Influence of organic and mineral fertilizers on agronomic traits of potato

Utjecaj gnojidbe organskim i mineralnim gnojivima na agronomska svojstva krumpira

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INFLUENCE OF ORGANIC AND MINERAL FERTILIZERS ON AGRONOMIC TRAITS OF POTATO

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SUMMARY

The aim of research conducted on the experimental field of Faculty of Agriculture in Zagreb during 2012 and 2013 was to determine the influence of organic and mineral fertilizers on the agronomic properties of potato. The research comprised two organic fertilizers, Biorex and Italpollina, mineral fertilizers and a combination of mineral and organic fertilizers. The highest yield of tuber and dry matter was achieved when the fertilization was conducted using solely mineral fertilizers or a combination of mineral and organic fertilizers. Fraction 35-55 mm had the highest share in the total tuber yield. Fertilization with mineral fertilizers and with the combination of mineral and organic fertilizers had a positive effect on the share of fractions >55 mm particularly in favourable 2012 year.

Key-words: potato, agronomic traits, mineral and organic fertilizers

INTRODUCTION

Potato is one of the most important nutritional plants in the world. Its cultivation is limited by environmental conditions, and balanced fertilization with both mineral and organic fertilizers is necessary for its successful production. In order to achieve high yield of potato, a large quantity of nutrients is needed (Harris, 1992; Marschner et al., 1996; Haase et al., 2007). Kołodziejczyk (2014) states that the presence of nitrogen of up to 180 kg/ha has a positive influence on potato yield, but also on a market-sized tuber. However, the usage of nitrogen in large quantities is not acceptable from agronomical, ecological or economic standpoint (Poljak, 2007). Although an increased quantity of nitrogen had a positive influence on potato yield, dry matter content and protein content in some potato varieties, Fontes et al. (2010) state that the efficiency of nitrogen usage declines as its quantity increases. The same authors claim that the profitability of nitrogen usage depends on the potato variety and the price of nitrogen fertilizer. Poljak et al. (2011) state that the increase in nitrogen quantity reduces its absorption efficiency. However, as nitrogen quantity increases up to 150 kg/ha, the yield of tuber increases as well, while the share of small tuber (<35 mm) decreases.

Haase et al. (2007) state that the yield of dry matter, the share of tuber fraction 40-65 mm and the share of tuber larger than 55 mm depend on fertilization, variety and vegetation year.

Since the application of farmyard manure fertilizer is expensive and limited to areas with livestock production, the use of concentrated organic fertilizer contributes to the increase in tuber yield and soil fertility. However, nutrients in mineral fertilizers are more accessible and efficient than those in organic fertilizers (Bagdoniene et al., 1998). The combination of mineral fertilizers and farmyard manure has a positive influence on potato tuber yield, but the content of dry matter and starch is higher when fertilization is carried out solely with mineral fertilizers (Baniuniene i Zekaite, 2008). Haase et al. (2007) obtained the highest potato tuber yield when using a combination of mineral potassium and organic nitrogen. Cattle manure did not have a consistent effect on the yield of potato tuber during different vegetation seasons which makes it an unreliable source of nitrogen for plants.

The aim of this research was to determine the influence of organic and mineral fertilizers on the agronomic properties of potato.

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MATERIAL AND METHODS

The research was carried out on the experimental field of Faculty of Agriculture in Zagreb during 2012 and 2013. The research comprised two organic fertilizers, Biorex and Italpollina, mineral fertilizers and a combination of mineral and organic fertilizers. Biorex is processed manure that contains 2.8% N, 3% P_2O_5, 2% K_2O and 65% organic matter. Italpollina is dehydrated poultry manure that contains 4% N, 4% P_2O_5 and 4% K_2O in the organic matter. Mineral fertilizers used were NPK 7:20:30, KAN 27% N and 60% potassium salt.

Fertilization variants were the following:

1. Control – no fertilizer
2. Biorex – 1.5 t/ha
3. Italpollina -1.5 t/ha
4. NPK 7:20:30 + KAN (total: 160 kg/ha N, 140 kg/ha P_2O_5 and 210 kg/ha K_2O)
5. Biorex 1.5 t/ha + NPK 7:20:30 + KAN 27% N lessened for nutrients added with Biorex (total: 160 kg/ha N, 140 kg/ha P_2O_5 and 210 kg/ha K_2O)
6. Italpollina 1.5 t/ha + NPK 7:20:30 + KAN 27% N lessened for nutrients added with Biorex (total: 160 kg/ha N, 140 kg/ha P_2O_5 and 210 kg/ha K_2O)

In the initial tillage 80 kg/ha N, 140 kg/ha P_2O_5 and 210 kg/ha K_2O (variants 4, 5 and 6) were used. Before the potato was planted, Biorex and Italpollina were applied in the quantity of 1.5 t/ha (variants 2, 3, 5, and 6) and nitrogen in the quantity of 40 kg/ha (variants 4, 5 and 6). During ridging of the potato, 40 kg/ha of nitrogen were applied in the form of KAN 27% N (variants 4, 5 and 6).

Medium early potato variety Red lady (C2 seed reproduction) was used in the research. The experiment was set up in random block design in five repetitions. Plot size was 15.4 m^2 (4 rows x 0.70 m distance between rows x 5.5 m^2 row length). Sugar beet was grown as forecrop. Planting was conducted on March 23rd 2012 and April 16th 2013. The distance within the row was 30 cm, while the distance between the rows was 70 cm. Ridging and topdressing were conducted on May 24th 2012 and May 24th 2013. Protection from weeds was conducted using Sencor WG 70 herbicide (active ingredient metribuzin 700 g/kg) in the quantity of 1 kg/ha and Stomp 330 E herbicide (active ingredient pendimethalin 330 g/l) in the quantity of 4 l/ha. During vegetation fungicides Ridomil Gold MZ 68 WP (active ingredient metalaxil-M 40 g/kg and mancozeb 640 g/kg) in the quantity of 2.5 kg/ha and Quadris (active ingredient azoxystrobin 250 g/l) in the quantity of 1 l/ha were used for suppression of blight in both years of research. Suppression of Colorado potato beetle was conducted using insecticides Actara 25 WG (active ingredient thiamethoxam 250 g/kg) in the quantity of 80 g/ha, Rotor 1.25 EC (active ingredient deltamethrin 1.25%) in the quantity of 0.6 l/ha and Mospilan 20 SG (active ingredient acetamiprid 200 g/kg) in the quantity of 0.08 kg/ha. Potato was harvested on August 23rd 2012 and August 23rd 2013.

The studies were conducted on eutric-brown soil, neutral reaction (pH in KCl 7.12), poorly supplied with humus (2.2%), well supplied with nitrogen (0.125%), phosphorus and potassium (32.1 mg P_2O_5/100 g of soil and 25.3 mg K_2O /100 g of soil, respectively).

Tuber number and tuber weight per plant were determined on the sample of 10 plants per plot before harvest. Yield, tuber number and tuber weight per fractions <35 mm, 35-55 mm and >55 mm were determined after harvest. Dry matter content in potato tuber was determined by drying the tuber sample, first at the temperature of 70^0C and then at the temperature of 105^0C until constant mass was reached.

The obtained data was analysed with the program MSTAT-C (Michigan State University, 1990).

RESULTS AND DISCUSSION

In 2012 the highest yield of tuber was achieved with mineral fertilizers (51.55 t/ha), while in 2013 the highest yield was achieved with a combination of mineral fertilizers and Biorex (37.21 t/ha), Tables 1 and 2. The difference in potato tuber yield between varieties fertilized with mineral fertilizers and a combination of mineral and organic fertilizers was not statistically significant. In 2012 the lowest tuber yield was achieved by control variant (32.10 t/ha). In 2013, although the control variant achieved the lowest yield (26.56 t/ha), the difference in yield between this variant and the variant fertilized with Biorex and Italpollina was not statistically significant. There was no significant difference in the tuber yield using Biorex and Italpolline. However, since the concentration of nutrients in Biorex is lower, it is to be assumed that with a higher amount of Biorex, the difference in yield would be more pronounced.

In 2013 the yield of potato tuber was lower compared to 2012 due to unfavourable weather conditions during vegetation. June and July of 2013 had less precipitation than average, while the mean monthly air temperatures were higher compared to 2012 and long-term average (tables 3 and 4). Márton (2004) states that potato yield is heavily influenced by the interaction between fertilization and quantity and distribution of precipitations. Palmer (2013) mentions weather conditions and preceding crop as factors which have profound effect on tuber yield and quality in organic production. The author also states that nitrogen supply is the main limiting factor of potato yield in ecological systems of production. László (2009) claims that the influence of climate anomalies on potato yield depends on their time of occurrence and length.

In both years of research, variants with different fertilizers showed no difference in dry matter content (Tables 1 and 2). In 2012, dry matter content varied between 26.4 and 27.7%, while in 2013 it varied between 22.3 and 23.9%. Poljak et al. (2007) also state that fertilization with nitrogen did not significantly influence dry matter content in potato tuber.

Table 1. Tuber yield, dry matter content, dry matter yield, tuber number and weight per plant in 2012

Tablica 1. Prinos gomolja krumpira, sadržaj suhe tvari, prinos suhe tvari gomolja, broj i masa gomolja po biljci u 2012. godini

Treatment *Varijanta*	Tuber yield (t/ha) *Prinos gomolja (t/ha)*	Dry matter (%) *Suha tvar (%)*	Dry matter yield (t/ha) *Prinos suhe tvari (t/ha)*	Tuber number per plant *Broj gomolja po biljci*	Tuber weight per plant (g) *Masa gomolja po biljci (g)*
Control	32.10 c	26.4	8.45 c	12.5	816 c
Biorex	42.71 b	27.7	11.80 b	13.7	1094 ab
Italpollina	41.29 b	26.6	11.29 b	14.5	1061 b
Mineral fertilizers	51.55 a	26.7	13.73 a	14.9	1279 a
Mineral fertilizers + Biorex	49.14 a	27.1	13.33 a	13.6	1257 a
Mineral fertilizers + Italpollina	49.59 a	27.1	13.41 a	13.4	1237 ab

Values followed by the same letter within the column are not significantly different at the 5% level of probability

Table 2. Tuber yield, dry matter content, dry matter yield, tuber number and weight per plant in 2013

Tablica 2. Prinos gomolja krumpira, sadržaj suhe tvari, prinos suhe tvari gomolja, broj i masa gomolja po biljci u 2013. godini

Treatment *Varijanta*	Tuber yield (t/ha) *Prinos gomolja (t/ha)*	Dry matter (%) *Suha tvar (%)*	Dry matter yield (t/ha) *Prinos suhe tvari (t/ha)*	Tuber number per plant *Broj gomolja po biljci*	Tuber weight per plant (g) *Masa gomolja po biljci (g)*
Control	26.56 b	23.8	6.32 b	9.3	570 d
Biorex	27.27 b	23.4	6.40 b	10.6	704 bc
Italpollina	29.69 b	22.3	6.63 b	10.0	675 cd
Mineral fertilizers	36.89 a	23.9	8.84 a	10.6	788 ab
Mineral fertilizers + Biorex	37.21 a	23.7	8.83 a	11.9	887 a
Mineral fertilizers + Italpollina	36.14 a	23.5	8.48 a	11.0	824 a

Values followed by the same letter within the column are not significantly different at the 5% level of probability

The highest dry matter yield in 2012 was achieved through fertilization with only mineral fertilizers (13.73 t/ha) and a combination of mineral fertilizers, Biorex (13.33 t/ha) and Italpollina (13.41 t/ha), Table 1. Conversely, Baniuniene and Zekaite (2008) achieved higher starch and dry matter content with only mineral fertilizers. Fontes et al. (2010) also mention mineral nitrogen as a positive factor on dry matter yield in potato tuber. In 2013, the highest dry matter yield was achieved by the same variants as in 2012, but due to lower tuber yield it varied between 8.48 and 8.84 t/ha (Table 2). Unfavourable weather conditions, more specifically the lack of precipitation in June, July and August and high mean air temperatures during those months, negatively influenced dry matter content in potato tuber (Tables 3 and 4). Other researchers also state that unfavourable weather conditions during vegetation negatively affect yield and quality of potato (Márton, 2004; Baniuniene and Zekaite, 2008).

Table 3. Total month precipitation (mm) during the 2012 and 2013 growing seasons and long-term average (1981-2010) in Zagreb-Maksimir

Tablica 3. Ukupna količina oborina (mm) tijekom vegetacije 2012. i 2013. godine i višegodišnji prosjek (1981.-2010.), Zagreb-Maksimir

Month *Mjesec*	Growing season *Vegetacijska sezona*		Long-term average *Višegodišnji prosjek*
	2012	2013	1981-2010
March	4.5	121.7	54.1
April	51.3	56.1	59.5
May	81.8	94.0	68.6
June	127.9	48.7	97.4
July	56.3	33.2	71.4
August	9.8	145.2	96.2
Total	331.6	353.7* (498,9)	447.2

*Total quantity of precipitation until harvest

Table 4. Mean monthly air temperature (^{0}C) during the 2012 and 2013 growing seasons and long-term average (1981-2010) in Zagreb-Maksimir

Tablica 4. Srednje mjesečne temperature (^{0}C) tijekom vegetacije 2012. i 2013. godine i višegodišnji prosjek (1981.-2010.), Zagreb-Maksimir

Month *Mjesec*	Growing season *Vegetacijska sezona*		Long-term average *Višegodišnji prosjek*
	2012	2013	1981-2010
March	9.4	4.8	6.8
April	12.5	13.0	11.4
May	16.7	16.4	16.5
June	22.0	20.0	19.6
July	24.2	23.3	21.5
August	24.0	22.5	20.8
Average	18.1	16.7	16.1

In 2012, the highest number of tuber per plant was achieved with mineral fertilizers (14.9), but compared to the other variants, the difference was not statistically significant (Table 1). In 2013, the number of tuber per plant varied from 9.3 in control variant to 11.9 in the combination of mineral fertilizers and Biorex, but the difference was also not statistically significant (Table 2).

In 2012, the highest tuber weight per plant was achieved with mineral fertilizers and a combination of mineral and organic fertilizers, but the obtained number did not significantly differ from when the fertilization was conducted only with Biorex (Table 1). In 2013, significant differences in tuber weight per plant ($p<0.05$) were achieved between variants with mineral and a combination of mineral and organic fertilizers compared to control variant and the variant with only organic fertilizers (Table 2). In 2013, lower tuber weight per plant was achieved compared to 2012, which negatively impacted the total potato yield. In 2012, tuber weight per plant varied from 816 g in control variant to 1279 g in the variant with mineral fertilizers, while in 2013 tuber weight per plant varied from 570 g in control variant to 887 g in the variant with a combination of mineral fertilizers and Biorex.

In 2012, the lowest share of the smallest fraction was achieved with a combination of mineral fertilizers and Italpollina, but it did not significantly differ compared to the combination of mineral fertilizers and Biorex, only mineral fertilizers or only Biorex (table 5). In 2013, the lowest share of the smallest fraction was also achieved with the combination of mineral and organic fertilizers and only mineral fertilizers (Table 6). The highest share of large tuber (>55mm) was achieved with a combination of mineral and organic fertilizers and with only mineral fertilizers (Tables 5 and 6). The share of the largest fraction of tuber in 2012 varied from 4.28% in control variant to 18.28% in the variant with mineral fertilizers and Biorex. Due to unfavourable weather conditions in 2013, the share of the largest tuber was lower compared to the previous year, while the share of 35-55 mm fraction was higher. Other researchers also state that the structure of potato yield is dependent on the environment (MacKerron et al., 1988; Sawicka, 2007).

Table 5. Effect of mineral and organic fertilizers on relative tuber size share in total tuber number in 2012

Tablica 5. Utjecaj mineralnih i organskih gnojiva na udio frakcija u ukupnome broju gomolja u 2012. godini

Treatment *Varijanta*	Relative tuber size share in total tuber number (%) *Udio frakcija u ukupnom broju gomolja (%)*		
	<35 mm	35-55 mm	> 55 mm
Control	35.83 a	59.88 a	4.28 d
Biorex	30.58 ab	59.20 ab	10.22 bc
Italpollina	38.40 a	54.03 bc	7.56 cd
Mineral fertilizers	30.62 ab	53.62 bc	15.77 ab
Mineral fertilizers + Biorex	30.90 ab	53.31 c	18.28 a
Mineral fertilizers + Italpollina	25.54 b	59.91 a	14.56 ab

Values followed by the same letter within the column are not significantly different at the 5% level of probability

Table 6. Effect of mineral and organic fertilizers on relative tuber size share in total tuber number in 2013

Tablica 6. Utjecaj mineralnih i organskih gnojiva na udio frakcija u ukupnome broju gomolja u 2013. godini

Treatment *Varijanta*	Relative tuber size share in total tuber number (%) *Udio frakcija u ukupnom broju gomolja (%)*		
	< 35 mm	35-55 mm	> 55 mm
Control	38.03 a	59.87	2.11
Biorex	34.38 ab	61.49	4.14
Italpollina	34.16 ab	62.05	4.05
Mineral fertilizers	28.82 bc	65.29	5.90
Mineral fertilizers + Biorex	27.27 c	68.21	5.25
Mineral fertilizers + Italpollina	26.73 c	68.50	4.78

Values followed by the same letter within the column are not significantly different at the 5% level of probability

Fraction of 35-55 mm had the highest share in total potato tuber yield in both years of research (Tables 7 and 8). In 2012, the highest share of this fraction was obtained in control variant, the variant with only organic fertilizers and the variant with a combination of mineral fertilizers and Italpollina. In 2013, the highest share of this fraction was achieved in the variant with a combination of mineral and organic fertilizers.

Table 7. Effect of mineral and organic fertilizers on relative tuber size distribution in total tuber yield in 2012

Tablica 7. Utjecaj mineralnih i organskih gnojiva na udio frakcija u ukupnom prinosu gomolja u 2012. godini

Treatment *Varijanta*	Relative tuber size share in total tuber yield (%) *Udio frakcija u ukupnom prinosu gomolja (%)*		
	<35 mm	35-55 mm	> 55 mm
Control	9.51 a	79.03 a	11.46 d
Biorex	7.65 abc	68.01 b	24.34 bc
Italpollina	8.16 ab	71.29 ab	20.55 cd
Mineral fertilizers	6.00 bc	57.49 c	36.51 a
Mineral fertilizers + Biorex	5.71 bc	53.57 c	40.71 a
Mineral fertilizers + Italpollina	4.95 c	61.93 bc	33.12 ab

Values followed by the same letter within the column are not significantly different at the 5% level of probability

Table 8. Effect of mineral and organic fertilizers on relative tuber size distribution in total tuber yield in 2013

Tablica 8. Utjecaj mineralnih i organskih gnojiva na udio frakcija u ukupnom prinosu gomolja u 2013. godini

Treatment *Varijanta*	Relative tuber size share in total tuber yield (%) *Udio frakcija u ukupnom prinosu gomolja (%)*		
	<35 mm	35-55 mm	> 55 mm
Control	12.32 a	81.48	6.20
Biorex	11.49 ab	77.28	11.24
Italpollina	11.47 ab	75.44	13.09
Mineral fertilizers	8.73 bc	74.60	16.67
Mineral fertilizers + Biorex	8.34 c	77.54	14.12
Mineral fertilizers + Italpollina	8.58 c	78.81	12.62

Values followed by the same letter within the column are not significantly different at the 5% level of probability

CONCLUSION

The use of mineral or a combination of mineral and organic fertilizers had a positive influence on tuber yield, dry matter yield and tuber weight per plant. In both years of research, tuber fraction of 35-55 mm comprised the highest share of tuber yield. Fertilization with mineral or a combination of mineral and organic fertilizers had a positive influence on tuber fraction >55 mm, especially in weather-favourable 2012, which resulted in greater tuber yield. Therefore, the use of organic fertilizers in combination with mineral fertilizers is recommended because, apart from the yield increases, they also have a positive effect on soil properties.

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UTJECAJ GNOJIDBE ORGANSKIM I MINERALNIM GNOJIVIMA NA AGRONOMSKA SVOJSTVA KRUMPIRA

SAŽETAK

Cilj istraživanja provedenih na pokušalištu Agronomskoga fakulteta u Zagrebu tijekom 2012. i 2013. godine bio je utvrditi utjecaj gnojidbe organskim i mineralnim gnojivima na agronomska svojstva krumpira. U istraživanju su bila dva organska gnojiva, Biorex i Italpollina, mineralna gnojiva te kombinacija mineralnih i organskih gnojiva. Najveći prinos gomolja i prinos suhe tvari ostvareni su gnojidbom samo mineralnim gnojivima i mineralnim i organskim gnojivima. U ukupnome prinosu gomolja krumpira najveći udio imala je frakcija 35-55 mm. Gnojidba mineralnim gnojivima i kombinacija mineralnih i organskih gnojiva imale su pozitivan učinak na udio frakcije >55 mm, osobito u vremenski povoljnijoj 2012. godini.

Ključne riječi: krumpir, agronomska svojstva, mineralna i organska gnojiva

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