# Processing and Baking Quality of Organic Winter Wheat in Switzerland

## The influence of cultivar, environment and their interaction and stability analysis

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**Summary: Processing and baking quality traits of cultivars of winter wheat grown under organic conditions have been recorded. Analysis of variance has revealed that yield, protein content and zeleny are strongly influenced by the environment whereas the quality traits extensograph area and bread volume showed a high genotypic variance component and high heritability. This allows for efficient selection and cultivar recommendation. The considerably low environmental effect on these quality parameters indicate that also under low-input conditions flour of good quality can be produced if appropriate cultivars are chosen. Stability estimates showed high variation amongst cultivars and the usage of such estimates is suggested to be used in cultivar recommendation to enable more stable levels of yield and quality across environments and years.**

### Background

Bread quality is dependent on the dough processing and baking properties of the flour used. Effects of cultivar, site specific environmental factors, management and their interactions on these properties have been investigated before, but rarely under organic conditions. Knowledge about the magnitude of the sources of variation is important for breeders as well as for extension to develop best strategies for an efficient recommendation. Traits with a high genotypic variance component facilitate common recommendation whereas traits with a high cultivar x environment (CxE) interaction hinder common recommendation but can be exploited by either local selection or specific recommendation. Since with increasing extensification site specific conditions have a greater impact, CxE interaction becomes more important (Cooper and Hammer, 1996). In order to evaluate, whether specific recommendation could increase overall levels of production and quality, the impact of wheat cultivar and the sites-specific factors were investigated.

### Main chapter

*Material and Methods*

Within the Swiss cultivar testing network of winter wheat for organic farming, 10 cultivars have been grown at 9 organically managed sites in the years 2011 - 2013. Processing and baking parameters have been recorded. Variance components and Shukla's stability variance (Shukla, 1972) were analysed with SAS 9.2.

*Results*

Analysis of variance components revealed a strong environmental effect, low heritability and a CxE interaction term of 13.9 to 22.3 percent for grain yield (GY), grain protein content (GP) and zeleny sedimentation value (SED) (Table 1). For these traits specific cultivar recommendation can lead to better performances at each site. Both, extensograph area (EAR) and loaf volume (LV), showed high levels of genotypic effect, which is also confirmed by the heritabilities of 0.71 and 0.64, respectively. The performance of these quality traits is thus mostly influenced by the cultivar and less by the environmental conditions meaning that common cultivar recommendation is possible for these traits.

Table 1: Variance components, percent of the sum of cultivar, environment and cultivar x environment interaction, and heritability for yield and quality traits[a] of 10 winter wheat cultivars grown at 9 organically managed sites in Switzerland over three years (2011-2013).

| Source of Variation | GY | GP | SED | EAR | LV |
|---|---|---|---|---|---|
| **Variance components** | | | | | |
| **Cultivar** | 3.35 *[c] | 0.22 * | 10.54 * | 849.14 * | 27346.00 * |
| **Environment** | 99.11 *** | 1.30 *** | 90.21 *** | 142.45 ** | 3559.12 * |
| **Rep** | 8.35 | 0.10 | 1.80 | --[b] | --[b] |
| **Cultivar x Environment** | 16.54 *** | 0.44 *** | 21.93 *** | 197.40 *** | 12130.00 *** |
| **Residual** | 15.28 | 0.26 | 9.04 | 1.04 | 1.01 |
| **Percent of the sum of cultivar, environment and cultivar x environment interaction variance** | | | | | |
| **Cultivar** | 2.8 | 11.2 | 8.6 | 71.4 | 63.5 |
| **Environment** | 83.3 | 66.5 | 73.5 | 12.0 | 8.3 |
| **Cultivar x Environment** | 13.9 | 22.3 | 17.9 | 16.6 | 28.2 |
| **Heritability ($h^2$)** | 0.03 | 0.11 | 0.09 | 0.71 | 0.64 |

[a] GY = grain yield, GP = grain protein, SED = sedimentation value, EAR = extensograph area, LV = loaf volume
[b] no term for replication was estimated as analysis was carried out on pooled samples per cultivar within trials
[c] significant ($H_0$:Var=0,Wald Z-test) at *:P<0.05, **:P<0.01, ***:P<0.001

Means and estimates of stability variance are presented in Table 2. There is significant variation between cultivars at each trait. The cultivar Ekolog, that has been selected for organic conditions, has the highest yield. The cultivars Runal and Suretta show the lowest GY but the highest GP. A very pronounced difference of means per cultivar is shown at LV: the best cultivar Runal having a LV of 1935 ml, almost 1.5 times greater than the cultivar with lowest LV, A7T, having a LV of only 1396 ml. No cultivar is among the best ones over all traits and vice versa.

Table 2: Means and Shukla's stability variance (S.V.) for yield and quality traits[a] of 10 winter wheat cultivars grown at 9 organically managed sites in Switzerland over three years (2011-2013).

| Cultivar | GY (dt/ha) | | GP (%) | | SED (ml) | | EAR (cm2) | | LV (ml) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | S.V. | Mean | S.V. | Mean | S.V. | Mean | S.V. | Mean | S.V. |
| **A7T.9** | 42.6 | 9.6 | 13.71 | 0.08 | 62.8 | 27.3 | 182.9 | 285.0 | 1396 | 42535 |
| **Arnold** | 43.8 | 26.6 | 13.70 | 0.52 | 65.9 | 11.3 | 141.4 | 467.0 | 1851 | 8581 |
| **Butaro** | 42.7 | 9.6 | 12.66 | 0.51 | 59.1 | 48.2 | 100.3 | 165.0 | 1709 | 10409 |
| **Ekolog** | 44.1 | 13.7 | 13.41 | 0.48 | 59.1 | 23.6 | 81.0 | 169.3 | 1767 | 4956 |
| **Lorenzo** | 41.3 | 0.9 | 14.02 | 0.25 | 67.9 | 5.9 | 150.3 | 229.7 | 1789 | 5573 |
| **Montdor** | 42.9 | 27.7 | 13.19 | 0.12 | 62.8 | 11.9 | 119.7 | 128.6 | 1777 | 5874 |
| **Runal** | 39.9 | 5.7 | 14.24 | 0.74 | 61.7 | 8.8 | 138.9 | 259.6 | 1945 | 17638 |
| **Suretta** | 39.2 | 32.0 | 14.29 | 1.17 | 58.2 | 21.4 | 79.1 | 130.8 | 1792 | 12649 |
| **Titlis** | 41.5 | 6.9 | 13.22 | 0.14 | 64.9 | 24.7 | 116.7 | 193.7 | 1885 | 8861 |
| **Wiwa** | 42.1 | 6.9 | 13.35 | 0.29 | 63.7 | 32.8 | 127.6 | 127.5 | 1765 | 9097 |
| **s.e.**[b] | 2.14 | | 0.26 | | 2.11 | | 4.83 | | 40.8 | |
| **Mean** | 42.0 | | 13.58 | | 62.6 | | 123.8 | | 1768 | |
| **Nr. of trials** | 27 | | 27 | | 26 | | 15 | | 12 | |

[a] GY = grain yield, GP = grain protein, SED = sedimentation value, EAR = extensograph area, LV = loaf volume
[b] s.e. = standard error of the cultivar means

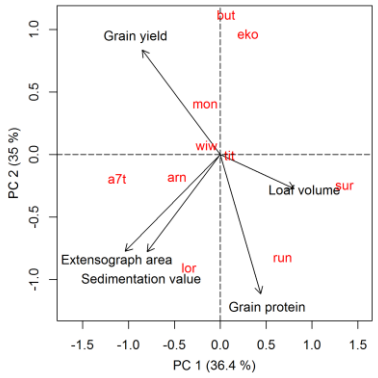


Figure 1 Principal component analysis of traits by cultivar means. Cultivars: a7t = A7T.9, arn = Arnold, but = Butaro, eko = Ekolog, lor = Lorenzo, mon = Montdor, run = Runal, sur = Suretta, tit = Titlis, wiw = Wiwa

This complex genetic tradeoff between traits is also confirmed by principal component analysis (PCA) over cultivar means (Figure 1). GY is negatively correlated with GP and LV. The cultivars Lorenzo, Runal and Suretta group towards high GP and LV, whereas the cultivars Butaro and Ekolog are better in GY. EAR is strongly correlated with SED and LV is correlated with GP.

Stability analysis reveals pronounced differences between the cultivars investigated (Table 2). According to Lin et al. (1986) Shukla's stability variance corresponds to the Type II concept of stability: a genotype is stable if its response to environments is parallel to the mean response of all genotypes in the trial. Cultivar Lorenzo is the most stable at GY and SED. A7T.9, has the lowest mean LV and is the most unstable at LV. Similar to the cultivar means, cultivars that are stable at one trait are not necessarily among the stable ones at other traits and vice versa.

## *Discussion*

In contrary to the strong influence of environmental factors on GY, GP and SED, it was found that quality characteristics like EAR and LV are strongly influenced by the cultivar and less by environmental factors. Although all trials in this study were under organic management the strong effect of cultivar on these baking quality traits suggest that sufficient baking quality can also be produced under low-input conditions if appropriate cultivars are chosen. However, the traits considered are only a subset of a multitude of traits related to processing and baking quality and the inter-relation of these is even more complex. In order to facilitate the identification of breeding goals and allow for classification of cultivars for recommendation, weighted index-schemes have been introduced (e.g. Saurer et al. (1991) for Switzerland).

Stability estimates did not correlate with the means of the corresponding trait and estimates did vary substantially among cultivars. As environmental variation between sites is assumed to be greater under organic management and due to seasonal variation and unpredictability, stability is of increased importance. Using stability estimates as an additional measure in breeding and recommendation could lead to more stable and secure levels of production.

For traits that show that show pronounced levels of CxE interaction, breeding for general adaptation to different environments and different management intensities as well as common cultivar recommendation is complicated. However, CxE interaction can also be exploited by breeding and recommendation for e.g. specific regions or management intensities. To identify groups of environments for which the same cultivars can be recommended, environments need to be characterized by climatic, soil and management properties and prevailing pests.

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