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FOREST REVIEW

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EMERGENCE OF NATURAL REGENERATION OF ARIZONA CYPRESS (*CUPRESSUS ARIZONICA* GREENE) IN BURNT AREAS AT THE LOCALITY "MILADINOVCI" IN SKOPJE

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ABSTRACT: This paper presents the results of the research on the emergence of the natural regeneration of the *Cupressus arizonica* Greene on completely burnt forest areas in the Miladinovci site – Skopje. These areas were afforested with *C. arizonica* Greene and black pines in 1977 and they successfully developed until the fire. The high forest fire in 2013 burnt 94% of the trees on a total surface area of 766.5 ha. In the following two years natural regeneration of the *C. arizonica* was notable in close proximity to the parent plantations. This paper presents the research on the emergence of natural regeneration of *C. arizonica* in the seedling development phase, as well as the qualitative and quantitative characteristics of regeneration unitsin different locations of the burned areas. The results of the research indicate that as a result of the fire and the burning of the plantations of *C. arizonica*, there is the appearance of natural regeneration in large numbers and of good quality. This situation leads to a successful natural regeneration of *C. arizonica* in the burnt forest areas.
Keywords: *Cupressus arizonica* Greene, natural regeneration, forest areas, forest fire.

1 INTRODUCTION

Afforestation of barren lands in Macedonia has decades of tradition. Especially intensive activities were performed in the 1965-1980 period, when different forest plants of various tree species were planted on large areas in Macedonia. Besides seedlings of indigenous tree species, non-indigenous tree species were also planted. The central parts of Macedonia were a particular challenge for afforestation, since these parts have less favorable natural conditions for the development of forest vegetation and the soils are shallow and poor. That is why afforestation was conducted primarily with non-indigenous tree species, including the *C. arizonica*. Thus, forest plantsof *C. arizonica* have been planted in multiple sites in Macedonia, such as: the Gevgelija, Negotino, Veles, and Skopje regions. The aim of theseafforestation measureswas to find the most favorable tree species which according to their bio-ecological features best suit the needs for afforestation of arid areas in Macedonia. However, for the ultimate success of the afforestations performed, monitoring and implementation of protective and growing measures was also necessary. Several researchers have dealt with the results of the performed afforestations in Macedonia and the regeneration of burned forests: Andonovski&Bebekoski (1989); Kamilovski&Nikolov (1989); Kolevska&Velkovski (2009); Popovski (1989, 2000); Velkovski *et al.*, (2008, 2012); Petrova (2015) and others who have made a contribution to the enrichment of data on the development of thisnon-indigenous species in Macedonia. *C. arizonica*, originally from Arizona (USA), as a species with a wide ecological adaptability, has been used for afforestation of bare lands in most Mediterranean European countries (Portugal, Spain, Italy, Greece, Macedonia, etc.). Its resistance to low winter temperatures and the strongly developed and adjustable root system, as well as the rapid growth makes this species suitable for afforestation in arid and eroded areas. First afforestations of this kind in Macedonia were conducted in 1968 on the territory of Negorci and then in 1972 in the Veles and Negotino regions, where acceptance of the *C. arizonica* seedlings ranged between 80 and 96% (Popovski 1989). In the period between 1972 and 1980 *C. arizonica* forest plants were planted in several other areas, including in the Skopje region. The ability of *C. arizonica* for intensive growth in early youth, high resistance to drought and low winter temperatures, good resistance against pests and phytopathological diseases was the reason for the planting of a number of *C. arizonica* forest plantsin arid areas in central Macedonia. Early and rich production of quality seeds from the 11th year was the reason for collection of seeds for seedling production of *C. arizonica*. The average number of seeds in a cone is 46-112, but the most prevalent cones have 50-60 seeds, which means that in the bottom of every cone shell there is an average of 6-14 seeds (Popovski 2000). The seeds of the *C. arizonica* show significant germination in the conditions present in Macedonia. Thus the seeds collected from *C. arizonica* in Goceva Gora around Negotino showed average laboratory germination of 26.67 to 37.15% while the seeds collected from certain trees showed even up to 89%, which represents a very high percentage for this species (Popovski 1989). The average germination of seeds from *C. arizonica* is greater than the average germination of seeds in Arizona, which amounts to 30.4% (Toumey&Korstian 1952).

C. arizonica forests in the area of Goceva Gora around Negotino already began providing seeds even at the age of 12-15, abundantly and each year providing seeds with high quality properties (Popovski 1989). The average energy of germination (germination for 13 days) ranges from 17.48 to 23.67%, which represents a high value and is proof of the great vitality of *C. arizonica* seeds (Popovski 1989).

In the Miladinovci site – Skopje region, *C. arizonica* plant ssubject of this research were planted in 1977 on a surface area of 821.80 hectares. Afforestation was performed by planting in previously prepared furrows and rows with a distance of 2.5 to 3.5 m between two rows and distance between seedlings in a row of 2 to 2.5 m. In the same plantations, certain growing measures were performed in the past for protection of young plantations, filling and trimming the branches, and in some places spacing was performedwith lower intensity. Before the fire, the plantations planted artificially were well developed and adapted to the conditions of the place of vegetation (Fig. 1 and Fig. 2).

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Figure 1, 2: Un-burnt plantations of *Cupressus arizonica*

Figure 3, 4: Burnt plantations of *Cupressus arizonica*

Until the fire (6th until 10th September, 2013) the parent plantations had the age of 38 years and height of up to 15 m and with diameter at breast height of 14cm. The reason for the fire was the burning of stubbles in the neighboring Kumanovo region. The fire was high and burned 94% of the trees on a total surface area of 766.50 ha (Fig. 3 and Fig. 4).

After the fire, in 2014 a sanitary cutting of the burnt trees was performed and forest order was introduced. Such activities contributed to the improvement of the conditions for natural regeneration of the burnt areas.

Thick offspring of *Cupressus arizonica* appeared in a major portion of the burnt areas in 2014 and 2015 (Fig. 5 and Fig. 6).

Figure 5, 6: Natural regeneration of *Cupressus arizonica* of 1 and 2 years

The emergence of natural regeneration of *C. arizonica* in the burnt areas in the first and second years is remarkable and in great numbers, especially near the parent trees of the burnt plantation. Forest fires, in addition to the damage they cause, often cause the emergence of offspring in some species of forest trees, especially those whose seed is located in the cone, which due to certain reasons is difficult to open naturally (some three-spike pines, cypresses, species of *fam. Leguminoseae*, etc.). The forest fire, i.e. the high temperatures that develop, act as a strong incentive for the opening of cones or fruits and weakeningof the seed coating (Kolevska&Velkovski 2009). The impact of high temperatures on the release of seeds from cones and mass offspring emergence of *C. arizonica* was observed in the burnt areas in theGevgelija region (Kolevska&Velkovski 2009).

Artificial foreststands of coniferous species fall into

the category of most vulnerable forest areas regarding wildfire. Damages incurred as a result of the fires are multiple and have long-lasting consequences. As a result of fire in artificial forest stands and depending on the amount of combustible material there is total destruction of the fragile physical-mechanical and chemical properties of the soil. The soil dries, cracks and the entire micro fauna in the solum (surface and subsoil layer) is destroyed which is why it remains sterile. Given that bare areas are usually shallow soils, in case of fire they are quickly washed and active processes of erosion occur due to which the subsoil appears on the surface (Kamilovski&Nikolov 1989).

2 INVESTIGATION AREA AND METHOD

For the purposes of obtaining relevant data on the emergence of a natural regeneration of the *C. arizonica* in the burnt areas of the "Miladinovci site in Skopje, 11 trial areas sizedfrom 2 to 4 m² were analyzed. The trials areas were located at representative locations in order to reflect the real situation of the natural regeneration of the plantation.

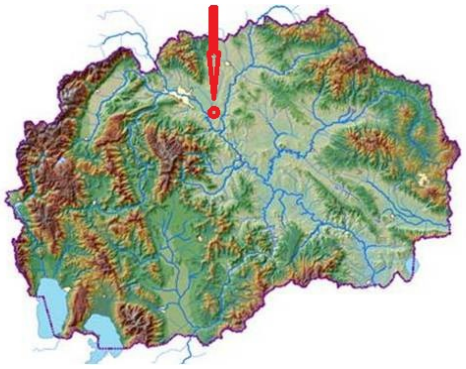

Figure 7: Location of the investigation area

Detailed measurements of the height in cm and the thickness of root neck in mm were made for all units in the trial areas. All measured units were grouped according to the methodology of Šafar (1958), in two developmental stages: (1) undeveloped seedling with height of 0.30 cm and (2) developed seedling with a height between 0.30 and 1.30 cm. In addition, all individuals in the trial areas were assessed by their quality and vitality in three groups according to the following features:

- Group 1: (Good). This group includes all the individualsthat are healthy and vital, with upright stem and well developed canopy.
- Group 2: (Medium). This group includes all the individuals that are healthy and have good quality features, but are lagging in their development behind those in the first category.
- Group 3: (Poor). Covers all the individuals with poor quality and poor vitality, crooked stem and irregularly distributed canopy and poor health condition or are far behind the others in their development.

An analysis was made using the collected data which determined their height, thickness and quality structure. The abundance of natural regeneration is calculated per 1 hectare so that the number of the regeneration is the quotient of the product of the number of individuals in the trial area contained in one hectare and the size of the trial area. The appropriate conclusions were drawn from the estimates and analyzes.

Figure 8, 9: Trial areas for data collection (and estimation) of natural regeneration

3 RESULTS AND DISCUSSION

Large areas under bare and eroded lands, unproductive forest areas overgrown with bushes, shrubbery and other degradation forms of vegetation that can be found in Macedonia, especially in its central parts, were the reason to carry out afforestations with different species of trees. Simultaneously, introduction was also made of non-indigenous species that originate from areas with similar natural characteristics and have a strong environmental adaptability such as the *C. arizonica*. Such afforestations and still present and the results of the preceding afforestations and researches are useful for planning further measures and activities for achieving better results in silvicultural practices.

The results from the researches on the occurrence of natural regeneration of *C. arizonica* in the area of Miladinovci contribute towards enriching the information base regarding the use of this type and its natural potentials for regeneration, which become prominent after a forest fire.

Table I contains values on the abundance of the natural regeneration within two years, for each trial area according to its exposition and altitude, as well as data on the heights and diameters of the natural regeneration individuals.

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Table I: Number of individuals of *Cupressus arizonica*

Sample plot (SP)	Total individuals per 1ha	Height (cm)	Diameter (mm)	Exposition	Altitude (m)	Coordinates
1	1 020 000	29.1	2.6	SW	368	E00557649 N04648121
2	885 000	35.9	3.1	SW	375	E00557661 N04648096
3	550 000	38.4	3.5	S	378	E00557638 N04648112
4	60 000	55.4	8.6	E	389	E00556262 N04648970
5	185 000	32.4	3.3	N	398	E00556190 N04649047
6	210 000	32.6	3.7	S	371	E00557655 N04648103
7	365 000	16.5	2.0	W	375	E00557689 N04648103
8	135 000	26.9	3.4	E	391	E00556226 N04648985
9	195 000	20.3	2.1	NE	396	E00556218 N04649003
10	175 000	30.3	2.8	Flat terrain	386	E00556241 N04649005
11	125 000	44.8	5.6	Flat terrain	392	E00556263 N04649013
Average	355 000	32.9	3.7			

It can be seen from the data given in Table I, that the frequency of the natural regeneration of *C. arizonica*is ranging between 60 000 and 1 020 000 individuals per 1 ha, or in average, there are 355 000 individuals per 1 ha. The abundance of the natural regeneration is the highest in the areas on Southeastern exposition, from 885 000 to 1 020 000 individuals/ha, and the lowest on East exposition, from 60 000 to 135 000 individuals/ha. The medium height of the natural regeneration (individuals) is ranging between 16.5 cm in SP-7, located on West exposition up to 55.4 cm in SP-4, located on East exposition, or 32.9cm in average. The mean values of the individual's base thickness are ranging from 2.0 in SP-7 to 8.6 mm in SP-4, or the mean thickness is 3.7 cm. Often in the science and in practice is determined that the types introduced from some more distant areas of particular territories produce better results than some types of indigenous trees or species that have closer distribution areas. Thus, it has been determined at Choloshovski Rid – Veles area that the *C. arizonica* has reached a diameter of 1.30m from the initial 12.71cm, medium height of 6.93m and mean annual growth of 5.28m^3 in the 15th year of age, while the black pine raised on the same place, had a diameter at breast height of 7.58cm, medium height of 4,44m and average annual growth of 1.32m^3 (Andonovski&Bebekoski 1989). The 9 years old *C. arizonica* inartificial forest standsin Negotino and Veles has a medium height ranging from 326.2 cm to 414.7 cm and medium diameter at breast height from 4.5 cm to 6.7 cm (Popovski&Stamenkov 1989).

Taking into consideration that the natural regenerationis 2 years old and the individuals have various height and quality features, according to the Šafar methodology, they have been divided into: (1) undeveloped seedling (h<30 cm), which covers the units with height less than 30 cm and (2) developed seedling (h>30<130 cm), which covers the units with height from 30 cm to 130 cm. The results obtained from the conducted measurements of the abundance, quality and the growth stadium of the natural regeneration, as well as the exposure of each of the trial areas are given in the following tables.

From the data on the natural regeneration on Southwestern exposition given in Table II can be seen that 45.4% of the individuals are in the growth stadium of undeveloped seedling, while 54.6% are in the growth stadium of developed seedling. Out of the total number of individuals, 21.5% have good quality, 43.8% have medium quality and 34.7% have bad quality.

It can be seen from the data on the natural regeneration on South exposition, given in Table III, that 33.2% of the individuals are in the growth stadium of undeveloped seedling, while 66.8% are in the growth stadium of developed seedling. Out of the total number of individuals, 19.7% have good quality, 44.7% have medium quality and 35.6% have bad quality.

It can be seen from the data on the natural regeneration on East exposition, given in Table IV, that 46.2% of the individuals are in the growth stadium of undeveloped seedling, while 53.8% of the individuals are in the growth stadium of developed seedling. Out of the total number of individuals, 25.6% have good quality, 39.7% have medium quality and 34.7% have bad quality.

From the data on the natural regeneration on flat terrain, given in Table V can be seen that 38.3% of the individuals are in the growth stadium of undeveloped seedling, and 61.7% are in the growth stadium of developed seedling. Out of the total number of individuals, 22.5% have good quality, 40.0% have medium quality of 37.5% have bad quality.

Table II: Abundance, quality and growth stadium of the natural regeneration on Southwestern exposition

Quality / Growth stadium	Good		Medium		Bad		Total	
	ind/ha	%	ind/ha	%	ind/ha	%	ind/ha	%
SP-1								
h< 30 cm	20 000	8.0	270 000	64.3	330 000	94.3	620 000	60.8
h>30< 130 cm	230 000	92.0	150 000	35.7	20 000	5.7	400 000	39.2
Total	**250 000**	**24.5**	**420 000**	**41.2**	**350 000**	**34.3**	**1 020 000**	**100.0**
SP-2								
h< 30 cm	0	0.0	35 000	8.4	210 000	67.7	245 000	27.7
h>30< 130 cm	160 000	100.0	380 000	91.6	100 000	32.3	640 000	72.3
Total	**160 000**	**18.1**	**415 000**	**46.9**	**310 000**	**35.0**	**885 000**	**100.0**
SP1+ SP2:2								
h< 30 cm	10 000	4.9	152 500	36.5	270 000	81.8	432 500	45.4
h>30< 130 cm	195 000	95.1	265 000	63.5	60 000	18.2	520 000	54.6
Average	**205 000**	**100**	**417 500**	**100**	**330 000**	**100**	**952 500**	**100**
	21.5		**43.8**		**34.7**		**100**	

Table III: Abundance, quality and growth stadium of the natural regeneration on South exposition

Quality / Growth stadium	Good		Medium		Bad		Total	
	ind/ha	%	ind/ha	%	ind/ha	%	ind/ha	%
SP-3								
h< 30 cm	0	0,0	30 000	12.5	130 000	61.9	160 000	29.1
h>30< 130 cm	100 000	100.0	210 000	87.5	80 000	38.1	390 000	70.9
Total	**100 000**	**18.2**	**240 000**	**43.6**	**210 000**	**38.2**	**550 000**	**100,0**
SP-6								
h< 30 cm	0	0.0	37 500	37.5	55 000	91.7	92 500	44.0
h>30< 130 cm	50 000	100.0	62 500	62.5	5 000	8.3	117 500	56.0
Total	**50 000**	**23.8**	**100 000**	**47.6**	**60 000**	**28.6**	**210 000**	**100.0**
SP3+SP6 :2								
h< 30 cm	0	0	33 750	19.9	92 500	68.5	126 250	33.2
h>30< 130 cm	75 000	100.0	136 250	80.1	42 500	31.5	253 750	66.8
Average	**75 000**	**100**	**170 000**	**100**	**135 000**	**100**	**380 000**	**100**
	19.7		**44.7**		**35,6**		**100**	

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Table IV: Abundance, quality and growth stadium of the natural regeneration on East exposition

Quality / Growth stadium	Good		Medium		Bad		Total	
	ind/ha	%	ind/ha	%	ind/ha	%	ind/ha	%
SP-4								
h< 30 cm	0	0.0	0	0.0	0	0.0	0	0.0
h>30< 130 cm	17 500	100.0	25 000	100.0	17 500	100.0	60 000	100.0
Total	**17 500**	**29.2**	**25 000**	**41.6**	**17 500**	**29.2**	**60 000**	**100.0**
SP-8								
h< 30 cm	2 500	7.7	37 500	71.4	50 000	100.0	90 000	66.7
h>30< 130 cm	30 000	92.3	15 000	28.6	0	0	45 000	33.3
Total	**32 500**	**24.1**	**52 500**	**38.9**	**50 000**	**37.0**	**135 000**	**100.0**
SP4+SP8 :2								
h< 30 cm	1 250	5.0	18 750	48.4	25 000	74.1	45 000	46.2
h>30< 130 cm	23 750	95.0	20 000	51.6	8 750	25.9	52 500	53.8
Average	**25 000**	**100**	**38 750**	**100**	**33 750**	**100**	**97 500**	**100**
	25.6		**39.7**		**34.7**		**100**	

Table V: Abundance, quality and growth stadium of the natural regeneration on flat terrain

Quality / Growth stadium	Good		Medium		Bad		Total	
	ind/ha	%	ind/ha	%	ind/ha	%	ind/ha	%
SP-10								
h< 30 cm	2 500	6.3	17 500	25.0	62 500	96.2	82500	47.1
h>30< 130 cm	37 500	93.7	52 500	75.0	2 500	3.8	92500	52.9
Total	40 000	22.9	70 000	40.0	65 000	37.1	175000	100.0
SP-11								
h< 30 cm	0	0.0	2 500	5.0	30 000	63.2	32500	26.0
h>30< 130 cm	27 500	100.0	47 500	95.0	17 500	36.8	92500	74.0
Total	27 500	22.0	50 000	40.0	47 500	38.0	125000	100.0
SP10+SP11 :2								
h< 30 cm	1 250	3.7	10 000	16.7	46 250	82.2	57 500	38.3
h>30< 130 cm	32 500	96.3	50 000	83.3	10 000	1.8	92 500	61.7
Average	**33 750**	**100**	**60 000**	**100**	**56 250**	**100**	**150 000**	**100**
	22.5		**40.0**		**37.5**		**100**	

It can been seen from the data on the natural regeneration on North exposition, given in Table VI, that 45.9% of the individuals are in the growth stadium of undeveloped seedling, while 54.1% are in the growth stadium of developed seedling. Out of the total number of individuals, 17.6% have good quality, 37.8% have medium quality and 44.6% have bad quality.

It can be seen from the data on the natural regeneration on West exposition, given in Table VII, that 93.2% of the individuals are in the growth stadium of undeveloped seedling, while 6.8% are in the growth stadium of developed seedling. Out of the total number of individuals, 16.4% are with good quality, 42.5% are with medium quality and 41.1% are with bad quality.

It can be seen from the data on the natural regeneration on Northeastern exposition, given in Table VIII, that 92.3% of the individuals are in the growth stadium of undeveloped seedling, and 7.7% are in the growth stadium of developed seedling. Out of the total number of individuals, 18.0% have good quality, 42.3% have medium quality and 39.7% have bad quality.

The overall share of the natural regeneration of *C. arizonica* in the growth stadium undeveloped seedling is 54.5%, and 45.5% in the growth stadium developed seedling.

Table VI: Abundance, quality and growth stadium of the natural regeneration on North exposition

Quality / Growth stadium	Good		Medium		Bad		Total	
	ind/ha	%	ind/ha	%	ind/ha	%	ind/ha	%
h< 30 cm	0	0.0	17 500	25.0	67 500	81.8	85 000	45.9
h>30< 130 cm	32 500	100.0	52 500	75.0	15 000	18.2	100 000	54.1
Total	32 500	17.6	70 000	37.8	82 500	44.6	185 000	100.0

Table VII: Abundance, quality and growth stadium of the natural regenerationon West exposition

Quality / Growth stadium	Good		Medium		Bad		Total	
	ind/ha	%	ind/ha	%	ind/ha	%	ind/ha	%
h< 30 cm	40 000	66.7	150 000	96.8	150 000	100.0	340 000	93.2
h>30< 130 cm	20 000	33.3	5 000	3.2	0	0.0	25 000	6.8
Total	60 000	16.4	155 000	42.5	150 000	41.1	365 000	100.0

Table VIII: Abundance, quality and growth stadium of the natural regeneration on Northeastern exposition (SP10)

Quality / Growth stadium	Good		Medium		Bad		Total	
	ind/ha	%	ind/ha	%	ind/ha	%	ind/ha	%
h< 30 cm	20000	57.1	82500	100.0	77500	100.0	180000	92.3
h>30< 130 cm	15000	42.9	0	0	0	0	15000	7.7
Total	35000	18.0	82500	42.3	77500	39.7	195000	100.0

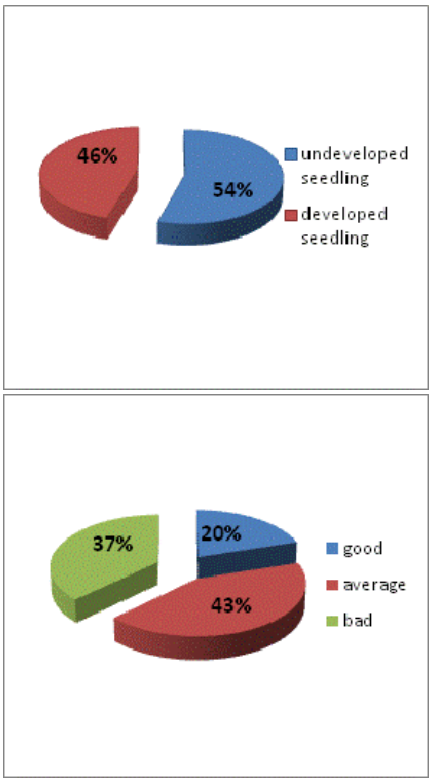

Figure 10, 11: Quality structure and growth stadium of the natural regeneration (%)

The information that a large number of individuals (45.5%) has entered the stadium of developed seedling in the second year of their growth i.e. that they are higher than 30 cm, indicates on intensive and fast growth of the *C. arizonica* in the burnt forest areas in Miladinovci. In relation to the total quality structure of the natural regeneration, 20.1% of the individuals have good quality, 42.7% have medium quality and 37.2% have bad quality. The obtained results indicate that *C. arizonica* in the examined area has strong regenerative potential which comes to the fore after occurrence of a forest fire. The heat makes cones to open and their seed to spread and form numerous natural regeneration.

5 CONCLUSIONS

Based on the obtained results from the conducted researches on the occurrence of natural regeneration of *C. arizonica* Greene on the burnt areas in Miladinovci, the following has been concluded:

The high forest fire that occurred in 2013 burnt 94% of the parent plantations at the age of 38 and height up to 15m and diameter of breast height 14 cm. Numerous natural regeneration of the *C. arizonica* has been noticed after the forest fire, varying between 60 000 to 1 020 000 individuals per 1 ha or, in average, 390 000 individuals per 1 ha. The natural regeneration is highest in the areas on South exposition, from 885 000 to 1 020 000 individuals/ha, and the lowest on East exposition, from 60 000 to 135 000 individuals/ha.

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The overall share of the natural regeneration of *C. arizonica*in the growth stadium undeveloped seedling, is amounting to 54.5%, and 45.5% for the developed seedling. The information that a large number of individuals (45.5%) has entered the stadium of developed seedling in the second year of their growth i.e. they are higher than 30cm, indicates on intensive and fast growth of the *C. arizonica* in the burnt forest areas in Miladinovci. In relation to the total quality structure of the natural regeneration, 20.1% of the individuals have good quality, 42.7% have medium quality and 37.2% have bad quality. The obtained results indicate that the *C. arizonica*in the examined area has strong regenerative potential which comes to the fore after occurrence of a forest fire. The heat makes cones to open and their seed to spread and form numerousnatural regeneration.

The strong bio-ecological features of *C. arizonica* which successfully adapted to the unfavorable and dry growing sites at the examined area, its ability to produce quality seed which quickly develops into a seedling following a forest fire, as well as the quick development during its first years, make *C. arizonica* very competitive to the weeds and an important sort for afforestation of the dry and unfavorable terrains in Central Macedonia.

C. arizonica has great ability to regenerate naturally on burntareas; however, appropriate protection and silvicultural measures are necessary for a complete successful and proper regeneration as a support of the development of the natural regeneration.

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