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Effect of mineral fertilization on the quality parameters of head cabbage (*Brassica oleracea* L. var. *capitata* L.)

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Abstract

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The effect of mineral fertilization – increasing norms of nitrogen (N_{80}, N_{160} and N_{240}, kg.ha^{-1}) and background levels of phosphorus and potassium (P_{150} K_{100}, kg.ha^{-1}) on the quality characteristics of head cabbage was studied in the conditions of field experiment. Absolutely dry weight of cabbage head and inner stem decreased by 7.8% and 8.2% respectively in the variants were fertilization was applied compared to the control. The total sugars content of cabbage head of variants T1-N_{80} and T2-N_{160} increased by 18–22%. The total nitrogen and nitrates content in cabbage head biomass were within the tolerable concentrations. Only in the inner stem of the variant fertilized by $N_{240}P_{150}K_{100}$ the concentration of – 386.6 mg NO_3.kg^{-1} fresh weight was above the admissible norms. A positive correlation relationship was found between absolutely dry weight and total sugars content (R = 0.812). Most of the quality parameters determined as optimal the fertilization applied in the variant $N_{160}P_{150}K_{100}$.

Keywords: head cabbage; mineral fertilization; quality; production

Introduction

Cabbage, as tomatoes and onion is one of the most popular vegetable crops worldwide. For its development and growth cabbage needs a lot of nutrients, especially of nitrogen (Raid et al., 2009). The nitrogen is very important nutrient, which defines not only the yield but also the quality of the head cabbage production. Balanced mineral fertilization needs an appropriate proportion between nitrogen and the other nutrients so their optimal accumulation and plant growth to be provided (Raikova & Petkova, 1987; Atanassova et al., 2007; Dumičić et al., 2014).

The definition and the measurement of plant production quality are more complicated than the yield determination (Dinev & Mitova, 2012). The quality standards are defined by different parameters, related to the aim of the production obtained, if it is designed for a fresh consumption or for a processing and conservation (Mihov, 2002 a, b).

The aim of the present study was to assess the change of some basic quality parameters of the plant production of head cabbage (*Brassica oleracea* L. var. *capitata* L.) under the effect of increasing nitrogen fertilization levels and background concentrations of phosphorus and potassium.

Materials and Methods

A field experiment was carried out on Alluvial-Meadow soil (Fluvisol – FAO) at the experimental field of Tsalapitsa village, Plovdiv with late head cabbage (*Brassica oleracea* L. var. *capitata* L.), variety Srabski melez-4 as a part of a long term vegetable rotation. Three rates of increasing nitrogen fertilization and background concentrations of phosphorus and potassium were applied in the following variants – T1 ($N_{80}P_{150}K_{100}$), T2 ($N_{160}P_{150}K_{100}$) and T3 ($N_{240}P_{150}K_{100}$). The effect of fertilization was assessed compared to the control variant – T0 ($N_0P_0K_0$). The nitrogen was applied under

the form of NH_4NO_3 twice – one half before planting the cabbage and the other half as additional feeding. Phosphorus and potassium were applied once – before cabbage planting – under the form of triple superphosphate and KCl. The soil was characterized by light texture, low clay content and good water permeability (Simeonova et al., 2015). The organic matter content is low – 1.07%, and the $pH_{(KCl)}$ values were about 6.2. The initial content of nutrients in the arable soil horizon was the following: total N –19.0 mg.kg^{-1}, P_2O_2 – 12.1 mg.100g^{-1}, K_2O – 15.5 mg.100 g^{-1}. A randomized block design with 3 replicates was used and each experimental plot was 200 m^2 (Nenova & Mitova, 2018).

The following quality parameters of cabbage biomass were determined: absolutely dry weight (%) – after fixation of the plant samples at 105°C followed by drying at 65°C until a constant weight was reached; total sugars (%) – using a Digital Refractometer – 32 145; total N (%) in plants – by wet digestion and distillation by Kjieldahl method (Peterburgskii, 1986); the content of nitrates (mg NO_3. kg^{-1} fresh weight) was determined by Nitrachek.

The statistical processing of the data was performed using correlation analysis from the package Statgraphics Centurion XVI.

Results and Discussion

The main factors controlling the quality of plant production are usually genetically determined. A lot of studies with different agricultural crops have proved that absolutely dry weight is such a factor, which varies within narrow limits depending on the variety characteristics (Petkova, 1984; Antonova et al., 2014). However, in the present study a regular change of the values of absolutely dry weight of cabbage head and inner stem is found, which indicates that fertilization has some effect on the parameter studied (Figure 1).

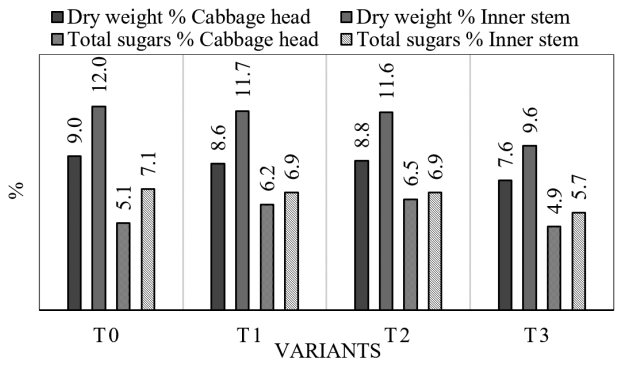

Fig. 1. Dry weight % and total sugars % content, in cabbage head and inner stem

Absolutely dry weight in cabbage heads varies between 7.6 and 9.0%, it is higher in the inner stem – between 9.6 and 12.0%, and these results are comparable to the results obtained by other authors (Atanassova et al., 2007; Kolota & Chohura, 2015). Dry weight in the control variant is higher than in the variants with fertilization (Figure 1). This could be explained by the disturbed – deficient feeding conditions in the control variant and their overall impact on the metabolic processes in the plant. In a three years field experiment with different varieties of head cabbage by addition and omission of nutrients Petkova (1984) also had found that highest contents of absolutely dry weight are established in plants without fertilization. The content of absolutely dry weight in cabbage heads and inner stem decrease considerably (by 16–20%) when $N_{240}P_{150}K_{100}$ fertilization norm is applied. Obviously, in that study, both in terms of yields (Nenova & Mitova, 2018) and in the case of dry matter, the 240 kg N.ha^{-1} norm is proved to be ineffective.

Endogenous factors associated with the photosynthetic activity of plants and the rate of translocation of photosynthetic enzymes to the accumulation organs of the plants can influence the synthesis of sugars in plant organs (Petkova, 1984). Total sugars in cabbage heads are between 4.9 and 6.5%, and they are higher in the inner stems – between 5.7 and 7.1 % (Figure 1). Regarding this parameter, the lowest values are also measured when N_{240} fertilization norm is applied. The highest average total sugars content is measured in plants of the variant T2 – $N_{160}P_{150}K_{100}$. Total sugars reported in the present investigation from the variety Srabski melez – 4 at the maturity phase of the cabbage are considerably higher than those measured in the varieties Ditmarsko and Puldiner (Antonova et al., 2014)

Significant correlation relationship is established between absolutely dry weight and the content of total sugars in cabbage (R = 0.812) (Figure 2). This indicates that the

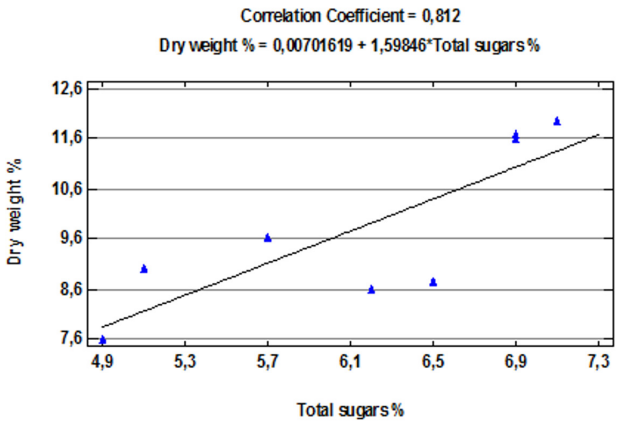

Fig. 2. Correlation relationship between dry weight % and total sugars % in white cabbage biomass

content of dry biomass in cabbage heads and inner stems depends on the increase of total sugars in plants. Similar correlation relationship was found by Krasteva et al. (2013) when studying the quality characteristics of different varieties of small fruited tomatoes.

Total nitrogen content and nitrate accumulation are important quality parameters that determine the biological value of the production. In the Commission Regulation (EC) No 1881/2006 of 19 December 2006, setting maximum levels for certain contaminants in foodstuffs, it is stated in (19) "As regards nitrate, vegetables are the major source for the human intake of nitrate. The Scientific Committee on Food (SCF) stated in its opinion of 22 September 1995 (4) that the total intake of nitrate is normally well below the acceptable daily intake (ADI) of 3.65 mg.kg^{-1} body weight (bw). It recommended, however, continuation of efforts to reduce exposure to nitrate via food and water." However, in Annex 1 of the same document regarding "Maximum levels for certain contaminants in foodstuffs" for leafy vegetables only spinach, lettuce and iceberg type-lettuce are presented.

The results for total nitrogen content vary between 1.38 and 2.22% for cabbage head and between 1.79 and 2.53 for the cabbage inner stem (Table 1). Fertilization affects the accumulation of nitrogen in plant biomass, but clear trends are not observed. Recalculated to fresh weight (f. w.), these contents are from 1244.8 to 1907.0 mg N.kg^{-1} for cabbage heads and from 2140.8 to 2934.8 mg N.kg^{-1} for the inner stems. According to Tashev (1975) permissible level of total nitrogen in fresh production is 2220 mg N. kg^{-1}. In the production obtained, only in the inner stem of the variants with fertilization the content of total nitrogen is above the permissible 2220 mg N. kg^{-1} fresh weight. The results for the total nitrogen in the production obtained are encouraging and they are a consequence of the adequate choice of fertilization norms. Nitrogen fertilization levels, used in the investigation are recommended based on of the previous studies by the team (Mitova & Dinev, 2012).

Among the valuable qualities that cabbage deserves as one of the most preferred vegetable crops, the genetic predisposition for nitrate accumulation is rather a negative characteristic. The existing standard for Maximum permissible concentrations of nitrates in vegetable production since 1987 (Ordinance No. 5, 1987) has determined as permissible nitrate content in vegetable crops up to 300 mg.kg^{-1} fresh weight. Although, this standard is not working at the present moment, the problem of nitrate pollution is not getting smaller but on the contrary. The lack of a clear standard increases the potential risks for the crop production.

In the present investigation the nitrate content is between 12.4 and 208.2 mg.kg^{-1} f. w. in cabbage heads and between 64.8 and 386.6 mg.kg^{-1} f. w. in the inner stems (Table 1). As it was expected, with the increasing of fertilization norm the nitrate content in plants increases, too. If we recalculate the acceptable daily intake of nitrates with food stuff – 3.65 mg.kg^{-1} body weights (Commission Regulation (EC) No 1881/2006 of 19 December 2006) with an average body weight of 70 kg, a permissible daily intake of 255.5 mg NO_3.kg^{-1} body weight will be obtained. In this case, nitrates measured in cabbage heads are within the permissible limits, similarly to the results for the total nitrogen.

The contents of nitrate nitrogen (NO_3–N mg.kg^{-1} f. w.) in cabbage plants are within the acceptable levels, compared to other investigations (Raikova & Petkova, 1987). Regarding this indicator the levels in cabbage heads (2.8–47.0 mg.kg^{-1}) are almost twice lower compared the inner stem (14.6–87.3 mg.kg^{-1}), as the highest are the values of the variant fertilized by N_{240}. With the increasing of nitrogen fertilization norm, the quantity of unmetabolized nitrogen increased, too (Table 1). Although the amount of nitrate nitrogen compared to the total nitrogen is low – from 0.23 to 2.96% in cabbage

Table 1. Influence of mineral fertilization on the transformation of total nitrogen in head cabbage

Variants	Total N %	Total N mg.kg^{-1} f. w.	mg NO_3.kg^{-1} f. w.	NO_3–N mg.kg^{-1} f. w.	NO_3–N in % from total N
	Cabbage head				
T0 ($N_0P_0K_0$)	1.38	1244.8	12.4	2.8	0.23
T1 ($N_{80}P_{150}K_{100}$)	2.22	1907.0	90.6	20.5	1.07
T2 ($N_{160}P_{150}K_{100}$)	1.88	1646.9	128.7	29.1	1.77
T3 ($N_{240}P_{150}K_{100}$)	2.09	1590.5	208.2	47.0	2.96
	Inner stem				
T0 ($N_0P_0K_0$)	1.79	2140.8	64.8	14.6	0.68
T1 ($N_{80}P_{150}K_{100}$)	1.99	2326.3	120.4	27.2	1.17
T2 ($N_{160}P_{150}K_{100}$)	2.53	2934.8	297.1	67.1	2.29
T_3 ($N_{240}P_{150}K_{100}$)	2.46	2369.0	386.6	87.3	3.69

heads and from 0.68 to 3.69% in the inner stems, the strong increase of non-metabolized nitrogen in the variant N_{240} is noticeable.

Between the total nitrogen content – N% and the nitrate content – mg NO_3.kg^{-1} f. w. it was established a significant correlation relationship – R = 0.770. Among the others quality characteristics correlation relationships were not established.

Many of the quality parameters such as taste and aroma are difficult to measure, and as these factors are very subjective, the absolute quality assessment is often too difficult. The density of the cabbage heads in the study was determined by evaluation scores. The highest average quality evaluation was obtained for the $N_{160}P_{150}K_{100}$ variant. The cabbage heads of this variant are almost equal as regards their form and size, they have dense texture and regular shape. Cabbage heads of variants T0 and T3 are loose-textured, which is a problem for their storage and preservation (Mihov., 2000a,b). The cabbage of variant T1 has a good texture, but is significantly smaller than the cabbage fertilized with more nitrogen. Obviously, along with higher yields, the fertilization rate of variant T2 ($N_{160}P_{150}K_{100}$) also ensures good quality of the production obtained.

Conclusions

The reduced content of absolutely dry weight and total sugars in the cabbage heads and in the inner stems of the variant T3 – 240 kg N.ha^{-1} shows that the highest fertilization norm has a negative effect on the quality parameters studied.

The contents of total nitrogen and nitrates in the production obtained are within the permissible levels (2200 mg N.kg^{-1} f.w. and 300 mg NO_3^-.kg^{-1} f.w.) for all of the variants with fertilization, as a consequence of the appropriate choice of fertilization norms.

The subjective assessment of some quality parameters as density, shape and taste of cabbage is highest for the variant T2 – $N_{160}P_{150}K_{100}$, where cabbage heads have similar size, form and dense texture, while in variants T0 – $N_0P_0K_0$ and T3 – $N_{240}P_{150}K_{100}$ cabbage heads are loose-textured and more inappropriate for storage.

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