

Effect of Late Cultivation under Low Tunnels on the Growth and Productivity of Some Leafy Vegetables

Prof. Dr. Rida DRAIE

Faculty of Agricultural Engineering, Horticulture Department, Specialization of Plant Biology, Idlib University, Syria

Author's E-mail: rida.draie@idlib-university.com

Abstract - The experiment was carried out in 2022-2023, on agricultural land in Idlib governorate, in the West Northern of Syrie. Experimental treatments were planted under low tunnels and covered with transparent plastic, to study the effect of late planting of spinach and lettuce crops in protected conditions. The seeds of local varieties of spinach and lettuce were used for the research. The experiment was carried out according to a randomized complete block design.

The experiment results indicated that using protected cultivation methods led to significantly better outcomes in various aspects compared to open-field cultivation. For both spinach and lettuce crops, protected cultivation resulted in higher seed germination percentage (1.3 times), increased leaf area of seedlings (3.3 times), more marketable plants (1.8 times), greater number of leaves per plant (1.3 times), taller plant height (1.3 times), higher seedling weight (3 times), and greater plant weight at harvest (1.5 times). Overall, the total productivity per unit area increased using protected cultivation. The average increase rate for all studied traits was 1.9 times higher in protected cultivation compared to open cultivation. As a result, we recommend late cultivation of spinach and lettuce crops under low tunnels to shorten the cultivation period after the completion of long-season summer cultivation.

Keywords: Low Tunnel-Protected Cultivation, Late Cultivation, Spinach, Lettuce, Productivity.

I. INTRODUCTION

Protected agriculture contributes to the protection of crops from unsuitable climatic conditions, and to ensuring conditions for growth for early production on the one hand, and permanent supply on the other. Their importance is gained through their remarkable role in intensifying production and increasing land investment following the increase in the population and the lack of sources of food. The need for new means and methods to increase agricultural production and achieve food security is a necessity (Butler and Ross, 1999; Ken, 2004; Demchak, 2009; Singh *et al.*, 2012; Struck-Faivor; 2014).

Agriculture in low tunnels is a form of protected farming. The tunnels are in the form of semi-circles characterized by simple structure and ease of implementation. They are less expensive than high greenhouses, which increased the area cultivated for vegetable crops in recent years. These tunnels are covered with plastic sheeting (plastic tunnels) to avoid cold and frost damage during the winter months to produce seedlings or early production of vegetable crops (Salman *et al.*, 1992; Wien, 2009; Lodhi *et al.*, 2013; Draie, 2022).

Agriculture under low plastic tunnels is one of the important and effective economic technologies for protected crops worldwide in general and in the Mediterranean countries in particular to protect vegetable plants that need warm weather when grown in the winter without resorting to industrial heating (Enoch, 1999; Hassan, 1999; Ken, 2004; Singh *et al.*, 2012).

Agriculture under low plastic tunnels is achieving many objectives. Where the tunnel is more suitable to receive sunlight throughout the day and therefore the temperature inside the tunnel is higher than outside during the day, especially at low temperatures. It also contributes to the early production of many vegetable crops, which need warm weather when growing in winter for up to 3-4 weeks compared to plants implanted in the open land, which leads to the availability of these vegetables during the scarcity of the crop. It is easy to move and move from place to place depending on the agricultural cycle, which is considered an important agricultural operation to avoid the problems of soil diseases, especially fusarium, verticillium, and nematodes. Therefore, soil sterilization can be dispensed with, thus reducing production costs. In addition to the low cost of construction of greenhouses. Where the cost of establishing low tunnels for a 1000 m² area does not exceed 25% of the cost of constructing a single high greenhouse of 60 m². It is also possible to close the tunnels, and do not need industrial heating while explaining the use of water (Salman *et al.*, 1992; Enoch, 1999; Wien, 2009; Singh *et al.*, 2012; Lodhi *et al.*, 2013; Struck-Faivor; 2014).

Green leafy vegetables (GLVs) are very important for human nutrition. They consist of pectin, cellulose, and

hemicellulose substances that confer texture and firmness. They are very important protective foods and are convenient for maintaining health and preventing several diseases (Al-Obeid and Al-Shtewi, 2004; Mohammed and Sharif, 2011). GLVs are recommended for weight management as they are naturally low in calories (Nwanekezie and Obiakor, 2014). They are useful in reducing the risk of cancer, cholesterol, and cardiovascular disease since they are low in fat, high in dietary fiber, and rich in folic acid, and vitamin C, as well as containing a host of antioxidants (Olabi and Al-Waree, 1997; Homedan and Zedan, 2004). Leafy vegetables contain numerous minerals such as Ca, Fe, Cu, P, Zn, Cl, and Na which are vital for growth and metabolism. The predominant elements found in green leafy vegetables are Ca, K, Fe, and Na. These provide an alkalizing effect to the acidity produced by other foods, especially those of animal origin (Al-Obeid and Al-Hajji, 1997; Rahman, 2006; Angela *et al.*, 2010).

Spinach is an important vegetable in the canning and freezing industries. It is useful in baby foods and diet foods, especially gastroenteritis. The use of spinach in nutrition prevents the evolution of malignant tumors and anemia because of its richness in iron. Spinach is a vegetable rich in nutrients, containing 15% dry matter, 5% carbohydrates, 4% proteins, 0.5% fats, and 1% fibers. Spinach protein is an easily digestible protein that competes with proteins found in milk. Spinach leaves contain a high percentage of vitamins, especially vitamin C (50 mg %), carotene (8 mg %), vitamin D, and group B vitamins. It also contains mineral salts, mainly potassium, calcium, phosphorus, magnesium, and iron (Samra and Sheikh Sulaiman, 1998; Buraq *et al.*, 2003; Draie, 2019).

Lettuce is also considered an important leafy vegetable due to its rapid maturity, high productivity, and fresh consumption, which ensures the optimum profit from vitamins, salts, and other nutrients it contains. The leaves contain about 5-10% dry matter, which consists of sugars, proteins, organic acids, and fats, and contain vitamins of high proportions (mainly C, A, E, K, B) and mineral salts (calcium, iron, magnesium, and others). It comes after spinach in terms of mineral salt content. The lettuce juice contains lactose glycoside, which calms the nerves, reduces pressure, helps sleep, and improves appetite and digestion by adjusting the acidity of the stomach. Lettuce also helps in the secretion of choline, which prevents atherosclerosis and helps to remove cholesterol from the body. It also helps to digest fats and is used in weight management regimes (Al-Hajji, 1997; Homedan and Zedan, 2004; Draie, 2019).

In the field conditions in Syria, spinach is planted in August and September, and seeds begin to germinate at a temperature of 4°C. The ideal germination temperature is 18°C. The lettuce is sowed in September and the seedlings are

transplanted at the end of October. Seeds begin germination at a temperature of 2°C and the ideal degree of germination is 15°C. This means that these crops occupy the field land for a long time. So, the farmer needs to plant them in the summer (where temperatures help rapid and homogenous germination and good vegetative growth) to get production in the winter. This reduces the possibility of investing the land in the cultivation of summer crops in the same agricultural plot thus reducing the economic profits that the farmer can obtain and may cause the farmer to neglect the field and not cultivate it (Al-Obeid *et al.*, 1994; Buraq *et al.*, 2003; Homedan and Zedan, 2004; Draie, 2019).

We conducted this research to determine the possibility of delaying the cultivation of winter leafy vegetables until the completion of summer crops, especially those belonging to the *Cucurbitaceae* and *Solanaceae* families, which continue to grow until the end of November. On the other hand, to know the extent to which low tunnels can be used as a protected agriculture technique and its effect on the growth productivity of leafy vegetables. We have experimented with vegetable crops belonging to different plant families to study the effect of applying this technique on the production of a wide range of vegetable crops.

II. MATERIALS AND METHODS

Experiment location:

The experiment was carried out in 2022-2023, on agricultural land in Idlib governorate. It is rising about 700 m above sea level, with an annual rainfall of 505 mm and an annual temperature average of 18.4 °C.

Plant material:

The seeds of local varieties of spinach and lettuce were used for the research.

Treatments Experimental:

Only experimental treatments were covered with transparent polyethylene sheeting, and reed arches were used to lift the plastic cover from the plant level (low tunnels). After germination and the arrival of the seedlings to the appropriate size of the transplantation, the required readings were taken. The seedlings were then transplanted at the planting distances between the lines 1 m and within the lines 50 cm.

The parcels assigned for the research plowed deep cultivation, during which the following fertilizers were added: fermented organic fertilizer 3 kg/m², 30 g/m² P₂O₅, 30 g/m² K₂SO₄, 40 g/m² NH₄NO₃. These fertilizers were then turned into the soil at a depth of 20 cm. The soil surface was then

smoothed and divided into terraces with dimensions of 1×1 m². Planting was done using seeds, which were planted on lines within the beds at a depth of 2 cm on 11/25/2017. After planting, the germination and growth of plants were monitored and service operations performed, especially the removal of herbs that were carried out within the experimental pieces and manually whenever needed.

Measured parameters:

The following measurements were taken:

- Seed germination ratio.
- Leafy area of seedling (cm²).
- Weight of seedling.
- Number of leaves per seedling.
- Length of seedling.
- Length of mature plant.
- Weight of mature plant.
- Leafy area of plant (cm²).
- Number of leaves per mature plant.

Experimental design:

A randomized complete block design (RCBD) was used. The experiment was conducted on two plant species: spinach and lettuce. Two treatments for each species (cultivation covered with transparent polyethylene [low tunnels], and non-covered cultivation [control]), with three replicates per treatment, were adopted. Cultivation was carried out in a parcel with dimensions of 1×1 m²; in each parcel, 100 seeds were planted. Therefore, the total number of seeds in the experiment = 3 × 2 × 3 × 100 = 1800 seeds.

Statistical analysis:

All statistical analyses were performed by the statistical program (Sigma-Stat). ANOVA analysis of variance was done to calculate the least significant difference (LSD) at the significance level of 5%.

Results:

The results of the planting of spinach under low tunnels were collected and then analyzed statistically. Table (1) shows the obtained results.

Table (1): Results of production of spinach and lettuce under low tunnels

Trait	Spinach		Lettuce		L.S.D. (5%)
	Protected agriculture	Open agriculture	Protected agriculture	Open agriculture	
Germination percentage (%)	48	43	25	15	3.2
Seedling leaf area (cm ²)	14.6	2.1	18.9	8	2.43
Seedling weight (cm)	3	1	3	1	0.44
Number of leaves per plant	12	8	4	4	1.6
Plant height (cm)	30	25	26	18	2.05
Plant leaf area (cm ²)	64	45	160	78	3.65
Plant weight (g)	400	230	360	290	14.8

Table (1) shows a significant superiority of protected cultivation under low tunnels over cultivation in the open field in all studied characteristics.

The germination rate and percentage of spinach and lettuce seeds were calculated after 30 days of sowing the seeds. The germination percentage of spinach and lettuce seeds in protected cultivation within low tunnels was higher than in open ground with clear significant differences. The germination percentage reached 48% in protected cultivation and 43% in open cultivation for spinach seeds (an increase of 111.63%). While the germination percentage reached 25% in protected cultivation and 15% in open cultivation for lettuce seeds (an increase of 166.67%). In general, spinach seeds outperformed lettuce seeds in germination percentage with average germination of 45.5% and 20%, respectively (an increase of 227.5%). This can be explained by ensuring better

thermal conditions for germination, as germination does not occur at low temperatures close to zero degrees Celsius. In contrast, germination is in its best condition at a temperature of about 18 degrees Celsius, and below this temperature, germination occurs at varying rates depending on the vegetable crop grown (Draie, 2019).

Readings were taken on seedlings prepared for planting one month after germination for both low tunnel and open field seedlings when the seedlings reached the appropriate size for transplanting. The leaf area of spinach seedlings grown in low tunnels was 14.6 cm² and that of open field seedlings was 2.1 cm² (a 6.95-fold increase in favor of low tunnel seedlings). The leaf area of lettuce seedlings grown in low tunnels was 18.9 cm² and that of open field seedlings was 8 cm² (a 2.4-fold increase in favor of low tunnel seedlings). Comparing the average leaf area for spinach and lettuce seedlings, the lettuce

leaf area was 13.45 cm² and the spinach leaf area was 8.35 cm² (a 1.61-fold increase). As for seedling weight, it was 3 g for seedlings grown under low tunnels and 1 g for seedlings grown in the open field (an increase of 3 times in favor of seedlings grown under low tunnels). Seedling weight was generally equal in spinach and lettuce with an average of 2 g per seedling. Regarding the number of leaves per seedling, it was 12 leaves in spinach seedlings grown under low tunnels and 8 leaves in spinach seedlings grown in the open field (an increase of 150% in favor of seedlings grown under low tunnels). As for lettuce seedlings, there was no difference between seedlings grown under low tunnels and seedlings grown in the open field with a value of 4 leaves/seedling. Comparing spinach and lettuce seedlings, the average number of leaves in spinach seedlings was 10 leaves, while the average number of leaves in lettuce seedlings was 4 (an increase of 2.5 times in favor of spinach seedlings).

For fully mature lettuce and spinach plants ready for marketing and consumption, readings were taken two months after planting for both low tunnel and open field plants. The average height of the economically mature spinach plant was 30 cm for tunnel plants and 25 cm for open-field spinach plants (an increase of 120%). As for lettuce plants, the average plant height was 26 cm for low tunnel plants and 18 cm for open field plants (an increase of 144%). Comparing spinach and lettuce plants, we note that spinach plants outperformed in plant height, with the average height of spinach plants reaching 27.5 cm, while the average height of lettuce plants reached 22 cm, an increase of 5.5 cm.

The leaf area of marketable plants produced under protected conditions was 64 cm² and 45 cm² in plants produced under open field conditions (an increase of 1.42 times in favor of protected plants). In marketable lettuce plants, the leaf area was 160 cm² in plants produced under protected conditions and 78 cm² in plants produced under open field conditions (an increase of 2.05 times in favor of protected plants). The leaf area of cultivated lettuce was larger than that of cultivated spinach, with values of 54.5 cm² and 119 cm² in spinach and lettuce, respectively, and the increase in the leaf area of lettuce leaves was about 2.18 times that of spinach leaves.

In terms of productivity, protected cultivation significantly outperformed open field cultivation in the weight of one spinach plant, with values reaching 400 g and 230 g for both protected cultivation and open field cultivation, respectively, with an increased rate of 1.74 times in protected cultivation compared to open field cultivation. Protected cultivation also significantly outperformed open field cultivation in the weight of one lettuce plant, with values reaching 360 g and 290 g, respectively, with an increase rate

of 1.24 times in favor of protected cultivation. There were no significant differences between the average weight of lettuce and spinach plants, with values reaching 325 g and 315 g for both lettuce and spinach plants, respectively.

These results demonstrate the importance of protected cultivation of vegetable crops and its role in providing the appropriate thermal and moisture conditions for the germination, growth, and development of these crops, thus increasing production and improving their quality. Previous studies have shown the importance of using low tunnels in field cultivation to provide the appropriate thermal conditions for the growth of vegetable crops and thus improve their productivity in terms of quantity and quality (Thakurand Devi, 2013). In general, low tunnels are used to produce vegetable seedlings in late winter conditions to prepare and equip these seedlings under the tunnels early and plant them in the field as soon as suitable climatic conditions are available (Butler and Ross, 1999; Struck-Faivor, 2014; AVRDC, 2015). Low tunnels can also be used in the production of early vegetables, starting from planting seeds until the crop matures and is harvested. It has been used in the production of melon (Hemphill, 1986; Ibarra *et al.*, 2001), pepper (Gerber *et al.*, 1988; Lodhi *et al.*, 2013), cucumber (Wolfe *et al.*, 1989), tomato (Wolfe *et al.*, 1989; Sandri *et al.*, 2003; Cowan *et al.*, 2014), cabbage (Gaye and Maurer, 1991), watermelon (Libik and Siwek, 1994), lettuce (Libik and Siwek, 1994), strawberry (Lamarrel *et al.*, 1996; Singh *et al.*, 2012), green squash (Kumar *et al.*, 2015; Kumar *et al.*, 2018), and blackberry (Carlen and Kruger 2009; Ogden and Van Iersel, 2009; Li *et al.*, 2012), and other vegetable crops.

Most of the studies mentioned focus on early planting of vegetable crops, whether winter or summer vegetable crops. The studies did not mention any attempts to test the effectiveness of low tunnels in late planting of winter vegetable crops, and therefore our research is the first of its kind. We obtained very positive results in terms of improving production in quantity and quality compared to the control planted in open ground at the same time.

III. CONCLUSIONS

This research showed the importance of protected cultivation under low tunnels in improving the production of the studied vegetable crops (spinach, and lettuce). The germination rate of seeds planted in low tunnels increased compared to the control. The leaf area of seedlings and plants grown in low tunnels increased, as did the number of leaves and the height of plants compared to the control. Finally, the weight of both seedlings prepared for transplanting and the weight of plants at harvest increased, and thus the total productivity increased significantly compared to the control.

Accordingly, we recommend late cultivation of spinach and lettuce crops under low tunnels to shorten the cultivation period after the completion of long-season summer cultivation.

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