3

The Influence of Cultivation Region and Variety of Maize on Demand for Energy Carriers for Grain Drying

Leszek Styszko, Diana Fijałkowska, Monika Sztyma
Politechnika Koszalińska

Adam Majewski
Limagrain Polska Sp. z o.o., Poznań

1. Introduction

Maize is one of the most effective cultivated plants. The maize grain has the universal use, including feedstuff, food industry and production of biofuels (Michalski 2007). Despite of curbing of cultivation area after 2004, then in 2006 maize was cultivated in Poland on the area of 659300 ha, of which 309000 ha was used for grain. Maize makes up the basic material for production of bioethanol and biogas in the economy of many countries (Gradziuk 2003). It is estimated, that the demand for bioethanol from maize in Poland in 2020 will be 850 millions of liters, and area of 383000 ha should be allot for cultivation (Gradziuk 2006). Introduction of biofuels law will extort growth of maize sowings for grain up to 850000 ha (Michalski 2007). The profitability of this plant cultivation will still depend on the course of weather in the vegetation period, selection of varieties and the cost of the grain drying, which at present is 29.3% of total maize cultivation costs (Sulewska 2007).

The aim of the work was evaluation of influence of cultivation regions of and how early varieties are on the consumption of fuel oil and three-phase current for drying maize grain.

2. Materials and methods

Analyses also included data from field experiences carried out in Poland in the years 2002-2005 in 12 localities with 8 early and mid early varieties of maize (FAO 220-260). In every cultivation region four experimental points were located (table 6), for which meteorological data was taken from the publication of Polish Institute of Meteorology and Water Management for the closest measuring station.

Values of water content in grain (ton-percents), were statistically analyzed, and significance of dependence was verify the F test. Amount of fuel oil (1.5 l) and three-phase current (0.6 kWh) for 1 ton-percent of water when drying the grain were adopted from Dreczka (2001). Coefficients of the line correlation (*r*) and multiple correlation (*R*) were determined, regression equations were created and data for 1 standard deviation from the average were made in tabular form.

3. Results and discussion

The course of weather conditions in the period of maize vegetation in the years 2002-2005 in the cultivation regions is shown in tables 1-3. Years 2002, 2004 and 2005 were characterized with similar quantity of precipitation in relation to the average sums of precipitation for the period May-September. Year 2003 was characterized with smaller precipitation, but its distribution in regions and months was uneven (table 1). In the period from two weeks before the blooming to three weeks after the blooming rain falls are essential for correct growing and yielding of maize. This period in the majority of Poland's area starts at the beginning of July and ends in the mid of August (Michalski 2007). Hydrothermal Sielianinow coefficient helps to determine drought periods and dry periods (Molga 1970). Coefficients in the range 0,0-0,5 indicate drought, 0,6-1,0 – dry weather, and above 1,0 – moist weather. Table 3 shows data of Sielianinow coefficient values in regions of maize cultivation in the years 2002-2005. Droughts and dry periods occurred in each year of investigations, but in the year 2003 they were most intensive.

Years 2002-2005 were characterized with diverse air temperature. Years 2002-2003 were warmer than 2004 and 2005, and 2004 was the coolest (table 2). On the base of mean air temperatures in the May-September period, according to Michalski (2001) classification, unfavorable stands for maize cultivation are those where temperature of the vegetation period is in the range 13.5-14.4°C, boundary – 14.5-15.4°C, average – 15.5-16.4°C, favorable – 16.5-17.4°C and very favorable – >17,5°C. In analyzed period very favorable temperature conditions for maize cultivation were in years 2002 and 2003 in regions I and II, favorable – in 2002 in region III and in 2005 in region II, average – in 2003 in region III, in 2004 in regions I and II and also in 2005 in region I and boundary in 2004 and 2005 in region III.

Unfavorable weather conditions, both drought and excessive precipitation at low air temperature, negatively influence crop of maize and its quality. This influence is shown in crop of maize grain decrease and drop of the dry mass content. The smaller dry mass content in grain causes enlarged non-cash and financial outlays on drying the grain to the moisture content of the dry grain (14-15%). The grain straight from harvester is not suitable for storing, because it contains, depending on the conditions of cultivation, 26-40% of water. If wet grain is left for longer than one day, it begins to get warm, evaporate and go moldy. Hot air with temperature 60-90°C is always the drying medium, and it is pumped into the mass of grains. Therefore crop size and water content in grain, cost of used energy carriers (fuel oil and three-phase current), cost of amortization and cost of repairs and service (Dreczka 2001) have essential influence on costs of maize grain drying. Conditions of cultivation have very big influence from among given factors.

Own research allows to rank following factors in order of decreasing influence on fuel oil and three-phase current demand for drying of maize grains: co-operation of cultivation regions with years (17.6%), co-operation of years with cultivation regions and localities within regions (16.5%), how early variety is (15.7%), years (14.2%), co-operation of localities in regions with years (9.2%), co-operation of localities with regions (6.1%), regions of cultivation and localities in regions (3.3% each), co-operation of years with varieties and regions (2.8%) and co-operation of years with varieties (1,7 %) (table 4). Very big importance of years and their co-operations which together occupied 70.9% of changeability was gained in analyses.

Correlational relationship among cultivation regions, how early varieties are and course of weather in the period of maize vegetation and demand on the energy carriers for drying grin was shown in table 5. The average correlation ($0.3 \leq r_{xy} < 0.5$) positive occurred with how early varieties are and the sum of precipitation in August, and negative with the air temperature in June. Weak correlation ($0.1 \leq r_{xy} < 0.3$) positive occurred with the sum of precipitation in the period V-IX, precipitation in September and June and cultivation regions, and negative – with air temperatures in the period V-IX, July, June and September.

Studied factors significantly diversified demand for energy carriers for grain drying (table 6). On the average from years for drying grain from the area of 1 hectare 268.9 l ha^{-1} of fuel oil and 107.6 kWh ha^{-1} of three-phase current were used. Most of those energy carriers were used for drying grain in 2002, and the least in 2003 (less about 43.3% than the average from years). On the average most fuel oil and current was used for drying grain of LG 32.25 (FAO 250) variety, and the least for Banquise (FAO 220) variety (about 56.6% less). In region III 16% more energy was used than in regions I and II. Within the cultivation region there were large differences among localities e.g. in region III 47.7% of the average value, in II – 10.7% and in I – 24.4%.

Regression equations were created for determination of demand for fuel oil and the three-phase current in cultivation regions for drying the crop of maize grain from the area of 1 hectare (table 7). Following independent variables were considered: x_1 – cultivation region, x_2 – how early variety is (FAO), x_3 – precipitation in the V-IX period, x_4 – co-operation of cultivation region with how early variety is, x_5 – co-operation of how early variety is with precipitation and x_6 – co-operation of cultivation region with precipitation. Regression equations created this way described 25.1-51.2% of changeability.

After putting values of independent variables in tabular form 1 standard deviation from average, this data is given in tables 8 and 9 for individual years, how early variety is, cultivation region and precipitation in the vegetation period. Those tables show, that in each cultivation region demand for energy carriers used for drying maize grain grows, if later varieties are cultivated, in conditions of precipitation affluence and in regions with worse natural conditions, yet this growth this is not equal in years.

Presented investigations show diverse demand for energy carriers for drying maize grain in dependence form cultivation year, how early variety is, cultivation region and locality within the region. During last ten years the border of maize cultivation has moved north, which causes necessity of paying attention to costs of grain drying. These costs during production of biofuels can be reduced, if wet of silage grain is applied for production of bioethanol and biogas, which is also noticed by Sulewska (2007).

Table 1. Precipitation in maize cultivation regions in the period of May–September of 2002-2005 according to Polish Institute of Meteorology and Water Management

Tabela 1. Opady w rejonach uprawy kukurydzy w okresie maj – wrzesień 2002-2005 według IMiGW

Year	Month	Precipitation in cultivation regions, mm					
		I	II	III	Mean	Extreme values	
						min.	max.
2002	V	75.0	60.5	76.0	70.5	27	134
	VI	84.5	34.5	85.0	68.0	18	132
	VII	78.0	58.0	60.7	65.6	28	91
	VIII	68.5	64.2	35.5	56.1	14	106
	IX	42.0	41.0	48.0	43.6	6	62
	total	**348.0**	**258.2**	**305.2**	**303.8**	**195**	**495**
2003	V	78.7	21.5	37.5	45.9	17	106
	VI	44.5	25.5	31.7	33.9	19	75
	VII	72.5	134.0	92.8	99.7	57	227
	VIII	31.5	17.7	63.7	37.7	7	96
	IX	34.3	32.0	52.0	39.4	14	78
	total	**261.5**	**230.7**	**277.7**	**256.6**	**197**	**316**
2004	V	51.2	51.7	45.5	49.5	20	91
	VI	61.5	61.3	63.5	62.1	40	98
	VII	102.3	65.2	105.7	91.1	49	180
	VIII	77.7	60.8	101.5	80.0	49	147
	IX	23.0	33.5	51.8	36.0	17	112
	total	**315.7**	**272.5**	**368.0**	**318.7**	**212**	**436**
2005	V	93.7	73.7	71.8	79.7	52	107
	VI	54.0	30.4	35.7	40.0	13	110
	VII	86.3	87.2	74.0	82.8	47	140
	VIII	87.8	50.2	67.7	68.6	34	124
	IX	32.7	31.9	38.8	34.5	10	62
	total	**354.5**	**274.4**	**288.0**	**305.6**	**197**	**512**
Mean	V	74.7	51.9	57.7	61.4	17	134
	VI	61.1	37.9	54.0	51.0	13	132
	VII	84.7	86.4	83.3	84.8	28	227
	VIII	66.4	48.2	67.1	60.6	7	147
	IX	33.0	34.6	47.6	38.4	6	112
	total	**319.9**	**259.0**	**309.7**	**296.2**	**195**	**512**

Table 2. Average day air temperature in maize cultivation regions in the period of May–September of 2002-2005 according to Polish Institute of Meteorology and Water Management

Tabela 2. Średnia dobowa temperatura powietrza w rejonach uprawy kukurydzy w okresie maj – wrzesień 2002-2005 według IMiGW

Year	Month	Mean day air temperature in cultivation regions, °C					
		I	II	III	Mean	Extreme values	
						min.	max.
2002	V	16.9	16.4	14.4	15.9	13.2	17.5
	VI	17.6	17.6	15.7	17.0	13.8	18.2
	VII	20.5	19.9	19.2	19.9	18.2	21.2
	VIII	19.9	21.1	20.0	20.3	18.7	21.3
	IX	12.9	14.1	13.8	13.6	12.2	14.6
	total	**17.6**	**17.9**	**16.6**	**17.4**	**16.0**	**18.1**
2003	V	16.0	15.5	13.6	15.0	12.4	16.5
	VI	18.4	18.9	16.6	18.0	15.5	19.5
	VII	19.6	19.5	19.0	19.4	18.1	20.4
	VIII	19.6	19.1	19.9	18.8	17.2	20.4
	IX	13.8	14.5	13.8	14.0	12.4	14.8
	total	**17.5**	**17.5**	**16.2**	**17.1**	**15.6**	**17.9**
2004	V	12.2	12.6	11.2	12.0	10.7	12.8
	VI	16.3	15.7	14.3	15.4	13.8	16.8
	VII	18.1	17.6	16.2	17.3	15.6	18.5
	VIII	18.7	19.5	18.4	18.8	17.9	19.8
	IX	13.4	14.0	13.5	13.6	12.4	14.4
	total	**15.8**	**15.9**	**14.7**	**15.5**	**14.2**	**16.4**
2005	V	13.8	13.5	11.9	13.0	10.8	14.0
	VI	16.4	16.2	14.7	15.8	14.0	16.8
	VII	19.6	19.8	18.5	19.3	18.0	20.4
	VIII	17.2	17.2	16.3	16.9	16.1	17.5
	IX	14.9	15.8	14.9	15.2	13.9	16.1
	total	**16.4**	**16.5**	**15.2**	**16.0**	**14.8**	**16.8**
Mean	V	14.7	14.5	12.8	14.0	10.7	17.5
	VI	17.2	17.1	15.3	16.5	13.8	19.5
	VII	19.5	19.2	18.2	19.0	15.6	21.2
	VIII	18.8	19.2	18.1	18.7	16.1	21.3
	IX	13.7	14.6	14.0	14.1	12.2	16.1
	total	**16.8**	**16.9**	**15.7**	**16.5**	**14.2**	**18.1**

Table 3. Hydrothermal Sielianinow coefficient temperature in maize cultivation regions in the period of May–September of 2002-2005

Tabela 3. Współczynnik hydrotermiczny Sielianinowa w rejonach uprawy kukurydzy w okresie maj – wrzesień 2002-2005

Year	Month	Sielianinow coefficient in cultivation regions					
		I	II	III	Mean	Extreme values	
						min.	max.
2002	V	1.44	1.18	1.73	1.45	**0.51**	2.99
	VI	1.61	**0.65**	1.86	1.38	**0.34**	2.95
	VII	1.23	**0.94**	1.02	1.06	**0.44**	1.47
	VIII	1.11	**0.98**	**0.56**	**0.88**	**0.23**	1.66
	IX	1.08	**0.97**	1.14	1.06	**0.16**	1.59
	total	1.30	**0.94**	1.20	1.15	**0.72**	1.87
2003	V	1.58	**0.45**	**0.90**	**0.98**	**0.35**	2.18
	VI	**0.82**	**0.45**	**0.64**	**0.63**	**0.35**	1.38
	VII	1.20	2.22	1.57	1.66	**0.90**	3.79
	VIII	**0.52**	**0.30**	1.17	**0.66**	**0.12**	1.77
	IX	**0.82**	**0.73**	1.25	**0.94**	**0.35**	1.87
	total	**0.98**	**0.86**	1.13	**0.99**	**0.73**	1.25
2004	V	1.37	1.33	1.32	1.34	**0.60**	2.51
	VI	1.26	1.30	1.49	1.35	**0.85**	2.37
	VII	1.81	1.20	2.12	1.71	**0.88**	3.14
	VIII	1.35	1.01	1.80	1.39	**0.82**	2.65
	IX	**0.57**	**0.79**	1.27	**0.88**	**0.42**	2.71
	total	1.31	1.12	1.65	1.36	**0.85**	1.98
2005	V	2.20	1.76	1.94	1.97	1.53	2.47
	VI	1.08	**0.62**	**0.81**	**0.84**	**0.31**	2.18
	VII	1.42	1.45	1.30	1.39	**0.81**	2.40
	VIII	1.64	**0.94**	1.35	1.31	**0.63**	2.29
	IX	**0.74**	**0.67**	**0.87**	**0.76**	**0.23**	1.40
	total	1.41	1.09	1.24	1.25	**0.78**	2.02
Mean	V	1.65	1.18	1.47	1.43	**0.34**	2.98
	VI	1.19	**0.76**	1.20	1.05	**0.31**	2.95
	VII	1.41	1.45	1.50	1.46	**0.44**	3.79
	VIII	1.15	**0.81**	1.22	1.06	**0.12**	2.65
	IX	**0.80**	**0.79**	1.13	**0.91**	**0.16**	2.71
	total	1.25	1.00	1.30	1.19	**0.73**	2.02

Tabela 4. Influence of tested factors on demand for energy carriers for drying of maize grains in the years 2002-2005

Tabela 4. Wpływ badanych czynników na potrzeby nośników energii do suszenia ziarna kukurydzy w latach 2002-2005

Variation component	Degrees of freedom	Percentage structure of variation components
Years [D]	3	14.2***
Varieties [C]	7	15.7***
Localities in regions [B]	3	3.3***
Cultivation regions [A]	2	3.3***
Sum of co-operations		63.5
including: DC	21	1.7***
DB	9	9.2***
CB	21	0.1
DCB	63	0.1
DA	6	17.6***
CA	14	0.2
DCA	42	2.8***
BA	6	6.1***
DBA	18	16.5***
CBA	42	0.4
DCBA	126	8.8

Significance at confidence level - * α=0.05; ** α=0.01; *** α=0.001

Table 5. Correlation coefficients between demand for energy carriers for drying of maize grain and elements of weather, cultivation regions and how early varieties are

Tabela 5. Współczynniki korelacji pomiędzy zapotrzebowaniem na nośniki energii zużyte do suszenia ziarna kukurydzy a elementami pogody, rejonami uprawy oraz wczesnością odmian

Dependent variable	Independent variables	Correlation coefficients
Demand for energy carriers	Cultivation regions	0.183***
	how early varieties is (FAO)	**0.345*** **
	Precipitation sum in May	-0.017
	Precipitation sum in June	0.148***
	Precipitation sum in July	-0.001
	Precipitation sum in August	**0.315*** **
	Precipitation sum in September	0.271***
	Precipitation sum in period V-IX	0.273***
	Day temperature V	-0.165***
	Day temperature VI	**-0.338*** **
	Day temperature VII	-0.179***
	Day temperature VIII	0.025
	Day temperature IX	-0.145***
	Day temperature V-IX	-0.225***

Table 6. Influence of tested factors on demand for energy carriers for maize grain drying
Tabela 6. Wpływ badanych czynników na zapotrzebowanie na nośniki energii do suszenia ziarna kukurydzy

Tested factor	Levels of factor	Demand for fuel oil, $l \cdot ha^{-1}$	Demand for three-phase current, $kWh \cdot ha^{-1}$
Years	2002	311.8	124.7
	2003	195.5	78.2
	2004	292.7	117.1
	2005	275.6	110.2
	$NIR_{0.05}$	11.4***	4.5***
Varieties	LG 32.25	323.3	129.3
	LG 22.75	320.2	128.1
	LG 22.65	311.2	124.5
	LG 22.44	293.5	117.4
	LG 22.22	244.4	97.8
	LG 32.15	224.9	90.0
	LG 22.43	262.6	105.1
	Banquise	171.1	68.4
	$NIR_{0.05}$	16.1	6.4***
Cultivation regions	III	297.6	119.1
	II	253.2	101.3
	I	255.8	102.3
	$NIR_{0.05}$	9.8***	3.9***
Localities in region III	Dretyń	356.4	142.5
	Złocieniec	276.8	110.7
	Wolinia	329.3	131.7
	Lenarty	228.1	91.2
Localities in region II	Kurzycko	243.6	97.5
	Mieszkowice	271.4	108.6
	Piaski	242.7	97.1
	Gliszcz	255.2	102.8
Localities in region I	Gniechowice	291.2	116.5
	Cieleśnica	262.1	104.8
	Głuchów	244.1	97.6
	Głogówek	225.8	90.3
$NIR_{0,05}$ for localities		21.8***	8.7***

Table 7. Regression equations for prediction of demand for energy carriers for maize grain drying in the years 2002-2005

Tabela 7. Równania regresji do prognozy potrzeb na nośniki energii przy suszeniu ziarna kukurydzy w latach 2002-2005

List	Year	Components of regression equation	Determination, %
Demand for fuel oil, $l \cdot ha^{-1}$	2002	Y=-1361.61 +254.244**A** +8.386**B** -0.278**O**p -2.040**AB** -0.002**BOp** +0.586A**Op**	51.2***
	2003	Y=-177.821 -171.6916**A** +**0.467B** **+1.094O**p +1.030**AB** -0.002**BOp** -0.043**AOp**	48.7***
	2004	Y=-307.817 -110.6036**A** +2.294**B** **+**0.672**O**p +0.622**AB** -0.004**BOp** -0.060**AOp**	43.6***
	2005	Y= 125.259 –241.841**A** +1.241**B -** 0.554**O**p +0.424**AB** -0.0002**BOp** +0.534**AOp**	28.4***
	mean	Y=-30.644 -77.653**A** -1.064**B** -0.845**O**p +0.166**AB** +0.004**BOp** +0.197**AOp**	25.1***
Demand for three-phase current, $kWh \cdot ha^{-1}$	2002	Y=-544.645 +101.698**A** +3.355**B** -0.111**O**p –0.816**AB** -0.0007**BOp** +0.234**AOp**	51.2***
	2003	Y=-71.128 –68.676**A** +0.187**B** +0.4371**O**p +0.412**AB** -0.001**BOp** +0.017**AOp**	48.7***
	2004	Y=-123.127 –44.241**A** +0.917**B** +0.269**O**p +0.249**AB** -0.0015**BOp** +0.024**AOp**	43.6***
	2005	Y= 50.104 –96.736**A** +0.496**B** –0.222**O**p +0.170**AB** -0.00008**BOp** +0.214**AOp**	28.4***
	mean	Y=-12.258 –31.061**A** +0.426**B** –0.338**O**p +0.0665**AB** +0.0014**BOp** +0.079**AOp**	25.1***

Table 8. Prediction of demand for fuel oil for maize grain drying in the years 2002-2006, data from regression equation

Tabela 8. Prognoza zapotrzebowania na olej opałowy do suszenia ziarna kukurydzy w latach 2002-2006, dane z równania regresji

Year of study	How early variety is, FAO	Precipitation sum in the period V-IX, mm	Demand for fuel oil for grain drying in maize cultivation regions, $l \cdot ha^{-1}$		
			I	II	III
Average from 2002-2005	210	200	172.7	169.4	166.1
		400	195.3	231.5	267.7
	250	200	250.9	254.2	257.6
		400	302.5	345.3	388.2
2002	210	200	211.1	154.0	96.9
		400	196.8	156.8	316.9
	250	200	450.5	311.8	173.1
		400	421.8	400.2	378.6
2003	210	200	74.0	110.0	145.9
		400	183.2	210.6	237.9
	250	200	114.7	191.8	268.9
		400	204.7	273.2	341.7
2004	210	200	186.0	218.0	250.1
		400	177.9	222.0	266.1
	250	200	273.2	330.2	387.2
		400	235.8	304.7	373.7
2005	210	200	220.7	174.7	128.6
		400	208.4	269.1	329.8
	250	200	285.7	256.6	227.5
		400	271.8	349.5	427.2

Table 9. Prediction of demand for three-phase current for maize grain drying in the years 2002-2006, data from regression equation

Tabela 9. Prognoza zapotrzebowania na prąd trójfazowy do suszenia ziarna kukurydzy w latach 2002-2006, dane z równania regresji

Year of study	How early variety is, FAO	Precipitation sum in the period V-IX, mm	Demand for three-phase current for grain drying in maize cultivation regions, l·ha^{-1}		
			I	II	III
Average from 2002-2005	210	200	69.1	67.8	66.4
		400	78.1	92.6	107.1
	250	200	100.4	101.7	103.0
		400	121.0	138.1	155.3
2002	210	200	84.4	61.6	38.8
		400	78.7	102.7	126.8
	250	200	180.2	124.7	69.2
		400	168.7	160.1	151.5
2003	210	200	29.6	44.0	58.4
		400	73.3	84.2	95.2
	250	200	45.9	76.7	107.6
		400	81.9	109.3	136.7
2004	210	200	74.4	87.2	100.1
		400	71.2	88.8	106.4
	250	200	109.3	132.1	154.9
		400	94.3	121.9	149.5
2005	210	200	88.3	69.9	51.4
		400	83.3	107.6	131.9
	250	200	114.3	102.7	91.0
		400	108.7	139.8	170.9

4. Conclusions

1. Demand for fuel oil and three-phase current for drying maize grain depends on weather conditions in vegetation period, how early cultivated variety is and region of maize cultivation.
2. Following factors have the biggest influence on quantity of energy carriers used for drying crop of maize grain from area of 1 hectare: years, their co-operations with cultivation regions and localities and maize varieties.
3. The average correlation ($0.3 \le r_{xy} < 0.5$) positive was gained between how early variety is, precipitation sum in August and demand for energy carriers for grain drying, and negative with air temperature in June.
4. Regression equations describing demand for fuel oil and three-phase current for grain drying were created with the determination 25.1-51.2 %.
5. Demand for energy carriers for grain drying grew up each maize cultivation region if later varieties were cultivated, in conditions of precipitation affluence and in regions with worse natural conditions, yet this growth was not equal in years.

References

1. **Dreczka M.:** *Czym wysuszyć ziarno?.* [W:] Profesjonalna uprawa kukurydzy. Magazyn Nowoczesnego Rolnictwa. Top agrar extra: 100÷101, 2001.
2. **Gradziuk P.:** *Biopaliwa. Pod redakcją Piotra Gradziuka*. Warszawa 2003: 160 ss. 2003.
3. **Gradziuk P.:** *Możliwości wykorzystania produktów pochodzenia rolniczego na cele energetyczne w świetle unormowań prawnych Polski i Unii Europejskiej*. Koszalińskie Studia i Materiały Nr 9, Wydawnictwo Politechniki Koszalińskiej, Koszalin 2006. s. 9÷20.
4. **Michalski T.:** *Podstawowe problemy agrotechniczne uprawy kukurydzy*. Biul. Informacyjny IZ, R.XXXIX, 1, 2001. s. 5÷18.
5. **Michalski T.:** *Kukurydza – doskonały surowiec do produkcji biopaliw*. Agroserwis, Warszawa 2007. s. 3÷9, 2007.
6. **Michalski T.:** *Kukurydza w 2006 roku – rozczarowania i nadzieje.* Wieś Jutra nr 3(104). 2007. s. 3÷5.
7. **Molga M.:** *Meteorologia rolnicza*. PWRiL. Warszawa 1970.
8. **Sulewska H.:** *Opłacalność uprawy kukurydzy na ziarno*. Agroserwis, Warszawa 2007. s. 14÷18.