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THE INFLUENCE OF SOIL TYPE AND CLIMATIC CONDITIONS ON THE YIELD AND MORPHOLOGICAL CHARACTERISTICS OF POTATOES

SUMMARY

Soil is the basic substrate, which, with its physical, chemical and biological properties, greatly influences the productivity of cultivated plants. Soil investigations are often reduced to a minimum, and one of the goals of this research is to give importance to the land itself and its influence on both the yield and the quality of cultivated plants.

Research in the open field was carried out in a two-year period (2017-2018) at three locations with different altitudes (550, 90 and 1100 m) and three different types of soil (Eastern Sarajevo - fluvisol soil type, Rogatica - district cambisol soil type, Bijeljina - soil type humofluvisol).

The field research included factors such as soil type (A) and year (B).

The tested soil types differed significantly in terms of chemical, physical and microbiological characteristics and, in combination with climatic factors, significantly influenced the yield and morphological characteristics of potatoes. The yield of potatoes in the open field was significantly influenced by the type of soil and the year. Potatoes grown in the Bijeljina location (humofluvisol) had the highest yields, and the lowest in the Istočno Sarajevo location (fluvisol). Higher yields were achieved in 2018, compared to 2017, which was mostly influenced by the agroecological conditions at the time of the test. The favorable physical, chemical and microbiological properties of the humofluvisol soil in the Bijeljina locality influenced the yield of potato tubers, so the highest yield was achieved in this locality.

Keywords: soil type, climate conditions, tuber yield, morphological characteristics of potatoes

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INTRODUCTION

Potato is a nutritiousvegetable that is regarded as one of the most beneficial crops for reducing hunger, malnutrition and poverty around the world because of its great productivity, as can be seen by its remarkably high harvesting index of over 75% (Wijesinha-Bettoni and Mouille B., 2019). Hence, potato has the potential to significantly contribute to human nutrition as an addition to other staple crops like rice and wheat (Campos and Ortiz, 2020). For food security, understanding the effects of climate change on potato yield is critical. Extreme heat and drought brought on by global climate change pose a significant threat to long-term crop production by reducing plant performance and output. Such a negative influence on agicultural productivity is projected to worsen in the future (Chourasia *et al.,* 2021) due to increasing greenhouse gas emissions which will lead to increased evapotranspiration and drought severity (Dahal *et al*., 2019).

The growth and quality of potatoes are influenced by environmental factors such as temperature, humidity, light, soil type and nutrient content (Khan *et al*., 2011). Potato is a plant with specific and moderate temperature requirements according to many authors. A combined effect of temperature and precipitation is crucial (Borkowska and Grundas, 2007). High temperature can decrease yield due to physiological and biochemical changes occurring in the plant, suchas photosynthesis, respiration and water status. A negative impact of too high temperature can, howewer, be partially reduced by evenly distributed optimum precipitation. Unlike most other plant species for which the soil serves only as a substrate from which they take water and nutrients through the root system, potatoes also form vegetative organs in the soil - tubers, and form other vegetative organs with fruit (berries) above the surface of the soil. As much as 80% of the total mass of the potato is formed in the soil (Lazić *et al*., 1998). Potatoes have great requirements regarding the air regime of the soil. The soil must be sufficiently loose. On compacted soil, the stolons branch and form small tubers, and therefore it is preferable to grow potatoes on soils with a light mechanical composition. As a result of soil compaction, the soil structure deteriorates, which determines the total and differential porosity, and in this connection the water-air, thermal and biological regime of the soil deteriorates. Deterioration of these land regimes adversely affects obtaining high and stable yields of appropriate quality (Nikolić *et al.,* 2003). The aim of this study was to determine the influence of climatic and soil factors on the morphological characteristics and yield parameters of potatoes. Different types of tested soil in combination with variable climatic factors (precipitation and air temperature) will affect the variation of potato yield, as well as the resulting tubers will have different quality and market value.

Productive properties of potatoes are significantly influenced by non-genetic factors, i.e. factors of the external environment, such as soil and climate factors.

MATERIAL AND METHODS

Field experiments were conducted in area Bosna and Herzegovina (Fig.1) in three different localities, which significantly differed from each other in terms of soil types, fertility, altitude (550, 90, 1100 m), and climatic conditions. The research was carried out over two years (2017, 2018) at three locations: in the municipality of Istočna Ilidža - experimental field of the Faculty of Agriculture, soil type fluvisol (Fig.4); in Bijeljina (Fig.2) - on the private estate of the Perković family in the village of Kojčinovac, soil type humofluvisol; and in Rogatica (Fig. 3) - on the property of Solanum produkt in Borike, soil type district cambisol. The medium-to-late Agria potato variety was used as plant material for planting potatoes. Table 1. shows the factors used in this research.

Table 1. Factors of research in the field

No.	Factors	Treatment
1.	Soil type (A)	A_1 – fluvisol, A_2 - humofluvisol, A_3 – district kambisol
2.	Year (B)	B_1 – first year, B_2 – second year

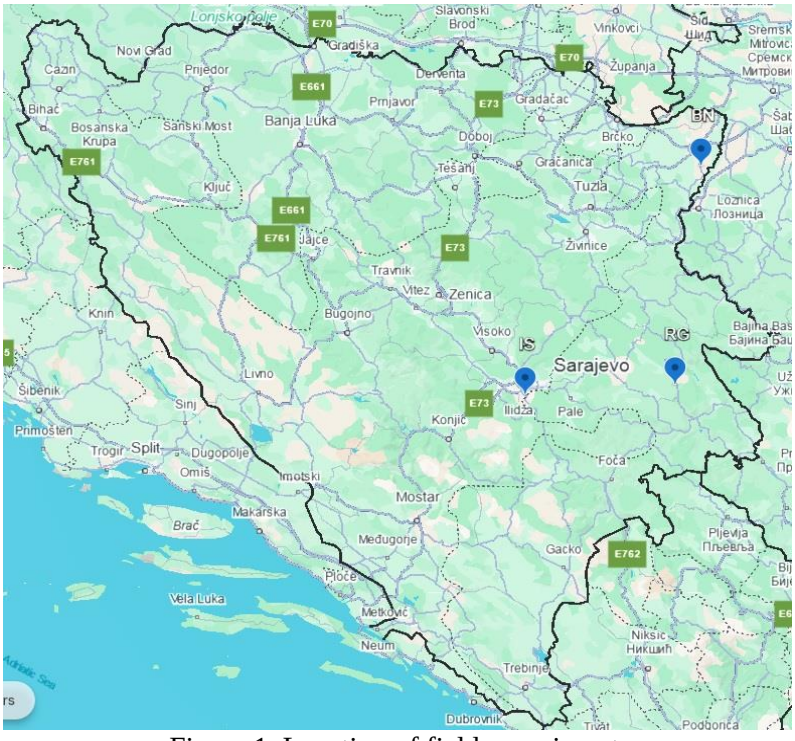

Figure 1. Location of field experiment

Meteorological data on average monthly temperatures and precipitation were taken from the Hydrometeorological Institute of the Republic of Srpska and the Federal Hydrometeorological Institute of Bosnia and Herzegovina, from the measuring stations closest to the locations of the field experiments. From the morphological and productive characteristics of potatoes in the full flowering phase, the following were determined: plant height (cm) (measured from the surface of the land to the top of the upper flower); the number of above-ground shoots and the fresh above-ground mass of the plant (g).

At the end of the vegetation period, the following were analyzed: the number of tubers per house; average tuber mass (g); the yield of potato tubers, which was calculated per hectare (t ha^{-1}) and tuber fraction structure. The number of above-ground shoots and their height (cm) were determined on a sample of twenty houses from each basic plot, and the fresh mass of the plant was determined on a sample of 5 houses. To determine the number of tubers per house, the average weight of the tuber (g), the yield of tubers and the fractional structure of the tubers, samples of twenty houses were taken from each basic plot at the technological maturity of potatoes.

The data obtained from the two-year experiments in the field (AxB) were processed using the method of descriptive statistics. The significance of the differences between the treatments was tested by analysis of variance (ANOVA), and the correlation of the phenomena by correlation-regression analysis. The significance of differences was tested by Fisher's LSD test. Statistical processing of the obtained data was done using the statistical program STATISTICA 10 (StatSoft, Inc. Corporation, Tulsa, OK, USA).

Figure 2. Locality Kojčinovac - Bijeljina (soil type humofluvisol)

Figure 3. Locality Borike - Rogatica (soil type district kambisol)

Figure 4. Locality Kula – Istočno Sarajevo (soil type fluvisol)

RESULTS AND DISCUSSION

Air temperature and precipitation are the meteorological elements that have the greatest influence on the volume of plant production, the height and quality of the yield of cultivated plants. The average annual temperatures in East Sarajevo and its surroundings in 2017 were 11 °C, and in 2018 they were 11.4 °C and were higher than the multi-year average (Table 2), and during the potato growing season, the average monthly temperatures in 2017 in 2018 (17.5 °C) and in 2018

(17.7 °C) were higher than the long-term average (16.2 °C). In 2017, the average monthly temperatures for April, May and September were lower compared to the average temperatures for these months in 2018. The total amount of precipitation for East Sarajevo and its surroundings in 2017 was 937.3 mm, and in 2018 it was 1043.3 mm, which is more than the multi-year average (932 mm). The average annual temperature for Bijeljina and its surroundings in 2017 was 12.9 °C, and in 2018 it was 13.3 °C and were higher than the long-term average of 11.5 °C (Table 2), while ongoing potato vegetation mean monthly temperatures in 2017 (19.83 °C) and 2018 (20.58 °C) were higher than the multi-year average (18.18 °C). In 2017, average monthly temperatures were lower in April, May and September than average temperatures for the same period in 2018. The total amount of precipitation for Bijeljina and its surroundings in 2017 was 678.9 mm, and in 2018 it was 717.6 mm, which is lower than the multi-year average (778.2 mm). The average annual temperature for Rogatica (Borike) in 2017 was 7.9 °C, and in 2018 it was 8.6 °C and were higher than the long-term average of 7.0 °C (Table 2), while potato vegetation mean monthly temperatures in 2017 (16.1 °C) and 2018 (15.66 °C) were higher than the multi-year average (14.46 °C). In 2017, during the potato growing season, the average monthly temperatures were lower than the average temperatures for the same period in 2018 for May and September. The total amount of precipitation in 2017 was 949.9 mm, which is less compared to 2018, in which a total of 974.2 mm of precipitation was recorded and more than the multi-year average (859.0 mm).

Table 2. Average monthly air temperatures (°C) and precipitation (mm) in 2017 and 2018 and multi-year average

Year \ Month			I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Average / sum
E. Sarajevo	2017.	°C	-4,8	5,2	8,5	9,2	15,3	20,3	21,8	22,6	15,5	10,4	5,4	2,2	11,0
		mm	57,9	69,1	43.6	132,4	73,8	55	66,5	38,7	93,2	89,3	74,9	142,9	937,3
	2018.	°C	4,1	0,6	5,4	14,8	16,6	17,9	19,7	20,7	16,2	13,1	7,6	0,5	11,4
		mm	66,7	76,7	109,8	61,4	178,1	131,5	119,6	87,5	25,9	47,5	54,7	83,9	1043,3
	1981-2010	°C	-0,1	1,4	5,3	9,9	15,0	17,7	19,8	19,7	15,1	10,9	5,2	1,1	10,1
		mm	67	63	71	78	73	94	72	70	86	85	91	85	932
Bijeljina	2017.	°C	-4,9	5,2	10,6	11,6	17,9	23,2	24,6	24,7	17,0	12,6	7,4	4,7	12,9
		mm	35,3	45,1	42,4	92,8	67,5	39,9	47,3	35,4	102,3	60,9	45,7	64,3	678,9
	2018.	°C	4,7	1,4	5,6	16,8	20,0	21,4	22,8	24,1	18,4	14,5	7,9	2,5	13,3
		mm	65,4	82,3	88,6	34,6	91,7	125,4	53,5	16,0	29,9	27,4	35,4	67,4	717,6
	1981-2010	°C	0,3	1,9	6,9	11,8	16,9	19,9	22,1	21,2	17,2	11,6	6,0	2,3	11,5
		mm	54,1	43,5	59,7	66,1	68,2	100,0	74,6	60,7	55,8	67,6	64,0	63,9	778,2
Borike	2017.	°C	-8,0	2,1	5,2	6,0	12,7	17,5	18,6	19,2	12,5	7,4	2,2	-0,7	7,9
		mm	50,6	51,2	43,8	165,1	51,7	90,0	97,8	16,6	85,8	121,7	67,9	107,7	949,9
	2018.	°C	-0,1	-1,8	2,9	11,6	14,3	15,5	17,6	18,1	12,8	9,4	4,5	-2	8,6
		mm	60,5	65,5	85,1	49,1	89,5	166,5	136,7	117,2	43,1	27,6	60,0	73,4	974,2
	1981-2010	°C	-3,5	-1,9	2,4	6,9	11,8	14,7	17,0	16,3	12,5	7,7	1,9	-2,0	7,0
		mm	52,7	52,9	56,8	65,3	73,9	93,7	74,9	72,1	80,2	78,0	88,6	69,9	859,0

Morphological characteristics of potatoes such as: plant height, number of trees in a potato bush, plant weight directly affect the productive characteristics, total yield and quality of potatoes. Table 3 shows the morphological

characteristics of potatoes tested in 2017 and 2018 at selected localities (Rogatica, East Sarajevo and Bijeljina) on different types of land.

Table 3. Morphological characteristics of potatoes from the study of localities and types of land in the years of testing

		Plant height (cm)	Number of trees in a potato bush	Plant weight (g)
Soil type	fluvisol (A_1)	59,2b	3,0	230,0a
	humofluvisol(A_2)	54,2b	3,5	212,2a
	district kambisol (A_3)	65,4a	3,2	147,5b
Year	2017 (B_1)	53,2b	2,9	207,5
	2018 (B_1)	66,1a	3,6	185,7
2017(B_1)	fluvisol (A_1)	59,2bc	2,8bc	238,8
	humofluvisol (A_2)	45,8d	3,8ab	236,2
	district kambisol (A_3)	54,5c	2,3c	147,5
2018 (B_1)	fluvisol (A_1)	59,2bc	3,3abc	221,2
	humofluvisol (A_2)	62,7b	3,3abc	188,2
	district kambisol (A_3)	76,2a	4,3a	147,5
Soil type		*	ns	*
Year		**	ns	ns
Soil type *x* Year		*	*	ns

*Values marked with different lowercase letters per column for year, locality and their interaction are significantly different at the P≤0.05 level according to the LSD¬test; **F test significant at level; ns¬ F test is not significant.*

The height and growth of potatoes depends on the variety, climatic conditions and applied agrotechnical measures (Singh and Ahmed, 2008). In the two-year tests, the height of the plants was highly influenced by the year, while the soil type and the interaction of locality x soil type had a significant effect. At the location in Rogatica (soil type district cambisol), potatoes had the largest stems, and the smallest in Bijeljina (soil type humofluvisol). In the second year of testing, the height of the stems was higher compared to the first year of testing, and Oljača (2016) obtained similar results in her three-year research, where the influence of the year of research is evident.

The number of trees in a potato bush varies depending on the variety, production conditions, the size of the planted tuber (Khan *et al.*, 2004; Poštić *et al.*, 2012) and affects the number of transplanted tubers (Jovović, 2001; Khan *et al.*, 2004). Bus and Wustman (2007) claim that the optimal number of trees is achieved by planting the optimal number of tubers. The number of trees depends on temperature conditions, and the amount and distribution of precipitation during the intensive formation and growth of above-ground organs. Levy and Veilleux (2007) state similarly.

The number of trees per plant in the two-year surveys and on the three land types was influenced by the land type x year interaction. The largest and smallest number of trees had potatoes grown on the land type district cambisol (Rogatica),

the smallest was in the first and the largest in the second year of the test. During the second year of testing, there was no difference between the other two localities and soil type, and in the first year of testing, the highest number of trees per plant was on the soil type humofluvisol (Bijeljina) (Table 3). A significant influence of production conditions and year on the number of trees per plant was determined by Momirović *et al.* (2016). Higher air temperatures affect the higher productivity of above-ground mass (Tadesse *et al*., 2001). The obtained results indicate that the largest mass of potato plants was in the location of East Sarajevo, which had lower temperatures than Bijeljina, while the lowest mass was of plants in the location of Rogatica, which has the lowest temperatures. The obtained results are partially in agreement with (Tadesse *et al*., 2001). The influence of the year and the interaction of soil type x year on the plant weight was not determined.

The number of tubers per house was significantly influenced by the year, while the influence of the interaction type of land x year was highly significant. The number of tubers per plant is a varietal trait, but it also depends on the number of trees per plant, agroecological conditions and technological conditions (Barkley, 2005; Poštić *et al.*, 2012). Meteorological conditions in combination with the land affect the extent to which these characteristics will be manifested. In the first year of testing, there was a greater number of tubers. This year is characterized by lower temperatures compared to the second year of testing. The presented results are in accordance with the results of Barkley (2005), who in his research obtained a higher number of tubers per plant at lower than at higher air temperatures. The largest number of tubers per plant was at the location in East Sarajevo (soil type fluvisol) during the second year of testing, while in the first year of testing the fewest tubers were at the location of Bijeljina (soil type humofluvisol) (Table 4).

The average mass of tubers was significantly influenced by soil type and year, while the influence of the interaction was highly significant. Tubers produced on the humofluvisol soil type (locality Bijeljina) had the highest average mass, and the smallest on the soil type fluvisol (locality East Sarajevo) (Table 4). Average tuber weight is a varietal characteristic, but it also depends on agroecological conditions, agrotechnical measures, number of trees per plant, number of tubers per plant (Poštić *et al.* 2012). Higher temperatures stimulate vegetative development, reduce tuber formation and average tuber weight and tuber yield (Tadesse *et al*., 2001). The lowest average mass of the tuber per plant was determined in the first year of the test when in June, July and August there were higher air temperatures and less rainfall, compared to the second year in which the tubers had a higher average mass, which is in accordance with the results Tadesse *et al.* (2001). Higher air temperatures stimulate the vegetative development of the above-ground assimilative part and delay the initiation of stolons and tubers and the earlier development of tubers (Tadesse *et al*., 2001).

Table 4. Yield components and potato yield in the years of testing on selected land types

		The number of tubers per house	Average mass of tubers (g)	Tuber yield (t ha^{-1})
Soil type	fluvisol (A_1)	10,9	72,7b	41,2b
	humofluvisol (A_2)	9,1	104,2a	48,8a
	district kambisol (A_3)	10,5	87,8ab	42,0b
Year	2017 (B_1)	11,2a	76,3b	41,3b
	2018 (B_1)	9,2b	100,2a	46,7a
2017(B_1)	fluvisol (A_1)	11,3b	66,0bc	39,3
	humofluvisol (A_2)	8,3cd	112,7a	47,1
	district kambisol (A_3)	14,0a	50,1c	37,4
2018 (B_1)	fluvisol (A_1)	10,5bc	79,3bc	43,0
	humofluvisol (A_2)	10bc	95,7ab	50,4
	district kambisol (A_3)	7d	125,5a	46,5
Soil type		ns	*	*
Year		*	*	*
Soil type *x* Year		**	**	ns

As a consequence of higher temperatures, the number of tubers per plant, the average mass of tubers and the yield of tubers decrease (Tadesse *et al.*, 2001). Air temperatures close to optimum in the month of June in the stage of stolon formation, tuber seeding and the beginning of tuber filling, which were accompanied by a high amount of precipitation, played a key role in the formation of larger tubers, as proven by the following authors (Jovović, 2011; Poštić *et al.*, 2012). In 2017, tubers produced on district cambisol (Rogatica) had the smallest mass, and tubers produced on humofluvisol (Bijeljina) had the largest mass, while in 2018, tubers produced on fluvisol (Istocno Sarajevo) had the smallest mass, and tubers produced on district cambisol had the largest mass (Rogatica) (Table 4). The yield of potatoes depends on the variety and its genetic potential, agroecological conditions, the level of applied agricultural techniques, the size of the seed tuber, the number of trees per plant and the number of tubers (Poštić *et al.*, 2012). Jovović (2001) states that there is a strong relationship between tuber yield and number of trees per plant, as well as between yield, tuber size and number of trees per plant.

In two-year tests on three types of land, the yield was significantly influenced by the type of land and the year, while the influence of the interaction was not significant. Potatoes grown on humofluvisol soil type (Bijeljina locality) had the highest yields, and the lowest on fluvisol soil type (Istočno Sarajevo locality). Higher yields were achieved in 2018, compared to 2017. These results were influenced by the agroecological conditions at the time of the test, as well as the average mass of the tuber. The distribution of precipitation during the growing season in 2018 fully satisfied the water needs of potatoes, which was reflected in the total yield of tubers being significantly higher compared to the previous year of testing. Such results are in accordance with the research of many

authors (Milić *et al.*, 2010; Momirović *et al.*, 2010; Poštić *et al*., 2012), who state that production conditions affect the total yield of potato tubers. The yield variation depends on the type of land, relief, physical and chemical properties of the land and availability of nutrients (Penney *et al*., 1996), which is in accordance with our research. The most favorable physical, chemical and microbiological properties of the soil at the Bijeljina location influenced the yield of potato tubers, so the highest yield was achieved at this location.

CONCLUSIONS

The agroecological conditions of production in the examined years at the three investigated localities differed significantly, 2018 was significantly more favorable in terms of rainfall compared to 2017 for all three investigated localities (Kula-Istočno Sarajevo, Borike-Rogatica and Kojčinovac-Bijeljina). High temperatures during the months of July and August, in addition to the lack of precipitation, were also a limiting factor for the growth and development of potato tubers. The number of trees per potato plant grown in the field in the two-year research and on three different land types was affected by the interaction of land type x year, while no influence of year was determined on plant mass, nor was the interaction of land type x year. The number of tubers and the average weight of the tubers were significantly influenced by the type of land and the year, while the influence of the interaction was highly significant. The yield of potatoes was significantly influenced by the type of land and the year, while the influence of the interaction was not significant. Potatoes grown in the Bijeljina locality (humofluvisol soil type) had the highest yields, and the lowest in Istočno Sarajevo (fluvisol soil type). Higher yields were achieved in 2018, compared to 2017, which was mostly influenced by the climatic and agroecological conditions at the time of the test. Favorable physical properties, primarily the mechanical composition, chemical and microbiological properties of the soil at the Bijeljina locality influenced the yield of potato tubers, so the highest yield was achieved at this locality.

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