Bulgarian Journal of Agricultural Science, 27 (No 1) 2021, 161–166

Growth indicators and structure of headed cabbage production depending on the fertilization applied

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Abstract

Mitova, I. G. & Dinev, N. S. (2021). Growth indicators and structure of headed cabbage production depending on the fertilization applied. *Bulg. J. Agric. Sci., 27 (1)*, 161–166

A long-standing vegetation field experiment in crop rotation has been conducted with the aim to establish effect of applied foliar and mineral fertilization on the vegetative indicators and the yield of head cabbage (*Brassica oleraceae* L. *var. capitata*). The experiment was performed with the following variants: Variant 1 – non-treated control; Variant 2 – without soil fertilization and two foliar feeds; Variant 3 – $N_{24}P_{12}K_{12}$; Variant 4 – $N_{12}P_6K_6$ and one foliar treatment. The applied foliar fertilizer was Tekamin Max – a neutral organic fertilizer that contains 14.4% amino acids, 60% organic matter and 7% total nitrogen. The plants fertilized with $N_{24}P_{12}K_{12}$ show the best vegetative development, the maximum weight of the cabbage and highest yield. The double-leaf-treated green plants show better results in the number of rosette leaves formed. The yield improvement compared to the non-fertilizer control was 3.3 times for the variant $N_{24}P_{12}K_{12}$, 2.6 times for the two leaf fertilized plants and 1.96 times for the variant $N_{12}P_6K_6$ + one foliar treatment. The results show the need to create good root nutrition conditions regardless of foliar treatment.

Keywords: cabbage; foliar fertilizer; yield, mineral fertilizers, crop rotation

Introduction

Sustainable agriculture is part of the global sustainable development strategy for the Earth. Sustainable development brings together two main aspirations of society: 1. Achieving economic development providing an increasing standard of living; 2. Preserving and improving the environment in the future.

Excessive use of organic and mineral fertilizers to achieve ever higher yields leads to controversy in so-called „cross-compliance“: fertilization as a factor of productivity and the environmental impact of its application. Thus, in addition to a decline in the economic profitability of production, the balance between environmental components (Stankov, 2013) also deteriorates. A significant part of the non-organic fertilizer nitrogen fertilizer falls into groundwater, many of which create conditions for sanitary unsuitability (Koutev & Ikonomova, 1998; Mitova & Dinev, 2018).

Comparative assessments of organic and mineral fertilization in field and vegetable crops in our and foreign literature are one-sided and in many cases do not conform to the modern varietal structure and yields requiring high fertilization standards (Mitova & Dinev, 2018). On the other hand, the topicality of this theme is also determined by the exceptional soil and climatic diversity in the country, necessitating different systems of agriculture, wide base of species and variety of production, and therefore the results of the comparative studies obtained abroad can not be transferred and used directly under other specific conditions.

Cabbage yield is determined by many factors, e.g. fertilizer application rates, irrigation regimes, environmental conditions, etc. As a common practice, ample nitrogen (N) fertilizer input is the predominant way to guarantee crop yields and maintain soil fertility. However, the overuse or misuse of N fertilizer has influenced the soil quality and resulted in significant yield decrease of crops in many regions. In this sense, yield monitoring has become an important aspect of N management scheme for cabbage production. In the past, researchers estimated cabbage yield by counting the head number, volume and density or developing a dynamic model with the soil properties and complex weather conditions (Ji et al., 2017).

Aim of the study is to establish the direct and indirect results of the applied organic and mineral fertilization on the vegetative indicators and the yield of head cabbage.

Material and Methods

The experience is set as crop rotation on the same area by „enforcing“ the options for 7 years. The variants of the crop rotation included: Variant 1 – control (not treated); Variant 2 – 100% manure; Variant 3 – 100% mineral fertilizer; Variant 4 – 50% manure + 50% mineral fertilizer. At the beginning of the experiment, manure and mineral fertilizers (ammonium nitrate, superphosphate and potassium sulphate) were equalized with N, P and K content.

Due to the high content of total phosphorus in manure in the following years, the quantities of mineral fertilizers and manure were equalized only with total nitrogen content.

Agrochemical analysis of soil samples after completion of the onion (previos culture in crop rotation) determines the soil as a weak humus (1.83-2.06%). The results presented in Table 1 characterize the low alkaline soil reaction in experimental variants with low mineral nitrogen content, a good supply of mobile potassium and a very good to depressingly high phosphorus supply.

Depressing the high content of mobile phosphorus in Variant 2, resulting from fertilizing with manure according to fertilization scheme:

The superphosphate and 2/3 of the potassium chloride are introduced with the main soil treatment (in the autumn). Prior to transplanting in the spring, the rest of the potassium norm and 1/3 of the ammonium nitrate were introduced. The rest of the nitrogen fertilizer is incorporated as two feedings at the beginning of the vegetation before the first morphological analysis of the plants is carried out. Variants 2 and 4 have a foliar feeding with Tekamin Max (product of Agria S.A., Bulgaria) with a working solution concentration of 0.3%. Tekamine Max is a neutral liquid organic fertilizer that contains 14.4% amino acids, of which 12.0% free L-amino acids; 60.0% organic matter and 7.0% total nitrogen. The leaf spraying in variant 2 is in the 10-12-leaf stage and turn of the cabbage, and in the variant 4 – once in the phase 10-12 leaf.

The experience is based on the cabbage variety Kiosse-17 (cannonball green cabbage) late production according to block method with a plot size of 30 m^2 in 4 replicates. Plants are planted in a double-row band in the 100+60x40-45 scheme. The row spacing is 60 cm, inside the row 40-45 cm, and between the strips 160 cm. Irrigation is dripping in accordance with field and botanical crop requirements (Moteva et al., 2016).

During the vegetation and at the end of the study, the following morphological features were taken into account: mean mass of 1 plant (g/plant), leaf rosette weight (g/plant), height of plants (cm), number of rosette leaves, rosette diameter (cm), inner cube diameter (cm), height (cm), total biological yield ($kg.ha^{-1}$), cabbage yield ($kg.ha^{-1}$).

The results obtained are processed through the Statgraphics Centurion statistical package.

Results and Discussion

Changes in biometrics as a result of applied fertilization

In addition to genetic factors, the influence of the studied biometric parameters is also influenced by the applied fertilization (Boteva & Rankov, 1995; Atanasova et al., 2007; Mitova & Dinev, 2012; Dumičić et al., 2013; Nenova & Mitova, 2018). Most of the morphological indicators included in the study show statistically significant differences depending on the fertilization applied, but also the likely cause of the differences between the variants is the residual effect of the fertilization against the previous crop.

The number and mass of rosette leaves are a kind of markers, but their parameters also depend largely on mineral and, in particular, nitrogenous nutrition (Petkova, 1984; Stoikov et al., 2005; Mitova & Dinev, 2012). It can be seen from the data in Table 2 that the number of leaves in economic maturity phase varies from 15.33 to 19, with proven differenc-

Table 1. Agrichemival analyses of 0–30 cm soil depth before starting of the experiments

Variant	pH_{H2O}	pH_{KCl}	NH_4-N+ NO_3-N	P_2O_5	K_2O
			$mg.kg^{-1}$	$mg.100g^{-1}$	$mg.100g^{-1}$
1. Non-treated- control	7.4	6.8	20.6	18.6	20.0
2. Variant without soil fertilization and 2 leaf treatments	7.9	7.1	27.6	84.3	23.6
3. Variant with N_{24} $P_{12}K_{12}$	7.1	6.5	19.0	24.5	22.3
4. Variant with $N_{12}P_6K_6$ and 1 leaf treatment	7.4	6.8	18.6	35.3	20.9

es between Variant 2 (with two foliar feedings) and Variant 3 (with complete mineral fertilization). Leafy plants in the Variant 2 formed 10.2% more leaves of the average number of rosette leaves (17.25 units/plant) in the experiment. These plants also formed the largest leaf mass – 1016.67 g/plant, 22.9% greater than the average value (827.5 g/plant) in the experiment. The explanation of the high values of these vegetative indicators in the non-soil fertilization variant can be related to both the high P_2O_5 and good K_2O soil reserve of this variant with the available forms of phosphorus and potassium and the mechanism of action of applied leaf manure. Tecamine Max is an organic liquid fertilizer of plant origin with a high concentration of L-amino acids in the plant-digestible form resulting from enzymatic hydrolysis, which yields much more pure L-amino acids, resulting in improved osmosis, opening of estuar, vegetative development, antioxidant activity, hormonal activity, etc. Plants of the fertilizer variant with $N_{24}P_{12}K_{12}$ as a result of applied fertilization have also formed a significant leafy mass, with the differences in leaf mass of plants with soil fertilization and twice foliar feeding being statistically unproven. Plants fertilized with $N_{24}P_{12}K_{12}$ have formed a leaf mass 20.9% above the average of variants.

The only indicator that plants with reduced fertilization and one leaf feeding statistically proven to be superior to all other variants of the experiment is the diameter of the leaf rosette. The diameter of leaf rosettes (75.67 cm/plant) of plants of this variant is 19.3% greater than the experimental average and 31.2% of the fertilizer variant with $N_{24}P_{12}K_{12}$ and it was the highest yield.

Diameter of the cop is usually associated with the variety, but in this case the high fertilizer application (Variant 3) has a strong influence on the size of the inner basket. At an average test diameter of 4.24 cm/plant, the diameters of the cabbage's cob from the fertilizer variant with $N_{24}P_{12}K_{12}$ were 14.9% higher. The same trend is also observed with the measured masses of the outer leaves. The highest mass (18.77 g/plant) is again the stubs of the full mineral fertilization variant, 21.7% above the average mass of the stub for the trial. While the measured diameters of the stub lack proven differences between the fertilization variants, the masses have proven differences between the full mineral fertilizer variant and the other variants – variant with foliar feeding only and variant with reduced foliar and soil fertilization.

In the complex of morphological features, the mass and size indicators are important indicators of plant productivity

Table 2. Biometrical parameters of head cabbage in the stage "market maturity"

Variants	Number rosette leaves	Mass rosette leaves (g)	Diameter rosette (cm)	Diameter cob cabbage (cm)	Mass cob cabbage (g)	Height of cabbage (cm)	Width of cabbage (cm)	Mass of cabbage (g)	Yield (kg/ha)
1. .Non-treated- control									
average	15.33	670.00	53.67	3.33	12.80	15.03	14.94	716.67	215.00
median	15.17	710.00	52.83	3.32	12.75	15.02	15.04	758.33	240.00
Std	1.08	118.19	2.70	0.11	0.19	0.32	0.47	116.03	48.6
2. Variant without soil fertilization and 2 leaf treatments									
average	19.00	1016.67	66.67	4.47	15.47	18.60	19.23	1886.67	566.00
median	19.00	1070.00	70.00	4.50	15.60	18.60	19.80	1810.00	543.00
Std	1.00	176.16	5.77	0.15	0.61	0.60	2.50	159.48	47.8
3. Variant with N_{24} $P_{12}K_{12}$									
average	16.33	1000.00	57.67	4.87	18.77	22.93	16.37	2330.00	699.00
median	16.00	1000.00	58.00	4.80	18.40	23.00	16.30	2340.00	702.00
Std	5.51	314.66	19.37	1.51	5.60	6.88	5.51	828.67	37.6
4.Variant with $N_{12}P_6K_6$ and 1 leaf treatment									
average	18.33	623.33	75.67	4.30	14.63	17.53	15.60	1406.67	4220.00
median	19.00	650.00	74.00	4.40	14.70	17.60	15.20	1420.00	4260.00
Std	1.15	112.40	4.73	0.36	0.40	1.00	2.62	200.33	601.00
Average of experiment	17.25	827.5	63.42	4.24	15.42	18.52	16.54	1585.0	4755.5
F-Ratio	7.00	4.76	22.63	9.41	41.29	54.81	2.99	53.28	53.28
P- Value	0.01	0.03	0.00	0.01	0.00	0.00	0.10	0.00	0.00
P = 1%	2.10	313.60	6.39	0.69	1.27	1.45	3.57	308.67	926.00
P = 0.1%	3.06	456.32	9.29	1.01	1.84	2.11	5.19	449.13	1347.39

(Petkova, 1984; Mihov & Filipov, 2001; Antonova, 2009). The dimensions of the cabbage heads are determined by the longitudinal and transverse diameters of the cabbages. In the experiment, in the control variant, as well as in plants with 2 foliar feedings and those with reduced mineral fertilization + 1 foliar feeding, the cabbage heads are almost round, i. e. with close dimensions for height and transverse diameter. Cabbage of Variant 3 (with soil fertilization), has an extended and quite non-typical form for the variety (Antonova, 2009). Its height is significantly higher (22.93 cm/plant) than that of the other variants or 23.8% above the average height of cabbage in the experiment. At a median experimental width of 16.54 cm/plant, twice-foliar spray plants had 16.3% wider cabbage leaves than the others in the experiment. Unlike the height of heads, which have the same proven differences as the masses of the cobs, the differences between the variants are not as high as the measured width of the cobs, and for P = 0.1% is no evidence.

The fertilizer variant with $N_{24}P_{12}K_{12}$ is with the largest mass of formed heads of 2330 g/plant. The differences in the measured masses are statistically proven, with a median experimental weight of 1585 g/plant.

Interest in the presented experience is represented by the low results in almost all measured growth indicators and realized yield of Variant 4 (with reduced mineral fertilization and 1 foliar feed). At the expense of the relatively large number of rosette leaves and broad leaf rosettes, some of these plants are poorly developed and formed small and loose heads. Despite the fact that statistically there is a proven difference in the height of the cabbage cobs from the non-fertilized plants but, visually the sizes of the cabbage and the obtained with reduced mineral fertilization and 1 foliar feeding did not differ (Variant 4). The probable cause for the unsatisfactory results in these plants is both the low starting mineral content of the soil and the insufficient and untimely leaf and soil nitrogen feeding, which has not provided the necessary nutrients for optimal growth and development.

Productivity and structure of organic fertilization

In Figure 1 are presented the results for the production of cabbage and vegetative mass. The relationship between the obtained yields of cabbage and vegetative leaf mass (coefficient of determination between the two parameters r^2 = 0.68) and the applied fertilization are described by polynomial equations with high coefficients of determination: for cabbage with R^2 = 0.985 and for the leaf mass at R^2 = 1. The yields obtained by us are completely comparable to those in other studies with Kiosse-17 (Petkova, 1984; Antonova et al., 2007; Kancheva et al., 2012; Mitova & Dinev, 2012). In the case of our experience, the comments on the yields obtained should take into account not only fertilizer introduced during the experiment but also the effect of the presence or absence of nutrients from previous fertilization. Consistent with the significantly higher mass of the high-fertilizer variant, compared with the other experimental variants and the yield obtained with the plants fertilized with $N_{24}P_{12}K_{12}$, it is highest – 6990 kg/da. The yield of cabbage in plants fertilized with $N_{24}P_{12}K_{12}$ is 47% above the average yield (4755 kg/da) of the whole experiment (Table 2)

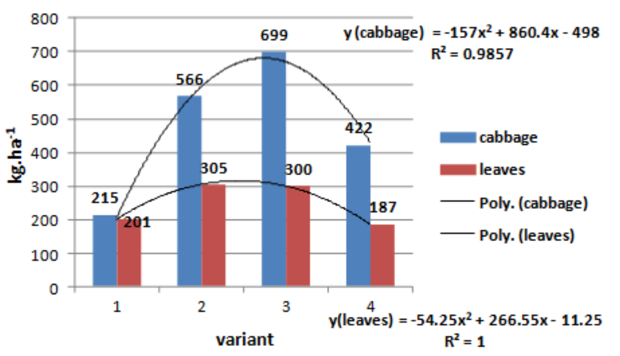

Fig. 1. Yeild of cabbage depending the fertilization

The increase in cabbage yield after 8 years of planting compared to the control (no fertilization) is 3.3 times for fertilizer variant with $N_{24}P_{12}K_{12}$, 2.6 times for plants with two foliar feedings and 1.96 times for the $N_{12}P_6K_6$ + 1 foliar feeding variant. It should be noted that in the beginning (2011) of the experiment with vegetable crop rotation we started with head cabbage Kiosseva (Mitova & Dinev, 2012; Kancheva et al., 2012). The yield of the implimented variants in this first year of the vegetable trial was 3616.7 $kg.da^{-1}$, i. e. irrespective of the difference in climatic conditions (provided the yields in the other variants are comparable), yields after 8 years of use of the soil without compensatory fertilization is 59.5% of the obtained in 2011.

The structure of organic yields includes the percentage of vegetative and reproductive part of the crop yield and has an important scientific and economic significance in order to efficiently fertilize and expend the means to form optimal yields of high quality without unnecessary residues in the nutrient medium. According to Zhurbitskiy (1963), the most economical consumption of nutrients to build 1000 kg of cabbage production occurs when the weight of the commercially valuable portion is 70-72% of the total biomass. In the reported experience of fertilization options, we obtained close (Petkova, 1984; Mitova & Dinev, 2012) and somewhat lower than those quoted in the literature (74.5-76.6%, Nen-

Table 3. Yeild's structure

Variant	Cabbage heads	leaves	Outer cobs	Total	Cabbage heads	leaves	Outer cobs
	(kg/ha)				% of the total yield		
1.	215	201	3.9	420	51.2	47.9	0.93
2.	566	305	4.8	876	64.6	34.8	0.55
3.	699	300	5.7	985	69.6	29.8	0.56
4.	422	187	4.5	655	68.8	30.5	0.74

ova & Mitova, 2018), 6 and 69.6% (Table 3). Plants fertilized with $N_{24}P_{12}K_{12}$ have the highest yield of cabbage and they have also the highest percentage of the commercially valuable part of the yield in the total yield. In the untreated variant with poorly garnished plantation, with poor general development resulting from the nutritional deficit, the predominantly formed cabbages are small, deformed and lean. The relatively high percentage of foliage in the formation of the total yield of the plants fed twice with Tekamin Max can be explained precisely by the way this organic fertilizer acts, the effect of which would probably be more effective in leafy vegetables.

Conclusions

Plants fertilized with $N_{24}P_{12}K_{12}$ show the best vegetative development, expressed in: foliage by 20.9%, cabbage cobs by 14.9%, mass of the outer cobs by 21.7%, the height of the cabbage by 23.8% above the average for the trial. The double apllication of foliar treatments show better results in the number of rosette leaves formed.

The fertilizer variant with $N_{24}P_{12}K_{12}$ is with the largest mass of formed heads of 2330 g/plant. The differences in the measured masses are statistically proven, with a median experimental weight of 1585 g/plant.

At the expense of the relatively large number of rosette leaves and wide leaf rosettes, small plants (1407 g/plant) and narrow heads were formed in plants with reduced mineral fertilization and 1 foliar feeding.

The highest yield was obtained in plants fertilized with $N_{24}P_{12}K_{12}$ – 699 kg/ha, 47% above average yield (476 kg/ha) of total experience. The increase in headed cabbage yield after a yearly planting of vegetables compared to the control (no fertilization) is 3.3 times in the fertilizer variant with $N_{24}P_{12}K_{12}$, 2.6 times in the plants with two foliar feedings and 1.96 times for the $N_{12}P_6K_6$ + 1 foliar feeding variant.

Percentage participation (for fertilization variants) of the cabbage yield in organic yield is between 64.6 and 69.6%. Plants fertilized with $N_{24}P_{12}K_{12}$ with the highest yield of cabbage also have the highest percentage of the commercially valuable part of the yield in the total yield.

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Received: January, 3, 2020; *Accepted:* January, 27, 2020; *Published:* February, 28, 2021