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The effect of cultivation technology on the plant development of organically grown garlic

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Abstract. The new technological solutions for the hardneck garlic production were tested to prevent the influence of unfavourable soil and climatic conditions on the rooting, sprouting and wintering ability of hardneck garlic - factors that affect significantly the hardneck garlic production in Latvia. Field studies were carried out at the experimental field of the organic farm, located at the Koknese district, Latvia, during the seasons of 2018/2019 and 2019/2020, on sandy loam soil using hardneck garlic cultivar `Liubasha` and local clones. Two variants of garlic growing were compared - traditional planting in the autumn in the field as control, and planting in the trays as an innovative solution. Results indicated that low temperature treatment (below +7 °C) for the period of at least 50 days initiates cloves primordia development. The using of trays is effective technology to prevent unfavourable agroecological conditions on the field in the case if controlled conditions are available and technically feasible in the farm.

Key words: *Allium sativum* var. *ophioscorodon* (Link) Döll, bulb, clove, stalk development.

INTRODUCTION

Garlic (*Allium sativum* var. *ophioscorodon* (Link) Döll) is a bulbous plant of relatively short vegetation season (90–140 days from the sprouting in the spring until harvest). The part of plant consumed in the food is a bulb consisting of a number of lateral buds transformed into storage organs (cloves). The clustered bulb, enveloped by layers of dry thick leaf bases, consists of one or more whorls of cloves; each one is made of a vegetative bud embedded inside a thick storage leaf enveloped by an external dry, protective cylindrical leaf sheath (Mann, 1952; De Mason, 1990). Cloves are placed on the bulb basal disc around a long flower stalk (scape) producing topsets (inflorescence bulbils). Hardneck or bolting garlic tend to have four to twelve cloves in each bulb, depending on the genotype.

Young cloves develop from the buds initiated from the base of planted (mother) clove. Cloves initiating is determined by environmental factors, such as temperature (in the storage period prior planting and after planting) and light conditions (Rahim & Fordham, 1988). The optimal storage temperature for cloves prior planting is between

10–12 °C (Baumane, 1973). Higher storage temperature reduces clove development and promotes vegetative growth of the plant.

In order to ensure optimal plant development conditions, traditionally hardneck garlic in boreal climatic zone is planted in the autumn (September - October). Such planting time ensures vernalisation conditions for the cloves, thus initiating the formation of new cloves in the planted mother clove and subsequent bulb development. According to different authors, the initiation of cloves takes place in the period of 6–8 weeks at a temperature of 4 to 7 °C (Rahim & Fordham, 1988; Põldma et al., 2005). Exposing the bulbs to low temperatures stimulates cytokine and gibberellin accumulation, modifying the hormonal balance and leading the bulb development (Resende et al., 2011). Thus, in the field conditions two-month period of temperature between 0 and 10 °C is sufficient for proper bulb development. In order to ensure proper rooting of planted cloves and increase plant ability to survive in low temperature, the period of cloves rooting for 1–1.5 months should be ensured in the field prior temperature drops below 0 °C (Põldma et al., 2005).

Changing climate conditions often burdens proper garlic development or even planting in the autumn so endangering yield (Muska & Saksone, 2019. In recent years, more intense precipitation has been observed in the autumn period (data from the Latvian Environment, Geology and Meteorology Centre), which makes it difficult or impossible to plant garlic in the field. Also often thaws during the winter period worsen plants overwintering ability. In order to overcome the changing climate conditions, and implement precisions agriculture, the innovative method of garlic planting using controlled conditions was tested in the project 'The modernization of winter garlic cultivation to ensure guaranteed yield in the organic production system' in the period of 2018–2020. The aim of the study was to develop the growing technology ensuring proper plant development conditions and efficiently use available resources.

MATERIALS AND METHODS

The field trials were performed in the farm 'Lazdiņas Aagro', Koknese district, Latvia (56°39'21.6"N 25°29'31.2"E). The experiment was carried out in sandy loam soil without irrigation possibilities. A hardneck garlic cultivar of Ukrainian origin Liubasha and local Latvian garlic clone were used as planting material.

In the season 2018/2019 using traditional technology, garlic was planted at the beginning of November, 2018. Uniformed cloves were planted with a 3-row configured planter where the distance between rows was 0.6 m and cloves were planted at a distance of 0.15 m in the row. To test the innovative technology, garlic cloves were planted in the 3rd decade of March, 2019 in trays (cell size 73×38 mm) filled with substrate prepared from the mixture of sphagnum peat and manure. Trays were placed in the refrigerated dark room, where air moisture was between 70 and 80%. Trays irrigation was not performed, as the substrate well kept the humidity. Due to technical problems, trays with plantlets were exposed to continuous low-temperature of 4.0–7.0 °C for only 20-days period. During the remaining period until the planting (30 days), the temperature ranged between 2 and 18 °C (Fig. 1).

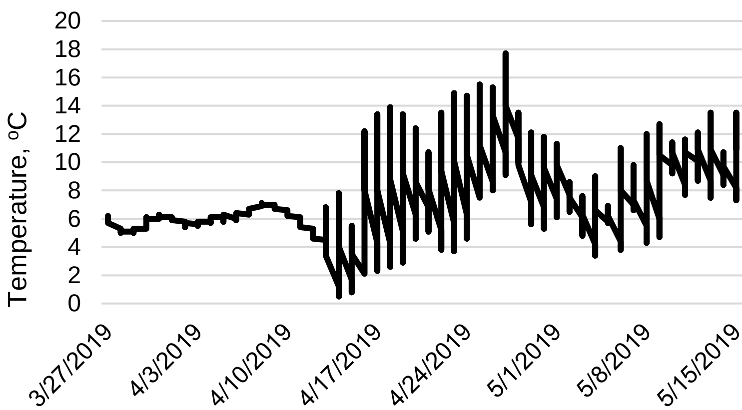

Figure 1. Temperature conditions in 2019 for plantlets grown in trays.

In 2019, container plantlets from trays were planted on the field in the 2nd decade of May at phenological growth stages BBCH 101-104, according to Lopez-Bellido et al. (2016) (Fig. 2).

Figure 2. Trays with garlic plantlets.

In the season of 2019/2020, in the traditional technology, garlic was planted on the field at the beginning of December, 2019, using the same technology as in the previous year. In the innovative technology variant, garlic cloves were planted in trays in the 3rd decade of March, 2020. The substrate was similar to that used in the previous year. Trays were exposed to low-temperature of 4–7 °C for 50 days and garlic plantlets were planted on the field in the 1st decade of May, at BBCH 104-106. Planting density was the same as for the control plants planted in the autumn.

As overwintering of control variant garlic on the field was good, there were no drop-off plants observed for both winters. Therefore overwintering of control variant plants was not measured.

Plant development in trays was evaluated by measurements of root length and plantlet height in the day of planting in the field (15.05.2019 and 10.05.2020), and plant height measurement in the 1st decade of July on the field. Plant measurement was performed also for the plants growing in the field accordingly to the traditional growing technology at the same days. Stalk development for plants of both variants was evaluated in July for both years, to assess bulb development completeness.

Clove initiation for plantlets grown in trays and for field-grown plants was inspected microscopically in 21.05.2019 and 12.05.2020. The number of clove primordia was registered for each inspected plant.

All measurements were performed in three replications. Garlic yield in each technological variant was evaluated after harvest and expressed in t ha^{-1}.

The data were subjected to analysis of variance (ANOVA) and *Duncan's* criteria, $p < 0.05$, to evaluate the differences in plant development and yield between garlic cultivation methods.

RESULTS AND DISCUSSION

The results obtained in the two-year investigation proved the possibility to obtain satisfactory yield by using innovative trays method for garlic production in controlled conditions.

The initiation of cloves primordia and complete plant development cycle, yielding in well-developed bulbs and stalk, for the plants grown in trays took place only in the case if plantlets were subjected to low temperature for appropriate period. This is supported by the data obtained in two different seasons - 2018/2019, when the low temperature was not ensured for necessary period (20 days), and season of 2019/2020, when the low temperature period was of sufficient length (50 days) (Tables 1 and 2).

Table 1. Parameters characterizing bulb development in two seasons of the trial

Growing method	Variety/ clone	Clove primordia, pc 1st decade of May		Stalk development 1st decade of July	
		2019	2020	2019	2020
Traditional	Liubasha	4.6 ab*	5.3 a	yes	yes
	Clone No 2	7.3 b	7.3 b	yes	yes
Innovative	Liubasha	0.6 a	5.0 a	no	yes
	Clone No 2	2.0 a	7.0 b	no	yes

* Means in a column followed by same letter (s) are not significantly different for growing technology factor.

The data presented in Table 1 clearly indicated the linkage between clove and stalk development. When clove initiation did not occur in the 1st year of the trial due to a too short period of low temperature, it also negatively affected stalk development.

In the study of given genotypes, we observed that stalk development is the indicator of appropriate bulb development i.e. cloves formation. This feature was used as indicator of complete bulb development. In the 2nd year, clove primordia and stalk were initiated under appropriate temperature conditions, thus the proper development of the bulb took place.

Adequate yield formation followed and sufficient garlic yield was harvested (Fig. 3)

Morphological parameters of garlic plants, such as plantlet height and root length on the day of planting and plant height later in summer, in the 1st decade of July, at the maximum plant size prior maturation, were compared with the same parameters for traditionally field-grown plants (Table 2).

Table 2. The garlic plants height measurements in two seasons of the trial

Growing method	Variety/clone	Plant height, m			
		1st decade of May		1st decade of July	
		2019	2020	2019	2020
Traditional	Liubasha	0.38 a*	0.24 a	0.58 c	0.61 b
	Clone No 2	0.38 a	0.26 a	0.62 d	0.61 b
Innovative	Liubasha	0.41 b	0.20 a	0.29 b	0.35 a
	Clone No 2	0.42 b	0.21 a	0.24 a	0.34 a

* Means in a column followed by same letter (s) are not significantly different for growing technology factor.

As root length did not differ significantly for the tested variants, it was not included in the table. The plant height parameters were used to evaluate overall development of plant, its ability to produce vegetative part, thus influencing production of assimilates for bulb development. It was clearly indicated in the 1st season, when plants were kept too long in trays prior planting out, at the planting day they were significantly longer than plants growing in the field conditions. After planting out, they delayed in development, as suffered from transplanting stress, the leaves partially were destroyed, and finally in July, transplanted plants had significantly smaller canopy in comparison to traditionally grown plants and in comparison to their size at the transplanting. In the 2nd season, when plantlets in trays were stored in appropriate low temperature for 50 days, the plants were shorter, more compact. Thus they less suffered from transplanting and had higher ability to adapt in the field conditions. In the mid-season, they were smaller in size than traditionally grown plants, but completely developed.

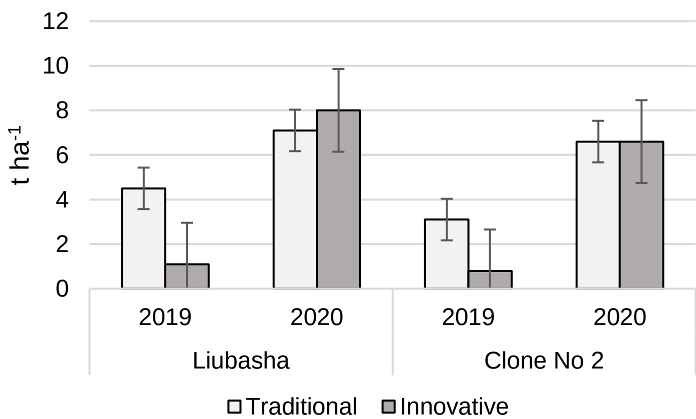

Figure 3. Garlic yield in both growing variants, in 2019 and 2020.

Consequently, the garlic yield in 2019 was relatively low in comparison to average hardneck garlics yield in the region - it fluctuated between 0.8 and 4.5 t ha^{-1} (Fig. 3). The yield outcome of 2019 was affected by insufficient precipitation during the garlic active vegetation season (March - August), when total precipitation reached only 288 mm and the drought periods overlapped with critical periods of garlic yield formation (May – June).

The garlic yield in 2020 was much more appropriate, reaching up to 8.0 t ha^{-1}. This vegetation season had higher precipitation (336 mm), which had a positive effect on the yield development.

The yield of 2020 is of average level for the region, as it is referred by others (Põldma et al, 2005; Juškevičiene et al, 2016), having between 4.3 and 16.8 t ha^{-1}.

There is clear evidence of the effect of clove initiation intensity on the garlic yield formation. In 2019, when cold treatment in the innovative growing variant was of insufficient period according to Resende et al. (2011), thus negatively influencing clove initiation, the yield in this variant was negligible - it did not exceed 1.1 t ha^{-1}. In turn, the yield of 2020 in the innovative technology variant, when appropriate period of low temperature was ensured for plantlets grown in the trays, was insignificantly higher (for cultivar Liubasha) or similar (for local clone) to the traditional technology reaching up to 8 t ha^{-1} for Liubasha and 6.6 t ha^{-1} for local clone. The yield for Liubasha in traditional growing technology was 7.1 t ha^{-1} and for local clone there were 6.6 t ha^{-1} harvested.

It is evident, that in the given seasons the innovative technology variant did not show significantly superior yield to traditional technology. The yield results of 2018/2019 season were negatively influenced by the inappropriate cold storage conditions and extreme drought in the vegetation season of 2019 which influenced transplanted plant establishment and yield formation. Whereas the insignificant yield difference between variants in 2019/2020 season was caused by the very good overwintering conditions in the field, therefore the innovative method could not show superior yield to traditional technology. We assume, that in harder winter when field overwintering conditions would be harsh for garlic, the yield difference would be for the sake of innovative technology.

CONCLUSIONS

The results of performed trial confirm initial idea that innovative hardneck garlic growing technology by using controlled conditions is appropriate for obtaining safe yield in changing climate conditions. The period of 50 days with temperature of 4.0–7 °C ensured clove initiation and complete bulb development.

In the study of given genotypes we observed that stalk development is the indicator of appropriate bulb development i.e. cloves formation.

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