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INFLUENCE OF LIQUID ORGANIC FERTILIZERS ON THE YIELD STRUCTURE CHARACTERISTICS AND PRODUCTIVITY OF CHICKPEA (*Cicer arietinum* L.)

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Abstract

The aim of this study was to determine the effect of liquid organic fertilizers Naturamin Plus and Amalgerol Essence on the yield structure characteristics and productivity of chickpea (Cicer arietinum L.). The experiment was conducted in the period 2019-2021 in the region of South-Central Bulgaria. The trial was designed by the block method in 4 repetitions and 3 doses of fertilizers were tested in two phases of chickpea development: growth phase (4th leaf) and beginning of flowering. Results obtained for the yield were statistically processed by ANOVA. It was found that the treatment with the tested fertilizers increases the values of the structural elements of yield (number of pods per plant, number of grains per plant, grain mass per plant and 1,000 grain mass). The maximum increase in productivity was obtained with treatment with liquid organic fertilizer Amalgerol Essence in dose 1,000 ml.ha^{-1} - 21.8% more compared to the control. A higher effect on productivity was found when applying the tested fertilizers in the beginning of flowering.

Key words*: chickpea, fertilization, productivity, yield structure characteristics.*

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is a typical grain legume crop, grown since ancient times in the Mediterranean region, and the third most important grain legume crop, after soybean and bean, that is produced worldwide in the present day. Studies show that it's a plant that can be grown in various ecological conditions, including saline soils in arid and semi-arid regions (Krouma, 2009; Rao et al., 2002). It is grown traditionally in Central, West and South Asia, South Europe, Australia and North Africa, where it is an important source of cheap protein with high energy and nutritional value (Zia Ul-Haq et al., 2007). As a legume plant which is harvested early and enriches the soil with nitrogen, chickpea is a good predecessor to winter cereals and many other crops. This is why it plays an important role in the systems for organic farming (Cokkizgin, 2012). Conducted studies (Zhelyazkova, 2016; Zhelyazkova et al., 2016) show that due to the good drought resistance, high and stable yields, this legume crop is suitable for growing in the region of South-Central Bulgaria.

The increasing need for plant protein in order to solve the protein problem for human and animal nutrition, necessitates using the maximum potential of legumes production. A possible way to achieve that is to influence the yield through foliar application of nutrients in critical phases of the development of the cultures. Many authors reported data on the influence of various liquid foliar fertilizers and their combinations on the productivity of chickpea and its structural elements (Ali & Mishra, 2001; Burman et al., 2013; Kolev et al., 1999; Menaka et al., 2018; Montenegro et al., 2010; Valenciano et al., 2011). It's emphasized that the positive effect on the productivity is related to increasing the resistance to unfavorable external factors, stronger development of the plants and increasing the values of the structural elements of the yield (Drostkar et al., 2016; Janmohammadi et al., 2018; Nandan et al., 2014; Venkatesh & Basu, 2011). El-Habbasha et al. (2012) consider that a possibility for receiving high and stable yields from chickpea, grown on sandy soils, with low content of organic matter, low water holding capacity, and deficit of macro- and microelements as a result of losses from leaching, is the integrated application of soil and foliar fertilizing. According to data from

Rathod et al. (2020) foliar treatment of chickpea with micronutrient fertilizers leads to bigger impact on the total biomass and yield, compared to soil fertilizing. Positive effects from the treatment were also the increased content of crude protein and microelements in the seeds of chickpea, as well as the increased yield of protein (Nandan et al., 2014; Rathod et al., 2020; Venkatesh & Basu, 2011). It's emphasized that the effect from applying foliar fertilizers is determined by the chickpea development phase (Bahr, 2007; Bhowmick, 2006; Bhowmick et al., 2013). Kirnapure et al. (2020) reported highest grain yield, straw yield, and total biological yield, as well as rate of profitability, by using two treatments - at vegetative and at the beginning of flowering stage. According to data from Ganga et al. (2014), maximum chickpea grain yield, grown on sandy clay loam soil, was achieved by applying potassium fertilizers at sowing, combined with foliar spraying at pre-flowering stage with a complex of macro- and microelements. Some authors determined there were specifics in the reaction of the different varieties of chickpea to the applied foliar fertilizers (El-Habbasha et al., 2012).

In order to decrease the negative impact on the environment and to comply with the new trends and demands on the market, Shinde & Ravi (2020) applied liquid biofertilizers to optimize the feed rate of chickpea and determined a positive influence on the yield at two treatments (in flowering stage and 15 days after flowering) in combination with soil fertilizing with organic fertilizers. Conducted studies established biofertilizers and growth regulators as an alternative to reducing mineral fertilization and receiving ecologically clean production from chickpea (Seleiman & Abdelaal, 2018).

The aim of the study was to determine the effect of liquid organic fertilizers Naturamin Plus and Amalgerol Essence on the yield structure characteristics and productivity of chickpea (*Cicer arietinum* L.), grown in the region of South-Central Bulgaria.

MATERIALS AND METHODS

The study was conducted in the period 2019-2021 in the fields of the Agricultural cooperation for production and services (ZKPU) "Trakia" in the town Radnevo, situated in the region of South-Central Bulgaria. For the field experiment was used the chickpea variety Balkan.

The experiment was conducted by the block method in 4 repetitions, size of the experimental plot was 10 m^2, in non-irrigated conditions, with predecessor wheat.

The soil type was Haplic Vertisol, containing medium available humus (Table 1), neutral to low alkaline reaction, low in available nitrogen and phosphorus and high in available potassium.

Table 1. Soil characteristics

pH (KCl)	Humus, %	Mineral N, mg.1,000 g^{-1}	N –NH_4, mg.1,000 g^{-1}	N-NO_3, mg.1,000 g^{-1}	Available P_2O_5, mg.100 g^{-1}	Available K_2O, mg.100 g^{-1}
7.2	3.7	37.9	4.6	33.3	1.5	47.3

Tested was the influence of the combined fertilizers: Naturamin Plus (total 400 $g.l^{-1}$ amino acids, free amino acids - 200 $g.l^{-1}$, Nitrogen (N) - 75 $g.l^{-1}$, Iron (Fe) - 12 $g.l^{-1}$, Manganese (Mn) - 7.5 $g.l^{-1}$; Boron (B) - 1.3 $g.l^{-1}$, Copper (Cu) - 1.2 $g.l^{-1}$, Molybdenum (Mo) - 0.5 $g.l^{-1}$, Zinc (Zn) - 2.5 $g.l^{-1}$) in dose 1,500, 2,500 and 3,500 $ml.ha^{-1}$ and Amalgerol Essence (free amino acids, organic Nitrogen (3%) and organic potassium (3%), plant herb extracts, seaweed extract, plant hormones, antioxidants, total organic carbon 22.7%) in does 1,000, 2,000 and 3,000 $ml.ha^{-1}$.

The treatment was in two phases of chickpea development: growth phase (4th leaf) and beginning of flowering**.** For application was used a small sprayer pump with 300 $l.ha^{-1}$ spraying solution and air temperature up to 20-25°C. Applied was the commonly accepted technology for growing chickpea.

Reported were the parameters: height of the plants at harvest, yield structure characteristics (number of pods per plant, number of grains per plant, grain mass per plant, and 1,000 grain mass) and grain yield at standard humidity (13%). Data processing was performed by a two-way dispersion analysis (Lidanski, 1988), using MS Excel software - 2010.

RESULTS AND DISCUSSIONS

The climate conditions during the period of the study are shown on Table 2. Regarding the rainfall, the years of the study are charactarised as comparatively favorable.

The vegetation sums of the rainfall in both years of the study are over the average multiannual sum. The largest sum of rainfall during the vegetation period was registered in 2019 - 323.2 mm (25.7% above average). During the vegetation on average for the multiannual period the rainfall was distributed unevenly, and the highest values were for the months May and June.

In the years of the study, this unevenness was also well pronounced, especially in 2019. That year was characterized with intense spring drought lasting until the third ten-days of April, and was especially severe in March.

In both years of the trial, the predominant part of the vegetation rainfalls (75-81%) fell in the second half of the vegetation period (May-June).

Table 2. Climate conditions of South-Central Bulgaria

Years	Months													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I-XII	III-VII
Total rainfall, mm														
2019	40.0	10.6	3.0	62.2	118.8	78.6	60.6	50.6	23.2	30.8	63.4	16.2	558.0	323.2
2021	110.0	37.0	63.2	60.8	41.4	110.0	25.6	14.4	1.0	127.4	22.4	99.0	712.2	301.0
1936 - 2018	41.7	35.8	37.2	45.1	62.8	61.7	51.2	43.5	34.7	42.7	48.9	47.8	553.1	258.0
Average temperature, ^{0}C														
2019	2.3	4.5	8.9	11.6	17.4	23.4	23.9	25.2	20.6	14.2	11.7	4.0	14.0	17.0
2021	3.7	5.1	5.5	10.6	17.7	20.8	25.9	26.1	19.4	11.5	8.0	4.6	13.2	16.2
1936 - 2018	1.0	2.8	6.6	12.0	17.1	21.2	23.7	23.3	19.0	13.0	7.4	2.7	12.5	16.1

The annual air temperature during the vegetation for the multiannual period (1936-2018) was 16.1ºC. Higher deviation from the norm was found in 2019 when the average air temperatures for the vegetation period were with 0.9 ºC above normal.

That year of the study, the average daily temperatures of the air in the beginning phases of plant development (March) were with 2.3ºC above the average multiannual.

In the months May and especially in June 2019, during the flowering and ripening phases, the average monthly air temperatures were above the average multiannual.

In 2021 the average air temperatures for the vegetation period do not differ significantly from the average multiannual.

The yield of grain as a resulting parameter shows best the effect from the applied agricultural technique (Table 3).

The yield in 2021 was characterized with more favorable climate conditions which created the precondition for more optimal growth and reproductive processes and formation of higher yields - average 2,296.74 kg.ha^{-1}. The results for the received grain yields show that by years, as well as by average for the period of the study, the lowest yield was received for the untreated control (2,017.11 kg.ha^{-1}).

Treatment with liquid organic fertilizers in both testing phases (growth phase and beginning of flowering) had positive influence on the productivity of the chickpea as well.

The highest statistically significant grain yield ($P<0.001$) for the different years and average for the period of the study was received from the variant treated with liquid organic fertilizer Amalgerol Essence in dose 1,000 ml.ha^{-1}.

Average for the period of the study, the grain yield from this variant was higher than the control with 13.80% (growth phase) and up to 21.79% (beginning of flowering phase).

Application of higher doses (2,000 and 3,000 ml.ha^{-1}) from the same organic fertilizer during the beginning of flowering phase also gave positive differences compared to the basic variant, which are statistically proven.

These differences, however, are smaller than the tested lower dose (1,000 ml.ha^{-1}), which leads to the conclusion that the lower dose would be more efficient economically. In treatment of the chickpea in the growth phase

(4th leaf) with the liquid organic fertilizer Amalgerol Essence in dose 3,000 ml.ha-1, difference compared to the untreated variant was not proven.

Table 3. Grain yield of chickpea, treated with leaf fertilizers (Naturamin Plus and Amalgerol Essence) at different stages of their development, by the years and average for the period 2019-2021, kg.ha-1, n=104

Variant	Dose ml.ha-1	Years		Average	
		2019	2021	kg.ha-1	%
Control (untreated)		1,915.04	2,119.17	2,017.11	100.00
Growth phase (4th leaf)					
Naturamin Plus	1,500	2,027.38	2,168.51	2,097.94a	104.01
Naturamin Plus	2,500	2,113.88	2,228.95	2,171.41b	107.65
Naturamin Plus	3,500	2,175.99	2,282.27	2,229.13***c	110.51
Amalgerol Essence	1,000	2,274.32	2,316.53	2,295.42***c	113.80
Amalgerol Essence	2,000	2,099.54	2,220.41	2,159.98**b	107.08
Amalgerol Essence	3,000	2,026.55	2,156.94	2,091.74ab	103.70
Beginning of flowering					
Naturamin Plus	1,500	2,093.50	2,269.97	2,181.74***b	108.16
Naturamin Plus	2,500	2,247.18	2,359.72	2,303.45***c	114.20
Naturamin Plus	3,500	2,385.97	2,456.80	2,421.39***d	120.04
Amalgerol Essence	1,000	2,415.94	2,497.23	2,456.59***d	121.79
Amalgerol Essence	2,000	2,359.91	2,411.93	2,385.92***cd	118.28
Amalgerol Essence	3,000	2,168.90	2,369.16	2,269.03***c	112.49
Average		2,177.24	2,296.74	2,236.99	110.90
LSD.P< 0.05		128.10	45.00	86.55	4.29
LSD.P< 0.01		171.20	60.10	115.65	5.73
LSD.P< 0.001		224.50	78.90	151.70	7.52
SD				167.2	
CV				7.47	
SE				16.4	
Min				1855.14	
Max				2723.45	

*Different letters indicate statistically significant differences among variants at P < 0.05
*, **, *** - Statistically significant differences of the variants and control at P< 0.05; 0.01 and 0.001, respectively

Positive and highly statistically proven (P<0.001) was the difference in treatment with the liquid organic fertilizer Naturamin Plus in dose 3,500 ml.ha-1. The surplus in grain yield compared to the untreated plants was highest at treatment in beginning of flowering phase and was on average 20.04%. In the treatment of chickpea in the growth phase (4th leaf) with liquid organic fertilizer Naturamin Plus in doses 1,500 and 2,500 ml.ha-1 the received differences in the grain yield compared to the untreated plants were not statistically proven both by years as well as by average for the studied period.

During vegetation, using liquid leaf fertilizers had a positive effect on the growth parameters of chickpea (Table 4), but the difference compared to the control group was not statistically proven not only by years but also on average for the duration of the experiment.

The yield structure elements of chickpea – number of pods and grains per plant, grain mass per plant, and 1,000 grain mass, are species and variety characteristics and as such are a comparatively constant quantity, however according to a number of authors (Drostkar et al., 2016; Janmohammadi et al., 2018; Nandan et al., 2014; Venkatesh & Basu, 2011) the application of leaf fertilizers, as part of the technology for growing, has an effect on them. Average for the period of the study, the smallest number of pods and grains per plant, grain mass per plant, and 1,000 grain mass was received from the untreated control (Table 4).

Table 4. Morphological structure parameters of chickpea, treated with leaf fertilizers (Naturamin Plus and Amalgerol Essence) at different stages of their development, average for the period 2019-2021, n = 78

Variant	Dose ml.ha^{-1}	Stem height, cm	Pods per plant, number	Grains per plant, number	Grain mass per plant, g	1,000 grain mass, g
Control (untreated)		72.0	33.5	42.8	12.6	383.7
Growth phase (4th leaf)						
Naturamin Plus	1,500	73.8	35.3a	45.0a	13.0a	385.8a
Naturamin Plus	2,500	76.7	36.3a	47.2**a	13.7a	388.9a
Naturamin Plus	3,500	77.0	38.7**b	49.0***ab	14.6ab	393.9***b
Amalgerol Essence	1,000	77.0	39.3***c	49.8***ab	14.9*ab	396.0***b
Amalgerol Essence	2,000	75.3	36.8*a	46.7*a	14.1ab	392.7**ab
Amalgerol Essence	3,000	74.7	36.1a	45.7a	13.7a	390.1*ab
Beginning of flowering						
Naturamin Plus	1,500	74.0	37.0*ab	45.9a	13.1a	385.1a
Naturamin Plus	2,500	74.4	37.7*ab	47.8**a	13.6a	387.4a
Naturamin Plus	3,500	75.0	40.9***c	50.8***b	15.3**b	400.1***c
Amalgerol Essence	1,000	76.7	42.0***c	51.8***b	15.5**b	400.8***c
Amalgerol Essence	2,000	76.7	38.4**b	47.2*a	14.9*ab	392.0**ab
Amalgerol Essence	3,000	74.6	35.9a	45.8a	14.2ab	390.3**ab
Average		75.2	37.5	47.3	14.1	391.3
LSD.P< 0.05		5.3	3.2	3.5	2.1	5.3
LSD.P< 0.01		7.2	4.3	4.7	2.8	7.3
LSD.P< 0.001		9.5	5.7	6.2	3.8	10.2
SD		6.8	5.8	4.3	2.1	6.4
CV		9.0	15.5	9.0	15.2	1.6
SEE		0.8	0.7	0.5	0.2	0.9
Min		61.2	25.6	38.0	10.2	378.0
Max		89.0	49.0	56.0	19.8	405.0

*Different letters indicate statistically significant differences among variants at P < 0.05
*, **, *** - Statistically significant differences of the variants and control at P< 0.05; 0.01 and 0.001, respectively.

The highest and well proven statistically (P<0.001) differences in the values of the yield structure characteristics compared to the control were received when the chickpea was treated in the beginning of flowering with liquid organic fertilizer Amalgerol Essence in dose 1,000 ml.ha^{-1} – 18.98% (6.7 numbers) more pods per plant, 15.11% (6.8 numbers) more grains per plant, 19.23% (2.5 g) more grain mass per plant, and 3.88% more mass for 1,000 grain mass. The differences in the values of the yield structure elements between the varieties treated with Naturamin Plus in dose 3,500 ml.ha^{-1} and Amalgerol Essence in dose 1,000 ml.ha^{-1} were not statistically proven.

In calculating the correlation between grain productivity and the yield structure characteristics in chickpea treated with liquid leaf fertilizers (Table 5) was determined that applying Naturamin Plus in the beginning of flowering phase had strong positive correlation with the number of pods per plant (r = 0.907), number of grain per plant (r = 0.900) and 1,000 grain mass (r = 0.893).

Table 5. Correlation analysis among the yield and morphological structure parameters of chickpea, treated with leaf fertilizers (Naturamin Plus and Amalgerol Essence) at different stages of their development, average for the period 2019-2021

Variant	Dose ml.ha^{-1}	Pods per plant, number	Grains per plant, number	Grain mass per plant, g	1,000 grain mass, g
Control (untreated)		0.834	0.779	0.656	0.412
Growth phase (4th leaf)					
Naturamin Plus	1,500	0.772*	0.643	0.64	0.765*
Naturamin Plus	2,500	0.769*	0.775*	0.469	-0.582
Naturamin Plus	3,500	0.493	0.734*	0.224	0.355
Amalgerol Essence	1,000	0.249	0.204	0.232	0.338
Amalgerol Essence	2,000	0.438	0.633	0.032	-0.283
Amalgerol Essence	3,000	0.652	0.795*	0.729*	-0.842*

Beginning of flowering					
Naturamin Plus	1,500	0.907*	0.449	0.563	0.893*
Naturamin Plus	2,500	0.710*	0.900*	0.670	0.123
Naturamin Plus	3,500	0.526	0.758*	0.574	-0.252
Amalgerol Essence	1,000	0.642	0.373	0.077	0.517
Amalgerol Essence	2,000	0.199	0.049	0.050	0.114
Amalgerol Essence	3,000	0.300	0.277	0.318	-0.349

* - Statistical significance at P < 0.05

In treatment of chickpea with the liquid fertilizer Naturamin Plus in the growth phase between the grain yield and the number of pods per plant correlation exists as well, however it has a lower value (r = 0.769-0.772). In growth phase the correlation of the yield with the number of grains per plant (r = 0.734-0.795) was lower as well.

The dispersion analysis showed that stronger and well proven (P<0.000) influence on the grain yield had the phase of treatment - 26.76% from the total variation of the data (Table 6).

Table 6. Influence of factors on the grain yield, average for the period 2019-2021, n=96

Source of variation	Sum of squares	Degree of freedom	Mean squares	F*	P<	%
Factor analysis for treatment phase						
Year	3,034.6	1	3,034.63	19.63	0.000	12,88
Treatment phase	6,304.8	1	6,304.76	40.79	0.000	26.76
Year * Treatment phase	2.3	1	2.34	0.02	0.902	0.01
Degree of random factors	14,221.7	92	154.58			60.35
Factor analysis for type of preparation						
Year	3,034.6	1	3,034.63	13.90	0.000	12.88
Type of preparation	428.8	1	428.83	1.96	0.164	1.82
Year * Type of preparation	15.1	1	15.13	0.07	0.793	0.06
Degree of random factors	20,084.9	92	218.31			85.24

*F - ratio among the variables; P - Statistical significance

The force of influence of the conditions of the year on the grain yield was also well proven (P<0.000), but significantly lower – respectively 12.88%. There is no proven influence on the grain yield by the type of preparation used, and no proven relation between the year and phase of treatment with fertilizers, between the year and the type of preparation.

CONCLUSIONS

Treatment with liquid organic fertilizers had a positive influence on the productivity of chickpea grown in the region of South-Central Bulgaria. Maximum increase in the yield was obtained with treatment of the chickpea in flowering phase with the liquid organic fertilizer Amalgerol Essence in dose 1,000 $ml.ha^{-1}$ (up to 21.8% more grain yield) and Naturamin Plus in dose 3,500 $ml.ha^{-1}$. Using higher doses of the liquid organic fertilizer Amalgerol Essence, the effect on the productivity decreases. The main influence on the grain yield in chickpea had the phase of fertilization and the conditions of the year. There is no proven influence on the grain yield by the type of preparation used. The productivity of chickpea had a strong positive correlation with the number of pods and grains per plant and the 1,000 grain mass. The applied liquid organic fertilizers Amalgerol Essence and Naturamin Plus increased the values of the yield structure characteristics of chickpea (number of pods per plant, number of grains per plant, grain mass per plant, and 1,000 grain mass) by creating possible opportunities for higher productivity. Maximum increase in the values of the yield structure characteristics was obtained with treatment with the liquid organic fertilizer Amalgerol Essence in dose 1,000 $ml.ha^{-1}$. Treatment of chickpea with liquid organic fertilizers had no effect on the height of the plants.

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