0	5.8	0.0
8	0.0	0.2	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.3
9	0.0	2.8	4.6	0.0	0.0	0.6	0.0	2.4	0.0	2.8
10	0.0	7.8	1.8	0.1	10.5	0.2	0.0	0.0	0.8	0.0
11	0.0	14.2	0.2	1.9	2.3	0.0	2.0	0.0	0.1	0.0
12	0.0	9.1	0.4	11.6	10.4	0.1	0.8	0.0	4.0	27.2
13	0.0	5.5	0.3	14.4	0.0	1.5	0.0	0.0	0.8	8.2
14	0.4	7.6	0.0	14.5	2.7	1.4	0.0	0.0	0.0	29.4
15	8.7	0.0	0.4	0.0	0.5	0.0	0.0	2.0	0.3	3.9
16	0.3	0.0	12.1	0.0	0.1	0.0	0.0	2.4	12.9	17.3
17	0.0	0.0	1.9	0.9	0.0	0.0	0.0	0.7	1.5	4.0
18	0.0	0.0	0.6	8.2	0.0	5.3	0.0	0.0	7.6	1.6
19	20.3	0.0	3.0	3.2	0.0	0.0	0.0	0.1	10.9	0.2
20	3.5	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.2
21	1.8	0.0	0.8	0.3	0.0	0.0	0.0	0.0	0.4	11.2
22	0.0	0.0	0.1	0.2	0.0	0.0	0.0	5.3	0.5	1.5
23	5.7	0.1	1.0	0.7	3.3	0.0	0.0	0.0	1.9	6.5
24	1.1	0.0	1.2	0.4	2.9	0.0	0.0	0.0	0.5	21.9
25	0.0	0.1	0.1	4.7	0.6	0.0	0.0	0.0	5.1	0.4
26	0.5	0.0	3.0	0.6	4.4	0.0	0.0	0.0	0.0	0.7
27	8.5	0.0	0.1	0.0	19.7	0.0	0.0	1.4	0.0	0.0
28	0.4	0.1	0.0	0.0	0.5	0.0	5.6	0.5	22.0	0.8
29	0.0	1.4	0.0	0.0		0.0	0.0	0.0	1.1	0.0
30	1.3	0.3	0.0	0.0		1.1	0.0	0.0	0.1	0.0
31	1.0		1.4	0.0		5.3		2.2		0.0

Source : Haarweg weather station data (Wageningen)