Geophysical Research Abstracts,
Vol. 11, EGU2009-1395, 2009
EGU General Assembly 2009

CLIMATE CHANGE: NATURAL WATER AND FERTILIZATION EFFECTS ON WINTER RYE (Secale cereale L.) YIELD IN MONOCULTURE

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Abstract: Interaction of rainfall on crop fertilization factors, such as macronutrients and yield, were studied during a long-term field experiment on a calcareous sandy soil with a low humus content in north Hungary at Örbottyán Experimental Station of RISSAC-HAS from 1961 to 2004. When the experiment was commenced (1959) the plowed portion of experimental soil (top soil) had a pH (H2O) 7.5-7.8, pH(KCl) 6.9-7.1, humus content of 0.6-1.0%, clay content about 5%, CaCO3 content 3-7%, AL (ammonium-lactate) soluble P2O5 content 40-60 mg . kg-1 and AL soluble K2O content 50-100 mg . kg-1. The experiment consisted of ten treatments in five replications, giving a total of 50 plots arranged in a Latin square design. The gross plot size was 35 m2. From the 1st to the 25th year the fertilization rates were 0, 50, 100 kg . ha-1 . year-1 nitrogen, 0, 54 kg . ha-1 . year-1 P2O5 and 0, 80 kg . ha-1 . year-1 K2O and their combinations. From the 26th year onwards these rates were 0, 120 kg . ha-1 . year-1 nitrogen, 0, 60, 120 kg . ha-1 . year-1 P2O5 and 0, 60, 120 kg . ha-1 . year-1 K2O. The major results were as follows:

i., In average years the yield in the control plots stabilised at around 0.8 t . ha-1. The yield doubled (1.8-1.9 t . ha-1) in the N, NP and NK treatments, while the full NPK doses gave the maximum yield of 2.1 t . ha-1.

ii., In dry years yields of 0.7 t . ha-1 could be harvested in the control plots. These was a yield reduction of 13% compared with the many years' mean. Yield depressions of 33, 16, 21 and 20% were caused by drought in the N, NP, NK and NPK treatments.

iii., In wet years the yield was little more than 0.5 t . ha-1 (0.6 t . ha-1) in the control plots, representing a yield loss of 25% compared with average years. The N, NP, NK and NPK treatments led to yield depressions of 28, 26, 26 and 26%. Rye grown in a monoculture has approx. 5% less tolerance of wet years than of drought.

iv., Depending on the nutrient supplies, significant quadratic correlations were observed between the rainfall quantity and the yield (0: R=0.7489***, N: R=0.8974***, NP: R=0.8020***, NK: R=0.7370***, NPK: R=0.9047***, mean R2=0.8180; 66.9%) during the vegetation period.

v., The increase in grain yield per mm rainfall ranged from 3.0 to 6.4 kg . ha-1 in the case of optimum rainfall supplies, while the quantity of rainfall during the vegetation period required for the production of 1 kg air-dry yield ranged from 1529 to 3360 liters in the case of maximum yield.

vi., Based on the meteorological database for the 44 years of the long-term experiment (1961-2004) the frequency of years in which the rainfall was optimum for various levels of nutrient supply was as follows: control: 2%, N: 7%, NP: 7%, NK: 9%, NPK: 7%, giving an average of 6% over the treatments. This suggests that the occurrence of optimum rainfall supplies and the possibility of achieving optimum yields in a rye monoculture will be decline in the future.

vii., The yield average of rye grown in a monoculture on calcareous sandy soil (Őrbottyán) was 86% less than that achieved in a biculture on acidic sandy soil (Nyírlugos) under the similar fertilization and rainfall conditions.

viii., The results show rye production is totally (66.9%) dependent on rainfall and fertilization changes.

Key words: rye, monoculture, rainfall, artificial fertilization, yield

Introduction: Climate change is recognized as a serious environmental issue (Easterling et al., 1999; Johnston, 2000; Harnos, 2005). It has repeatedly affected much or all of the earth (Láng, 2005). Available evidence suggests that such changes are not only possible but likely in the future, potentially with large impacts on ecosystems and societies (Barrow et al., 2000; NRC, 2002; Hulme et al., 2002; Rajendra, 2004; Márton, 2004; 2005ab). During the 20th Century green house gases, especially CO2, in the atmosphere increased markedly (Szász, 2005). Nearly concurrently with this, relative global temperatures of the 19th Century increased 0.6 0C (Hulme et al., 2002; Láng et al., 2004; Jolánkai, 2005; Várallyay, 2005).

In the coming decades, global plant production faces the prospect of a changing climate and environment, too the known challenge of continuing to feed the world's population, predicted to double its present level of six billion by about the year 2050. The prospective climate change is global warming with associated changes in hydrological regimes and other climatic variables induced by the increasing concentration of radiatively active greenhouse gases. Climate change could have far-reaching effects on patterns of trade among nations, development, and food security (Rosenzweig et al., 1993). These changes (largely caused by human activities) are likely to affect crop yields differently form region to region across the globe (Márton, 2004., 2005ab., Seth & Jeffrey 2005). Significant issue that becomes apparent from even a cursory summary of existing knowledge is that from the crop's perspective the important point is the net effect of all the environmental changes that occur, or might occur, at any given place and time.

Today, plenty of agricultural investigations focused on understanding the relation between mean climate change and crop production (Várallyay, 1992; Rajendra, 2004; JolánkaI, 2005). Few investigations, however, studied the effects of climate variability on agriculture crop yields (Németh, 2004). The response of agricultural crop yield to changes in climate variability were attributed primrily to changes in the frequency of extreme climatic events (EU, 2003). Recent studies demonstrated a greater effect on the frequency of extreme climatic events than changes in the mean climatic response (EM, 2004). Hence, in studying the effects of climatic change on crop production, the changes in the climatic variability and associated weather patterns should be included (Barrow et al., 2000).

Changes in weather patterns were observed thoughout Europe (including Hungary) as early as 1850. Among the natural consequences of changing weather patterns, years of drought (rainfall deficit) and wet (rainfall excess) conditions, resulted in problems among plant nutrition and field crop production (EU, 2003). Whereas rye (Secale cereale L.) is a crop of worldwide importance, limited research exists about the effects of climate change on these crop (Kádár et al., 1984; Kádár, 2005; Márton, 2002). These crop has sensitive reactions to the prevailing weather conditions (such as rainfall) and, for this reason, understanding the effects of anthropogenic climate change on it's production has a great importance. In addition to rainfall, the crop require an optimal level of soil macronutrients: nitrogen, phosphorus and potassium (Várallyay, 1939; Kádár, 1992; Kárár et al., 1982; Kádár et al., 1984; Kádár & Szemes, 1994).

Most environmental research focuses on only one, or a very few changes instead of the concomitant multiple changes occurring in our world. Unfortunately, however, the bulk of past research has focused on one factor at a time. As a result for example, much is known about the effects of a change in a geochemical element (macro, meso, micro or trace) loading on yield of some crops, but much less is known about the effects of a change in a geochemical element in combination with a change in rainfall quantity and distribution on the yield of those same crops. It is obviously the effects of all the environmental changes occurring, rather than just a geochemical element (or just other geochemical elements, or just raifall quantity and distribution, etc.), that is of importance to any crop. Although much of this paper focuses on single factors (rainfall quantity, rainfall distribution, N-, P-, K-fertilization), it was our intent to emphasize that the net effect of multiple environmental changes on rye is far more important than the effect of a single factor on that crop.

So, we show interaction findings related to rainfall quantity, rainfall distribution changes and N, P, K fertilization effects on rye yield formation on a calcareous sandy soil with a low humus content in an ecologically fragile experimental site at Örbottyán in Hungary from 1961 to 2004 for 44 years.

Materials and Methods: The effect of rainfall (quantity and distribution) on crop fertilization factors, such as macronutrients and yield, were studied during a long-term (1961 to 2004) field experiment on a calcareous sandy soil with a low humus content in north Hungary at Örbottyán Experimental Station of RISSAC-HAS. When the experiment was commenced (1959; in LÁNG, 1973) the plowed portion of experimental soil (top soil) had a pH (H2O) 7.5-7.8, pH(KCl) 6.9-7.1, humus content of 0.6-1.0%, clay content about 5%, CaCO3 content 3-7%, AL (ammonium-lactate) soluble P2O5 content 40-60 mg . kg-1 and AL soluble K2O content 50-100 mg . kg-1. The experiment consisted of ten treatments in five replications, giving a total of 50 plots arranged in a Latin square design. The gross plot size was 35 m2. From the 1st to the 25th year the fertilization rates were 0, 50, 100 kg . ha-1 . year-1 nitrogen, 0, 54 kg . ha-1 . year-1 P2O5 and 0, 80 kg . ha-1 . year-1 K2O and their combinations. From the 26th year onwards these rates were 0, 120 kg . ha-1 . year-1 nitrogen, 0, 60, 120 kg . ha-1 . year-1 P2O5 and 0, 60, 120 kg . ha-1 . year-1 K2O and their combinations in the form of 25 % calcium ammonium nitrate, 18 % superphosphate, 40 % potassium chloride. The groundwater table was at a depth of 2-3 m below the surface. Rainfall amounts, deviation in rainfall from the average over many years (dry year -10 - -20%, drought year -20% over, wet year +10 - +20%, year with excess rainfall +20% over) and other related data were determined based on traditional Hungarian (Harnos, 1993) and Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences (Márton, 2004) standards, and MANOVA (Multivariate Analysis of Variance) by SPSS test (SPSS Inc., 1988).

Results and Discussion: In average years the yield in the control plots stabilised at around 0.8 t . ha-1 (Table 5). The yield doubled (1.8-1.9 t . ha-1) in the N, NP and NK treatments, while the full NPK doses gave the maximum yield of 2.1 t . ha-1. In dry years yields of 0.7 t . ha-1 could be harvested in the control plots. These was a yield reduction of 13% compared with the many years' mean. Yield depressions of 33, 16, 21 and 20% were caused by drought in the N, NP, NK and NPK treatments. In wet years the yield was little more than 0.5 t . ha-1 (0.6 t . ha-1) in the control plots, representing a yield loss of 25% compared with average years. The N, NP, NK and NPK treatments led to yield depressions of 28, 26, 26 and 26%. Rye grown in a monoculture has approx. 5% less tolerance of wet years than of drought. Depending on the nutrient supplies, significant quadratic correlations were observed between the rainfall quantity and the yield (0: R=0.7489***, N: R=0.8974***, NP: R=0.8020***, NK: R=0.7370***, NPK: R=0.9047***, mean R2=0.8180; 66.9%) during the vegetation period (Figure 1). The increase in grain yield per mm rainfall ranged from 3.0 to 6.4 kg . ha-1 in the case of optimum rainfall supplies, while the quantity of rainfall during the vegetation period required for the production of 1 kg air-dry yield ranged from 1529 to 3360 liters in the case of maximum yield. Based on the meteorological database for the 44 years of the long-term experiment (1961-2004) the frequency of years in which the rainfall was optimum for various levels of nutrient supply was as follows: control: 2%, N: 7%, NP: 7%, NK: 9%, NPK: 7%, giving an average of 6% over the treatments. This suggests that the occurrence of optimum rainfall supplies and the possibility of achieving optimum yields in a rye monoculture will be decline in the future. The yield average of rye grown in a monoculture on calcareous sandy soil (Őrbottyán) was 86% less than that achieved in a biculture on acidic sandy soil (Nyírlugos) under the similar fertilization and rainfall conditions. These results show rye production is totally (66.9%) dependent on rainfall and fertilization changes.

Acknowledgement: We are grateful to Hungarian Academy of Sciences who supplied experiment, data and Internet URLs, as well as helping on other ways with this paper. Most of all, I would like to thank National Office for Research and Technology, Hungary and Hungarian Science and Technology Foundation, Hungary (Project No.: OMFB-00112/2005-E-2/04) for their support during the course of this research and my presentation.

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