Effect of irrigation regimes and the plant density on shear strength and physical properties of Azivash (Corchorus Olitorius) stem

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Abstract: Three irrigation regimes, 6, 12 and 18 days, the distance between seeds in four levels: 5, 10, 15 and 20 cm (density, respectively, 80, 40, 27 and 20 plants/m^2) and a row spacing of 25 cm was considered that was tested in a randomized complete block design with three replications. The results showed that the effect of irrigation on cutting force, shear strength and energy per unit area was meaningful at 5% level and the effect of plant density on cutting force was meaningful at 1% level, but was not meaningful on shear strength. In addition, the results showed that interaction between irrigation and plant density on cutting force, shear strength and energy per unit area is not meaningful. It was observed that the effect of irrigation and plant density on the length, diameter and stem weight was meaningful at 1% level. The interaction between irrigation and plant density on stem weight was meaningful at 1% level, respectively. The maximum weight value of stems in irrigation of every six days in density of 20 plants/m^2 has been made to 0.73 g and the minimum weight value of stems in irrigation of 18 days and a density of 80 plants/m^2 was obtained of 0.16 g.

Keywords: Azivash, plant density, shear strength, irrigation regime

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1 Introduction

Azivash with scientific name (*Corchorus Olitorius L*) belongs to the Tiliaceae family. Although this plant is found in parts of Asia, it is with much more genetic diversity in Africa. The parameters of shear strength and shear energy per unit area of plant stems are used in the development of cutting mechanisms. The physical properties of stem has significant effect on shear force, so that the increase in moisture content reduces the shear force and increase in stem cross-sectional area and mass per unit length cause increased shear force Tabatabaei Koloor et al.(2004). Alizadeh et al. (2011) expressed while stem thickness increases, shear energy will be high. Also Eshaghbeygi et al. (2009) reported that taller plants have less stem diameter and thus shear energy will be reduced. Shear force also influenced by factors such as the speed and type of blade is used. Increased cutting speeds from 20 to 200 mm/min, decreases shear strength and energy to cut saffron stems per unit area, while with further increase speed, shear strength and energy consumption is not reduced. Vale Ghozhedi et al. (2010); Khazaei et al. (2002) found that with the increasing cutting speed of 20 to 200 mm/min, Pyrtrom shear strength decreases and higher cutting speed could not significantly decrease shear strength. The required force in flat blade is greater than serrated blade. As ridged blade penetrates the stem skin and reduces the

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compression phase, it requires less amount of shear force and thus we will have less power consumption and reduced shear strength (Jafari, 2010). Oblique angle has a meaningful effect on shear strength and consumption energy in per unit area of Pyrtrom. In this way shear strength decreases with the increase in oblique angle and it increase with the increase in sharp blade angle (Koloor, 2004). Chancellor (1965) studied the effect number of stems and blade type on Shear force stems of rice. The maximum cutting force for those of 6, 12 and 24 stems in two toothed and toothless blades were measured. Increase in number of stems increased the cutting force but the ratio increase in number of stems and increase in shear force is not equal. The average maximum shear in flat blade type and serrated are 139.5 and 135 N, respectively. Bozorgi et al. (2011) found that, the effect of plant spacing and rice plants on the characteristics of the study was significant at the 1% level. The interactions between these two factors on yield, straw and harvest index at a rate of 1% were significant. Although the physiological efficiency was meaningful at 5% levels, while it was not meaningful on other features. The interactions between plant spacing of 20×20 cm and three plants on ridge was considered. The highest yield of 3612 kg/ha was recorded. Aminifard et al. (2012) reported that the growth characteristics of chlorophyl (plant height, number of stem end and leaf dry matter) and the reproductive factors (volume, weight and yield) of sweet pepper decreased with the increase in plant spacing but the total yield increased. Therefore, the interaction between density and nitrogen rates on fruit weight and volume of all treatments was meaningful. Fakouri Ghaziani et al. (2012) found that the effect of different methods of irrigation and plant density on the measured characteristics of marigold (pure weight, number of flowers per m^2, number of stems per plant, weight of flowers, flower diameter and the amount of oil) were significant at the 1% and 5% levels, respectively. Pirzad et al. (2011) demonstrated that different irrigation regimes and plant density on yield and harvest index, dry flowers, essential oil and biomass of local chamomile have significant effects.

To design harvester machines for each product, knowing the force required to cut energy consumption is essential and they can vary with different physical properties of the product such as diameter and crosscutting surface in different plant conditions. Force and energy are also affected. The purpose of this study was to evaluate effects of different irrigation regimes and density on shear strength and shear energy per unit area.

2 Materials and methods

To investigate the effects of density and irrigation regimes on shear strength and some physical properties of plant stem of Azivash, three flooding irrigation regimes, 6, 12 and 18 days, the distance between seeds in four levels of 5, 10, 15 and 20 cm (density, respectively, 80, 40, 27 and 20 plants/m^2) and a row spacing of 25 cm. The study was performed in the field of Gorgan University of Agricultural Sciences and Natural Resources, Iran. Experiment was conducted in a completely randomized block design with three replications. Seeds of germination percent were examined in the laboratory. Planting was done after seedbed preparation by the use of Nitrogen, Phosphorus and Potassium fertilizer in the order of 100, 100 and 50 kg/ha and mixing them with soil. Planting was done in four blocks so that in each square meter 80, 40, 27 and 20 plants were achieved. Until the emergence, irrigation was done every three to four days, and then treatments were applied. Finally, after upbringing plants from every block three samples and three replicates, in fact 36 treatments were selected from all blocks. In order to perform the cutting operation, samples were transferred to Laboratory of Gorgan University of Agricultural Sciences and Natural Resources. Experiments on stem cutting force by Instron testing device equipped with a load cell 1000 N with an accuracy of 0.01 N was executed. To measure the force required to cut the stem a jaw holder made according to Figure 1 was used.

Initial 5 cm length of Azivash stem was placed in the grooves embedded in the jaw holder. The distance between two jaws and the edge of jaw blades were 10.17 and 10.8 cm, respectively. In these experiments, the cutter mover with smooth section, with a straight edge angle of 45 °and a cutting speed of 23 mm/min was used.

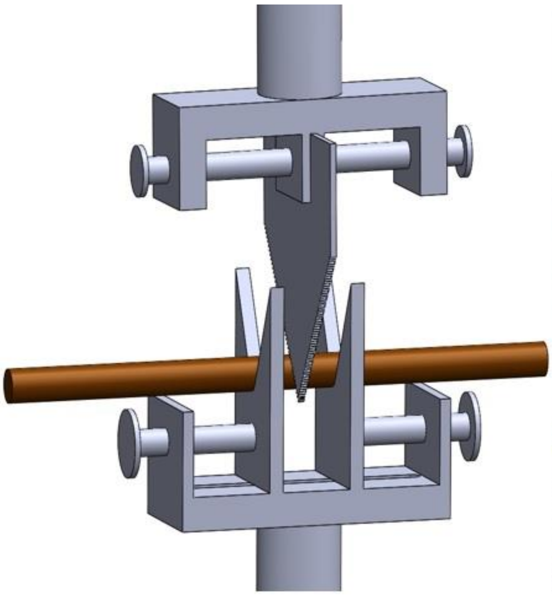

Figure 1 Blade and jaw holder

Then by a digital caliper with an accuracy of 0.02 mm and load cell, shear force values and the blade shift and also maximum cutting force was demonstrated and the corresponding graphs were plotted. In addition, by calculating the area under the curve by excel software, energy expenditure was calculated to cut the stem. In the following by dividing the maximum force and energy to cut the stem cross-sectional area of the incision, shear strength, and the energy per unit area were calculated, respectively (Equations 1 and 2).

$$\tau = \frac{F_{max}}{A} \qquad (1)$$

Where, τ is shear strength, MPa; F is maximum force, N; and A is stem cross-sectional area, mm^2.

$$Energy\ consumption = \frac{Cutting\ energy}{A} \qquad (2)$$

Where, Energy consumption, mJ/mm^2; Cutting energy, mJ; and is stem cross-sectional area, mm^2.

In each experiment by measuring the diameter of the stem in the cut, stem surface area as well as some physical properties such as weight, diameter and length were calculated. Data were analyzed using SAS software and LSD test was conducted in a factorial experiment in a completely randomized design.

3 Results and discussion

3.1 The physical properties of stem

The results of the density variance analysis and irrigation regime on the length, diameter and weight are given in Table 1. This table shows the effect of irrigation regime and the density on the three characters of length, diameter and weight were meaningful at 1% level. The data in the table showed that the interaction between irrigation and seed density on stem weight of Azivash was meaningful at the 1%, but it was not meaningful on the length and diameter.

Table 1 Analysis of variance due to irrigation and plant density on the length, diameter and weight

Source of variation	Degrees of freedom	Length, cm	Diameter, mm	Weight, g
Irrigation	2	358.33**	12.007**	0.16**
Plant density	3	453.26**	1.5**	0.063**
Irrigation × Density	6	3.04^{ns}	1.82^{ns}	0.057**
Error	24			

Note: ** Indicates significant at 1% and ns not being meaningful

As can be seen in Figure 2, irrigation periods of six days length stem was longer than the others so length of the stems decreased with increasing irrigation periods. Similar results were recorded by Masoudi et al. (2010) in terms of irrigation periods on yield and potato plant characteristics. They observed that with the increasing periods of irrigation during emergence to flowering stage, with the increase in irrigation or watering periods the plant height decreased. Kochaki et al. (2004) found the same conclusion in different irrigation intervals and density on yield and its components of two local fennels. They reported that with increasing irrigation intervals, plant height would be significantly reduced.

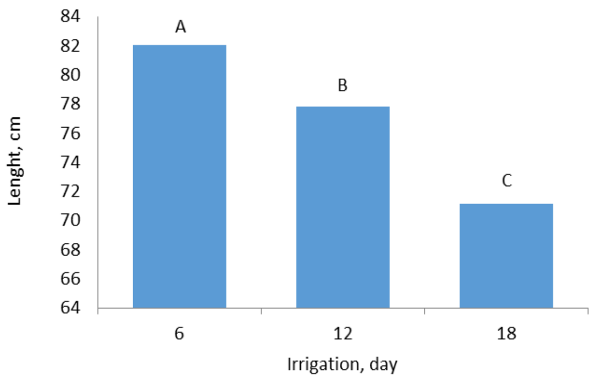

Figure 2 Effect of irrigation on Azivash's stem length

Similar letters means no meaningful difference

As is shown in Figure 3, with decreased density, the stem length decreased due to competition between bushes for absorbing the light regarding density increment. This result was similar to the study in which Alimohammadi et al. (2003) investigated the effect of density and plantation depth on growth and yield of Diamant potato varieties in Mianeh, Iran. They observed with increasing plantation density, length of longest stem increased.

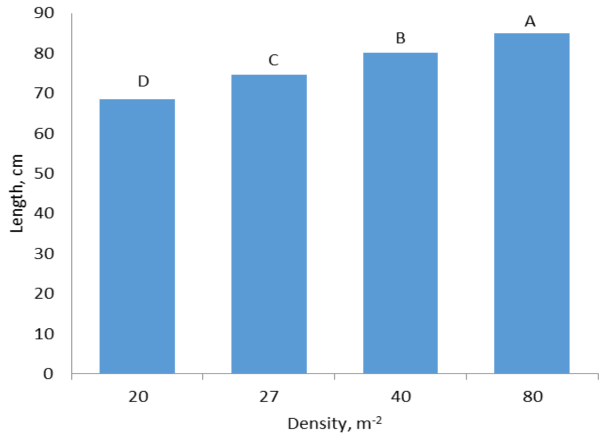

Figure 3 Effect of density on Azivash's stem length

Similar letters means no meaningful difference

In Figure 4, the effect of the different levels of irrigation on Azivash's stem diameter is shown. According to that, the average irrigation regimes of 12 and 18 days with each other have no meaningful differences, but the effects of irrigation regimes of six days on Azivash's stem diameter are significantly different from the other two levels. This means irrigation regime of six days, the stem diameter is the highest. Masoudi et al. (2010) reported similar results. They observed that the diameter decreased with increasing irrigation days in potato. Rafie et al. (2004) in terms of irrigation periods and nitrogen application on yield and some morphological characteristics of hybrid Gelshid obtained the minimum diameter in treatments had the lowest frequency of watering. They stated that the increase in irrigation, especially in the vegetative to flowering stage, the stem size increased.

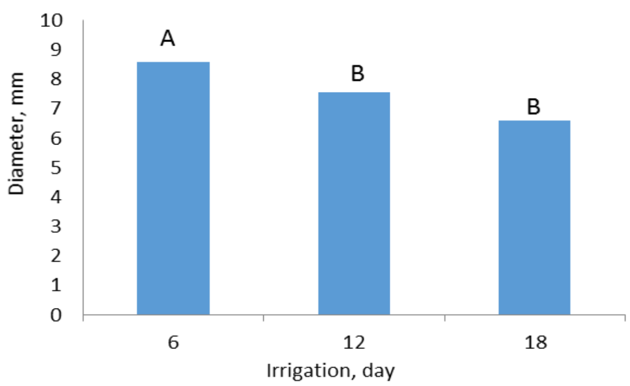

Figure 4 Effect of irrigation on Azivash's stem diameter

Similar letters means no meaningful difference

The effect of density on stem diameter of Azivash is shown in Figure 5. According to this the decrease in the density in watering level regime, the Azivash's stem diameter increases. The lack of competition among plants for absorbing light and specialty of greater dry matter to the growth part and this led to internode shortening distance and thickening of the stem. This result is similar to Seifi et al. (2012).

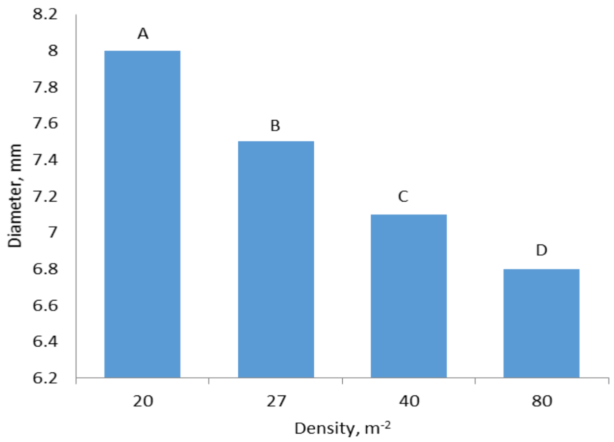

Figure 5 Effect of density on Azivash stem diameter

Similar letters means no meaningful difference

The results of the comparison of interaction between irrigation and seed density on Azivash stem weight is shown in Table 2. According to the data, the maximum weight value of stems has been occurred in irrigation of once in six days and density of 20 plants/m^2 equivalent to 0.73 grams and the minimum value in irrigation of once 18 days and density of 80 plants/m^2 is equivalent to 0.16 g.

Table 2 Analysis of comparison of the average interaction of irrigation and plant density on Azivash stem weight

Plant density, m^2	Irrigation, day		
	6	12	18
80	0.28^{Ba}	0.2^{Aa}	0.16^{Ba}
40	0.56^{ABa}	0.32^{Aa}	0.29^{ABa}
27	0.62^{Ba}	0.36^{Aa}	0.34^{Aa}
20	0.73^{Aa}	0.41^{Ab}	0.35^{ABb}

Note: Similar large letters in each column and same small letters in each line show meaningfulness at the 0.05 level, ($P \leq 0.05$).

According to Figure 6 with increasing irrigation regime in all the growth density, Azivash stem weight is decreased. With the decrease in the density in each level of watering regime, Azivash stem weight increased.

With the increasing bush density, light getting to focal floor decreases and competition among plant organs to absorb more radiation is higher and on the other hand, auxin light damage will not occur and the combination of these factors can reduce the diameter and height of the bush. So at low density, stems are thicker and with the increase in thickness and stem diameter, weight increases. This is similar to the results of Feyzbakhsh et al. (2010) who observed that with increasing density, height of maize single cross 704 increased and its diameter decreased. So similar results have been reported in two local fennel and potato (Kochaki et al., 2004; Masoudi et al., 2010).

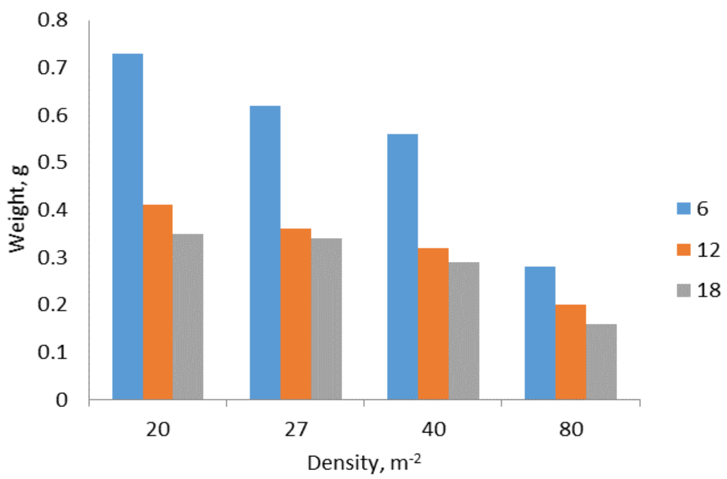

Figure 6 Effects of irrigation and seed density on stem weight of Azivash

3.2 Shear force and energy to stem

The results of the analysis of variance of density and irrigation regime on cutting force, shear strength and energy per unit area are shown in Table 3. The effect of irrigation on each attributed to cutting force, shear strength and energy per unit area is significant at 5% level. Effect of density on cutting force and shear energy is meaningful at 1%, but it is not meaningful on shear strength. The interaction between irrigation and plant density on cutting force, shear strength and shear energy per unit area is not significant.

Table 3 Analysis of variance of the effect of irrigation and plant density on shear strength, shear strength and energy consumption per unit of stem

Source of variation	Degrees of freedom	Shear force , N	Shear strength, MPa	Energy consumption, mJ/mm^2
Irrigation	2	32915.25*	10.32*	555.11*
Plant density	3	56294.13**	6.37^{ns}	768.9**
Irrigation × Density	6	8605.41^{ns}	2.31^{ns}	115.72^{ns}
Error	24			

Note: **, * Significant shows significantly difference at 1% and 5%, respectively, ns shows not being meaningful.

According to Figure 7 with increasing irrigation intervals and reduction in watering frequency from 6 to 12 days, shear force was reduced. However, no significant effect was observed from 12 days to 18 days. As can be seen in Figure 4, stem diameter decreased with increasing irrigation intervals. Therefore, with increasing irrigation intervals and reduced diameter, shear force decreases. These results were similar from those obtained by Tabatabaei Koloor et al. (2004) who investigated the factors affecting the strength and shear strength of the rice stem. They also observed with increasing in cross-section, cutting force of the stem and contact surface, and friction between the stem and blade increased.

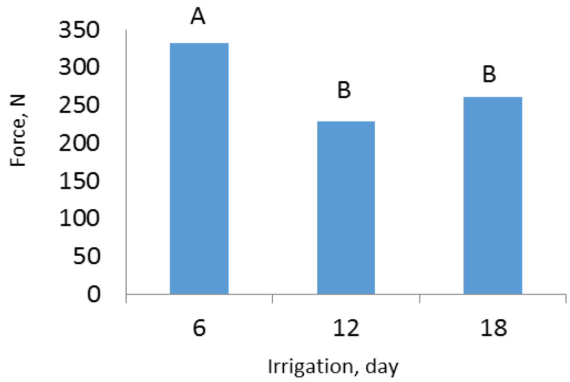

Figure 7 Effect of irrigation on cutting force of Azivash's stem Similar letters means no meaningful difference

It is observed that with the increasing of plantation density, shear force decreases as shown in Figure 8. In density of 80 plants/m^2, the amount of shear energy with the other densities have significant difference, as can be seen in Figure 5, stem diameter decreased with the increasing density. These factors led to reduction in shear force.

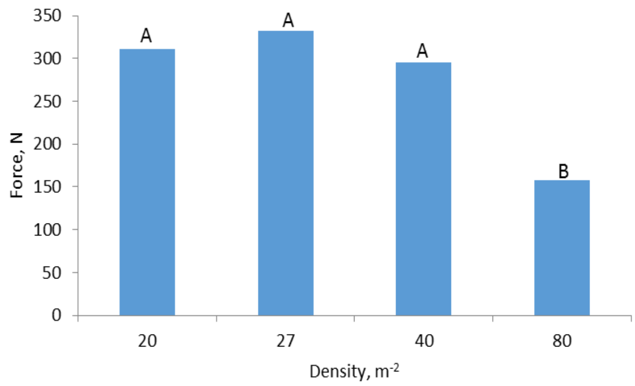

Figure 8 Effect of plant density on shear force of Azivash's stem

In Figure 9 it is shown that shear strength decreases with the increasing irrigation intervals. Because with increasing irrigation intervals and reduced watering frequency stem diameter and shear force decreased.

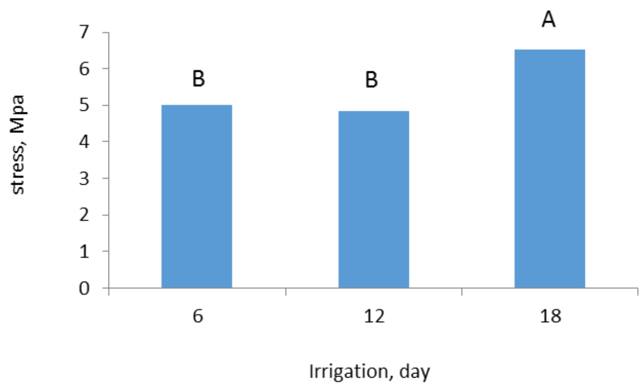

Figure 9 Effect of irrigation on shear strength of Azivash's stem

According to Fig. 10 with increasing irrigation intervals energy consumption per unit area of the stem reduced. The reason is that with increasing irrigation intervals diameter and shear forces reduce, so energy consumption per unit area decreased.

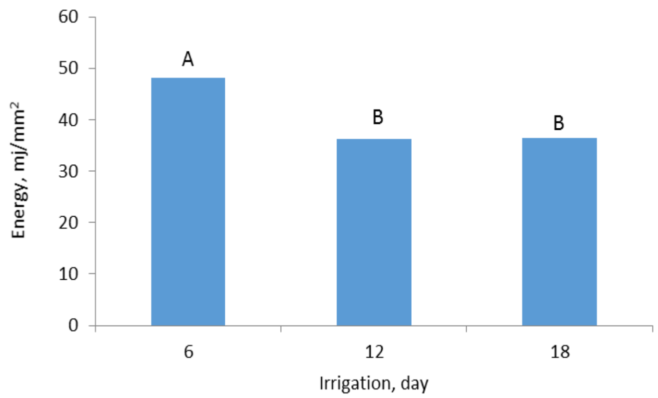

Figure 10 Effect of irrigation on energy consumption per unit of Azivash's stem Similar letters means no meaningful difference

Referring to Figure 11, density of 80 plants/m^2, energy consumption value is less than other densities and so it was significantly different with others.

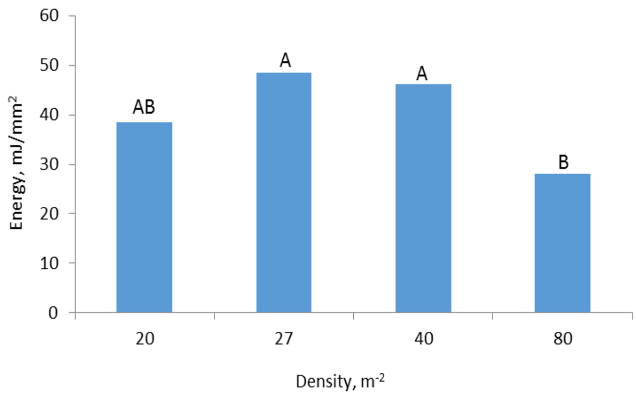

Figure 11 Effect of the energy on density per unit area of Azivash's stem

4 Conclusions

(1) In the period of six days irrigation, stem longer than other periods and with increase of watering periods and decreasing in plant density, stem length decreased.

(2) With reduction in plant density of every irrigation regime's level, diameter value of Azivash's stem increased.

(3) Increasing of irrigation regime in all plant density, Azivash's stem weight reduced and with reduction of density at the every level of irrigation regime, the amount of Azivash's stem weight increased.

(4) With the increase in plant density, shear force decreased. In the density of 80 plants/m^2 shear energy value than other densities had meaningful difference.

(5) Shear strength decreases with increasing irrigation intervals.

(6) With increasing irrigation intervals reduced energy consumption per unit area of the stem. In the density of 80 plants/m^2, energy required is less than other densities and it was significantly different from others.

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