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Headed Chinese cabbage growth and yield influenced by different manure types in organic farming system

E. Laczi, A. Apahidean, E. Luca, A. Dumitraş, P. Boancă

Department of Vegetable Growing, Faculty of Horticulture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania

Abstract

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Chinese cabbage is a less known, cultivated and consumed vegetable species in Transylvania, although previous studies have shown that it can be grown successfully in this area. The main purpose of the present research was to underline the effectiveness of various treatments on Chinese cabbage growth, yield and quality of the final product in organic farming system. The treatments included: different fertilisation types, place of the culture and several hybrids. Results showed that all the studied factors had a high influence on cabbage heads characteristics such as length, diameter, and weight, on the number of leaves and also on yield. The best yields were registered when horse manure was used (between 76.50 and 99.30 t/ha), followed by cattle manure (between 76.80 and 93.75 t/ha). A higher yield of better quality cabbage was obtained in a polyethylene tunnel (89.27 t/ha) compared to the open field culture (77.50 t/ha). Hybrid Super provided the highest yield (92.70 t/ha), followed by hybrid Vitimo (86.09 t/ha).

Keywords: *Brassica campestris* L. var. *pekinensis* Lour (Olson); ecological vegetables; hybrid; open field culture; protected culture

Headed Chinese cabbage (*Brassica campestris* L. var. *pekinensis* Lour (Olson)) is a member of the cole crops, and is an important fresh and processed vegetable, especially in Asian countries. With migration of Asian population to other parts of the world, it had become more and more known in countries from all over the world. Due to its good taste and high nutritional value the demand for this vegetable is constantly rising. This vegetable, as well as other cruciferous species, is characterised by high ability to adapt to a wide range of habitats and growing conditions (Larkcom 2003; Maršalkienė et al. 2014). Earlier studies showed that Chinese cabbage can be grown successfully in spring or fall in Transylvania Tableland specific conditions (Laczi et al. 2013, 2014); an improved cultivation technology is necessary for every region, because it has a high tendency to bolt. Bolting – next to the yield – is influenced by temperature, lighting conditions, soil humidity and the period of cultivation through the year (Toxopeus, Baas 2004; Larkcom 2008). To attain considerable production and quality yield, it is necessary to ensure the availability of essential nutrient components (Easmin et al. 2009), the growth

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and yield of cabbage vegetables being remarkably influenced by the application of organic and inorganic nutrients. It is an established fact that the use of inorganic fertilisers is not so good for human health compared with organic ones, because of the residual effect (Hasan, Solaiman 2012; Indrea et al. 2012).

The most crucial issues of the 21st century will include those relating to the quality of soil, water and air (Pósa et al. 2013). The quality of cultivated soil is affected by various agricultural practices (Ryan-Harshman 2010); the application of organic fertilisers takes part in the improvement of soil structure, humus content and water retention capacity, having a great impact upon the beneficial activity of the macro- and microorganisms (Guş et al. 2004). Moreover the soil fertilisation makes water usage efficiency increase – thereby saving water (Ertek et al. 2012). Manure application could reduce invalid crop water consumption, make use of soil water reasonable and improve water-use efficiency at different growth stages of a crop (Wang et al. 2013).

In order to obtain higher yields, farmers tend to fertilise crops with high quantities of chemical fertilisers, plants receiving an excess of nutrients. To avoid these effects it is recommended to use organic fertilisers – with an important role in the increase and maintenance of the soil fertility, causing a yield increase, too (Mărghitaş, Rusu 2003). While cattle manure was used and studied for a long time in vegetable production (Arancon et al. 2005), horse manure was left aside, even if it has a great value and potential. The quantity of nutrients in manures varies with type of animal, feed consumption, quality and quantity of bedding material, length of storage and storage conditions (Watson et al. 2002).

Organic farming benefits are substantially reducing pollution and flooding; conserving energy, soil, nutrients, fish, and wildlife; reducing federal costs for grain price supports; and insuring the supply of food for future generations. Lots of studies demonstrated that organic products are healthier than conventional ones (Woese et al. 1997; Jurica, Petříková 2014).

The main aim of the research was to underline the effectiveness of various treatments, namely: organic fertilisation (with cow- and less commonly used horse manures), two cropping systems and several hybrids, on Chinese cabbage growth, yield and quality of the final product, in organic farming system.

MATERIAL AND METHODS

A two-year study was conducted in the Poieni village, Cluj county, Transylvania, Romania in 2013 and 2014. The location of the experimental site is 46°55'11"N latitude and 22°51'55"E longitude. By position, the experimental site falls into the moderate continental climate which is characteristic for western and north western region of the country. A polyfactorial experiment (following randomised complete block design, with four replications) was organised; the combination of factors and their graduations gave 18 treatments as follows (Table 1). The biological material consisted of three Chinese cabbage hybrids, with a vegetation period of 65–80 days, all of them being adequate for fresh consumption and medium-term storage (Asian vegetable seeds 2015).

Sowing was done in greenhouse in different times according to planting sites; in the middle of March for protected culture and in the middle of April for the open field. The soil preparation started with ploughing in autumn of preceding years. One month before establishing the trial, air-dried cattle and horse manure (20 t/ha) was incorporated into the

Table 1. Experimental treatments of the research

Var.	Factor A (fertilization)	Var.	Factor A (fertilization)	Var.	Factor A (fertilization)	Factor B (place of the culture)	Factor C (hybrid)
1	a_1 – unfertilized	7	a_2 – cattle manure	13	a_3 – horse manure	b_1 – open field	c_1 – Golden Wa-Wa
2		8		14			c_2 – Vitimo
3		9		15			c_3 – Hybrid Super
4		10		16		b_2 – polyethylene tunnel	c_1 – Golden Wa-Wa
5		11		17			c_2 – Vitimo
6		12		18			c_3 – Hybrid Super

Var. – experimental variants

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soil manually using a short handle hoe. The day before planting the soil was processed with cultivator. Planting took place in the second decade of April for protected crops and in May in open field. During the vegetation period intercultural practices were done as per requirements. No remarkable attacks of diseases or pests were found during the study, so there were no treatments necessary. For supplementary fertilisation fresh cattle and horse manure, respectively, were macerated in water in proportion of 1:10 for 10 days. The obtained maceration was applied to the plants after 30 days from planting.

Data on the following parameters were recorded: plant height, rosette diameter, total weight, number of leaves in rosette, cabbage head length, diameter and weight, number of leaves of cabbage heads, total number of leaves and total yield. Ten plants were randomly selected from each unit plot for the collection of data. The average data obtained for different parameters were statistically analysed to find out the significant differences of fertilisation, place and time of the culture and hybrid on the yield contributing characteristics of Chinese cabbage. The significance of differences among the treatment combinations means was estimated by the Duncan's multiple range test at 5% level of probability and linear correlation coefficients were calculated between some characteristics at 99% of probability (Ardelean et al. 2007).

RESULTS AND DISCUSSION

Cabbage head length

Cabbage head length was influenced by the place of the culture and fertilisation. In Fig. 1a, it can be observed that cabbage heads which were cultivated in protected area were longer, having an average length of 36.03 cm. The difference was statistically assured and is due to better growing conditions in the polyethylene tunnel. The fertilisation had a significant role in the length of the cabbage heads, too. The best results were registered at plants grown in polyethylene tunnel fertilised with horse manure. Studies made by Easmin et al. (2009) showed that at harvest cabbage heads had a height which varied between 32.28 and 48.77 cm; these values were directly influenced by the

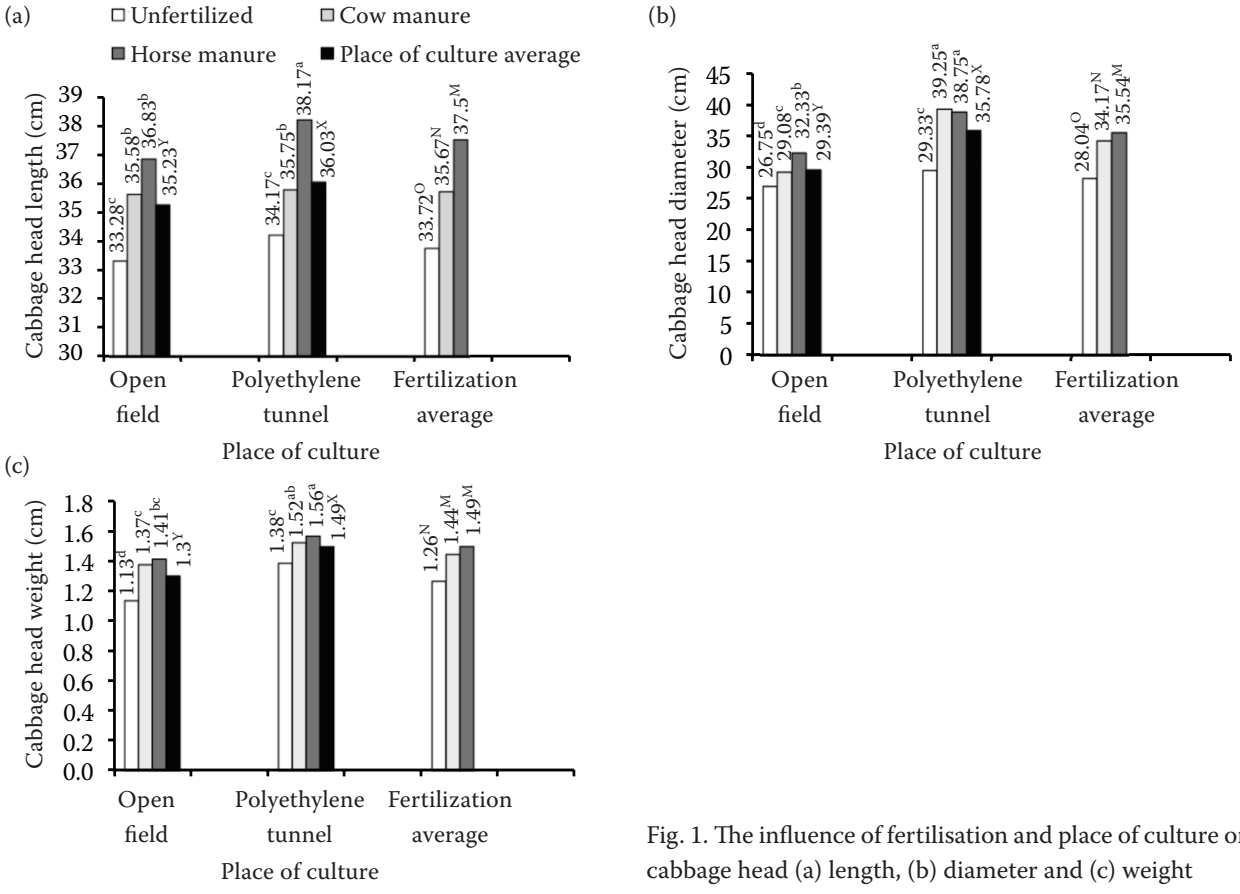

Fig. 1. The influence of fertilisation and place of culture on cabbage head (a) length, (b) diameter and (c) weight

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application of fertilisers – better results were registered when horse manure was applied. The length of cabbage heads was also influenced by variety (Tables 2 and 3); the varietal effect on plants height was reported earlier by Haque (2005).

Cabbage head diameter

Whole plants had a greater diameter in the field, but with the elimination of the outer leaves, the diameter decreased. Before the removal of rosette leaves, the diameter varied between 37.50 and 77.50 cm, results which are in accordance with those from the studies of Easmin et al. (2009). Diameter was influenced by the place of the culture and fertilisation, and varied between 28.04 and 35.54 cm under different fertilisations and between 29.39 and 35.78 cm when the culture place was different. In both cases, the differences were statistically significant. In Fig. 1b, it can be observed that the differences were smaller between the culture

Table 2. Influence of the hybrid and fertilisation on cabbage parameters

Hybrid	Fertilization			Mean hybrid
	unfertilized	cattle manure	horse manure	
Cabbage head length (cm)				
Golden Wa-Wa	29.67^{e}	29.00^{e}	32.75^{cd}	30.47^{O}
Vitimo	40.00^{b}	43.50^{a}	45.38^{a}	33.46^{N}
Hybrid Super	31.50^{de}	34.50^{c}	34.38^{c}	42.96^{M}
Mean fertilization	33.72^{Z}	35.67^{Y}	37.50^{X}	
Cabbage head diameter (cm)				
Golden Wa-Wa	23.50^{f}	30.75^{d}	28.13^{e}	27.46^{O}
Vitimo	28.38^{e}	34.50^{c}	38.75^{ab}	33.88^{N}
Hybrid Super	32.25^{d}	37.25^{b}	39.75^{a}	36.42^{M}
Mean fertilization	28.04^{Z}	34.17^{Y}	35.54^{X}	
Cobbage head weight (kg)				
Golden Wa-Wa	1.04^{f}	1.28^{e}	1.27^{e}	1.20^{O}
Vitimo	1.31^{e}	1.49^{c}	1.53^{bc}	1.44^{N}
Hybrid Super	1.42^{d}	1.56^{b}	1.66^{a}	1.55^{M}
Mean fertilization	1.26^{Y}	1.44^{X}	1.49^{X}	
Cabbage head leaves number				
Golden Wa-Wa	35.00^{e}	38.38^{d}	39.38^{cd}	37.58^{O}
Vitimo	34.25^{e}	40.88^{c}	44.88^{b}	40.00^{N}
Hybrid Super	30.88^{f}	45.25^{b}	49.38^{a}	41.83^{M}
Mean fertilization	33.38^{Z}	41.50^{Y}	44.54^{X}	
Yield (t/ha)				
Golden Wa-Wa	60.92^{e}	76.80^{d}	76.50^{d}	71.41^{O}
Vitimo	78.60^{d}	87.58^{c}	92.10^{b}	86.09^{N}
Hybrid Super	85.05^{c}	93.75^{b}	99.30^{a}	92.70^{M}
Mean fertilization	74.86^{Y}	86.04^{X}	89.30^{X}	

different letters within hybrids, fertilisation, place of culture and different treatment combinations denote significant differences (Duncan's test, $P < 0.05$)

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Table 3. Influence of the hybrid and place of the culture on cabbage parameters

Hybrid	Place of the culture		Mean hybrid
	open field	polyethylene tunnel	
Cabbage head length (cm)			
Golden Wa-Wa	29.69^{c}	31.25^{c}	30.47^{O}
Vitimo	42.75^{a}	43.17^{a}	33.46^{N}
Hybrid Super	33.25^{b}	33.67^{b}	42.96^{M}
Mean place of culture	35.23^{Y}	36.03^{X}	
Cabbage head diameter (cm)			
Golden Wa-Wa	25.92^{e}	29.00^{d}	27.46^{O}
Vitimo	30.42^{cd}	37.33^{b}	33.88^{N}
Hybrid Super	31.83^{c}	41.00^{a}	36.42^{M}
Mean place of culture	29.39^{Y}	35.78^{X}	
Cabbage head weight (kg)			
Golden Wa-Wa	1.08^{f}	1.31^{e}	1.20^{O}
Vitimo	1.37^{d}	1.52^{b}	1.44^{N}
Hybrid Super	1.45^{c}	1.64^{a}	1.55^{M}
Mean place of culture	1.30^{Y}	1.49^{X}	
Cabbage head leaves number			
Golden Wa-Wa	37.67^{c}	37.50^{c}	37.58^{O}
Vitimo	37.75^{c}	42.25^{a}	40.00^{N}
Hybrid Super	39.75^{b}	43.92^{a}	41.83^{M}
Mean place of culture	38.39^{Y}	41.22^{X}	
Yield (t/ha)			
Golden Wa-Wa	64.11^{e}	78.70^{d}	71.41^{O}
Vitimo	81.29^{d}	90.90^{b}	86.09^{N}
Hybrid Super	87.20^{c}	98.20^{a}	92.70^{M}
Mean place of culture	77.53^{Y}	89.27^{X}	

explanation under Table 2

systems when there was no fertiliser applied and when horse manure was used. When cattle manure was used the difference was more than 10 cm, which is very high taking into consideration that the producers and consumers always prefer a homogenous lot of vegetable.

The diameter values (Table 2) depended mostly on hybrid. The combined influence of place of the culture and hybrid revealed that in open field the lowest diameters for all hybrids were reported (Table 3).

Cabbage head weight

Cabbage head weight is one of the most important characteristics for measuring yield performance. Chinese cabbage can weigh even up to 4.5 kg (Larkcom 2008). Fig. 1c reveals that cabbages had higher weights (statistically assured) in protected crops and when fertilisation was used.

The weight depended on hybrid and fertilisation. All hybrids showed lower weights when no fertilisation was applied, the weight increased significantly with the manure application (Table 2). Higher weights were obtained at all hybrids in protected culture, 1.49 kg, compared to 1.30 kg recorded in open field. The lowest values were registered at hybrid Golden Wa-Wa, while the highest ones at hybrid Super (Table 3). In an experiment made by Sammis et al. (1988) the weight of Chinese cabbage heads ranged from 1.36 to 1.74 kg when the planting was done in April, and between 1.21 and 1.41 kg when the planting was performed in March.

Strong relationships were found between head weight and length, diameter and number of leaves: a significant positive correlation was between weight and length, and a distinct significant positive correlation was found between weight and diameter and between weight and leaves number. It can be concluded that with the increase of length, diameter and number of leaves the head weight was increasing too, in lower or higher extent (Fig. 2). Earlier studies did not show statistically significant relationship between the mentioned characteristics (Laczi, Apahidean 2012).

Cabbage head leaves number

Number of leaves and plant leaf area are important parameters considering their role in light interception and consequently of transpiration, photosynthesis as well as plant productivity. Plant physiologists and agronomists have demonstrated the importance of these factors in estimating crop growth, development rate, yield potential, radiation use efficiency, water and nutrient uptake (Olfati et al. 2010). Studies upon a collection of hybrids and varieties of Chinese cabbage showed that in spring culture the leaves number from cabbage heads varied between 19.83 and 43.33 (Laczi, Apahidean 2012), while in case of autumn crops between 28.17 and 58.33 (Laczi et al. 2014). The application

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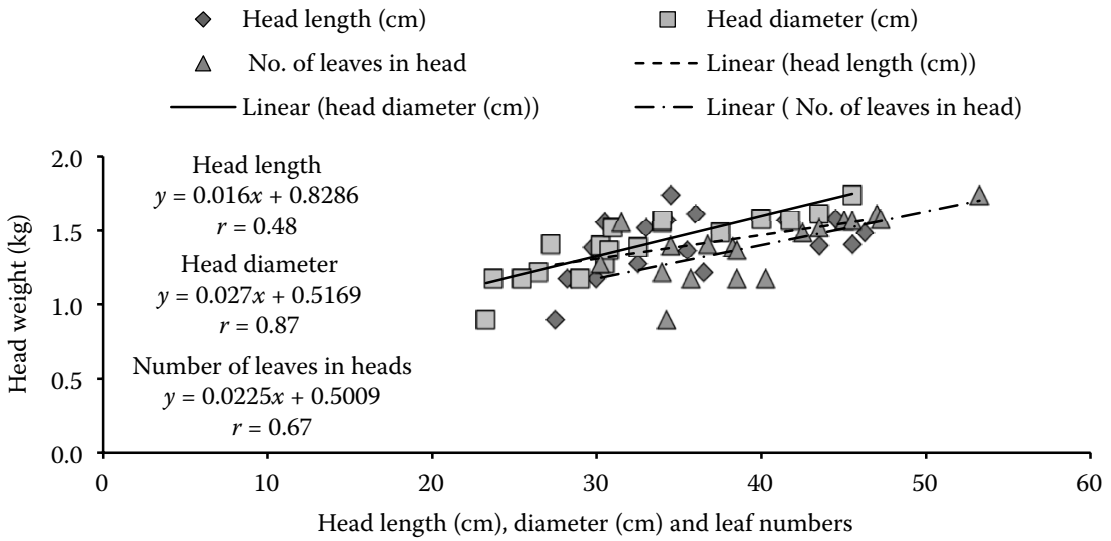

Fig. 2. Correlation between cabbage head weight (kg) and length (cm), diameter and the number of leaves (P (0.005) = 0.47, P(0.001) = 0.59); r – 0.48 ... 0.87

of horse manure and protection of crop increased significantly the number of leaves in cabbage heads. Not only the application of fertilisers takes part in increasing of leaves number – Easmin et al. (2009) showed that leaves number from cabbage heads was directly influenced by the quantity of fertilisers as well (Fig. 3a). Among the hybrids, Super gave the highest number of leaves, followed by Vitimo and Golden Wa-Wa, the differences being significant. The results might be due to genetic characteristics of cultivars that have an influence on higher or lower number of leaves during cabbage head formation. Interaction effect of the hybrid and type of fertilisation affected the number of leaves significantly: the highest number of leaves was observed at combination of hybrid Super × horse manure, followed by the same hybrid × cattle manure. These values were statistically identical with combination of Vitimo × horse manure. Low values were achieved by all hybrids at unfertilised treatments. Cabbage heads from open field crops had significantly fewer leaves than those from protected crops (Tables 2 and 3).

Yield

Yield is the most important characteristics for vegetable producers. Under the present study it was

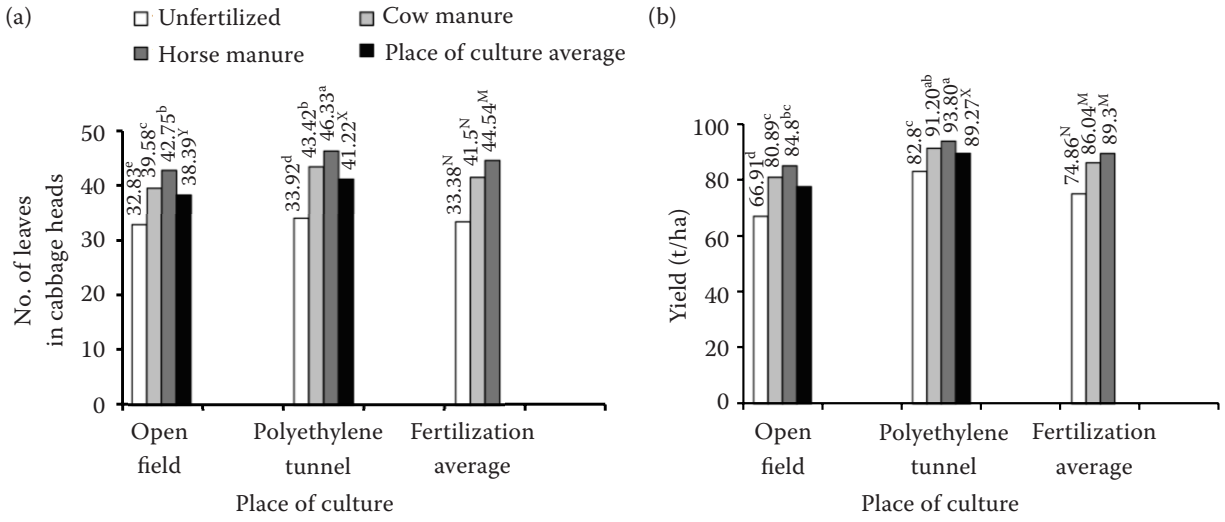

Fig. 3. Influence of fertilisation and place of culture on (a) cabbage head leaves number and (b) yield
explanation under Table 2

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influenced, as previous characteristics, by all three factors. Previous studies made on several vegetables showed that the application of organic fertilisers led to an increase of the yield (Gana 2009). The combined influence of the fertilisation and place of the culture (Fig. 3b) showed that the highest yield was registered in protected culture with application of horse manure (93.80 t/ha). The usage of manures had a high influence on yield increase. Easmin et al. (2009) demonstrated that without fertilisation yield was 67.90 t/ha, and increased up to 120.06 t/ha when the crop was fertilised. The hybrid (which depends in most cases on the genetic background) had the highest impact upon the yield. The highest yield, 92.70 t/ha, was achieved at Hybrid Super (Table 2). Different treatments showed statistically different yields: the highest one of 99.30 t/ha was registered at Hybrid Super fertilised with horse manure, the lowest one of 60.92 t/ha at Golden Wa-Wa without fertilisation. Head weight is in direct correlation with the fertiliser; this finding was shown also in the studies of Vavrina and Obreza (1993), where cabbage heads had weights which varied between 550 and 590 g, the heaviest ones being fertilised with $Ca(NO_3)_2$ or urea. The place of the culture is an important factor when yield is analysed; higher yields of better quality can be obtained in protected crops, which is the fact demonstrated in earlier studies (Laczi et al. 2013).

At all hybrids, the differences between the yields from open field and protected crops were statistically significant, the differences varied between 9.61 and 14.59 t/ha (Table 3). Sammis et al. (1988) found yields up to 57.1 t/ha, when the planting was made in March, while with the planting delay until April, the yields increased up to 63.2 t/ha. The irrigation of plants increased the total plant mass to 128.50 t/ha, while total yields of heads varied between 68.16 and 72.62 t/ha as shown in a study of Zhao et al. (2012).

CONCLUSION

Using cattle and horse manures the yield significantly increases and other important values such as head length, diameter, weight or number of leaves grow up substantially. Thus, in organic farming system the use of fertilisers is necessary to obtain high yields of good quality.

Even if horse manure was not used frequently in vegetable production in the past, it is recommended for Chinese cabbage crops because of its multiple benefits.

Protected culture of Chinese cabbage comes with higher costs but it is worth investments because of the higher yield of better quality and higher selling price.

The choice of hybrids remains very important and has to be made in function of the producer's possibilities: Vitimo gave a high yield but it cannot be stored for a long time; Golden Wa-Wa gave a lower yield, but in a shorter period; hybrid Super had the highest yield and it is recommended to be taken in culture. From the bolting point of view, it is important to choose bolting-resistant or slow-bolting varieties, like Hybrid Super.

Taking into considerations all the results, the best treatment in organic culture of Chinese cabbage is the cultivation of hybrid Super in protected culture and fertilisation with horse manure.

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Corresponding author:

PhD. Eng. Enikő Laczi, University of Agricultural Sciences and Veterinary Medicine, Faculty of Horticulture, Department of Vegetable Growing, Calea Mănăștur 3-5, 400372 Cluj-Napoca, Romania;
e-mail: eniko.laczi@yahoo.com