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(RESEARCH ARTICLE)

Growing forms of peppers

Besim Salkić [1,*], Nermin Čerkezović [1], Emir Imširović [1], Damir Aličić [1] and Adnan Hodžić [2]

[1] *Faculty of Technology Tuzla, Ulfeta Vejzovića 8, 75000 Tuzla, Bosnia and Herzegovina.*
[2] *Plant doo Tuzla, Bukinje b.b., 75000 Tuzla, Bosnia and Herzegovina.*

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Abstract

Pepper (*Capsicum anuum L.*) is a one-year-oldr plant from the *Solanaceae* family. Due to its long vegetation (April to November) it represents the most profitable vegetable culture in greenhouses and is one of the most represented crops in the greenhouse production of Bosnia and Herzegovina. Pepper as a year-round culture has several ways of growing.

The experimental part of the work was carried out in the Plant nursery Ltd Tuzla, with the aim of growing three different pepper hybrids on three different growing forms and determining which hybrid is best suited for a particular cultivation in terms of the number, size and quality of the fruits, ie. the yield of the plant and the speed of frut maturation.

The tested pepper hybrids (´Vedrana F1´, ´Blondy F1´ i ´Bobita F1´) responded in various ways to the removal of offshoots and thus to the formation of different growing forms. The pruning of plants into a growing form with three trees accelerated the development of fruits in the hybrids 'Blondy F1' and 'Bobita F1'. Hibrid 'Vedrana F1' had slower growth than the other two hybrids during the experiment. The pruning of the plants also affected the weight of the fruit, so the heaviest fruits of the hybrid 'Vedrana F1' were in the growing form 3V, the 'Blondy F1' in the growing form 1V, while the hybrid 'Bobita F1' had the heaviest fruit in the 2V growing form. The growing form of the plants also affected the share of market and non-market fruits.

Keywords: Peppers; Protected area; Growing forms

1. Introduction

Pepper is a highly valued vegetable, that is rich in medicinal ingredients and therefore recommended in the diet. The pepper fruit has great nutritional value. The proportion of nutrients in the fruits grows to their physiological maturity [1]. The objective of growing are fruits which are harvested when they reach the size, shape and color characteristic of the cultivated variety. Harvest time is in the technological or physiological maturity, depending on the further use of the fruit. In some varieties, physiological and technological maturity overlap [2].

The best and healthiest to eat is fresh, heat-untreated pepper, and its meat and fruit parts are considered medicinal. Due to the large amounts of vitamin C it is recommended as a dietary supplement to strengthen the immune system. Due to the high content of vitamins, peppers are recommended as a means of preventing colds, periodontal disease and improving vision [3]. It is successfully grown both outdoors and in greenhouses.

Peppers are varied in shape, size, color and taste of fruits. According to Matotan, six types of pepper cultivars are distinguished: large-fruited (*Capsicum annuum var. macrocarpum*) - "bell-shaped", "rotund", "gate", "horn", spicy and small-fruited (*Capsicum annuum var. microcarpum*) [4].

Pepper growing technologies in greenhouse conditions are different, often focused on increasing the yield of crops, which is converted to a higher market price. One of the several measures to increase early harvesting is pruning or

* Corresponding author: Besim Salkić

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removing one or more sympodially grown offshoots, which means that the plant grows with one, two or more fertile branches (offshoots). When growing peppers in greenhouses, we must ensure that the plants grow in a suitable growing environment [5]. Since peppers is a heat-demanding crop, its cultivation usually begins with the seedlings in protected areas. The highest quality seedlings are grown with a lump of substrates in protected areas, keeping the temperature close to optimal, 20 to 25 °C by day and 15 to 18 °C at night, and a relative humidity of about 70% [6].

In the period after the transplanting of the seedlings, vegetative growth and development of the root system of the plants are promoted, most easily by performing the appropriate fertilization and regulating the temperature during the cultivation of the peppers in the protected area. Its cultivation is favored by well-structured and moist soil, while it is more sensitive during drought [7]. Peppers, and especially the yielding varieties, require a lot of moisture. Soil moisture until the beginning of fruiting should be 70 - 75% of the field water capacity (FWC) and during full fruiting 80 - 85% of the FWC. Low humidity can cause flowers and young fruits to fall off [8]. It is desirable to promote the growth of the root system by proper fertilization [9]. The peppers root is spindle-shaped and starts branching very quickly. It penetrates up to 60 cm deep, but most of it is rooted in the upper 30 cm soil, and extends up to 60 cm in diameter. However, the pepper has a poorly developed root, what causes a lower possibility of using nutrients and water from the soil [6].

The plants are well developed, while flowering accelerates. The flowers are white or light green in color and are located in the axils of leaves. Flower size correlates with leaf size and fruit size [10]. The leaves are large, simple, on the longer or the shorter petioles, on the main stem spirally arranged. They are green in color and oval-elliptical in shape. There is a correlation between the color and size of the leaves with the fruits. Plants with large leaves will give large fruits. If the leaves are yellow-green, the fruits will be milky white, yellow or yellow-green in technological maturity. Plants with dark-green leaves produce fruits of dark-green color [2]. The fruits have different shapes that develop from three adult fruiting leaves. The shape of the fruit is characteristic of the variety, but can make a big change in unfavorable conditions [11].

For cultivation in greenhouses where growth is faster and plants are lush, there is no light and consequently the quantity and quality of crops is reduced. In practice, plant growth is controlled by pruning a tree. In this way are formed the breeding form with 2, 3 or 4 branches [1]. The stem is herbaceous and later on the base is woody. Main and lateral branches at cross-section are round, pentagonal or hexagonal and smooth, green or green with purple stripes [6]. The stem is usually smooth or covered with fine hairs [2].

When shaping a plant into 3 to 4 branches, the axial offshoot of the plant, from the root neck to the selected offshoots, is cleaned from the lateral leaves and offshoots. At the same time, we select three or four well-lit offshoots on which the plant will bear fruit, while removing the others. The selected offshoots are usually tied to supporting strings attached to the structure of the protected area so as not to break under the weight of the fruit [12]. Removal of leaves and offshoots from the axial offshoots is also recommended for outdoor cultivation, as it promotes the development of fertile offshoots and reduces the possibility of infecting plants through the lower leaves with spores of fungi overwintering in the soil [13]. Various authors believe that higher planting densities, the pruning of plants and shaping different growing forms (1, 2, 3 or 4 branches) can lead to higher quality crops ([14]), [15]) , [16]).

Marcelis and Ho explain that the occurrence of dry rot of the fruit is related to the reaction of the plant, which during high air temperatures stores all the water supply in the fully developed leaves to maintain transpiration. The result is that very little calcium enters the young, fast-growing tissue like the pepper fruit, resulting in a lack of calcium, which is certainly influenced by the way of the plant pruning [17]. The aim of this study was to examine 3 peppers hybrids, which were grown in three forms of cultivation, in order to determine the best ratio of quality and yield in cultivation forms of all hybrids.

2. Material and methods

The experiment examined how pruning plants and shaping them into breeding forms with one, two or three fertile branches (trees) can affect the growth rate and therefore the yield. Pruning was tested on three hybrid varieties in the type of pepper (*Capsicum anuum var.grossum L.*), which are already widespread among pepper producers in Bosnia and Herzegovina.

The experiment was conducted in the summer of 2019 in an unheated greenhouse on the experimental part of the nursery Plant Ltd Tuzla. The seedlings were transplanted into a greenhouse on April 20, where they were cultivated until the last harvest, on September 1. The first pruning was on May 3, and the first fruit picking was on July 4.

Three hybrid pepper cultivars ''Vedrana F1'', ''Blondy F1'' and ''Bobita F1'' were included in the experiment.

''Vedrana F1'' is an early hybrid of heavy, large fruits and thick pericarp (meat). The fruits are uniform, square, with a slightly expressed milky greenish hue. The plants have semi-open habitus, they are very strong and produce plenty of fruit. It is extremely yielding, adaptable and resistant bell pepper.

''Blondy F1'' is the leading pepper in terms of fruit quality, appearance and disease resistance. It is intended for outdoor production, but also can be used in the greenhouses. It is a early hybrid with a very strong plant and solid square fruits of whitish color that turns to yellow during ripening. The plant is highly resistant to fungal diseases that are almost unknown for this hybrid. Due to its thick-walled fruits and very strong root, unlike similar hybrids, for Blondy is an unknown occurrence of the "spots" of fruits resulting from a lack of Ca.

''Bobita F1'' is the most proper block bell, favored by manufacturers due to its successful yield from the greenhouse and from the open field. It is a pepper with probably the thickest wall, heavy for its size. Interesting is also the fact that this pepper at its biological maturity turns orange.

The experiment invluded 3 peppers hybrids, which were grown in three growing forms, giving a total of 9 treatments. By pruning is formed 1, 2 and 3 fertile branches. The repetition consisted of 10 plants. With growing form of three branches (3V) plants were planted at a spacing of 80 cm x 45 cm (plant assembly: 2.8 plants/m^2). The size of the plot was 3.6 m^2. When planting plants with two branches (2V) the planting distance was 80 cm x 40 cm (plant assembly: 3.1 plants/m^2). The size of the plot was 3.2 m^2. When planting growing plants on a single branch, the distance was 80 cm x 35 cm (plant assembly: 3.6 plants/m^2). The size of the plot was 2.8 m^2. The experiment was performed in triplicate, on three billets, randomly assigned 9 repetitions. The plants in the experimental plots were planted in a single row.

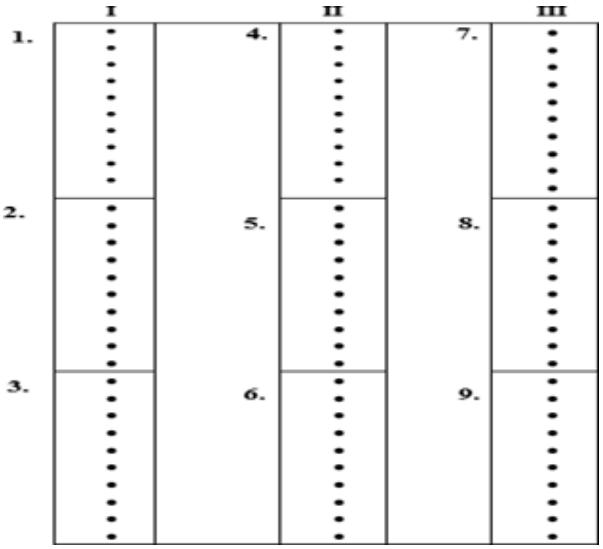

Figure 1 The plan of planting

The legend: I ´Vedrana F1´- 1. The growing on a single fertile branch; 2. The growing on two fertile branches; 3. The growing on three fertile branches; II ´Blondy F1´- 4. The growing on a single fertile branch; 5. Growing on two fertile branches; 6. The growing on three fertile branches; III ´Bobita F1´- 7. The growing on a single fertile branch; 8. The growing on two fertile branches; 9. The growing on three fertile branches;

The first pruning was done on May 3. Plants at the time of first pruning did not form flowers and other branches. The plants are pruned slightly above the first branch, leaving a different number of offshoots, depending on the growing form. At the growing form on the one fertile branch is left one offshoot in the first branching, at the growing form on the two branches are left two shoots in the first branching and in the growing form on the three branches, three shoots are left in the first branching. The shoots are evenly distributed according to the illumination. There were seven pruning in the growing season.

Table 1 Review of completed tasks, by date

Date	Task	Date	Task
03.05.2019	Pruning	20.06.2019	Pruning
10.05.2019	Removal of cotters	04.07.2019	Pruning
14.05.2019	Pruning	08.07.2019	Removal of cotters
28.05.2019	Pruning	29.07.2019	Pruning
04.06.2019	Removal of cotters	25.08.2019	Pruning

When the offshoots were large enough, on May 14 peppers were tied. To the construction of the greenhouse, 3 wire supports were attached to which, in accordance with the distances from planting, a PVC rope was placed and tied around each individual offshoot. For a better distribution of offshoots and lighting, strips are transversally tied to the plant. In order to establish the difference between individual varieties in the speed of development, the position at the time of the first flowers and fruits (1 month after transplanting) was counted and recorded, and then twice (May 14, June 24 and July 1), the flowers were counted and how much nodia was developed on the plant on all three growing forms.

There were seven harvests of technologically mature fruit in the growing season. The first harvest was completed on July 4, followed by July 12 and 29, August 6, 15 and 23, and the last harvest was done on September 1st. When harvesting technologically mature fruits, the fruits are counted and the mass of the fruit is weighed (g). The fruits are sorted into market and non-market fruits. Non-commercial fruits are considered to be those that have a mass below 100 grams, have a deformed shape or are damaged by snails, freckles, purple, damaged by a lack of calcium in the fruit and over ripped. At the last harvest, fruits weighing less than 50 grams are considered to be immature and non-marketable.

3. Results

In the text and Figures were used abbreviations: 1V - the formed shape that is led to one tree; 2V – the formed shape that is led to two trees; 3V - the formed shape that is led to three trees;

Figure 2, 3 and 4 show pepper yield measurements in g/m^2 for each hybrid and breeding form for individual harvests. The mass values of fruits harvested for the 'Vedrana F1 ' hybrid are shown in Figure 2. for individual harvests. For the first four harvest (July month and the beginning of August) the highest yields were achieved on plants with breeding form on three trees of the variety 'Vedrana F1' (3V). The yield was highest on 29 July (2146±13.43 g/m^2) when growing on three trees (3V). For the last three harvests (August and beginning of September), the highest yield was achieved when grown on two 'Vedrana F1' (2V) hybrid trees. During all harvest lowest yield was in the form of breeding in a one tree (1V).

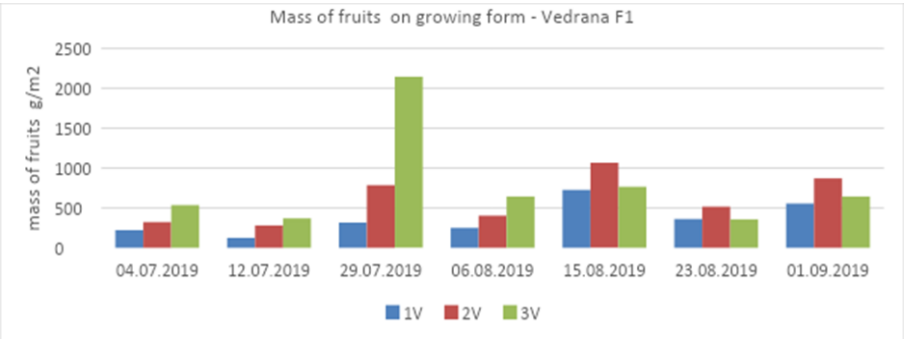

Figure 2 Mass of fruits g/m^2 of individual picking for the variety 'Vedrana F1'

The yield of 'Blondy F1' hybrids varied depending on the individual harvests according to the growing form of the plants. Figure 3 shows that most of the fruits harvested in late July to early September when grown on two trees (2V). The yield was highest on 29 July (1561.3±18.04 g/m^2) when growing on two trees (2V). In the third and fourth harvests, the yield was the same at growing form on one and three trees. The highest crop yield at growing form on one tree was also on

29 July (865.27±24.63 g/m², while at the second and fourth harvest it was higher than the yield at growing form on three trees. At other harvests, the yield on the growing form per one tree was lower than the other two growing forms.

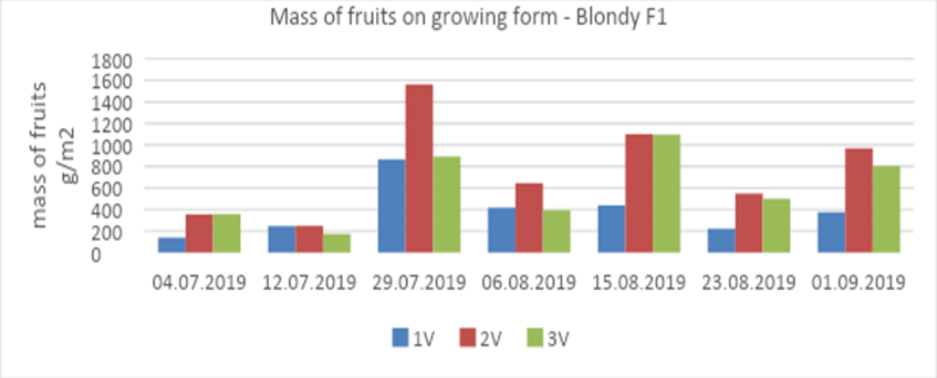

Figure 3 Mass of fruits g/m² of individual picking for the variety ´Blondy F1´

As in the previous two hybrids, the 'Bobita F1' hybrid yield varied according to the growing form of the individual harvests. In the first two harvests, the highest yield was achieved on the growing form with two trees (2V). At other harvests, the highest yield was with the growing form on three trees (3V). The yield was highest on 29 July (732.14±11.97 g/m²) when growing on three trees (3V). The yield for the harvest on August 23 was approximately the same for all three forms of growing. The highest yield in the growing form on one tree was 15 August (513.8±7.74 g/m²). The highest yield was achieved for plants with growing form on two and three trees.

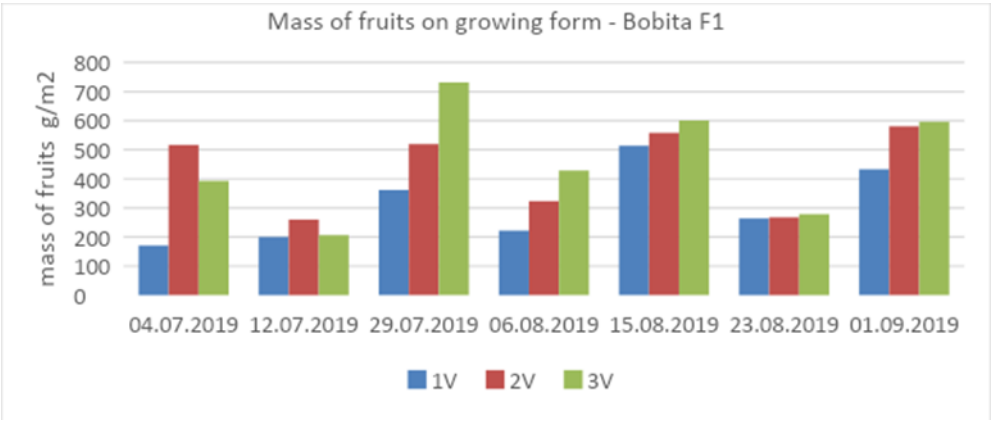

Figure 4 Mass of fruits g/m² of individual picking for the variety ´Bobita F1´

The average weight of the fruit with respect to the time of harvest for each variety and form of growing shows that during the first harvest, fruits had a lower mass than the later harvests, except for the 'Vedrana F1' hybrids on growing forms 1V and 2V and the 'Blondy F1' hybrid on the 2V growing form which had the heaviest fruits during the first harvest.

For hybrid 'Vedrana F1' the heaviest fruits in average (133.33±4.58. g) had a plants with a growing form on one tree, while the easiest fruits (108.75±6.32 g) were at the growing form on two trees.

For hybrid 'Blondy F1' plants with growing form on two trees had the heaviest fruits (157.14±9.14 g), while the easiest fruits were at the growing form with three trees (85.33±3.62 g).

The 'Bobita F1' hybrid had the heaviest fruits (144±5.89 g) when grown on one tree, while the easiest fruits (100.75±6.46 g) were growing in the form of two trees.

Figure 5 shows the mass of marketable and non-marketable fruits and the total weight of the fruit in g/m² for each hybrid and growing form. It can be seen that the yield of marketable and non-marketable fruits varied depending on the growing form and hybrid, that is, the pruning of plants into growing form 1V, 2V or 3V did not have the same effect on the crop in all hybrids which are considered.

Market yields from 1V treatments were highest for 'Blondy F1' hybrids (2701.61±23.14 g/m²) and 'Vedrana F1' (2556.8±17.08 g/m²) and lowest (2164.89±19.80 g/m²) for hybrid 'Bobita F1'. The yield of market fruits from cultivation 2V was the lowest for hybrids 'Bobita F1' (3024,36±23.68 g/m²), for hybrid 'Vedrana F1' (4243,46±29.18 g/m²) and the highest yield of market fruits for growing form 2V was for the Blondy F1 hybrid (5426.73±32.42 g/m²). The highest yield of marketable fruits from growing form 3V was for the hybrid 'Vedrana F1' (5459.84±26.75 g/m²), while the lowest was for the hybrid 'Bobita F1' (3234.97±18.37 g/m²).

Most non-marketable fruits were found in 'Vedrana F1' hybrid (2369.29±12.82 g/m²), at growing form 3V.

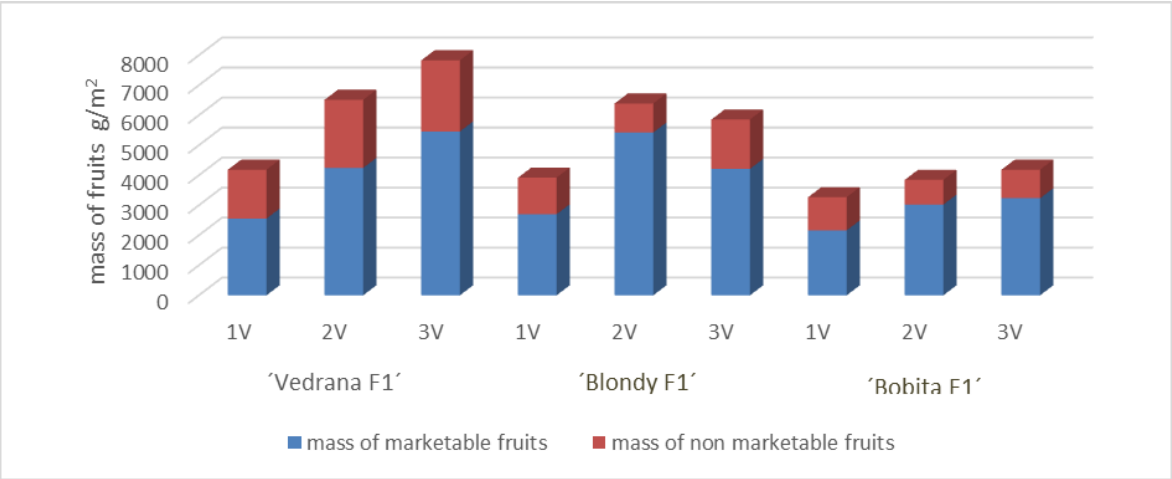

Figure 5 Mass of marketable and non-marketable fruits g/m²

Figure 6 shows number of marketable and non-market fruits per m2 for each hybrid and growing form.

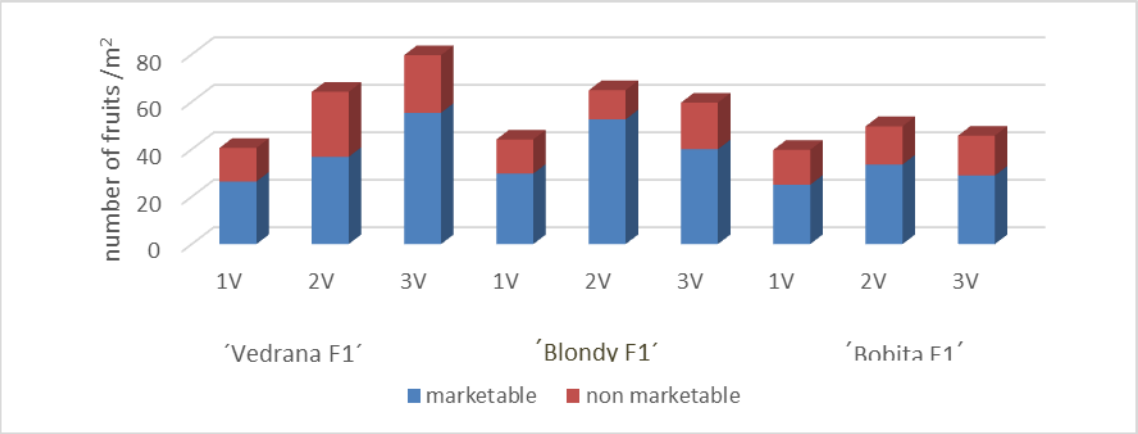

Figure 6 Number of marketable and non-marketable fruits per m²

In 'Vedrana F1' hybrid, plants in 3V growing form produced more market fruit per m² (55.36±6.18) than plants in the other two growing forms. For hybrids ´Blondy F1´and ´Bobita F1´, 2V growing form had a higher number of fruits per m² compared to the 1V and 3V growing forms. All three hybrids have the smallest number of fruits per m² in growing form 1V. Plant population primarily affects the amount of radiation intercepted per plant. Light quality as modified by different plant populations may also play an important role on early plant growth and partitioning responses in plants [18].

The highest number of non-market fruits per m^2 was represented in the growing form 2V of hybrid 'Vedrana F1'. The high rate of non-market fruits in the 'Vedrana F1' hybrid can be attributed primarily to the defective fruits produced by calcium deficiency.

According to the results of the mass market and non-market fruits and number of market and non-market fruits per plant for each hybrid and growing form, different growing forms for the three hybrids have different effects on yield. Blondy F1 hybrid in 2V at growing form had the highest yield per plant (1682.3±9.52 g and 16.3 fruits/plant), followed by the hybrid 'Vedrana F1' in 3V growing form (1528.76±14.83 g and 15.5 fruits/plant). The lowest yield per plant was in the 'Bobita F1' hybrid at 1V growing form (779.36±7.90 g), and least fruits per plant was also in hybrid 'Bobita F1' in 3V growing form (8.1 fruit/plant).

The effect of different growing forms was reflected in the amount of non-market fruits per plant. For 'Vedrana F1' and 'Blondy F1' hybrids, the highest non-market fruit per plant was recorded in growing forms 3V. In the case of 'Bobita F1' hybrid, the highest non-market fruit per plant was observed in 1V growing form and the least non-market fruit per plant was recorded on the 'Bobita F1' hybrid in 2V growing form.

The total average yields of peppers in t/ha for each hybrid and form of growing, it can be seen that the average total pepper yield for all three hybrids varied according to the growing form (Figure 7).

For 'Vedrana F1' and 'Bobita F1' hybrid cultivars had the highest total average yield was achieved by plants with growing form 3V (78.29 t/ha 'Vedrana F1' and 41.85 t/ha 'Bobita F1'), while for hybrids ´Blondy F1´ the highest total average yield of plants was achieved by plants with growing form 2V (63.91 t/ha).

The pruning of plants into 1V growing form was not a successful measure in any hybrid because the yield of these plants was many times less than the other two growing forms (2V and 3V). The yield advantage due to narrow spacing is usually attributed to the development of a full canopy in early development stages [19].

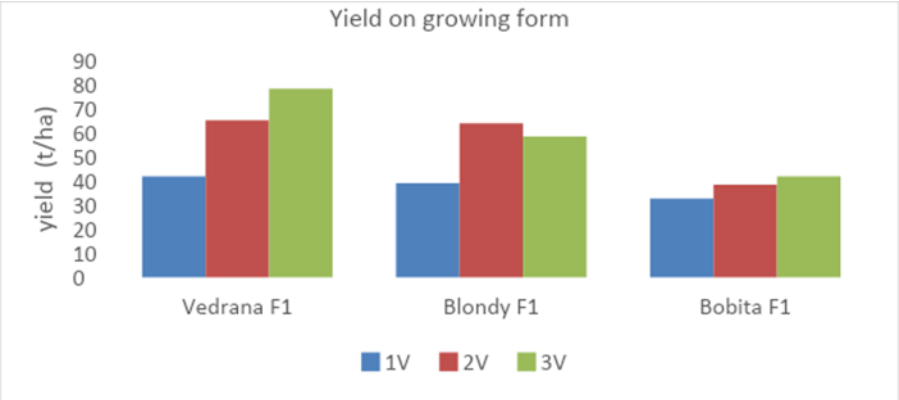

Figure 7 Total average yield in t/ha

Measurements of the morphological characteristics of the fruit showed that in the 'Vedrana F1´ hybrid, cultivar had the largest fruits were on the 3V growing form, while the smallest were on the 1V growing form. ´Blondy F1´hybrid had the largest fruit in the 1V growing form and the smallest in the 3V growing form. The largest fruits had the 'Bobita F1' hybrid cultivar on 2V growing form and the smallest fruits on the 3V growing form. The pericarp thickness varied from 0.3 cm (for ´Blondy F1´ hybrid on 1V growing form) to 1.2 cm (hybrids 'Vedrana F1' at 2V and 'Blondy F1' at 3V).

4. Conclusion

Based on the counted floral extensions in 8 and 10 weeks after planting, it can be observed that pruning the plants into growing form with three trees most rapidly accelerated the development of the fruits of the hybrids 'Blondy F1' and 'Bobita F1'. 'Vedrana F1' hybrid had slower growth than the other two hybrids during the experiment. The highest yield of fruits in July was given by plants with growing form on three fertile branches, while during August and September the highest yield of fruits was given by plants with growing form on two fertile branches.

Plants with three trees gave the highest market yield for the 'Vedrana F1' hybrid (5.46 kg/m^2) and the lowest (3.2 kg/m^2) for the 'Bobita F1' hybrid. When growing on two trees, the best was the ´Blondy F1´hybrid with a yield of 5.4

kg/m^2. The growing form with one tree did not prove to be a good measure in any of the hybrids included in the experiment, because the yield was lowest for all three hybrids led to this growing form (1V).

Plants with one tree had the heaviest fruits in 'Bobita F1' hybrid cultivar, plants with two trees had the heaviest fruits in 'Blondy F1' hybrid cultivar, while in growing form with three trees, the heaviest fruits had plants of 'Bobita F1' hybrid cultivar.

The highest non-market fruit was found in the 'Vedrana F1' hybrid (33.83%), while in the other two hybrids this percentage was slightly lower ('Bobita F1' 25.445 % and 'Blondy F1' 23.652 %). The reason for the high proportion of non-market fruits was the deformity of the fruit in growing form on three trees, and dry rot on the fruits of plants with one and two trees. The appearance of physiological disorders is the consequence of lack of calcium.

For all cultivars, the best ratio of quality and yield is at 2V, at 3V there are a large number of non-market fruits, while pruning the plants into a 1V cultivation has not proved a successful measure in any hybrid.

Compliance with ethical standards

Disclosure of conflict of interest

All authors declare no conflict of interest.

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