*Agronomy Research* **8** (Special Issue III), 749–754, 2010

# Factors influencing oat grain yield and quality under growing conditions of West Latvia

S. Zute, Z. Vīcupe and M. Gruntiņa

State Stende Cereals Breeding Institute, Dižstende, Talsi region, Latvia, LV-3258;
e-mail: sanita.zute@stendeselekcija.lv

**Abstract.** Ecological comparison of oat varieties are set up every year at the State Stende Cereals Breeding Institute, but five out of the test varieties were estimated in a longer period of time – from 1993 till 2009. For these varieties, productivity and quality indices were measured: grain yield, volume weight, 1000 grain weight, husk content, crude protein content. Meteorological conditions were characterized by two basic indices – the mean temperature and amount of precipitation in the vegetation period. Observations show that in the reporting period precipitation of the vegetation period (coefficient of variation for index variability between years was from 43.1% in June up to 55.3% in April) and mean temperature in April (coefficient of variation was 26.4%) varied most significantly. The average productivity of trial oats varied from 3.56 to 6.62 t ha$^{-1}$. The most stable yields of grain in the reporting period were provided by the oat varieties Stmara and Laima (the average yields respectively 5.35 ± 0.89 and 5.83 ± 1.07 t ha$^{-1}$, coefficient of variation respectively 14.9 and 17.0%). Significant, close to medium correlation was established between oat grain volume weight and mean daily temperature in May, July and August (respectively $r$ = –0.468, 0.464 and 0.549 > $r_{0.005}$ = 0.460). Relationships analyzed between oat grain yield, its quality characterizing indices and parameters characterizing meteorological conditions showed that grain yield and quality of oats in the Northwest region of Latvia were influenced mainly by rainfall in particular months of the vegetation period.

**Key words:** oats, grain quality, mean daily temperature, precipitation

## INTRODUCTION

According to data presented by the Central Statistics board, in the period 1990–2009, oats in Latvia occupied the area from 46.1 (1995) to 93.0 thousand ha$^{-1}$ (1991) annually, including 66.2 thousand hectares in 2009 (http://data.scb.). The total oat cultivation area has varied between years depending on several factors (demand for oat grain and purchase price in the market), but unstable yields between the years were also a significant reason mentioned by the oat breeders themselves. According to agricultural statistics data from 1990 till 2009 the average productivity of oats varied from 0.86 (1992) to 23.3 t ha$^{-1}$ (2009) in Latvian farms.

The yield limiting factors in field crops can be divided into several groups: variety efficiency, soil fertility, agrotechnics, and meteorological conditions (Karing et al., 1999). Prediction and planning of the first three factors is possible. Predicting the interaction of these factors with meteorological conditions in a specific year is more complicated. Quantity and quality characterizing indices in oat yield are influenced significantly by photosynthetically active radiation, heat and soil moisture in specific phases of plant development (Hellewell et al., 1996). The greater is the variation of meteorological conditions in a region, the more difficult it is to predict the actual productivity of field crops (Karing et al., 1999). The climate variability models developed for the Baltic Sea region give evidence that significant changes in temperature and moisture regimes will be observed in the future as well. Though in general, the growing period could be longer, more frequent maximum temperatures and uneven rainfall distribution are predicted in summer, when lasting drought periods interchange with heavy showers (Klavins et al., 2008). On the basis of long term observations (1993–2009), the objective of this study was to evaluate the stability of yielding capacity and most important grain quality indices in definite oat varieties between the years; variation between the years in the most frequently used meteorological indices – mean daily temperature and precipitation; and the impact of meteorological conditions on oat yield quantitative indices.

## MATERIALS AND METHODS

Data obtained in oat variety testing trials at the State Stende Cereals Breeding Institute from 1993 till 2009 was summarized in the research. Five oat varieties of different types out of the total test varieties were selected: Laima – the variety developed and registered in Latvia in 1993, vegetation period 100–105 days, highly productive, widely used in Latvia; Stmara (Mara) – the variety developed and registered in Latvia in 1986, vegetation period 98–103 days, highly productive; Stendes Liva (Liva) – the variety developed and registered in Latvia in 1987, vegetation period 112–117 days, medium productive, suited for herbage production; Arta – the oat variety developed and registered in Latvia in 1995, vegetation period 88–93 days, medium productive, good grain quality parameters; Selma – the oat variety developed in Sweden, registered in Latvia in 1974, vegetation period 98–103 days, medium productive, widely produced in Latvia till 1995. Treatments and varieties were laid out in four replications. Recorded plot area was 10 $m^2$.

The trials were established in plant breeding crop rotation fields with similar soil characteristics: sod weakly podzolized (WRB – Eutric Podzovisols) well cultivated loamy sand soils on morainic parent material with soil $pH_{KCl}$ 5.4–6.2, organic matter 16–25 g $kg^{-1}$, previous crop – potatoes.

Uniform oat management practice was performed in all trial years. Prior to sowing, fields received mineral fertilizer Kemira NPK 18:9:9, calculated in nitrogen a.i. 58–63 kg $ha^{-1}$ N. Oat was sown in the 2nd or 3rd decade of April considering soil readiness for sowing in a specific year. Grain yield was harvested in full ripeness – in the 2nd or 3rd decade of August. Economic and technological properties of grain: husk content (g $kg^{-1}$), volume weight (g $l^{-1}$), crude protein (g $kg^{-1}$) was analyzed in the laboratory of grain quality and agro-chemistry of the Institute.

Data was processed employing MS Excel software ANOVA. The Stende Hydrometeorological Station (Stende HMS) provided meteorological information. Weather conditions characterizing indices – the mean temperature and monthly precipitation were analyzed. To evaluate variation in these indices in the reporting period, their actual values in a specific month were compared to long-term averages.

## RESULTS AND DISCUSSION

Deviations from monthly long-term averages showed considerable difference in the mean temperature in April in the period of 1993–2009 compared to norm (Table 1). Besides, in nine years the mean temperature was considerably above the long-term averages and only in one case, in April 1997, it was significantly lower than the norm. Medium high variation between the years was observed also in May (coefficient of variation 14.2%).

**Table 1**. Mean daily temperature and precipitation in oat vegetation period, % deviation from monthly long-term average, Stende HMS, 1993–2009.

| Months | Deviation from monthly long-term, % | | CV, %* |
|---|---|---|---|
| | min-max | mean | between years |
| Mean daily temperature | | | |
| April | 65.1–218.6 | 136.8 | 26.4 |
| May | 75.0–138.8 | 102.1 | 14.2 |
| June | 88.9–120.4 | 100.4 | 9.8 |
| July | 88.3–109.8 | 102.1 | 9.3 |
| August | 83.8–121.3 | 103.2 | 9.5 |
| Sum of precipitation | | | |
| April | 21.7–215.7 | 98.9 | 55.3 |
| May | 35.6–180.0 | 99.4 | 46.2 |
| June | 68.4–265.9 | 135.8 | 43.1 |
| July | 10.5–133.7 | 93.8 | 54.1 |
| August | 5.6–183.5 | 94.2 | 54.9 |

*CV – coefficient of variation

Data of June, July and August show that the mean temperature variation between the years was comparatively low (coefficient of variation < 10%). Besides, years with mean temperatures even below norm were prevailing compare to long-term averages.

Analyzing deviations from the long-term average rainfall between months, considerably higher variation between the years was observed. In particular years the monthly norm of precipitation was higher even more than twice (e.g., April 1997 – 215.7%, June 1997 – 233.2%, July 2000 – 238.4% from the norm). In general, deviation from monthly precipitation was highest in June (in ten years out of recent 17 monthly norm was exceeded significantly).

Here genotype is of great importance as it is. For example, oat variety Arta, which is characterized by very good grain quality indices – in the last 17 years the average volume weight of grain was 521 g $kg^{-1}$, husk content in yield 210.3 g $kg^{-1}$, crude protein content 141.2 g $kg^{-1}$. However, in particular years all the estimated oat varieties showed considerably lower quality indices compare to optimal ones (1995, 2003, 2007, 2008, and 2009) thus giving evidence of the negative impact of annual meteorological conditions.

The formation of yield can be divided into two phases: till anthesis when the productivity potential of a plant is constructed – productive tillers, sprouts of spikes and flowers; and anthesis and post anthesis when the grain and its quality characterizing indices are being formed (Welch, 1995; Peltonen–Sainioet al., 2008). Since research data have been obtained in a longer period of time, they are, unfortunately, incomplete because they did not precisely indicate the beginning of developmental phases in oats in each specific year. For that reason, correlative relationships between oat yield, main indices of grain quality and indices characterizing meteorological conditions in a definite month of the vegetation period were studied (Table 2).

**Table 2.** Oat grain yield and most significant quality indices in variety testing trials, Stende SBI, 1993–2009.

| Varieties | Min-max, | Mean | CV, % between years |
|---|---|---|---|
| Grain yield, t ha$^{-1}$ | | | |
| Laima | 4.30–7.87 | 5.83 ± 1.07 | 17.0 |
| Arta | 2.35–5.31 | 3.85 ± 0.82 | 21.4 |
| Stendes Liva | 2.95–6.27 | 4.80 ± 1.04 | 20.9 |
| Stmara | 3.79–6.64 | 5.35 ± 0.89 | 14.9 |
| Selma | 2.60–7.70 | 5.30 ± 1.24 | 22.8 |
| Mean varieties | 3.56–6.62 | 5.02 ± 0.93 | 17.5 |
| Volume weight, g l$^{-1}$ | | | |
| Laima | 454–541 | 505 ± 21.6 | 4.4 |
| Arta | 490–562 | 521 ± 17.6 | 3.4 |
| Stendes Liva | 435–562 | 491 ± 25.7 | 5.2 |
| Stmara | 470–548 | 499 ± 28.1 | 5.2 |
| Selma | 470–550 | 516 ± 20.1 | 3.9 |
| Mean varieties | 461–546 | 506 ± 20.7 | 4.1 |
| Husk content, g kg$^{-1}$ | | | |
| Laima | 229–292 | 251.1 ± 15.4 | 6.1 |
| Arta | 185–238 | 210.3 ± 13.2 | 6.3 |
| Stendes Liva | 225–295 | 249.4 ± 17.4 | 6.9 |
| Stmara | 235–285 | 258.8 ± 14.0 | 5.4 |
| Selma | 234–305 | 258.1 ± 20.7 | 8.0 |
| Mean varieties | 229–283 | 245.6 ± 13.4 | 5.5 |
| Crude protein content, g kg$^{-1}$ | | | |
| Laima | 99–134 | 112.2 ± 12.4 | 11.1 |
| Arta | 121–189 | 141.2 ± 18.6 | 13.2 |
| Stendes Liva | 103–171 | 116.1 ± 17.8 | 15.3 |
| Stmara | 103–156 | 121.0 ± 14.2 | 11.8 |
| Selma | 91–134 | 102.4 ± 12.2 | 11.8 |
| Mean varieties | 107–158 | 117.4 ± 14.8 | 12.1 |

Employing linear correlation calculation method, the following correlations were established: the increase in mean temperature above norm in May have a negative impact on oat grain volume weight (correlation coefficient $r$ = –0.600 > $r_{0.05}$ = 0.460). Calculated determination coefficient shows, that the mean temperature in May affected the value of a trait by 36% ($r^2$ = 0.36, $y$ = –1.084x + 613.9). Similarly, medium close correlation was established between grain volume weight and the amount of monthly precipitation in May, July and August (correlation coefficient respectively $r$ = 0.468, –0.464, –0.549, $r_{0.05}$ = 0.460). In May, when the rainfall was above the long-term averages, it had a positive effect on the formation of grain volume weight ($r^2$ = 0.219, $y$ = 0.209x + 484.6). When the rainfall in July and August was above norm, the volume weight of grain decreased significantly ($r^2$ = 0.215, $y$ = –0.170x + 521.3 and $r^2$ = 0.301, $y$ = –0.210x + 525.0) (Table 3).

**Table 3.** Correlative relationships between quantitative indices characterizing oat productivity and indices characterizing monthly meteorological conditions, Stende SBI, 1997–2009.

| Month | Grain yield | Volume weight | Husk content | Crude protein |
|---|---|---|---|---|
| Monthly mean daily temperature | | | | |
| April | –0.211 | –0.190 | –0.016 | –0.015 |
| May | 0.252 | –0.600* | 0.330 | 0.216 |
| June | –0.098 | 0.008 | 0.269 | 0.159 |
| July | –0.046 | 0.032 | –0.006 | –0.026 |
| August | 0.373 | 0.248 | –0.004 | 0.177 |
| Amount of monthly precipitation | | | | |
| April | –0.032 | 0.103 | –0.104 | 0.046 |
| May | 0.178 | 0.468* | –0.041 | –0.061 |
| June | –0.261 | 0.152 | 0.235 | –0.395 |
| July | 0.361 | –0.464* | –0.311 | –0.286 |
| August | 0.148 | –0.549* | 0.144 | 0.042 |

* significance at 5% level respectively

Seeking for relationships between oat yield and analyzed indices characterizing meteorological conditions, it was found that rainfall above norm in June had a negative impact on oat yield formation, but the impact was positive with the increased rainfall in July (correlation coefficient respectively $r$ = –0.261; $P$ < 0.32 and 0.361; $P$ < 0.16). Estimation of these relationships for each of the analyzed oat varieties separately showed that correlation coefficient between yield and rainfall in June varied from $r$ = –0.224 (Arta) up to $r$ = –0.373 (Stmara) and between yield and rainfall in July from $r$ = 0.284 (Selma) up to $r$ = 0.512 (Stendes Liva). Validity of these mentioned correlation coefficients is below 95% in most cases because of the comparatively small number of observations ($\eta_{year}$ = 17, $r_{0.05}$ = 0.460). Nevertheless, the observed tendency shows the role of rainfall in specific period when oat yield is formed.

Analyzing correlations between husk content in grain yield and meteorological conditions in the vegetation period, highly close relationships were established between husk content in yield and mean daily temperature in May (correlation coefficients $r$ = 0.330 < $r_{0.05}$ = 0.460; $P$ < 0.18). Rainfall above the long-term averages in June significantly increased amount of husk in the grain yield of late-maturing oat variety Stendes Liva ($r$ = 0.530 > $r_{0.05}$ = 0.460). Less amount of husk in oat yield was observed in years when rainfall in July was higher than normal ($r$ = –0.311 < $r_{0.05}$ = 0.460; $P$ < 0.23). Estimation of each oat variety separately also showed similar relationships between husk amount in yield and rainfall in July: correlation coefficients varied from $r$ = –0.286 (Arta) up to $r$ = –0.351 (Laima). In the reporting period of the research, amount of precipitation in June showed the greatest deviations from the long-term averages. Increased amount of precipitation in June affected mainly crude protein content in oat grain ($r$ = –0.396 < $r_{0.05}$ = 0.460; $P$ < 0.12).

Analyzed relationships between oat grain yield, its quality characterizing indices and meteorological conditions characterizing indices show, that in the Northwest region of Latvia where the State Stende Cereals Breeding Institute is situated, the grain yield and quality of oats are influenced mainly by the amount of precipitation in definite months of the vegetation period.

## CONCLUSIONS

In variety testing trials conducted from 1993 till 2009, oat productivity was a trait, which varied the most – the averages varied between years from 3.56 to 6.62 t $ha^{-1}$. The most stable yields in the reporting period were provided by the oat varieties Stmara and Laima (average yields respectively 5.35 ± 0.89 and 5.83 ± 1.07 t $ha^{-1}$, coefficient of variation respectively 14.9 and 17.0%).

Out of the analyzed meteorological indices, amount of monthly precipitation varied most significantly (coefficient of variation for this trait variability between years was from 43.1% in June till 55.3% in April). The mean temperature, compared to long-term averages, varied most significantly in April (coefficient of variation 26.4%).

Medium close correlative relationship was established between oat grain volume weight and mean daily temperature in May ($r$ = –0.600> $r_{0.005}$ = 0.460), as well as between oat grain volume weight and amount of precipitation in May, July and August (correlation coefficients respectively $r$ = –0.468, 0.464 and 0.549).

Out of the analyzed indices characterizing meteorological conditions, productivity of oats was influenced mainly by the increased amount of precipitation in July, the content of crude protein in grain – by the increased amount of precipitation in June, husk content in the yield – by the mean daily temperature in May (significant at P < 0.23).

ACKNOWLEDGEMENTS. This study was performed by financial support of the Latvian State Research Program in Agro-biotechnology, and the European Social Fund co-financed the Project 2009/0218/1DP/ 1.1.1.2.0/09/ APIA/VIAA/099.

## REFERENCES

Central Statistics board. Available on the Internet:
http://data.csb.gov.lv/Dialog/varval.asp?ma=013_graudi_LV&ti=LSS13.+Graudaugu+s%E7jumu+plat%EEbas+re%ECionos+(t%FBkst.+ha)+++&path=../DATABASE/lauks/Ikgad%E7jie%20statistikas%20dati/Lauksaimniec%EEbas%20strukt%FBra/&lang=16 (March, 12. 2010)

Hellwell, K., Stuthman, D., Merkhart, F. & Erwin, J. 1996. Day and night temperature effects during grain-filling in oat. *Crop Science* **36**, 624–628.

Karing, P., Kallis, A. & Tooming, H. 1999. Adaptation princles of agriculture to climate change. *Climate research* **12**, 175–183.

Klavins, M., Blumberga, D. & Bruniniece, I. 2008. The climate variability and global warming. LU Academing Publishing, 176. p. (in Latvian).

Peltonen-Sainio, P., Muurinen, S., Rajala, A.,& Jauhiainen, L. 2008. Variation on harvest index of modern spring barley, oat und wheat ander northern condition. *The Journal of Agricultural Science* **146**, 35–47.

Welch, R.W. 1995. The oat crop: production and utilization. Chapman & Hall, London, p. 584.