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Review Article

Natural Rain, NPKCaMg-Fertilization Crop Yield Models

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Abstract

The (man made) effects of global climate change on water resources may be masked by natural climate variability, today. With a warming climate, drought and excess rainfall conditions could become more frequent, severe, and longer-lasting. It is well known the effect of fertilizer applications on crop production, but long-term changes in precipitation and plant yield are not well documented. For these reasons, long-term studies were conducted to determine the effect of precipitation and fertilization (NPKCaMg) on crop yield changes in a long-term field experiment set up in Nyírlugos (Nyírség region, Hungary: N: 47º 41' 60'' and E: 22º 2' 80'') on a Haplic Luvisol with popular rotation crops as rye-potato- winter wheat and triticale. Over the 50 year period from 1961 to 2010, averaged rainfall quantities of over many years; of experimental years; of over many years's and experimental's years phonological phases were significantly ($P<0.001$) for rye: 567 mm, 497 mm, 509 mm and 452 mm; for potato 551 mm, 537 mm, 337 mm and 294 mm; for winter wheat 586 mm, 509 mm, 518 mm and 467 mm; for triticale 551 mm, 537 mm, 489 mm and 497 mm respectively. Rainfall deviations (+/-) from the averaged over many years's in the experimental years and during the phenological phases significantly ($P<0.001$) had been having of rye -12% and -11%; potato -3% and -13%; winter wheat -13% and -10%; triticale -3% and 2%. During the vegetation period, the relationships between rainfall quantity, nutrition (N, P, K, Ca, Mg), and yield were characterized by polynomial correlations significantly ($P < 0.001$) "R" of rye: 0.65-0.99, of potato: 0.95-0.98, of winter wheat: 0.54-0.76, triticale: 0.28-0.67. Maximum yields for rye: 4.0 t. ha-1, potato: 21.0 t. ha-1, winter wheat: 3.4 t. ha-1, and triticale: 5.5 t. ha-1 were observed when the respective natural rainfall amount was in the range of 430-500, 280-330, 449-495 and 550-600 mm. At rainfall amounts above and below these ranges, there had a corresponding dramatic reduction in the yield. In case this trend - variable precipitation caused by climate change reduces crops yield on arable fields - will continue and is aggravated by warming temperatures and a more altering climate (as predicted by climate change forecasts), the livelihoods of many Hungarian and European farmers may be substantially altered. Thus, farmers must take into consideration the climate (WHY and SHY precipitation), fertilization (NPKCaMg), and cropping (tuber–seed–tobacco–protein–oil–forage) changeability to optimize their yield via soil sustainability and crop management in the nearest future.

Keywords: Precipitation; NPKCaMg-Fertilization; Plant Yield Models

Introduction

Climate change is recognized as a serious environmental issue [1-4]. The present increase of greenhouse gases (GHG) such as carbon dioxide, methane, water vapor, ozone, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons, perfluorocarbons and chlorofluorocarbons in the atmosphere probably will lead to significant climate changes in the 21th century [5-9]. A recent consensus has emerged that among the GHG, the increase of atmospheric CO_2 concentrations is of greatest concern [10,11]. Decades ago, researchers asked what effects climate change may have on the ecology [12-18]. Today, researchers are asking how to respond to, and take advantage of, the effects of climate change [10,11]. It has been discussed on a large scale in different studies. Most researchers believe that higher temperature, drought and rainfall excess caused by climate change will depress crop yields in many places in the coming decades [4,7,19,20]. On the other side, according to UK's scientist at the leading plant science center (Biotechnology and Biological Sciences Research Council; BBSRC) have uncovered a gene that could help to develop new varieties of crop that will be able to cope with the changing world climate. Answers to the above new question require information regarding the anticipated effects and associated adaptive measures required at local and regional scales. Important information should be gathered on whether yields can be maintained, if and where new crops should be grown, if new processing plants will be required, and degree of competition for water [7,8,11]. Information on methods of adaptation is required for government officials, landscape planners, stakeholders, farmers, producers, processors, supermarkets, and consumers [7,21].

In the last decades many agricultural investigations focused on understanding the relation between mean climate change and crop production [6,22-24]. Few investigations, however, studied the effects of climate variability on agriculture crop yields [21,25-28]. The response of agricultural crop yield to changes in climate variability were attributed primarily to changes in the frequency of extreme climatic events [29].

Recent studies demonstrated a greater effect of the climatic frequency on yield than the changes in the mean climatic response [30]. Hence, in studying the effects of climatic change on crop production, the changes in the climatic variability and associated weather patterns should be included [5]. Changes in weather patterns were observed throughout 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 [29]. Whereas rye (*Secale cereale* L.), potato (*Solanum tuberosum* L.), winter wheat (*Triticum aestivum* L.), and triticale are crops of worldwide importance, limited research exists about the effects of climate change on these crops. All four crops are sensitive to the prevailing weather conditions such as rainfall. For this reason, understanding the effects of anthropogenic climate change on their production is important. In addition to rainfall, these crops require a high level of the soil macronutrients nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg).

Most environmental research focus on only one, or very few changes instead of the concomitant multiple changes occurring in our world [31]. As a result, for example, much is known about the effects of a shift in a geochemical element (macro, meso, micro or trace) loading on yield of some crops, but much less information is available about the multifactorial shift of a change in a geochemical element in combination with a change in rainfall quantity and distribution on the yield of those same crops. Obviously, the effects of all the environmental changes, rather than just one factor like a geochemical element or just only rainfall is important for any crop production [4]. Therefore, we focused our study on the effects of multiple environmental changes on plants. The main objective was to study and to clarify the precipitation amount and distribution and the nitrogen (N)-, phosphorus (P_2O_5)-, potassium (K_2O)-, calcium (CaO)-, and magnesium (MgO) fertilization interaction effects.

Materials and Methods

The net-influence of rainfall (quantity, distribution) and mineral fertilization (N, P_2O_5, K_2O, CaO, MgO) had had studied in a long term field experiment established at the Institute for Soil Sciences and Agricultural Chemistry Centre for Agricultural Research, Hungarian Academy of Sciences Experiment Station (ISSAC-CAR-HAS ET) in Hungary on a Haplic Luvisol (sandy acidic lessivated brown forest soil) with different indicator crops [rye (*Secale cereale* L.), potato (*Solanum tuberosum* L.), winter wheat (*Triticum aestivum* L.), triticale (X Triticosecale W.)] under fragile agro-ecological circumstances at Nyírlugos for 40 years from 1962 to 2001. The ISSAC-CAR-HAS's Experiment Station Nyírlugos between Debrecen and Nyíregyháza is to be implemented in the so-called "Northern Great Plain Region" that is located in the Eastern-North-Eastern part of Hungary. The actual project location within the region is in its easternmost part (N: 470 41' 60'' and E: 220 2' 80'') in the Eastern-Nyírség region. This area is a typical lowland field. Very poor in mineral resources and its other endowments are not very favorable, either. There are no big differences in elevation within the region but the climate is rather variable. The local climate is somewhat dryer in the summer and a bit warmer in the winter than in the surrounding Hungarian Great Plain. The total number of sunny hours is 1900-2000 per year and the annual mean temperature is 10-12^{0}C. The area is very windy (SW and NE). It is one of the driest parts of Hungary with only 520-550 mm of precipitation a year. The distribution of precipitation is rather uneven and unpredictable. This is one of the major constraints why plant production is less successful. The main experiment's soil agrochemical characteristics in the plowed (0-25 cm) layer are presented in table 1. at the experimental set up at autumn of 1962.

From 1962 to 1980 the experiment consisted of 2 x 16 x 4 x 4 = 512 plots and from 1980 to 2001 of 32 x 4 = 128 plots in split-split-plot and factorial random block designs. The gross plot size was 10 x 5 = 50 m^2. The experimental treatments and combinations are shown in table 2. The fertilizers were applied in the form of 25% calcium ammonium nitrate, 18% superphosphate, 40% potassium chloride, calcium carbonate and magnesium sulphate. The groundwater table was at a depth of 2-3 m below the surface. The plant samples were taken by manually. Precipitation was measured by BES-01 collector (collects the precipitation on a standard 200 cm^2 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 [14] and Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences standards, and MANOVA (Multivariate Analysis of Variance) by SPSS test (SPSS Inc., 2000). Results are show on main effects (N, P, K, Ca, Mg, NP, NK, NPK, NPK-Ca, NPKMg, NPKCaMg) averaged level because by these ways can be summarized the principal experimental results from the database of 40 years.

Content	**pH**		**HA***	**hy_1**	**Humus**	**Total**	**AL****
	H_2O	KCl				nitrogen	P_2O_5
			1962				
	5.9	4.7	8.4	0.3			
%					0.7		
mg. kg^{-1}						34	43
			1983				
		4.16					
%					0.35		
mg. kg^{-1}							67
			1988				
		4.40					
%					0.54		
mg. kg^{-1}							59
			1998				
		3.41					
%					0.55		
mg. kg^{-1}							65

Table 1: The experimental main untreated soil agrochemical properties in the plowed (0-25 cm) layer in 1962, 1983, 1988 and 1998 (Haplic Luvisol, Nyírség Region, Nyírlugos).

* Hydrolytic acidity, ** ammonlactate (AL) soluble

From 1962 to 1980, kg. $ha^{-1.}$ yr^{-1}				
Control				
$N_1 = 30$	$P = 48 (P_2O_5)$			
$N_2 = 60$	$K = 80 (K_2O)$			
$N_3 = 90$	$Mg = 15 (MgO)$			
N, P, K, Mg combinations				
Control				
N_1	N_2	N_3		
N_1P	N_2P	N_3P		
N_1K	N_2K	N_3K		
N_1PK	N_2PK	N_3PK		
N_1PKMg	N_2PKMg	N_3PKMg		
From 1980, kg. $ha^{-1.}$ $y^{r-}1$				
Level	N	P_2O_5	K_2O	$CaCO_3$
Control	0	0	0	0
1	50	60	60	250
2	100	120	120	500
3	150	180	180	1000

Table 2: NPKCaMg fertilizer application on a Haplic Luvisol at Nyírlugos, from 1962 to 2001.

Results

Climate-rainfall-change and mineral fertilization effects on rye yield

Certain years were characterized by extremes in rainfall variability, according to Schulze., *et al.* [32]; Kenny., *et al.* [33] and Amissah's [34] assertions. For example, there was one average year with 450 mm of rainfall (1966), one wet year with 721 mm of rainfall (1970), and three dry years with 353, 369, 378 mm of rainfall (1964, 1968, 1972). Rainfall extremes characterized by drought or wet years, similar to Singh., *et al.* [35], Bryant., *et al.* [36], Weber and Grant's [37] and Asbjorn., *et al.* [38] climate change research results did not cause significant differences on the rye yield without fertilization (average year: 1.66 t. ha^{-1}, drought year: 1.51 t. ha^{-1}, over rainy year: 1.47 t. ha^{-1}). Yields varied from 2.01 to 3.04 t. ha^{-1} under low (N: 30 kg. ha^{-1} and NP, NK, NPK, NPKMg combinations) fertilization input. During drought and wet years, the yields decreased by 14% and 10%, respectively. At mean fertilization (N: 60 kg. ha-1 and NP, NK, NPK, NPKMg combinations) levels, the maximum yield reached 3.6 t. ha^{-1} during average rainfall year. In years with excess rainfall the rye yields decreased [39,40] with average fertilization treatments by 20%. During an average rainfall year with typical high fertilization (N: 90 kg. ha-1 and NP, NK, NPK, NPKMg combinations), the maximum yield reached 3.8 t. ha^{-1}; the maximum yields decreased by 17% and 52% during the respective conditions of drought and excess rainfall. The negative effects of excess rainfall conditions, contrarily Singh., *et al.* [35] and Asbjorn., *et al.* [38] decreased by 20-25% with the use of Mg treatments. Polynomial correlations between rye yields and rainfall during the 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) indicated that optimum yields develop in response to rainfall amounts in the 430-470 mm range. Under and above these rainfall ranges (Table 3), the yields decrease [39] alike to a quadratic relation.

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

The trial years (1963, 1965, 1967, 1969, 1971) were characterized by recurrent rainfall extremes [41] during the vegetation seasons for potato. Three periods had average rainfall, while two periods were dry. Droughts in the winter or summer half-year had similar negative effects on the yield, just the opposite of what Singh., *et al.* [35] and Asbjorn., *et al.* [38] declares. Precipitation deficiency in the winter could not be counterbalanced by average rainfall during the vegetation period, and the effect on yield was similar to that of summer drought [42,43]. Yield and quality were influenced by rainfall to a greater extent than by fertilization. In vegetation periods subject to drought conditions, the yield and quality of potato could not be maintained by fertilisation alone, as the yield decreased by 35%, quite the contrary for Asbjorn., *et al.* [38]. Also, economic yields could not be achieved with poor nutrient supply even with a normal quantity and distribution of rainfall [44]. The unfavorable effects of climate anomalies (drought or rainfall excess) on the yield formation, yield quantity, and quality of potato depended on the time of year [41]. Using regression analysis, the correlation between rainfall and yield were determined for the control nutrition system: R = 0.98, N: R = 0.95, NP: R = 0.96, NK: R = 0.95, NPK: R = 0.98, NPKMg: R = 0.96. Optimum yields (Table 3) of 17-20 t. ha^{-1} developed in response to rainfall in the 280-350 mm range.

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

Climate-rainfall-conditions during winter wheat years were determined primarily by precipitation during average (1982 and 1989), drought (1976 and 1990), dry (1974) and wet (1978 and 1980) years. The experimental 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). In average rainfall years without any mineral fertilization, the wheat yield stabilized at the level of 1.8 t. ha^{-1}. With N, P, K and Mg fertiliser input, the minimum and maximum yields were 2.7 and 4.1 t. ha^{-1}. The yield only increased with a whole NPK and Mg completed NPKMg treatment. Without mineral fertilization on the control plots, the yield decreased [39,45,46] by 39% during a drought year compared to average year. On N, NP and NK combinations yields were diminished to 48%. Drought damage on yield production [46] (Ghaffari and Lee, 2002) increased to 51% with NPK and NPKMg applications. In drought and average years, yields were similar on the control plots [36,38]. Yields were decreased for an average year by 20% and 16% with N, NP, NK and NPK, NPKMg treatments. During excess rain conditions and without fertiliser application, the yields crosswise for Asbjorn., *et al.* [38] decreased more dramatically (56%) as compared to drought conditions (39%). The yield was reduced by 47% with unfavorable (N, NP, NK) nutrition. But the negative effect of excess rainfall was diminished on NPK and NPKMg treatments to 41%. Correlations between yield and precipitation during vegetation seasons (control: R = 0.59, N: R = 0.57, NP: R = 0.76, NK: R = 0.54, NPK: R = 0.67, NPKMg: R = 0.71) (Table 3) indicated that optimum yields developed in response to rainfall in the 450-500 mm range. Above or below this rainfall range yields decreased quadratically.

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

During dry and drought conditions, in conformity with Adams., *et al.* [44], Rosenzweig and Tubiello [47] and McMaster [39] the respective yield of the control areas was 14% and 36% less than for average years. The application of N alone, or of NP and NK treatments, led to yield losses of 45% and 24%, respectively, while that of NPK, NPKCa, NPKMg or NPKCaMg caused a further 22% drop during both types of years. In the wet years, the yield decreased by 14% in the unfertilized plots; remained unchanged in the case of N, NP, or NK nutrition; and increased by 31% with NPK, NPKCa, NPKMg and NPKCaMg treatments. In the very wettest year, the yields were similar to those in the average year, reverse of Asbjorn., *et al.* [38]. The relationships between rainfall quantitiy during the vegetation period N, P, K, Ca and Mg nutrition and yield were characterized by polynominal correlations (control: R= 0.35, N: R = 0.28, NP: R = 0.47, NK: R = 0.37, NPK: R = 0.63, NPKCa: R = 0.67, NPKMg: R = 0.67, NPKCaMg: R = 0.62). Maximum yields of 5.0-6.0 t. ha^{-1} were achieved in the rainfall range of 550-600 mm. At values above and below this range (Table 3 and 4), the grain yield reduced quadratically.

However, the total regression coefficients ranged in the case of rye from 0.65 to 0.99, potato: 0.95-0.98, winter wheat: 0.54-0.76, triticale: 0.28-0.67 in depended on the different nutrient application. At values above and below this range, the grain yield reduced quadratically.

Treatmnt	MODEL	n	R
Rye			
Control	$Y'=-8.4661\cdot 10^3+1.1055\cdot 10^4x-3.5731\cdot 10^3x^2$	20	0.99
N	$Y'=-4.9371+0.0346x-0.0003x^2$	20	0.84
NP	$Y'=-6.0990+0.0402x-0.0004x^2$	20	0.84
NK	$Y'=-4.2457+0.0310x-0.0003x^2$	20	0.91
NPK	$Y'=-6.8253+0.0436x-0.0004x^2$	20	0.85
NPKMg	$Y'=-3.5539+0.0288x-0.0002x^2$	20	0.65
Potato			
Control	$Y'= 366.21-2.85x+0.0054x^2$	72	0.98
N	$Y'= 380.18-2.95x+0.0056x^2$	72	0.95
NP	$Y'= 387.19-3.04x+0.0059x^2$	72	0.96
NK	$Y'= 381.65-2.95x+0.0056x^2$	72	0.95
NPK	$Y'= 390.87-3.07x+0.0060x^2$	72	0.98
NPKMg	$Y'= 390.45-3.06x+0.0059x^2$	72	0.96
Winter wheat			
Control	$Y'=-6.5517+0.0375x-4.1774\cdot 10^5x^2$	28	0.60
N	$Y'=-6.7215+0.0401x-4.3882\cdot 10^5x^2$	28	0.57
NP	$Y'=-11.2460+0.0637x-6.9746\cdot 10^5x^2$	28	0.76
NK	$Y'=-4.4713+0.0274x-2.7693\cdot 10^5x^2$	28	0.54
NPK	$Y'=-9.6623+0.0560x-5.9789\cdot 10^5x^2$	28	0.67
NPKMg	$Y'=-11.6722+0.0648x-6.8361\cdot 10^5x^2$	28	0.71
Triticale			
Control	$Y'=-1.2667+9.3051E-03x-8.3606E-06x^2$	44	0.35
N	$Y'=1.2132+7.0393E-04x+1.3090E-06x^2$	44	0.28
NP	$Y'=-4.1239+0.0239x-1.9959E-05x^2$	44	0.47
NK	$Y'=0.5566+3.6298E-03x-3.4461E-07x^2$	44	0.37
NPK	$Y'=-4.1806+0.0216x-1.4278E-05x^2$	44	0.63
NPKCa	$Y'=-2.7134+0.0135x-1.9237E-06x^2$	44	0.66
NPKMg	$Y'=-5.1863+0.0243x-1.3594E-05x^2$	44	0.67
NPKCaMg	$Y'=-5.5393+0.0247x-1.2582E-05x^2$	44	0.62

Table 3: Plant yield models and different combinations of NPKCaMg nutrient supply.

(Haplic Luvisol, Nyírség Region, Nyírlugos).

Discussion

Since the 1950s, there have been significant expanses in the variability experienced by Hungarian and European farmers in terms of crop yields, prices, and farm incomes. Climate changeability has also increased. Over the same period. Supply of macro nutrients such as nitrogen, phosphorus, potassium, calcium and magnesium of major field crops (as the rye, potato, winter wheat and triticale) has enlarged their ranges in many regions. Hungarian crop losses from extreme weather events have substantial costs: estimated damages of the summer drought in 1990, 1992, 2000 and 2002 had been 35, 30, 60 and 18 thousand million HUF (Hungarian Forint) [26], while estimated damages of floods had had exceeded 18.44% under the last 35 year (MARD 2005). These detriment amounts are no normalized to today. If these trends continue and are aggravated by warming temperatures and a more altering climate, as predicted by climate change projections, the livelihoods of many Hungarian and European farmers may be substantially altered.

This study demonstrated that the properly calibrated and tested long-term experiment-based rye (*Secale cereale* L.), potato (*Solanum tuberosum* L.), winter wheat (*Triticum aestivum* L.) and triticale (*X Triticosecale* W.) models are capable of detecting yield responses to climatic-, at first growing season's precipitation variations parallel with Conor and Semenov [48] in interactions with several nitrogen, phosphorus, potassium, calcium and magnesium fertilization systems at Hungarian countryside and European level under the changeable climate conditions. By means of this treatise' outgrowths we state positively that both, drought and abundant rainfall [49] weather conditions may be result in negative effects between mineral fertilization and crop yields. In rye without fertilization the weather anomalies as drought and abundant rainfall did not cause significant yield differences (average year: 1.6 $t*ha^{-1}$, dry year: 1.5 $t*ha^{-1}$, wet year: 1.5 $t*ha^{-1}$). The yields were greater than 3.5 $t*ha^{-1}$ in average years with good nutrient supplies (N: 90 $kg*ha^{-1}$ + NP, NK, NPK, NPKMg combinations), while this was reduced by 17% on average in dry years and by 52% in wet years. The best yields of around 4.0 $t*ha^{-1}$ were recorded when the natural rainfall amounted to 430-500 mm. In potato no yield reducting effects was observed in dry and wet years at a high nutrient supply level (N: 150 $kg*ha^{-1}$ + NP, NK, NPK, NPKMg combinations). Yields close to the maximum 21.0 $t*ha^{-1}$ were achieved at rainfall quantities in the 280-330 mm range. In winter wheat the yield declined even more in wet years demonstrated than in the case of drought.

Maximum yield, its precipitation (mm) and kg mm^{-1}											
Treatment	Rye			Potato			Winter wheat			Triticale	
	t ha^{-1}	mm	kg mm^{-1}	t ha^{-1}	mm	kg mm^{-1}	t ha^{-1}	mm	kg mm^{-1}	t ha^{-1}	mm
Control	1.8	480	3.8	11.4	300	38	1.7	405	4.2	1.6	450
N	3.7	470	7.9	14.8	310	48	2.0	450	4.4	2.9	410
NP	4.3	470	9.2	16.5	330	50	2.7	500	5.4	3.7	430
NK	3.6	440	8.2	16.3	330	50	2.3	500	4.6	3.3	410
NPK	3.8	460	8.3	17.4	300	58	3.0	480	6.3	4.0	580
NPKMg	3.6	430	8.4	17.2	320	54	3.5	520	6.7	5.2	600
NPKCa	-									4.4	600
NPKCaMg	-									5.5	605
Median	3.5	458	7.6	15.6	315	50	2.5	476	5.3	3.8	511
Deviation in Drought climate											
Treatment	Priority	kg mm^{-1}	%	Priority	kg mm^{-1}	%	Priority	kg mm^{-1}	%	Priority	kg mm^{-1}
Control	1	-2	-53	6	-40	-105	6	-7	-167	6	-6
N	2	-5	-63	3	-32	-67	5	-5	-114	8	-15
NP	6	-9	-98	4	-35	-70	1	0	0	5	-11
NK	3	-6	-73	5	-52	-104	2	-2	-44	7	-15
NPK	5	-7	-84	2	-29	-50	3	-3	-48	4	-7
NPKMg	4	-7	-83	1	-18	-33	4	-4	-60	3	-6
NPKCa	-									1	-2
NPKCaMg	-									2	-5
Median	-	-6	-76	-	-34	-72	-	-4	-72	-	-8
Deviation in Wet climate											
Treatment	Priority	kg mm^{-1}	%	Priority	kg mm^{-1}	%	Priority	kg mm^{-1}	%	Priority	kg mm^{-1}
Control	2	-1	-26	6	-54	-142	6	-5	-119	4	-3
N	5	-3	-38	5	-43	-90	1	-2	-46	2	-4
NP	3	-3	-33	3	-23	-46	2	-3	-56	3	-5
NK	6	-5	-61	2	-21	-42	5	-4	-87	1	-3
NPK	1	-2	-24	1	-18	-31	4	-4	-64	6	-12
NPKMg	4	-3	-36	4	-32	-59	3	-4	-60	7	-16
NPKCa	-									5	-10
NPKCaMg	-									8	-20
Median	-	-3	-36	-	-32	-68	-	-4	-72	-	-9

Table 4: Deviations from maximum yield in drought and wet climate conditions of rye, potato, winter wheat and triticale between 1963 and 2001 (Haplic Luvisol, Nyírség Region, Nyírlugos).

Maximum yields 1.7-3.4 t*ha^{-1} were recorded when the natural rainfall amounted to 449-495 mm. In triticale the application of nitrogen alone or of NP and NK treatments led to yield losses of 45 and 24%, respectively, in dry and drouhty years, while that of NPK, NPKCa, NPKMg or NPKCaMg caused a further 22% drop in both types of years. Maximum yields in the region of 5.0-6.0 t*ha^{-1} were achieved in a rainfall range of 550-600 mm. In general close quadratic interrelations could be demonstrated between the rainfall quantity during the growth season and yield in case of these crops, depending on the nutrients (N, P, K, Ca, Mg) and their combination (NP, NK, NPK, NPKCa, NPKMg, NPKCaMg) rates. In case of rye, potato, winter wheat and triticale the precipitation quantities in lack and in excess of 430-500 mm, 280-330 mm, 449-495 mm and 550-600 mm caused several yield reductions.

Hungary is focused on the border of two agricultural zones. Rye and triticale are predominantly grown to the north whilst winter wheat and potato are cultivated in north and shout regions similarly. These three garin and a tuber crops account for one-third of arable land are in Hungary and changes in their production can have a large influence on national agricultural produce. The impacts of rainfall change on above listed crop production had been studied in Hungary using long term experimental databases.

Results obtainad in fertilization compensation (yield loss (kg mm^{-1} and%) of -/+ 100 mm precipitation interspace (-lessening/+increasing, mm) from maximum yield (t ha^{-1}) and its rainfall quantity (mm)) on negativ effects of droughty climate confirm that minimum and maximum crop yield losses had have changed among in case of rye: -63% (N) - -98% (NP), potato: -33% (NPKMg) - -104% (NK), winter wheat: 0% (NP) - -114% (N) and triticale: -28% (NPKCa) - -211% (N), and in wet of rye: -24% (NPK) - -61% (NK), potato: -31% (NPK) - -90% (N), winter wheat: -46% (N) - -87% (NK) and triticale: -37% (NK) - -220% (NPKCaMg)(Table 4). Under drought in instance of rye the N (-63%), potato: NPKMg (-33), wheat: NP (0%) and triticale: NPKCa (-28%), and in wet of rye the NPK (-24%), potato: NPK (-31%), wheat: N (-46%) and triticale: NK (-37%) loadings presented the best models. In these fertilization systems in drought conditions the yield loss reductions had been heving observed of rye: 35%, potato: 71%, wheat: 114% and triticale: 183%, and in wet of rye: 37%, potato: 59%, wheat: 41% and triticale: 183% respectively.

Major results of extreme droughty and rainfall excess effects on crops yield showed that the best adopted culture to these dramatic changes is rye because its yield losses in droughty and very wet years had been having the most smaller (droughty years: -6.0 kg mm^{-1}; -75.7% and very wet years: -2.8 kg mm^{-1}; -36.3%) among the four crops. Yields of potato (droughty years: -34.0 kg mm^{-1}; -71.5% and very wet years: -32.0 kg mm^{-1}; -68.3%), winter wheat (droughty years: -3.5 kg mm^{-1}; -72.2% and very wet years: -3.7 kg mm-1; -72.0%) and triticale (droughty years: -8.4 kg mm^{-1}; -118.0% and very wet years: -9.1 kg mm^{-1}; -118.6%) were likely to worsen under the temperate climatic conditions. These facts can be demonstrating that the Hungarian and European traditional plant production patters has to be modifying rapidly.

On the basis of above results we can state that farmer can be diminishing crop yield demages through his better fertilization scheme choising in drougt with an 100% and in wet with an 80% generaly. Thus, application these methods adapting crop production for recent climate variabilities should be strongly recommending to new farmer generatin in Hungary and in Europe paralel in the nearest future.

However, in the future farmers must monitoring continuously (Precision Plant Production) their farm microclimate, first able the precipitation, and farm soil properties, mainly the nutrient supplies. Following the current precipitation situation can adjust the crop fertilization system behind the presented models (Table 3) to expected optimum yield. Namely, farmer must increase the fertilization rates, taking into consideration the soil nutrient supply and the introduced models, proportionately with the timely rainfall quantities if necessary supplement with irrigation as long as reach the optimum yields. If the natural precipitation amount which connectible to optimum yield surpass these amounts should conclude the correction process because the surplus fertilization will rising more economical losses and ecological damages by the nutrient leachings (for example nitrogen) as well as. Generally speaking, following this basic scientific concrete results, findings and models under these changing climate conditions we draw the European farmers attention to the drought and excess rainfall extreme effects [48,50-52] are significantly negative on crop yields. For this reason, to their certain crop production optimization correct NPKCaMg fertilizer-, and irrigation rate calculation is highly recommended by our presented calibration models in the future. These conclusions are in line on the international sideways with studies of Horst [12], McMaster [39], Ghaffari and Lee [46], Louisa [7] and Eric [9] and on the Hungarian sidewise with researches of Harnos [14], Láng [11] and Márton [4] where rye, potato, wheat and triticale crop models were applied to estimate current crop productivity in different agricultural systems.

As the case may be the response of individual producers to changes of the climate regime will need to involve changes in the selection of crops (rye, potato, wheat, triticale) and in practices of cultivation as the plant nutrition (nitrogen, phosphorus, potassium, calcium, magnesium) and irrigation control. Changes on the farm can, in turn, modify regional energy use, water demand, storage and transportation providers, and food processing. Advance in climate forecasting possible improve preparations and help prevent some of the projected losses. Ultimately, the ability of farmers to adapt effectively can decide the success or failure of individual farms, and international economies. Under progressively changing climate conditions, adaptations will need to envolve continuously, and may be increasingly difficult to plan. The impact of trends in climate extremes and fertilization patterns in poorer and more vulnerable regions of the world could be substantial. Given the growing interconnectedness of world economic and ecological systems, decreased agricultural yields in underdeveloped nations [53,54] could affect the Europe and Hungary vis demands on relief efforts and international trade, as well as through impacts on political stability and the international movement of populations [55].

To sum up we can say climate change will gradually and, at some point, be even abruptly affects European and Hungarian agriculture. Warming temperatures and a greater incidence and intensity of extreme weather events possible lead to significant reductions in crop yields. Expanded ranges of crop agrochemicals and altered transmission dynamics of different irrigation solutions might exacerbate these reductions. Since farmers' strategies grow out of experience, they can find that the past will be a less reliable predictor of the future.

Climate change is recognized as a serious environmental issue. All region of the Earth has repeatedly warming affected today. Available evidence [1,2,5,8,13,16,34,44] suggests that such changes are not only possible but likely in the future, potentially with large impacts on ecosystems and societies. During the 20th century atmospheric GHG concentrations, especially that of CO_2, increased markedly. Nearly concurrently with this, relative global temperatures of the 19th century increased by 0.60C. In the coming decades, global plant production faces the prospect of a changing climate and environment, as well as the known challenge of feeding the world's population, predicted to double the present six billion by about the year 2050. Due to global warming climate change is 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. These changes (largely caused by human activities) are likely to affect crop yields differently form region to region across the globe. 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.

Conclusion

The effects of global climate change on water resources are hidden by natural climate variability. 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. We can state as well that both, drought and excess rainfall conditions resulted in significant negative effects between fertilization (N, P, K, Ca, Mg) and crop (rye, potato, winter wheat, triticale) yield on Haplic Luvisol in the Nyírlugos long-term field fertilization experiment in the fragile Hungarian (Nyírség) agro-ecosystem under forty years from 1961. to 2001. During drought years yield of rye, potato, winter wheat and triticale was decreased with an average of 14%, 35%, 46% and 28%, and in the wet years yield's drop was in the case of rye 10%, winter wheat 56%, triticale 9% and potato yield was comparable to produce in average years. The relationships between rainfall quantity during the vegetation period and N, P, K, Ca, Mg nutrition and crop yield can be characterized by polynomial correlations

Behind this basic scientific concrete findings and results under these changing climate conditions we draw the farmers attention to the drought and excess rainfall extreme effects are significantly negative on crop yields, generally. For this reason to their certain crop production optimalization correct NPKCaMg fertilizer-, and irrigation rate calculation is highly recommended by our presented calibration models in the future.

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