



ENVIRONMENTAL CHANGE: PRECIPITATION AND N, P, K, Mg FERTILIZATION INFLUENCES ON CROP YIELD UNDER TEMPERATE CLIMATE CONDITIONS

DD. M. László PhD

RISSAC-HAS, Agrochemistry, Budapest, Hungary (marton@rissac.hu, +36 1 3558491)

Summary: Agroecological quality has a well established dependence on climate-rainfall changes because the water problems are pressing. Therefore, there is, growing concern about the potentially wide ranging risks that climate change would have on these key industries as the nature and extent of anticipated changes have become more evident. It also includes changes in land use and in plant production and their management. These changes are unprecedented in terms of both their rate and their spatial extent. Changes in land use (agrotechnics, soil, cultivation, fertility, quality, protection etc.) and in plant production (plant, nutrition, rotation, protection etc.) are currently the main manifestations. As an interdisciplinary problem it is necessary to study such a complex matter in terms of agricultural production. Generally, among natural catastrophes, droughts and floods cause the greatest problems in field crop production. The droughts and the floods that were experienced in Hungary in the early 1980s have drawn renewed attention to the analyses of these problems. New research on climate change-soil-plant systems are focused on yield and yield quality. This paper reports of the climate changes (rainfall); soil (acidic sandy brown forest) properties, mineral N, P, K, Mg fertilisation level and plant interactions on rye (*Secale cereale* L.), on potato (*Solanum tuberosum* L.) and on winter wheat (*Triticum aestivum* L.) yields in a long term field experiment set up at Nyírlugos in north-eastern Hungary under temperate climate conditions in 1962. Results are summarised from 1962 to 1990. Main conclusions were as follows: 1. Rye: a, Experimental years were characterised by frequent extremes of precipitation variabilities and changes. b, By an average year, at a satisfactory fertilisation level (N: 90 kg ha⁻¹ and NP, NK, NPK, NPKMg combinations) the maximum yield reached 3.8 t ha⁻¹. But yield was decreased by 17% and by 52% due to drought and excess rainfall, respectively. Negative effects (drought, excess rainfall) were diminished by 20-25% with Mg treatments. c, Correlation between rye yields and precipitation during vegetation seasons showed that optimum yield (4.0 t ha⁻¹) develops in the 430-470 mm range. 2. Potato: a, Trial years were estimated by recurrent extremes of climate. b, In vegetation seasons poor in rainfall yield safety in potato cannot be secured by fertilisation (N, NP, NK, NPK, NPKMg) alone. Under this weather condition yield was decreased by 35%. c, Optimum yields range between 17-21 t ha⁻¹ at 280-350 mm. 3. Winter wheat: a, Climate was manifested mainly by precipitation using average, drought, dry and rainy levels. b, Yields from drought year effects with N, NP and NK combinations were diminished to 48% and with NPK and NPKMg treatments fell to 51%. c, Optimum yields (3.5-4.0 t ha⁻¹) were developed at 450-500 mm. This paper summarises quantified results of rye, potato and winter wheat research with regarding to interaction effects and relationships between climate (rainfall)-mineral nutrition-crop production changes in Hungary during a long term field experiment to agricultural sustainability.

Key words: ecology, rainfall, crop, fertilization, yield

Introduction: "Climate Change" are recognized as a serious environmental issues [1]. Presently the build up of greenhouse gases in the atmosphere and the inertia in trends in emissions means that we can expect significant changes for at least the next few decades and probably for the whole 21th century too [2]. It would badly need to understand what might be involved in adapting to the new climates. A decade ago, researchers asked the „what if” question. For example, what will be the impact if climate changes. Now, we must increasingly address the following question: how do we respond effectively to prevent damaging impacts and take advantage of new climatic opportunities [3]. This question requires detailed information regarding expected impacts

and effective adaptive measures. Information on adaptation is required for governments, landscape planners, stakeholders, farmers, producers, processors, supermarkets and consumers. Not only the local effects and options, but also the spatial implications must be understood. Will yields be maintained on the present range of farms. Where will new crops be grown. Will new processing plants be required. Will there be competition for water. Most recent agricultural impact studies have concentrated on the effects of mean changes in climate on crop production, whilst only limited investigations into the effects of climate variability on agriculture have been undertaken. The paucity of studies in this area is not least due to the considerable uncertainty regarding how climate variability may change in the future in response to greenhouse gas induced warming but also as a result of the uncertainty in the response of agricultural crops to changes in climate variability, effected most probably through changes in the frequency of extreme climatic events. That changes showed in variance have a greater effect on the frequency of extreme climatic events than do changes in the mean values. Hence, it is important to attempt to include changes in variability in scenarios of climate change. Weather change in Hungary was started about of 1850. Among the natural catastrophes, drought and flooding caused by over-abundant rainfall cause the greatest problem in plant nutrition and in field crop production nowadays too [4]. It is why we found it necessary to revise and to analyse this problem. Rye (*Secale cereale L.*), potato (*Solanum tuberosum L.*) and winter wheat (*Triticum aestivum L.*) are most important crops of many World countries [5] but little research in the field of climate change impact assessment has been undertaken. All three plant are sensitive to the prevailing weather conditions (rainfall) and, hence, it is important to evaluate the effects of anthropogenic climate change on their production. These crops are demanding indicator of soil nutrient status also. Have a particularly high requirement for supply of soil nitrogen, phosphorus, potassium and magnesium. From 1962 to 1990 this paper describes climate-rainfall-change and N, P, K and Mg-mineral fertilisation effects on rye, potato and winter wheat yield on a acidic sandy brown forest soil at long term experiment scale under temperate climate conditions at Hungary.

Material and Method: The effect of rainfall quantity and distribution on certain crop fertilisation factors (N, P, K, Mg and yield) were studied in a long-term field experiment on acidic sandy brown forest soil at North-Eastern Hungary set up in 1962 and 2002. Ploughed layer of the experiment soil had a pH(KCl) 4.5, humus 0.5%, CEC 5-10 mgeq 100 g⁻¹. The topsoil was poor in all four macronutrients N, P, K and Mg. Rye, potato and winter wheat experiments involved 2x2x16x8 = 512, 2x2x16x8 = 512 and 2x16x4 = 128 plots. The gross and net plot size was 10x5 = 50 m² and 35.5 m². The experimental design was split-split-plot. Average treatments were rye N:45 kg, P₂O₅:24, K₂O:40, MgO:7.5 kg ha⁻¹ year⁻¹, potato N:75 kg, P₂O₅:24, K₂O:75, MgO:15 kg ha⁻¹ year⁻¹, winter wheat N:45 kg, P₂O₅:24, K₂O:40, MgO:7.5 kg ha⁻¹ year⁻¹ from 1962 to 1980 and N:75 kg, P₂O₅:90, K₂O:90, MgO:140 kg ha⁻¹ year⁻¹ from 1981 to 1990 in the form of 25% calcium ammonium nitrate, 18% superphosphate, 40% potassium chloride, and magnesium sulphate. The groundwater table was at a depth of 2-3 m. Ecological (rainfall) and experimental data bases were estimated by Hungarian traditional [6] and RISSAC-HAS [3] standards and MANOVA (SPSS).

Results: Climate-rainfall-change and mineral fertilisation effects on rye yield

- a. Experimental years were characterised by frequent extremes of precipitation variabilities and changes. One year had an 450 mm average rainfall (1966), one year had a more humid (1970) and three years had a very dry (1964, 1968, 1972) character.
- b. Weather anomalies as drought or to much rainfall did not cause significant differences on rye yield without fertilisation (average year: 1.66 t ha⁻¹, drought year: 1.51 t ha⁻¹, over rainfall year: 1.47 t ha⁻¹).
- c. Yields varied from 2.01 to 3.04 t ha⁻¹ under low (N: 30 kg ha⁻¹ and NP, NK, NPK, NPKMg combinations) fertilisation input. Yields were decreased by 14% and 10% by drought and also by excess of rainfall.
- d. At mean fertilisation (N: 60 kg ha⁻¹ and NP, NK, NPK, NPKMg combinations) level the maximum yield had reached 3.6 t ha⁻¹ in average year. In years with excess rainfall, rye yields decreased as an average of fertilisation treatments by 20%.
- e. By an average year, at satisfactory fertilisation (N: 90 kg ha⁻¹ and NP, NK, NPK, NPKMg combinations) level the maximum yield reached 3.8 t ha⁻¹. But these yields were decreased with 17% and with 52% by drought and excess rainfall weather conditions respects. Negative effects (drought, excess rainfall) were diminished with 20-25% on the Mg treatments.
- f. Correlations between rye yields and the sums of precipitations during vegetation period (control: R = 0.99***, N: R = 0.84***, NP: R = 0.84***, NK: R = 0.91***, NPK: R = 0.85***, NPKMg: R = 0.65**) showed that

optimum yields will develop in 430-470 mm range. Under and above these range of rainfall yields will decrease.

Climate-rainfall-change and mineral fertilisation effects on potato yield

- a. Trial years (1963, 1965, 1967, 1969, 1971) were characterised by recurrent extremes of climate under vegetation seasons of potato. Three period had average rainfall, while two were very dry.
- b. All in all, droughts in the winter or summer half-year had much the same effect on yields. Precipitation deficiency in the winter could not be counterbalanced by average rainfall during the vegetation period, and its effect on the yield was similar to that of summer drought.
- c. Yield and quality were influenced by rainfall to a greater extent than by fertilisation.
- d. In vegetation periods poor in rainfall yield and quality safety in potato cannot be secured by fertilisation alone, they were decreased to 35%. It was also concluded that economic yields could not be achieved with poor nutrient supply even with a normal quantity and distribution of rainfall.
- e. The unfavorable effects of climate anomalies (drought, over-abundance of water in the topsoil) on the yield formation, yield quantity and quality of potato depended decisively on the time of year when they were experienced and the period for which they lasted.
- f. With the help of regression analysis it was found the polynomial correlation between rainfall and yield could be observed in case of the control: $R = 0.98^{***}$, N: $R = 0.95^{***}$, NP: $R = 0.96^{***}$, NK: $R = 0.95^{***}$, NPK: $R = 0.98^{***}$, NPKMg: $R = 0.96^{***}$ nutrition systems. The optimum yield ranges between 17-20 t ha⁻¹ at 280-350 mm of rainfall.

Climate-rainfall-change and mineral fertilisation effects on winter wheat yield

- a. Climate-rainfall-conditions of winter wheat years were determined by mainly precipitation on-, average (1982 and 1989)-, drought (1976 and 1990)-, dry (1974) and rainy (1978 and 1980) level.
- b. Experimental years climate-rainfall-character were formed by winter half-years (october-march), months (october-september), pre-months of sowing (august), critical sequential month number in vegetation seasons (september-july) and critical sequential month number in experimental years (september-august).
- c. In average years without any mineral fertilisation wheat yield was stabilized on the level of 1.8 t ha⁻¹. Under N, P, K and Mg fertiliser input minimum and maximum yields were 2.7 and 4.1 t ha⁻¹. Yield was only increased by whole NPK and Mg completed NPKMg treatment.
- d. Without mineral fertilisation on control plots yield was decreased by drought year effect compared with average with a 39%. On N, NP and NK combinations yields were diminished to 48%. Drought damage on yield production was rised more to 51% by NPK and NPKMg application.
- e. But in dry years and in average years yields were similar on control plots. Yields were decreased for average year effect on N, NP, NK and NPK, NPKMg treatments with 20% and with 16%.
- f. Under excess rainy weather conditions without fertiliser application yields were decreased more dramatically (56%) than under drought seasons (39%) to case of average rainfall effects. Yield was damaged with a 47% by unfavourable (N, NP, NK) nutrition. But this negative effect of excess rainfall condition was diminished on NPK and NPKMg treatments to 41%.
- g. Correlations of regression analysis between yields and the sums of precipitations during vegetation seasons (control: $R = 0.59^{***}$, N: $R = 0.57^{***}$, NP: $R = 0.76^{***}$, NK: $R = 0.53^{**}$, NPK: $R = 0.67^{***}$, NPKMg $R = 0.70^{**}$) showed that optimum yields will develop in 450-500 mm range. Above these range of rainfall yields will decrease swiftly.

This paper gives opportunities summarise quantified results of rye-potato-winter wheat researches with regarding to interaction effects and relationships between climate (rainfall)-mineral nutrition-crop production changes at Hungary in a long term field experiment system under temperate climate conditions to agricultural sustainability.

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References

- [1] Johnston A.E.: Some aspects of nitrogen use efficiency in arable agriculture. K. Scogs-o. Lantbr. Akad. Tidskr. 2000, 8, 139.
- [2] Márton L.: Climate change and N, P, K, Mg fertilization effect analysis at Tisza-river basin in a long term field

experiment. Szent István University, Gödöllő 2001, 9.

[3] Márton L.: Climate change, N-fertilisation effect on rye (*Secale cereale* L.) yield in a long term field experiment. [in:] Rural development-Ecologically farming-Agriculture, (Eds M Palkovics), University Veszprém, Keszthely 2001, 924-929.

[4] José A.B., Estáquio M.J. and Márton L.: Results of *Crotalaria* ssp. effects on soil conservation. Congress on Conservation Agriculture (Eds Armando MV), ECAF., Madrid, 2001. 5, 1-4.

[5] Kádár I., Márton L. and Horváth S.: Mineral fertilisation of potato (*Solanum tuberosum* L.) on calcareous chernozem soil. Plant Production, 2000, 49, 291-306.

[6] Harnos, Zs.: Időjárás és időjárás-termés összefüggéseinak idősoros elemzése, [in:] Aszály 1983 (Szerk.: Baráth Cs-né, Győrffy B., Harnos Zs.). KÉE. Budapest 1993.

[7] Márton L.: Climate-Rainfall Change (CRC) and mineral fertilisation (MF) effects on different crop production. [in:] Challenges of the new millennium our joint responsibility. (Eds A. Borhidi). MTA ÖBKI, Budapest 2002, 1, 110-111.

[8] Márton L.: Rainfall, mineral fertilisation and winter wheat (*Triticum aestivum* L.) yield relations. Plant Production, 2002, 51, 529-542.