Features of the cultivation technology of carrot hybrids in dry steppes of the Lower Volga region on drip irrigation

A I Bolkunov¹, M V Postnova² and G A Sroslova²

¹Research and production Company “Russian Field”, 3A Ciolkovskogo Street, Volgograd, 400001 Russian Federation
²Department of Bioengineering and Bioinformatics, Volgograd State University, 100 Prospekt Universitetsky, Volgograd, 400062 Russian Federation

E-mail: postnova@volsu.ru

Abstract. The paper studies the technology of the hybrid carrot cultivation with drip irrigation in a zone of the Lower Volga Region dry steppes. Carrots prefer medium-sized soil having the medium soil horizon and the pH of 6.0-7.5. However, it is cultivated in the majority of soil types. The crop yield depends on the quality the soil is cultivated with. Carrot taproots prefer the soil density of 1.0-1/3 g/cm³, so it is necessary to provide optimal water and air conditions of the soil. Sowing is done with pneumatic, electronic and mechanical seed drills. Pneumatic seed drills equipped with the metal pressure wheel, the tyne coulter, the small wheel for post-sowing pressing, the rubber wheel for soil smoothing and the distribution disk rotating in a direction opposite to seed drill wheels show the best seeding precision. The carrot cultivation performed under the conditions of the Lower Volga Region is possible only by means of irrigation. Carrot can be watered by corrugation, spray and drip irrigation methods.

1. Introduction

The carrot (Daucus carota L. ssp.sativus.) is a biennial plant in the umbellifer family Apiaceae. Carrot seedlings can withstand light freezes. The optimum temperature is +18°C. As for moisture, the carrot is a plant of oceanic climate and it develops well in a climate having no dry periods. These conditions provide the highest crop yield and high contents of provitamin A in taproots. High contents of carotene can be caused by warm temperatures as well. The carrot hardly withstands drought and hot weather. Carrot seeds start germinating at low temperatures. The lowest temperature of carrot seeds germinating is +1.3°C. At this temperature the plant development is slow and problematic. In order to achieve good seedlings it is necessary to provide sufficient moistening and maintain the temperature within the range from +8° to +9°C at the depth of 6-8 cm. The temperatures of +25°C and above can induce secondary dormancy of seeds and stop their germinating. The physiological limit is +35°C in the period of germinating. Seedlings grown in a cold spring can develop into a bolter. Carrot seedlings are sensitive to drought, a lack of aeration and the salt concentration in the soil. They are particularly sensitive to the soil crust forming on the heavy soil. Every single factor and their complex affect the stability of seed sprouting [1-3].

The carrot has a taproot system. While sprouting, the primary root appears and achieves the length up to 1 m. At first two seed leaf appear, after that the first true pinnately compound leaf unfolds. These true leaves form the rosette. The taproot appears in the process of the root secondary growth and the hypocotyl development.
The air temperature plays an important role in the process of the taproot development. The optimum temperature for growth of the nice and smooth taproot is +16° to +21°C, providing other conditions are observed (moisture, inorganic nutrition etc.). A temperature drop by 5-10°C leads to the taproot deformation due to the reduction of the physiological processes intensity. Photoperiodism has no practical significance at middle latitudes [4, 5].

Carrots prefer medium-sized soil having a medium soil horizon and pH (6.0-7.5). However, it is cultivated in the majority of soil types. The humus content is to be not less than 1.5% for the proper carrot development. The excess of humus layer contains plenty of nitrogen providing good conditions for pests. For this reason, soils with high organic contents are not the best choice for carrots.

Sandy soil and sandy loam are favorable for growth of the nice and smooth taproots. These soils have the low field capacity and lead to problems with watering and color intensity in a dry climate [6, 7]. Heavy-textured soils lead to reduction of the length of taproot but at the same time provides its intensive color and the high quality. Unfavorable soils for carrot cultivation are heavy soils which incline to form the crust, rocky soils and those soils that located close to groundwater. As for irrigated areas of the Volgograd Region, the carrot is cultivated mostly in the light chestnut soil.

The best predecessors for the carrot are the following ones:
— Ley;
— Onion, garlic;
— Cabbage;
— Potato;
— Radish.

Carrots should be cultivated with caution after the corn, the bean and cereals. It should be taken into account that these cultures are exposed to fungal infections such as brown patch, white mold and Pythium disease. If predecessors are found to have the diseases mentioned above, carrots should not be cultivated in these fields. Pythium is able to reduce corn yields by 45-55%.

The carrot should not be sown over the layer of perennial grasses, umbellifers and in fields where the white mold-exposed sunflower is cultivated in.

Secondary sowing of the carrot or sowing it in the same place before three years pass lead to nematode and root rot accumulation. The high quality taproots are possible to grow only if a crop rotation is observed.

Carrot harvest strongly depends on the quality the soil is cultivated with [8-10]. Carrot taproots prefer the soil density of 1.0-1/3 g/cm³, so it is necessary to provide optimal water and air conditions of the soil.

2. Results and discussion
Experimental sowing of carrot hybrids was carried out in the peasant farm holding “Zaitseva VA” located in Gorodishchensky district of Volgograd region. Sowing was being done in the period from 2014 to 2017 in several steps: soil preparation, planting, maintenance, fertilization, irrigation regimes, weed control, pest control, harvesting and storing.

3. Results and discussion
The soil layer involved in the carrot cultivation process can be divided into three levels: the high level (organic, 0-5 cm), the medium layer (surface, 5-27 cm) and the low (subsoil, 27 cm and deeper). Hence the scheme of soil cultivation is designed.

The system of the light chestnut soil tillage in the Lower Volga Region involves the autumn and the spring periods.

The autumn period involves:
— Harrowing of a stubble of a predecessor to a depth of 5-6 cm;
— Beardless ploughing (or mouldboard ploughing, if necessary) with putting of a fertilizer to the depth of 25-27 cm.
— Para-ploughing to a deep of 35-40 cm.
The quality of the soil cultivation influences on a shape and a colour of the taproot. Agrotechnical methods can be diverse but all of them should be focused on maintenance and improvement of the physicochemical soil properties [4].

In case weeds grow and some debris stays after a field has been ploughed it is reasonable to harrow the field again. As a last resort, it is possible to clean the field with nonselective herbicides.

Light chestnut soils of the Lower Volga Region are highly exposed to wind erosion. The spring sowing campaign should be started with harrowing.

There are two variants of the spring period:

The first variant:
— Double harrowing aiming to save moisture and smooth the soil;
— Complete cultivation to the depth of 10-12 cm with a single section harrow;
— Presowing cultivation to the depth of 2-4 cm with a single section harrow;
— Sowing seeds to the depth of 1.5-2 cm and fertilizer placement with a pneumatic seed drill.

The second variant:
— Double harrowing aiming to save moisture and smooth the soil;
— Placement of mineral fertilizers:
— Tilling to the depth of 14-16 cm with a one-roller or a two-roller rotary tiller;
— Sowing with a pneumatic seed drill with the pressure wheels.

Two-roller rotary tillers show the best results for summer field preparation in the Volgograd Region.

Soil particles should be sliced well. The primary constituent particle size should range from 0.5 cm to 1 cm. If there is a lot of trash in a field the appropriate herbicide needs to be used after sowing.

Sowing of carrot seeds is a very important stage influencing on the crop yield. Seeds are to be not lower than the first class. They should be calibrated according to their fraction size and treated with thiram and iprodione. Sowing is done with pneumatic, electronic and mechanical seed drills. Pneumatic seed drills equipped with the metal pressure wheel, the tyne coulter, the small wheel for post-sowing pressing, the rubber wheel for soil smoothing and the distribution disk rotating in a direction opposite to seed drill wheels showed the best seeding precision. This construction provides the best seeding precision.

The best crop yield results can be achieved provided accurate observing a distance between the plants. The low quality of production is observed after sowing with seed drills that are not able to control a distance between the seeds.

The Volgograd Region conditions allow the carrot to be sown two times per year. The first time the carrot is seeded in the early spring and harvested since the third June decade. This harvest is not put in storage but processed for sale.

The carrot sown in May is harvested in September and October. This harvest is put in storage and processed later. In the conditions of the Lower Volga Region dry steppes, the early varieties of carrot and its hybrids are to be sown with the early cereals when the soil temperature gets from +6°C to +8°C at the depth of 6-8 cm. The sowing density of the early carrot varieties is lower. There should be 900 to 1200 thousands carrots per hectare depending on the carrot variety. Certain varieties can be seeded at the density of 1700 thousand plants per hectare. This norm is larger for the late sowing as the plants are more likely to come under the adverse environmental conditions influence at this period (drought; dry wind which is also known as dry wind). The carrot should be sown at the density of 1800 to 2200 thousand first class seeds. The early sowing allows the plants to avoid being damaged by pests. The late sowing leads to crop yields reducing because of the high temperatures and pests.

The seeds should be sown at the depth of 1-2 cm. After sowing the field should be watered for uniform germination. It will provide uniformity of the product.

Conditions of the Lower Volga Region allow carrot cultivation to be possible only by means of irrigation. Carrot can be watered by corrugation, spray and drip irrigation methods. The technology we describe implies using the drip irrigation method. This technology means using the seed drill equipped with the pipe making machine. Sowing and pipe making are carried out at the same time. The seed drill
should not move faster than 4.5 km/h in order to provide the best seeding precision and avoid tube damage.

In the conditions of the Lower Volga Region the eight row planting system is optimal (Figure 1).

![Figure 1. Scheme of carrot sowing for drip irrigation.](image1)

This sowing method means placing 1900 thousand seeds per one hectare. This norm can be regulated by changing a distance between the seeds. Production trial showed that taproots located in the center rows have medium size but taproots located in the marginal rows have a larger size (figure 2). This can be explained by the better soil aeration and illumination of the marginal rows.

![Figure 2. Results of the carrot sowing.](image2)

Taking care of plants in the vegetation period means interrow soil cultivation, control of pests, weeds and diseases. The first interrow soil cultivation is carried out up to the depth of 6-8 cm at the early period of the plants development. The next two cultivations are carried out at the depth of 8-10 cm and 10-12 cm. The last one is carried out at the depth of 8-10 cm in August before harvest.

It is necessary to watch the plants state in the course of the vegetation period. In case deficiency of trace elements is observed, it is necessary to use foliar fertilizers. The intensive method of plant care means using a proper fertilizer system, irrigation regimes as well as treating with herbicides, insecticides and fungicides in a proper way.

The system of using fertilizers, pesticides and cultivation methods should be based on a clear understanding of the plants development stages.

The carrot vegetation period can be divided into the following stages:

- Sowing: appearing of seedlings, seed leaves and the first true leaf;
- Unfolding of 3-4 true leaves; taproot elongation;
- Unfolding of 4-6 true leaves; taproot thickening;
- 50% of leaves in a row overlap each other;
- Twenty days before harvest.

The responses of carrots to the usage of organic fertilizers are the same. Dung application leads to appearing of branching taproots and root rot accumulation (e.g. Pythium disease).
In order to grow the crop with the productivity of 60-70 t/ha it is necessary to fertilize a field on average with 100 kg N, 120 kg P₂O₅, 20-30 kg K, 20 kg MgO per hectare.

The carrot is very sensitive to deficiency of MgO. Magnesium deficiency can be detected if young leaves turn yellow between veins and old ones dry. Leaf roll can mean potassium deficiency. Potassium fertilizers should be used in the sulfate form. The carrot is very sensitive to soil acidification. In case of growth retardation, it is necessary to make sure whether the plant gets enough bor. Growth retardation can be observed in all types of alkaline soils. In order to get high yielding crops, it is necessary to put phosphate and potassium fertilizers in autumn before replowing. As for light chestnut soils of the Lower Volga Region steppes, it is 400-500 kg of the nitrogen-phosphorus-potassium fertilizer (also known as NPK) or diammonium phosphate. Depending on the type of a field, single superphosphate, double superphosphate and potassium magnesium can be used as well.

In spring in the course of sowing or before it 150-200 kg NPK should be applied. Foliar fertilizers should be used twice at every stage of the vegetation period. These fertilizers are water-soluble NPK 18:18:18 applied in the chelated form with trace elements at the rate of 3-4 kg per hectare.

In order to get high yielding crops, it is necessary to apply sodium nitrate 4-5 times with the gross weight of 300-400 kg. Nitrate should be applied with watering 4-5 times.

In order to get the exact system of inorganic nutrition the agrochemical map of field is needed.

In the course of the vegetation period, it is necessary to monitor different parts of the field. In case the symptoms of trace elements deficiency are found, foliar fertilizers must be applied. If a plant is damaged by pests or diseases it must be treated.

Watering is of paramount importance for achieving the best results of the carrot cultivation. Seedlings appear faster if the seeds are irrigated. The risk of soil crust forming is reduced, the taproot becomes larger and longer and the crop yield gets higher as a result. Watering radically reduces the risk of scab forming and upgrades the quality of the taproots. However, the excess of watering can cause negative effects. It can lead to soil crust forming, taproot damaging and appearing of root and bacterial rot as a result of poor soil aeration. It indicates the importance of the proper irrigation regime for the carrot cultivation.

Steppes of the Low Volga Region are remarkable for heavy soils and rapid dry winds. In these conditions the most critical period is the phase between the seedling appearing and the first true leaf unfolding. In the course of this period, it is necessary to maintain the soil moisture at the level of 80% of the field capacity. It is better to water frequently but with a little water for the reason of the low growth coefficient (0.3).

At the next stage (unfolding of 3-4 true leaves, taproot elongation) the soil moisture should be maintained at the level of 70% of the field capacity. It provides the taproot elongation. Watering should be less frequent but with more water. From the next stage (unfolding of 4-6 true leaves, taproot thickening) and up to the harvest the soil moisture is maintained at the level of 80% through watering with the medium frequency and larger amounts of water.

There can be 14 to 24 waterings in the vegetation period depending on climate indices and precipitations. The irrigation water requirement (IWR) can be 5500-6000 m³/ha. IWR changes depending on sowing density, harvest time, inorganic nutrition, soil type, precipitation and winds.

Water used for irrigation must be fresh and must not contain a large amount of salts. Otherwise more than half of harvest can be lost. In order to prevent harvest losing it is necessary to pay attention to weed control.

Weed control procedures should be systematic and should not disturb the fertilizing system.

Weed mapping over the years allows creating an accurate system of weed control at minimum expense.

Just after sowing and before seedlings appear it is encouraged to apply the Stomp herbicide (Stomp, Ks) at the rate of 3.25-3.5 l/ha (330 g/l). It controls annual gramineous and biennial weeds. Seedlings growth is a very long process. It takes 27-30 days after sowing before the first true leaf appears. In this period the growing degree days (GDD) values become higher and weeds grow rapidly. Timely crop treatment allows eliminating weeding costs.
At the next stage (1-2 true leaves unfold) prometryn is applied. It is used at the rate of 1.5-2 liters per hectare in 200-300 liters of water.

Exceedence of these standards can adversely affect the carrot growth and the taproot forming.

Harvest should be started when the taproots achieve the desired product quality. The carrot put in storage is prohibited to be washed. The crop can be harvested by hands or mechanically. Anyway, it is necessary to choose the way of harvesting which damages taproots least and meets economic opportunities. It is pulling the carrots out by their green tops in case of light soils. As for heavy soils, it is digging them out.

The carrot tops are cut with KIR 1.5 mowers. 4-5 cm of the petioles should be saved in order to prevent taproots diseases. Modern storages are equipped with washing and sorting lines where carrots are washed, graded, cooled and stored.

The carrot is kept in storages and storage clamps. In countries with mild winters it is kept in fields mulched with straw. In these conditions carrots are kept before product processing.

4. Conclusion
Carrot hybrids cultivation in the Volgograd Region vegetable crop rotations is of strategic importance if crop yield changes are observed. The soil and climatic conditions of Volgograd Region allow both harvests to be possible. The early one is necessary for a healthy human diet meanwhile the second one can be stored as a high quality product with a long shelf life. It is of strategic importance for Russian food security.

Experimental results were obtaining in the peasant farm holding “Zaitseva VA” located in Gorodishchensky district of Volgograd region. The crop yields depended on the conditions the pilot production was cultivated under as well as the right choice of the improved carrot hybrids cultivation technology which uses the drip irrigation systems and achieves sustainable carrot crop yields of about 80 t/ha.

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