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Possibilities of Maize Cropping for Feed on Acid Soil

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Abstract: Soil acidity is a limiting factor which affects growth, height and yield stability of many crops grown for food and feed all over the world. To combat soil acidity many measures were introduced: Acidity decrease with lime application with or without improvement with manure development or development of germplasm tolerant to acid soils. In this study, researchers examined influence of different cropping measures on productive characteristics of maize grown for feed on acid soil in rain-fed conditions. Cropping measures included fertilization (mineral fertilizers, lime and farmyard manure) and two cropping densities (54,900 and 59,500 plants ha^{-1}). Positive effects of liming were reflected at first on increase of pH values, particularly pH in KCl but it could increase available P and decrease exchangeable H^+ and Al^{3+}. Meteorological factors showed the significant impact on variations of maize growth and yielding parameters. Genotype also highly influenced maize growth, so hybrid with the highest height to tassel and to ear had the lowest average yield. Due to its height, this hybrid could be potentially appropriate for forage production. Treatments which include lime increased growth, yielding and their interdependence also. Favourable meteorological conditions increased variation of growth parameters between applied treatments, giving advantage to treatment with mineral fertilizer + lime + farmyard manure while unfavourable conditions suppress such variation, together with decrease of examined parameters. Higher yield potential obtained in variant with mineral fertilizer + lime under unfavourable conditions may suggest that manure incorporation could be inefficient measure for gaining high grain yields under this conditions.

Key words: Soil acidity, maize, yield parameters, liming, fertilization, crops

INTRODUCTION

Soil acidity is a limiting factor which affects growth, height and yield stability of many crops grown for food and feed all over the world. It is consequence of pedogenesis factors, intensive application of higher amounts of mineral fertilizers with low pH, low inputs of organic fertilizers and acid rains (Veskovic and Jovanovic, 1991). Land area affected by acidity is estimated at 4 billion ha, representing 30% of the total ice-free land area of the world (Sumner and Noble, 2003). In the Republic of Serbia, acid soils are widespread, accounting for over 60% of total arable land (Stevanovic *et al*., 1995). Soil acidity is associated with hydrogen, aluminium, iron and manganese toxicities and corresponding deficiencies of available phosphorus, molybdenum, calcium, magnesium and potassium (Jorge and Arruda, 1997). Plants sensitive to Al toxicity have greatly reduced yield and crop quality (Jovanovic *et al*., 2006, 2007).

To combat soil acidity, development of germplasm tolerant to acid soils was introduced as well as decrease of acidity through lime application and soil improvement with manure (The *et al*., 2012). Liming is well known as the most effective measure for correcting soil acidity due to its price and capacity to increase fertilizer efficiency (Stevanovic *et al*., 1995).

Liming improves soil quality by pH and available P increase due to reduction in Al levels and P sorption. Therefore, lime application is important for management of P deficient acid soils found in the different maize growing areas in Africa or other tropical areas (Kisinyo *et al*., 2013). Even though liming increase soil pH in KCl in higher degree than it was in combination of lime with mineral fertilizer, mineral fertilization significantly influenced maize yield, phosphorus and calcium removal comparing to production without fertilization (Loncaric *et al*., 2006). Soils could be additionaly improved with manure or some other organic fertilizer. Increase in soil organic matter and pH increment in treatments with manure (which could be explained by the high levels of exchangeable base forming cations) contributes to increase of soil quality and maize yields as final result of improvement (Mugendi *et al*., 2010).

Rojas *et al*. (2001) also gained the highest values of available P when they combined lime, phosphorus mineral fertilizer and manure. Same researchers emphasize that soil

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amelioration increase quality of produced crops. For maize crop, such yield increase is connected with increased height and number of leaves (Hassan *et al*., 2007) induced by application of hydrated lime + NPK 15-15-15 + farmyard manure. Castro and Crusciol (2013) obtained increase in 1000 grain weight, shelling and grain yield under the liming influence. From that point, Kisic *et al*. (2002) stressed that liming combined with higher mineral fertilizer rates and farmyard manure as a measure to improve unfavorable physical and chemical properties of acid soils, might be fully justified. Other than soil amelioration, breeding of tolerant maize genotypes could also be one of solutions for cropping possibility on acid soils. Rojas *et al*. (2001) achieved the highest response of sensitive maize genotypes on soils ameliorated with lime together with application of mineral and organic fertilizers while the tolerant genotypes showed yield stability irrespective to lime application.

The aim of this study was to relate the productive characteristics of maize grown for feed under the influence of different cropping measures which include fertilization (mineral fertilizers, lime and farmyard manure) and two cropping densities (54,900 and 59,500 plants ha^{-1}) on acid soil in rain-fed conditions.

MATERIALS AND METHODS

The trial was set up in the vicinity of Petkovica (44°39'56"N, 19°26'21"E, 127 m altitude) with six maize hybrids of FAO maturity group 500: ZPSC 544 (H1), ZPSC578 (H2), NSSC5043 (H3), NSSC540 (H4), KWS LUCE (H5) and KWS MIKADO (H6) which were generally aimed for feed production (either for forage or grain) during 2008, 2009 and 2010. The experiment was established on lowland pseudogley, under rain-fed conditions. The influence of different fertilization regimes (control (without fertilizer input), $N_{150}P_{120}K_{80}$-F1, $N_{150}P_{120}K_{80}$+lime (5 t ha^{-1})-F2, $N_{150}P_{120}K_{80}$+lime (5 t ha^{-1}) +farmyard manure-FYM (25 t ha^{-1})-F3) and two sowing densities (54,900 plants ha^{-1}-D1 and 59,500 plants ha^{-1}-D2) were examined. The experiment was aligned in a random block system with four replications. The elemental plot was 16.8×12.5 m. The sample size for analysis was 10 plants per elemental plot.

Primary tillage was performed in October at 30 cm with incorporation of lime, FYM and NPK 8:24:16 in amount of 500 kg. The rest of the nitrogen (400 kg) was applied as calcium ammonium nitrate before sowing. Sowing was performed 1.5.2008, 24.4.2009 and 2.5.2010. Weed control was carried out mechanically and by application of pre emergence herbicides Atrazin 500 (1 L ha^{-1}) and Dual Gold 960 EC (1.5 L ha^{-1}) and post emergence herbicides Talisman (1 L ha^{-1}) and Banvel 480 S (0.8 L ha^{-1}).

Soil samples for chemical analysis were collected from each experimental plot (fertilization variant) at the beginning of experiment (March 2008) and at the end of experiment (November 2010) from the depth 0-30 cm. Soil reaction was determined in H_2O and 1M KCl. Humus was determined by method of Tjurin (1937) with phenyl-anthranilic acid as indicator. Available phosphorus and potassium as slow mobile elements were determined by method of Egner *et al*. (1960). Exchangeable H^+ and Al^{3+} were determined by method of Sokolov (Jakovljevic *et al*., 1995).

Growth parameters (plant height to tassel, plant height to ear and number of leaves) were determined during anthesis. Yield parameters (shelling percentage, 1000 grain weight and grain yield) were determined after harvest.

The experimental data were statistically processed by Analysis of Variance (ANOVA) and LSD-test (5%) while dependence between grain yield, growth parameter and other yield parameters were obtained by regression analysis. Alterations and prediction of examined parameters under the variable meteorological conditions were presented with Weibull analysis (Dodson, 2006):

$$F(x) = 1 - e^{-\left[\frac{x}{\alpha}\right]^{\beta}}, \quad \text{for } x>0$$

Where:

β = Shape parameter

α = Measure of the scale-characteristic life were used for calculation of survival probability, to predict a parameter reaching a reliability of 0.10 (favourable meteorological conditions), 0.50 (moderate conditions) and 0.99 (unfavourable meteorological conditions)

RESULTS AND DISCUSSION

Meteorological data during vegetation of 2008 to 2010 period indicated that 2009 was the year with the highest average temperature (Table 1) what was particularly underlined during July and August. Vegetation of 2008 and 2009 was low in precipitations (<400 mm) and what is more important this sum was unequally distributed with the lowest values noted during June and August of 2008 as well as April and September of 2009 (Table 1).

According to results of soil analysis, acidity is high (about 5 in H_2O and <4.5 in Kcl), soil is low in humus and available phosphorus and moderate in available potassium in general (Table 2). Exchangeable acidity is high and Al^{+3} have high impact on it. From 2008 to 2010, pH was additionally decreased in control and F1 fertilization variant while in F2 and F3 variants it was increased (about 0.18 and 0.20 units, respectively). pH in KCl varied slightly in control and F1 fertilization variant while it was increased in F2 and F3 variants, particularly in F3 (it was about 0.21 higher, compared to 2008). Moreover, humus content decreased from 2008 to 2010 in all experimental treatments except in F3 where FYM was applied. The highest decrease of humus was observed in control. Similarly to that, phosphorus content show decreasing trend from 2008 to 2010 in control and increasing trend in variants with applied fertilizers. It increased most in F3 treatment (about 1.4 mg 100 g^{-1}). Opposite to that, potassium content decreased during experiment in all variants (mainly in F3) except in F1 where it increased to 2.2 mg/100 g. Soil exchangeable acidity decreased during experiment in variants with lime application as it was expected but the highest impact of applied treatments to exchangeable H^+ was observed in F2 variant (0.052 me) and exchangeable Al^{3+} in F3 variant (1.41 me, i.e., 12.69 mg/100 g) (Table 2).

Meteorological conditions affected maize height in higher or lesser degree. Year had the significant influence on maize height to tassel and ear with lowest values obtained in 2008 (Table 3 and 4) while the genotype influenced maize height to ear significantly (Table 4). The highest value was recorded at H4, what is about 20% higher comparing to H5. Other factors such as fertilization regimes and density, did not show significant impact on maize height to tassel and to ear. Similarly to the influence of year, interaction of year and density significantly influenced the increase of height to tassel in 2009 and height to ear in 2009 and 2010 at both densities while the interaction of year and genotype significantly increased height to tassel of H3, H4 and H6 in 2009 as well as height to ear of H4 in 2009 and 2010. Additionally, interaction of year and fertilization significantly increased height to tassel of F1, F2 and F3 in 2009 and height to ear, also of F1, F2 and F3 to ear in 2010. Significantly, higher height to ear was observed at H4 in both densities and fertilization regimes F3 and F4.

Among examined factors, only genotype significantly influenced number of leaves with the highest values obtained at H3 what is about 9% higher compared to H5 (Table 5). The same hybrid had significantly higher

Table 1: Meteorological conditions for maize growth period-April to September (2008 to 2010)

Years	April	May	June	July	August	September	Mean/Sum
Average temperature (°C)							
2008	12.4	17.1	21.2	21.7	21.7	15.4	18.3
2009	13.5	17.8	19.0	21.9	21.9	18.3	18.7
2010	12.8	16.2	19.4	22.2	21.4	15.8	18.0
Mean	12.9	17.0	19.9	21.9	21.7	16.5	
Sum of rainfalls (mm)							
2008	40.4	83.8	49.8	55.7	24.3	100.1	354.1
2009	15.5	32.4	188.8	75.7	56.6	11.0	380.0
2010	85.1	121.6	276.5	101.8	72.5	109.3	766.8
Mean	56.2	65.3	84.8	66.9	55.1	51.1	-

Table 2: Changes of the soil chemical properties and exchangeable H^+ and Al^{3+} from beginning (2008) to the end of experiment (2010); F1-$N_{150}P_{120}K_{80}$; F2-$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1}); F3-$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1})+manure (25 t ha^{-1})

	pH		pH (KCl)		Humus (%)		P_2O_5 (mg/100 g)		K_2O (mg/100 g)		H^+ (mg/100 g)		Al^{3+} (mg/100 g)		Al^{3+} (mg/100 g)	
Treatments	2008	2010	2008	2010	2008	2010	2008	2010	2008	2010	2008	2010	2008	2010	2008	2010
Control	5.11	5.00	4.08	4.14	1.77	1.66	7.4	5.7	18.2	17.5	0.098	0.111	1.40	1.38	12.60	12.42
F1	4.93	4.89	3.86	3.81	1.79	1.78	6.2	6.9	20.6	22.8	0.163	0.170	2.59	2.87	23.31	25.83
F2	4.98	5.16	3.98	4.16	1.81	1.73	6.4	6.9	19.0	17.0	0.137	0.085	1.91	1.14	17.19	10.26
F3	5.00	5.20	3.98	4.19	1.75	1.78	6.9	8.3	20.0	16.0	0.059	0.052	2.40	0.99	21.60	8.91

Table 3: The influence of different conditions on maize height to tassel (cm) during the growing seasons 2008 to 2010; H1-H6-maize hybrids; F1-$N_{150}P_{120}K_{80}$; F2-$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1}); F3-$N_{150}P_{120}$K80+lime (5 t ha^{-1})+manure (25 t ha^{-1}); D1-54,900 plants ha^{-1}; D2-59,500 plants ha^{-1}

Height	2008	2009	2010	Cont.	F1	F2	F3	D1	D2	Aver.
H1	213.73	283.35	272.67	246.83	260.53	260.95	258.03	254.21	258.95	256.58
H2	216.86	296.18	285.95	257.76	267.86	270.80	268.90	264.68	267.99	266.33
H3	214.37	313.73	289.81	260.04	273.28	277.57	279.68	269.26	276.01	272.64
H4	227.50	315.34	290.70	266.62	278.50	281.10	285.15	276.53	279.16	277.84
H5	209.46	288.54	264.08	234.46	258.98	261.17	261.50	252.67	255.39	254.03
H6	217.88	315.28	293.08	253.75	280.63	285.85	287.02	276.45	277.18	276.81
Aver.	216.63	302.07	282.72	253.24	269.96	272.91	273.38	265.63	269.11	-

	2008	2009	2010	Cont.	F1	F2	F3
D1	216.16	300.79	279.96	247.89	269.50	273.62	271.53
D2	217.46	303.19	286.68	258.60	270.42	272.20	275.23

	2008	2009	2010	D1	D2	LSD 0.05 Year	Fertil.	Density	Genot.	Y×F
Cont.	214.74	290.60	254.39	247.89	258.60					
F1	216.44	306.68	286.76	269.50	270.42	16.60	39.77	40.32	39.82	13.07
F2	216.81	305.85	296.06	273.62	272.20	Y×D	Y×G	F×D	F×G	D×G
F3	219.24	304.84	296.06	271.53	275.23	16.64	13.54	40.25	41.57	40.66

Table 4: The influence of different conditions on maize height to ear (cm) during the growing seasons 2008 to 2010; H1-H6-maize hybrids; F1-$N_{150}P_{120}K_{80}$; F2-$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1}); F3-$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1})+manure (25 t ha^{-1}); D1-54,900 plants ha^{-1}; D2-59,500 plants ha^{-1}

Heights	2008	2009	2010	Cont.	F1	F2	F3	D1	D2	Aver.
H1	88.42	113.40	117.83	98.40	108.47	107.39	111.94	104.58	108.52	106.55
H2	87.36	110.87	113.85	101.35	101.28	106.10	107.38	101.36	106.70	104.03
H3	83.70	118.46	119.42	101.95	106.95	111.87	108.00	105.70	108.69	107.19
H4	89.34	129.42	128.03	108.80	114.35	118.07	121.19	114.01	117.19	115.60
H5	78.24	99.06	98.56	84.88	91.91	94.23	96.80	91.14	92.77	91.95
H6	74.79	103.95	106.43	85.25	96.74	101.49	100.57	95.11	96.92	96.01
Aver.	83.64	112.53	114.02	96.77	103.28	106.53	107.65	101.98	105.13	-

	2008	2009	2010	Cont.	F1	F2	F3
D1	83.89	110.57	111.48	92.58	103.18	106.80	105.37
D2	83.73	114.59	117.08	100.96	103.39	106.25	109.93

	2008	2009	2010	D1	D2	LSD 0.05 Year	Fertil.	Density	Genot.	Y×F
Cont.	80.56	110.10	99.65	92.58	100.96					
F1	77.95	114.98	116.93	103.18	103.39	11.39	17.70	18.01	16.56	10.08
F2	86.16	111.69	121.73	106.80	106.25	Y×D	Y×G	F×D	F×G	D×G
F3	90.58	113.55	118.82	105.37	109.93	11.33	8.15	17.79	17.02	16.84

Table 5: The influence of different conditions on number of leaves during the growing seasons 2008 to 2010; H1-H6-maize hybrids; F1-$N_{150}P_{120}K_{80}$; F2-$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1}); F3-$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1})+manure (25 t ha^{-1}); D1-54,900 plants ha^{-1}; D2-59,500 plants ha^{-1}

Heights	2008	2009	2010	Cont.	F1	F2	F3	D1	D2	Aver.
H1	14.05	14.03	14.27	13.90	14.25	14.00	14.31	14.05	14.18	14.12
H2	14.38	14.28	14.53	14.21	14.56	14.33	14.48	14.33	14.46	14.40
H3	14.79	14.82	14.91	14.76	14.94	14.78	14.88	14.80	14.88	14.84
H4	13.86	13.91	13.79	13.78	13.89	13.91	13.84	13.82	13.89	13.85
H5	13.52	13.74	13.42	13.34	13.52	13.75	13.63	13.53	13.59	13.56
H6	14.18	14.03	14.47	13.84	14.34	14.38	14.53	14.12	14.42	14.27
Aver.	14.13	14.14	14.23	13.97	14.25	14.19	14.28	14.11	14.24	-

	2008	2009	2010	Cont.	F1	F2	F3
D1	14.07	14.04	14.22	13.80	14.25	14.19	14.20
D2	14.21	14.25	14.26	14.14	14.25	14.20	14.35

	2008	2009	2010	D1	D2	LSD 0.05 Year	Fertil.	Density	Genot.	Y×F
Cont.	13.96	13.91	14.04	13.80	14.14					
F1	14.22	14.48	14.05	14.25	14.25	0.53	0.52	0.53	0.35	0.51
F2	14.18	13.89	14.50	14.19	14.20	Y×D	Y×G	F×D	F×G	D×G
F3	14.19	14.29	14.35	14.20	14.35	0.53	0.35	0.52	0.33	0.34

number of leaves in all three experimental years as well as at both densities and fertilization regimes in particular at F2. F3 showed the significant impact on increase of number of maize leaves at 59,500 plants ha^{-1} while F1 induced increase in average maize leaves in 2009 and F2 in 2010.

The highest average 1000 grain weight values were achieved in 2009, at H6 and at all fertilization regimes except at control (Table 6). The interaction of year, density and fertilization pointed towards significantly higher values achieved in 2009 at both densities as well as F1, F2 and F3. At the same year, H1, H2, H4 and H6 were emphasized as hybrids with the highest 1000 grain weight, so as H6 realised the highest values at F1, F2 and F3 treatments. Other than that, H3 realized significantly lowest 1000 grain weight at the both densities. Opposite to 1000 grain weight, H3 achieved significantly higher shelling percentage among examined hybrids (about 3% higher than H6), what was particularly emphasized in 2009 (Table 7). Among 3 years, 2008 was characterised with significantly lower shelling percentage of all six hybrids and all four fertilization regimes.

When grain yield was considered, it could be assumed that 2009 was year with favourable conditions (Table 1) what was reflected on significantly higher grain yield (about 35% higher, compared to 2008 Table 8). That was present at both cropping densities and all six hybrids as well as F1, F2 and F3 fertilization variants. Among applied fertilization variants, in F3 at 59,500 plants ha^{-1} was achieved significantly higher grain yield.

The impact of examined parameters of growth and yielding on grain yield varied among fertilizing variants. In control (which did not include fertilizer application) yield and 1000 grain weight were significantly connected

Table 6: The influence of different conditions on 1000 grains weight (g) during the growing seasons 2008 to 2010; H1-H6-maize hybrids; F1-$N_{150}P_{120}K_{80}$; F2-$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1}); F3-$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1})+manure (25 t ha^{-1}); D1-54,900 plants ha^{-1}; D2-59,500 plants ha^{-1}

Heights	2008	2009	2010	Cont.	F1	F2	F3	D1	D2	Aver.
H1	261.05	352.44	296.92	265.65	314.42	317.37	316.44	305.61	301.33	303.47
H2	265.89	331.98	281.48	256.08	301.71	314.83	299.86	295.09	291.15	293.12
H3	217.49	280.28	260.73	229.56	252.83	266.75	262.21	254.55	251.12	252.84
H4	250.03	378.73	316.26	278.99	320.76	321.30	338.97	319.61	310.40	315.00
H5	254.04	344.05	302.19	275.95	302.46	306.58	315.38	304.99	295.19	300.09
H6	300.58	385.80	321.99	291.75	352.32	352.72	352.94	341.97	332.90	337.43
Aver.	258.18	345.55	296.59	266.33	307.41	313.26	314.30	303.64	297.01	

	2008	2009	2010	Cont.	F1	F2	F3
D1	258.91	348.92	303.08	265.31	311.17	318.98	319.09
D2	258.23	341.73	291.09	267.35	303.66	307.54	309.51

	2008	2009	2010	D1	D2	LSD 0.05 Year	Fertil.	Density	Genot.	Y×F
Cont.	251.54	305.32	242.13	265.31	267.35					
F1	258.92	354.38	308.94	311.17	303.66	38.72	49.02	52.49	46.55	32.02
F2	261.77	358.12	319.88	318.98	307.54	Y×D	Y×G	F×D	F×G	D×G
F3	262.04	363.49	317.37	319.09	309.51	38.92	28.47	49.54	44.47	47.45

Table 7: The influence of different conditions on shelling percentage (%) during the growing seasons 2008 to 2010; H1-H6-maize hybrids; F1-$N_{150}P_{120}K_{80}$; F2-$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1}); F3-$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1})+manure (25 t ha^{-1}); D1-54,900 plants ha^{-1}; D2-59,500 plants ha^{-1}

Heights	2008	2009	2010	Cont.	F1	F2	F3	D1	D2	Aver.
H1	77.65	84.15	83.97	81.37	81.04	82.45	82.84	81.77	82.07	81.92
H2	80.07	84.47	83.50	81.82	82.64	83.06	83.18	82.42	82.94	82.68
H3	80.14	86.62	84.80	82.98	83.32	84.64	84.47	83.64	84.06	83.85
H4	79.05	84.31	84.88	83.15	81.60	83.34	82.90	82.58	82.91	82.75
H5	77.52	83.28	82.73	80.41	80.62	81.50	82.17	80.98	81.37	81.17
H6	76.81	82.71	82.99	80.99	80.27	81.11	81.43	80.76	81.14	80.95
Aver.	78.54	84.26	83.81	81.79	81.58	82.68	82.83	82.03	82.42	

	2008	2009	2010	Cont.	F1	F2	F3
D1	78.45	84.14	83.48	81.67	81.21	82.61	82.62
D2	78.69	84.41	84.15	81.90	81.96	82.75	83.05

	2008	2009	2010	D1	D2	LSD 0.05 Year	Fertil.	Density	Genot.	Y×F
Cont.	78.47	83.44	83.45	81.67	81.90					
F1	76.50	84.42	83.82	81.21	81.96	1.57	3.01	3.03	2.91	1.38
F2	79.47	84.58	84.00	82.61	82.75	Y×D	Y×G	F×D	F×G	D×G
F3	79.85	84.66	84.00	82.62	83.05	1.57	1.21	3.05	3.04	2.97

Table 8: The influence of different conditions on grain yield (t ha^{-1}) during the growing seasons 2008 to 2010; H1-H6-maize hybrids; F1-$N_{150}P_{120}K_{80}$; F2-$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1}); F3-$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1})+manure (25 t ha^{-1}); D1-54,900 plants ha^{-1}; D2-59,500 plants ha^{-1}

Heights	2008	2009	2010	Cont.	F1	F2	F3	D1	D2	Aver.
H1	7.80	11.84	8.54	6.93	9.59	10.41	10.65	9.00	9.79	9.39
H2	7.67	10.89	8.13	5.97	9.66	10.07	9.88	8.60	9.19	8.90
H3	7.30	11.40	9.05	7.04	9.25	10.49	10.21	8.95	9.54	9.25
H4	7.05	11.30	8.18	6.71	8.95	9.68	10.04	8.74	8.95	8.85
H5	7.49	11.70	8.50	6.64	9.83	9.84	10.62	9.14	9.32	9.23
H6	7.54	11.54	8.23	6.69	9.78	10.36	10.33	9.07	9.51	9.29
Aver.	7.48	11.45	8.44	6.66	9.51	10.14	10.29	8.92	9.39	

	2008	2009	2010	Cont.	F1	F2	F3
D1	7.33	11.24	8.18	6.32	9.20	10.15	10.00
D2	7.69	11.71	8.75	7.01	9.82	10.13	10.58

	2008	2009	2010	D1	D2	LSD 0.05 Year	Fertil.	Density	Genot.	Y×F
Cont.	7.20	8.61	4.18	6.32	7.01					
F1	6.85	12.23	9.45	9.20	9.82	1.90	2.09	2.54	2.57	0.72
F2	7.87	12.48	10.08	10.15	10.13	Y×D	Y×G	F×D	F×G	D×G
F3	8.13	12.59	10.15	10.00	10.58	1.91	1.97	2.10	2.23	2.62

(R^2 = 0.361; Fig. 1) while the other factors did not show their impact. In F1 variant dependence between grain yield and 1000 grain weight was higher (R^2 = 0.579; Fig. 1) with also positive and significant impact of plant height to tassel (R^2 = 0.748), height to ear (R^2 = 0.444) and shelling percentage (R^2 = 0.617). The same trend was observed at

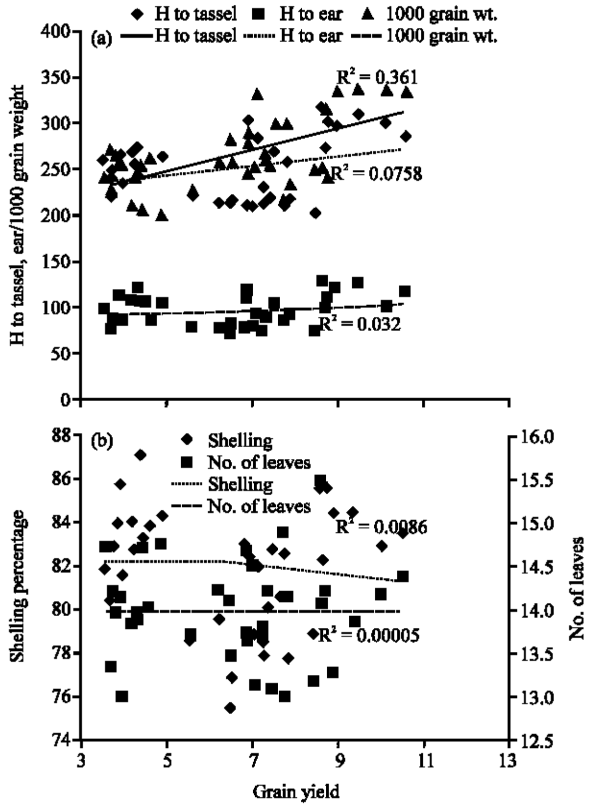

Fig. 1: Regression interdependence between grain yield, a) height to tassel, height to ear, 1000 grains weight and b) shelling percentage in control

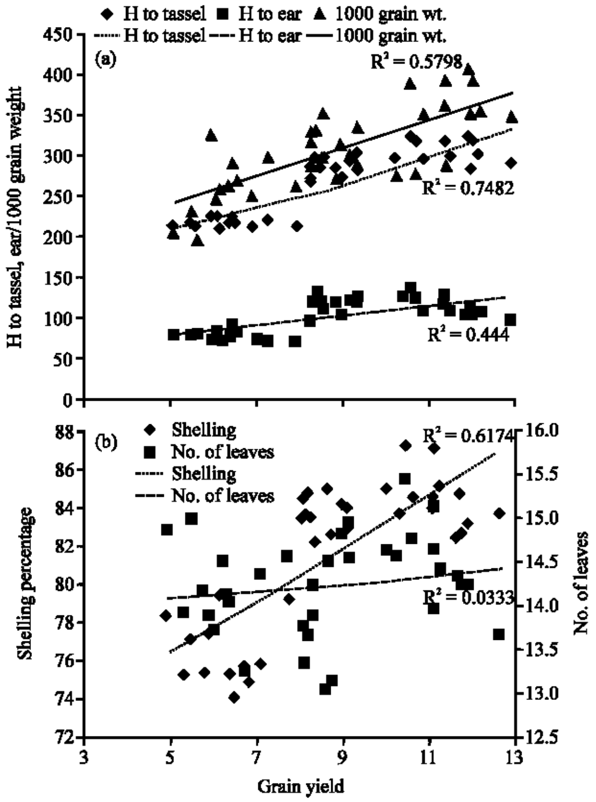

Fig. 2: Regression interdependence between grain yield, a) height to tassel, height to ear, 1000 grains weight and b) shelling percentage in fertilization regime F1 ($N_{150}P_{120}K_{80}$)

F2 and F3 variants with significant and positive dependence between grain yield and 1000 grain weight ($R^2 = 0.603$ for F2, Fig. 2; $R^2 = 0.561$ for F3, Fig. 3), plant height to tassel ($R^2 = 0.697$ for F2, Fig. 3; $R^2 = 0.525$ for F3, Fig. 4), height to ear ($R^2 = 0.309$ for F2, Fig. 3; $R^2 = 0.214$ for F3, Fig. 4) and shelling percentage ($R^2 = 0.591$ for F2, Fig. 3; $R^2 = 0.338$ for F3, Fig. 4).

According to results presented in Table 9, plant height to tassel and ear decreased with decreasing trend of meteorological favourability: For 147.53 and 64.87 cm, respectively as subtraction between favourable and unfavourable conditions. Moreover, the difference between examined plant densities is the highest in favourable conditions, giving advantage to 59,500 plants ha^{-1}, compared to 54,900 plants ha^{-1} (difference is 14.89 cm for height to tassel and 10.73 cm for height to ear). In unfavourable conditions this difference was reduced to 1.36 for height to tassel and 2.69 for height to ear. Fertilization treatments showed greater impact to plant height to tassel and ear and increased them in comparison with control but with lesser difference between fertilizing variants in favourable conditions. However, under unfavourable conditions F3 variant ascended height to ear (15.13 at 54,900 and 7.33 at 59,500 plants ha^{-1}). When number of leaves was considered there were minor variations in values between plant densities and applied fertilization treatments (±1) while the number was reduced with decrease in favourability of present conditions (3.85 on average). Fertilization showed high impact on increase of 1000 grain weight, particularly under favourable conditions where the average difference between control and F3 was 65.19 g while under unfavourable conditions it was 14.17 g. Furthermore, 1000 grain weight decreased with decrease in favourability with minor differences between plant densities. Shelling percentage varied slightly among densities and fertilization treatments under favourable conditions (≤1%) while under unfavourable conditions F3 showed the highest impact at density of 59,500 plants ha^{-1}, increasing it up to 3.58%, compared with control. Grain yield and variations in grain yield between fertilization variants and densities had decreasing trend, also by decrease in conditions' favourability. It is interesting that higher grain yields were obtained at control, F1 and F2 at 59,500 plants ha^{-1} while in F3 the highest yield was at

54,900 plants ha^{-1} at all three favourability levels. The highest expected value of grain yield was obtained in F2 variant at both densities. Positive effects of liming were reflected at first on increase of pH values, particularly pH

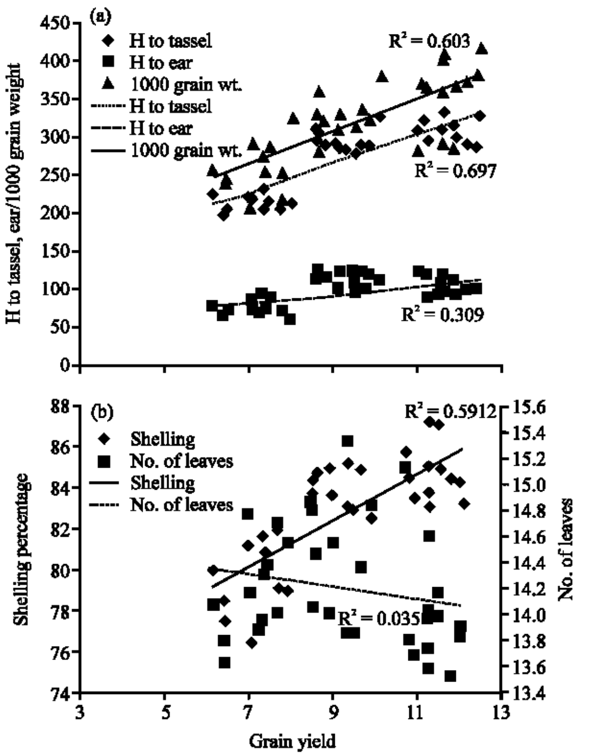

Fig. 3: Regression interdependence between grain yield, a) height to tassel, height to ear, 1000 grains weight and b) shelling percentage in fertilization regime F2 ($N_{150}P_{120}K_{80}$+lime (5 t ha^{-1}))

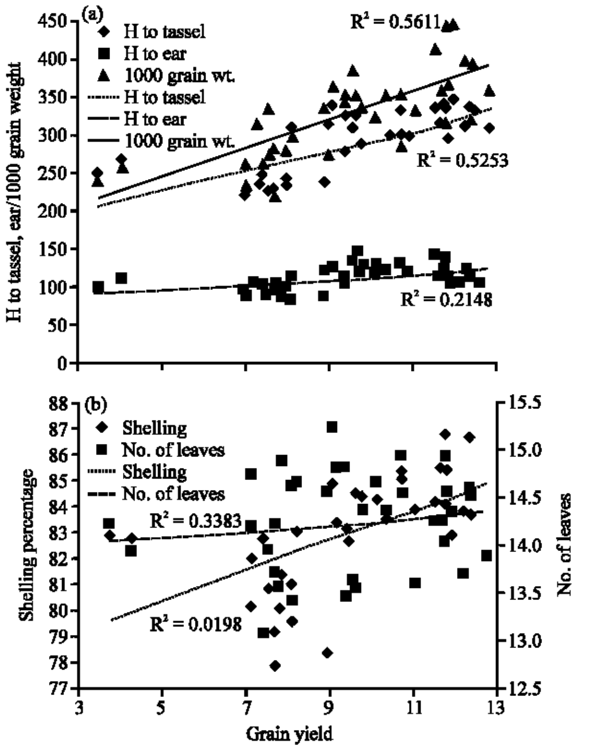

Fig. 4: Regression interdependence between grain yield, a) height to tassel, height to ear, 1000 grains weight and b) shelling percentage in fertilization regime F3 ($N_{150}P_{120}K_{80}$+lime (5 t ha^{-1})+manure (25 t ha^{-1}))

Table 9: Prediction of maize height to tassel, height to ear, number of leaves, 1000 grains weight, shelling percentage and grain yield in different meteorological conditions (favourable, moderate and unfavourable), influenced by different densities and fertilization regimes: (F1-$N_{150}P_{120}K_{80}$; F2 -$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1}); F3-$N_{150}P_{120}K_{80}$+lime (5 t ha^{-1})+manure (25 t ha^{-1})) according to Weibull analysis

	54,900 plants ha^{-1}				59,500 plants ha^{-1}			
Traits	Contr.	F1	F2	F3	Contr.	F1	F2	F3
Favorable conditions								
Height to tassel (cm)	293.08	324.41	329.39	328.22	307.96	326.63	332.29	331.33
Height to ear (cm)	113.07	129.75	128.21	123.61	123.79	132.72	132.90	133.22
No. of leaves	14.87	15.10	15.15	15.16	14.99	15.33	15.12	15.39
1000 grains weight	313.61	383.21	391.42	393.38	324.37	368.65	369.63	374.98
Shelling percentage	84.91	86.28	86.07	85.60	85.84	86.79	86.07	86.07
Grain yield (t/ha)	9.05	9.05	12.93	12.65	9.95	9.95	12.82	9.23
Moderate conditions								
Height to tassel (cm)	251.09	272.77	277.01	274.92	261.50	273.40	275.37	278.58
Height to ear (cm)	93.65	104.36	108.13	106.64	101.72	104.18	107.16	110.96
No. of leaves	13.91	14.34	14.30	14.30	14.21	14.33	14.28	14.45
1000 grains weight	268.69	314.94	322.87	322.96	269.97	306.61	310.60	312.51
Shelling percentage	82.03	81.74	83.02	82.97	82.29	82.46	83.11	83.37
Grain yield (t/ha)	6.31	6.31	10.25	10.10	6.99	6.99	10.21	9.97
Unfavorable conditions								
Height to tassel (cm)	145.55	148.01	150.39	147.15	146.91	146.00	141.94	151.15
Height to ear (cm)	48.20	48.41	59.29	63.33	50.89	44.35	50.17	58.22
No. of leaves	11.02	11.96	11.66	11.64	11.80	11.31	11.67	11.54
1000 grains weight	155.78	157.68	163.76	161.07	141.30	160.09	168.16	164.35
Shelling percentage	72.64	67.58	73.10	74.33	70.92	68.86	73.48	74.50
Grain yield (t/ha)	1.77	1.77	4.52	4.56	2.01	2.01	4.58	4.24

in KCl (F2 and F3, Table 2), similar to results obtained by Loncaric *et al*. (2006). Beside its positive effect on pH increase, liming also increased available P and exchangeable Al^{3+} decrease (Kisinyo *et al*., 2013), similar to the results. What is more important, pH in KCl was in the highest degree increased in F3 (variant with applied FYM) owing to the high increment in the concentration of base forming cations: Ca, Mg and K from FYM (Hue, 1992). FYM also showed positive effect on humus and P increase in the same fertilization variant, together with decrease of exchangeable Al^{3+} (over two times). It complies with results of Rojas *et al*. (2001) who gained the highest values of available P when they combined lime, phosphorus mineral fertilizer and FYM. On the other hand, decrease in K content during experiment in F2 and mainly in F3 except in F1 could be connected with increased maize growth and yield (Table 3 and 8) what was also obtained by Rastija *et al*. (2012).

Plant height and height of the main ear are important variety traits and are in close correlation with each other. Meteorological factors showed significant impact on maize growth by decreasing plant height to tassel and to ear in 2008 (Table 3 and 4) what was also reflected on the yielding potential with the lover values of 1000 grain weight, shelling percentage and grain yield (Table 6-8) at the same year. Genotype also indicated significant effect on height to ear, number of leaves as well as yielding parameters, accentuating H3 as hybrid with the highest number of leaves and shelling percentage (Table 5 and 7) but with the lowest 1000 grain weight (Table 6) and H4 as hybrid with the highest height to tassel and ear (Table 3 and 4) what could be attributed in some extent to higher heterosis effect for these traits (Gyenes-Hegyi *et al*., 2002). Begna *et al*. (2000) ascertained positive correlation between size of the plant (height, weight, etc.) and length of the vegetative phase and the dry matter yield: Taller hybrids produce higher dry matter yield. However, translocation rate of assimilates to the kernels of shorter hybrids was found to be greater than of taller ones. From that point, maize height, ear height and grain yield are traits that highly depend on crop density (Shafi *et al*., 2012) and it was expectable that noted traits could have higher values at 59,500 plant ha^{-1} than at 54,900 plant ha^{-1} but it was under the limit of significance. The number of leaves (Allen *et al*., 1973) and grain yield (McKee *et al*., 1974) are significantly correlated with plant height. From this point H5 and H6, hybrids with the lowest height to ear (Table 4) gained the highest grain yield (Table 8). Other factors such as fertilization regimes and density show lower impact on maize height to tassel and to ear, number of leaves and shelling percentage (Table 3, 4, 5 and 7).

Results of Uzoho *et al*. (2010) and Hassan *et al*. (2007) pointed positive effects of liming increased P inputs and FYM on maize height while in this experiments such results were obtained in 2009 and 2010, years with favorable meteorological conditions for maize production (Table 1) as well as at H4 as the highest hybrid (Table 4) and H3 as hybrid with the highest number of leaves (Table 5), mainly at F2 and F3. Beside reduction of maize height to tassel and to ear, favorable meteorological conditions highlighted 59,500 plants ha^{-1} as density that could provide maize height (Table 9) while unfavourable conditions suppress maize growth (height to tassel and ear and number of leaves) together with differences between applied measures (fertilization and densities).

The 1000 grain weight and shelling percentage behaved inversely proportional: H6 had the highest and H3 the lowest 1000 grain weight (Table 6) as well as H3 had the highest and H6 the lowest shelling percentage (Table 7) in 2009 at all three fertilization variants. Moreover, meteorological conditions stressed F3 as fertilization variant with the highest values of 1000 grain weight and shelling percentage (Table 9) irrespective of favourability of meteorological conditions. Difference between applied treatments (fertilization and plant density) in 1000 grain weight were lowered under unfavourable conditions while differences in shelling percentage were raised with unfavorability, giving advantage to F3 variant and density of 59,500 plants ha^{-1}. Beside year and genotype, the highest impact on two observed traits showed F2 and F3 fertilization variants which include lime, similarly to results of Kisic *et al*. (2002) and Castro and Crusciol (2013). The same researchers also indicated positive influence of liming on grain yield increase what was also noticed at F2 and F3 variants. Kisic *et al*. (2002) gained higher maize yields with NPK fertilizers and NPK+lime combination than it was in combination NPK+lime+FYM what could be explanation for slight difference between F2 and F3 fertilization variant (for 34 and 35% higher average grain yield, respectively compared to control). Growing season also showed significant impact on grain yield with the highest results achieved in 2009 (Table 1) as year with favourable conditions (about 35% higher, compared to 2008; Table 8).

Opposite to Rojas *et al*. (2001) who achieved the highest maize yields with genotypes sensitive to acidity under the positive influence of lime and its combination with mineral fertilizers and FYM, in this study genotype indicated lesser impact (Table 8). According to Allen *et al*. (1973) and McKee *et al*. (1974), number of leaves and grain yield are significantly correlated with plant height but it could be expressed in different degree under the influence of cropping conditions and applied measures.

Positive impact of liming as cropping measure as well as its combination in different fertilization variants as it was in F3 variant was reflected on yield increase as a result of increased positive dependence between growth and yielding parameters (Fig. 1-3). It is also interesting that dependence between height to tassel, height to ear, number of leaves and grin yield was smaller in some extent in F3 variant (lower regression coefficients; Fig. 4) than it was in F1 and F2 variants (higher regression coefficients; Fig. 2 and 3). From this point, Hassan *et al*. (2007) and Uzoho *et al*. (2010) emphasized increase of maize height, height to ear as well as yielding parameters by the mutual effect of lime and mineral fertilizers or manure while Kisic *et al*. (2002) also achieved yield decrease but in smaller extent by combination of lime, mineral fertilizers and manure together. Such results could be purported by the highest expected value of grain yield (Table 9) obtained in F2 variant under unfavourable meteorological conditions as well as results of Mugendi *et al*. (2010) who under poor conditions gained lower maize yields with combination of mineral fertilizers and manure than in was with single manure.

CONCLUSION

Positive effects of liming were reflected at first on increase of pH values, particularly pH in KCl. Combination of lime and NPK fertilizer and FYM showed positive impact on humus and available P increase together with decrease of exchangeable H^+ and Al^{3+}. Meteorological factors are the main reason for significant variations of maize growth and yielding parameters. Examined hybrids also responded differently to applied treatments: H4 had the highest growth potential (height to tassel and ear) but the lowest value of achieved average yield which could be, after further examination used for forage production. Differences between examined hybrids in grain yield were insignificant. Fertilization impact highlighted a priori treatments which include lime (F2 and F3) as measures which increase growth and yielding parameters and their interdependence having as a consequence high yield. Favourable meteorological conditions increased variation between applied treatments (fertilization variants and plant density) in maize height, number of leaves and 1000 grain weight giving advantage to F3 variant while unfavourable conditions suppressed such variation, together with nominal values of examined parameters. Moreover, higher yield potential obtained in F2 variant under unfavourable conditions could be the evidence that FYM incorporation could be inefficient measure (F3 variant) to obtain high grain yields, irrespective to positive FYM impact to soil and growth parameters. On the other hand, FYM application could be reasonable measure for forage maize, according to higher values of maize height and number of leaves, particularly achieved under moderate conditions what must be supported by further research.

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