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Studying the Adaptive Capabilities of Imported Apple-Tree Cultivars in Lowland Conditions of the Republic of Armenia

E.R. Stepanyan[a], D.A. Beketovskiy[b], M.M. Mukhsyan[a], A.A. Abrahamyan[a]

[a]*Armenian National Agrarian University*

[b]*Voskehat Educational and Research Center of Enology, ANAU*

eteri_stepanyan@mail.ru, beket.da.53@gmail.com, marinemukhsyan@yahoo.com, abrahamyan1994@gmail.com

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ABSTRACT

To study the adaptive and acclimatization capabilities of imported apple cultivars to expand the geographical boundaries of their use in the specific lowland conditions of the Ararat Valley as well as to understand their genetic resources in new growing conditions, production experiments were set up. The following encouraging data were obtained Based on a two-year study of five new novel cultivars of apple trees in three different areas.

Five apple tree cultivars were investigated: Granny Smith, Jonagold Decosta, Fuji, Mutsu, and Gala. During observation and study, they showed a high yield productivity. As a result, all five imported cultivars of apple trees are recommended for growing in intensive orchards and under similar agro-climatic conditions.

Introduction

The objective was to study five imported varieties of apple (Ibanez and Dandekar, 2007) trees in the three communities (Garni, Akunk, and Karbi), at the Kotayk and Aragatsotn marzes of Armenia. All communities were located in the Ararat Valley's foothill zone (at an altitude of 1000-1800 m above sea level), under relatively similar natural (soil, climate) and agro-technical conditions. It was also intended to identify the selected varieties' production and economic features compared with the control (C) variety – Golden Delicious accepted as a standard assortment in the Republic of Armenia since 1981. In 1930-1940, the different varieties of apple trees, namely, local (Margaryan.1960), imported (Zakarian et al., 1989), and selective (Karanyan and Agulyan,1981) were studied in the Armenian SSR. As a result, a list of standard apple varieties (Winter Banana, Bellefleur Jaune, Bellefleur Kitaika, Winter Golden Parmain, Pepin Saffron, Renet Simirenko, Virginia Pink), was compiled in 1959, which has practically remained unchanged until now. Out of 46 local apple varieties examined by Margaryan (1960), 12 varieties were recommended for State variety testing (1970) and identified as potential donors for breeding. The same happened with the variety Melba (1976) and

5 selective varieties examined by P.G. Karanyan and S.L. Agulyan (1981). Later, some new apple (Shaomin Chen et al., 2022) varieties were added to the list (Aurora Krimskaya, Cooper Zangi 3012 and 3006 (1989), Sima (2015) (2020). The current research aims to prove the efficiency of intensive gardening and explore the possibilities for its further development in the foothill zones of the Ararat Valley, as well as to identify possible distribution routes, and reveal the favorable properties of the new varieties.

Materials and methods

The imported apple tree varieties, namely Granny Smith, Jonagold Decosta, Fuji, Mutsu, and Gala, grown in Armenia, have been investigated. A preliminary analysis of soil composition was conducted. The studied orchards were cultivated using intensive horticultural methods: double-grafted saplings, crown creation according to the Spindelbusch system, drip irrigation, fertigation, and hail protection/anti-hail system The research was carried out by the methodological programs of the Lobanov,1973; Dospekhov, 1985; Popov, 200; Khachatryan 2002; Sahakyan, 1989. Three replications were conducted with five trees each. Field experiments were carried out in 2017-2018 in the Garni community (Kotayk Marz) on the Mutsu and control (C) varieties, which were grafted onto the rootstock MM106, with a feeding area of 4x3m^2 in the Akunk community (Kotayk marz).

During 2019-2020, field experiments were conducted on Granny Smith, Fuji, Jonagold Dekosta, and control varieties on rootstock M9, a feeding area of 4.0x1.20 m^2. Field experiments in Karbi (Aragatsotn marz) were carried out in 2020-2021 on the Gala, Granny Smith, and control (C) varieties on the M9 rootstock. The feeding area was 3.80x0.85 m^2. All trees were 3-5 years old in the observation period when fruiting started.

Results and discussions

Akunk community is situated at 1360 m above sea level. The garden exposure is northeast. Garni village is located 1000-1400 meters above sea level. In most of the district, the slopes do not exceed 8°, so they are relatively easy to exploit economically. The village of Garni is located in the Kotayk marz of Armenia, 63 km south of the marz capital (Ashtarak). The height of the Karbi community of Aragatsotn marz above sea level is on average 1700 meters. Orchards are located in the northeast.

The saplings were purchased from Holland. They were grafted on M9 and MM106 rootstocks; Paradise 9 or M9 is a dwarf rootstock, 2 m in height, drought-resistant, and frost-resistant. MM106 – issue of the Dusen subspecies is a medium-sized dwarf rootstock. The bushes are wide-spreading.

Trees were planted in Akunk and Karbi in 2014. They were planted in Garni in 2011. Production started in Akunk and Karbi in 2017 and Garni in 2014. In Garni, the orchard was established with 4 varieties, which pollinate each other. The varieties were planted in the orchard in a ratio of 3/1, with each variety covering 25 % of land area. In Karbi and Akunk, the ratio of the pollinating varieties in the park was 3/1. Every four tree was a seed pollinator.

The imported apple tree varieties – Granny Smith, Jonagold Decosta, Fuji, Mutsu, and Gala -growing in Armenia have been used for our research. Before the research, an analysis was carried out. The studied orchards were cultivated using intensive horticultural practices: double-grafted saplings, crown creation according to the Spindelbusch system, drip irrigation, fertigation, and hail protection systems. The study guides issued under the editorship of the following authors have been used (Lobanov, 1973; Dospekhov, 1985; Popov, 2000; Khachatryan, 2002; Sahakyan 1989).

Table 1 presents the results of the soil sampling analysis in the Aragatsotn marz, and Table 2 introduces the results of the soil sampling in the Kotayk marz.

Soil analysis shows that the soil is clay and heavy. Analysis of the content of soil nutrients in the field enables to determine the number of fertilizers and the timing of their introduction into the soil.

It is known that 4-5 hours after grafting, the scion's inoculation with the rootstock begins. This lasts for several years until complete adhesion. In our case, the varieties showed a high grafting assemblage of 85-90 %, and out of them, a growth of 90 % was recorded in the Gala variety.

Our study on the transition of phenological stages showed that vegetation duration was observed within 233-300 days, starting with swelling of the buds in the period of 02.03-07.04 in different years and different varieties, and ending with the end of leaf fall in the period of 15.11-18.12.

Based on the data obtained, it can be stated that vegetative buds developed in April-June. The formation of green cones and shoots lasted from 7 days (Mutsu) to 21 days (Golden Delicious) and went on until 15.04-20.05. The period of intensive bud growth lasted from 10 (Granny Smith) to 15 days in most varieties during the period 08.05-10.06. The period of apical bud formation lasted from 2 (Mutsu) to 7 days (Gala) in the period of 04.05-20.06.

Table 1. Experimental results of agrochemical analyses of soil samples in Akunk*

Soil sampling depth (cm)	Mechanical composition of soil	*pH*	$CaCO_3$	Composition of water-soluble salts	Water extract in 100 g soil, mg\ eq		The content of absorbed nutrients in the soil, mg\ 100 g		
			%		Ca^{2+}	Mg^{2+}	*N*	P_2O_5	K_2O
0-30	Clay, sandy, and heavy	7.8	n/a	0.056	0.6	1.0	3.00	26.77	111.34
30-60				0.037	0.5	1.0	2.01	13.00	92.87

Table 2. Experimental results of agrochemical analyses of soil samples in Karbi*

ha/soil	Humus (%)	Content of water-soluble salts (%)	*pH*	In water extract (mg/100 g)		The content of absorbed nutrients in the soil in mg\100 g				
				Ca^{+2}	MG^{+2}	$N\text{-}NH_4$	$N\text{-}NO_3$	$P\text{-}P_2O_5$	K_2O	*Fe*
1 (1.7 ha) 0-30 (cm)	0.8	0.2	7.6	2.0	1.6	0.3	3.4	19.2	3.24	0.2
2 (1.7 ha) 30-60 (cm)	1.2	0.8	7.9	1.4	1.1	3.4	0.3	6.0	59.6	0.3

* Composed by the authors.

It should be mentioned that these factors are important for the application of agro-technical measures in these conditions.

Observations and records show that various agricultural activities (including the repeated application of fertilizers) have exerted a significant effect on the development of the assimilation surfaces of tree leaves, as well as on the growing intensity of annual shoots in an apple tree. Observations showed that in comparison with the Golden Delicious variety, only the Mutsu variety surpassed the number of shoots on one of its trees in terms of length and leaf surface area (129.57 cm, 87975 cm^2).

Besides, the Mutsu variety, which has the largest leaf area (87975 cm^2), also has the highest yield capacity per tree (41.0 kg). In general, the problem comes down to the number of leaf-bearing branches and the size of the total leaf area on one tree capable of assimilating solar energy.

As a result, the indicator of total leaf surface becomes of paramount importance, since it directly correlates with the main economic indicator – productivity. Among the three varieties of leaves studied in Akunk, the total foliage indicators were quite similar to those found in control samples.

Picture 1. A design system applied in an intensive apple orchard (Akunk 2019-2020).

Table 3. Survival rate of grafted trees in Karbi, during 2020-2021*

Varieties	Budding/ grafting	Survived graft, adhesion	Survival rate
	(n)		%
Gala	1130	1017	90
Granny Smith	935	795	85
Golden Delicious	1031	896	87

Picture 2. Harvesting Golden Delicious and Galla apple varieties in the garden (Karbi 2020-2021).

Table 4. Duration of vegetation stages in Akunk, Karbi, and Garni*

Cultivar	Years	Bud swelling and scaling	Defoliation			Vegetation duration (days)
			beginning	mass	end	
Granny Smith	2017-2018	04.04-10.03	25.10-05.11	30.11-03.12	10.12-18.12	245-275
Fuji	2017-2018	25.03-02.03	23.10-27.10	27.11-30.11	07.12-10.12	247-275
Jonagold Decosta	2017-2018	04.04-05.03	20.10-25.10	25.11-30.11	05.12-10.12	240-273
Golden Delicious	2017-2018	02.04-02.03	20.10-25.10	25.11-30.11	05.12-10.12	242-275
Mutsu	2018-2019	25.03-03.04	23.10-27.10	27.11-30.11	07.12-10.12	240-248
Golden Delicious	2018-2019	27.03- 07.04	01.11- 05.11	15.11-03.12	30.11-18.12	233-248
Gala	2020-2021	25.03-27.03	15.10-25.11	22.10-25.10	18.11-10.12	239-248
Granny Smith	2020-2021	23.03-25.03	26.10-03.11	15.11-17.11	25.11-27.11	248-252
Golden Delicious	2020-2021	20.03-25.03	07.10-25.10	01.11-15.11	15.11-27.11	250-300

*Composed by the authors.

In Garni, the Mutsu variety slightly surpassed the control. In Karbi, the indicators of the Granny Smith variety exceeded the control in 1.6 times and 3.5 times the Gala variety. As we know, it is generative buds that provide fruit formation and yield. Therefore, timely and normal implementation of vegetative buds developmental phases ensures proper yield. The dynamics of generative buds' development and quantitative data of branches and leaf surfaces (Tables 3-8) indicate the normal adaptation and development of imported varieties in the lowland zones, timely and regular implementation of functions in their organs, which plays a favorable role in the normal formation and maturation

of their crops. On the other hand, wide opportunities are created to stimulate the further quality and quantity of yield of these varieties through agro-technical measures. Observations show that the feeding area indicator is directly proportional to the yield index.

In Akunk, generative buds swelled on March 23-30, they burst out on April 7-15, a single flowering took place on April 17-24, mass blossom – on April 28-03, and the end was recorded on May 6-14, fruit formation – on May 13-20, fruit ripening – on September 12-16, and the end was on 03-15.10.

In Garni swelling occurred on 25-29.03, bursting – on 07-13.04, single flowering –on 17-23.04, mass – on 25.04-01.05, end – 03-12.05, formation of fruits – on 11-16.05, beginning – 25-28.08, end – 01-07.10.

Table 5. Changes in vegetative buds (Akunk, Karbi, and Garni)*

Varieties	Years	Formation of green cones and shoots (1-5 cm)	Period of intensive bud development	Period of apical buds' formation
Granny Smith	2017-2018	05.05-20.05 15	10.05-25.05 15	06.05-10.05 4
Fuji	2017-2018	03.05-18.05 15	08.05-23.05 15	04.05-08.05 4
Jonagold Decosta	2017-2018	04.05-19.05 15	09.05-24.05 15	05.05-09.05 4
Golden Delicious	2017-2018	03.05-18.05 15	08.05-23.05 15	04.05-08.05 4
Mutsu	2018-2019	04.05-11.05 7	09.05-17.05 15	07.05-09.05 2
Golden Delicious	2018-2019	05.05-15.05 10	12.05-23.05 11	04.05-09.05 5
Gala	2020-2021	17.04-05.05 18	23.05-07.06 14	10.06-17.06 7
Granny Smith	2020-2021	15.04-02.05 17	25.05-05.06 10	10.06-15.06 5
Golden Delicious	2020-2021	19.04-10.05 21	27.05-10.06 13	15.06-20.06 5

Table 6. Growth indices of branches and leaf surfaces (Akunk 2019-2020, Karbi 2020-2021, Garni 2017-2018)*

Varieties	1 tree					
	Shoot length (10 n average per cm)	Number of branches	Number of scaffold branches	Number of leaves on a tree	Leaf surface	The surface of all leaves on a tree
		(n)			(cm^2)	
Granny Smith	54	16	13	290	71	20590
Fuji	50	13	10	300	68	20400
Jonagold Decosta	30	9	9	260	75	19500
Golden Delicious	87	15	16	320	78	24960
Mutsu	129	57	16	1173	75	87975
Golden Delicious	95	51	16	1126	75	84450
Gala	25	20	6	200	35	7000
Granny Smith	40	35	12	400	60	24000
Golden Delicious	35	30	10	300	50	15000

* Composed by the authors.

Table 7. Development of generative buds in Akunk, Karbi, and Garni*

Varieties	Years	Buds		Blossom			Fruits		
		swelling	bursting	beginning	mass	end	formation	ripening	
								beginning	full
Granny Smith	2017-2018	25.03-30.03	09.04-15.04	19.04-25.04	30.04-03.05	08.05-14.05	15.05-20.05	14.09-16.09	08.10-15.10
Fuji	2017-2018	23.03-28.03	07.04-13.04	17.04-23.04	28.04-01.05	06.05-12.05	13.05-18.05	12.09-14.09	05.10-10.10
Jonagold Decosta	2017-2018	24.03-29.03	08.04-14.04	18.04-24.04	28.04-02.05	07.05-13.05	14.05-19.05	13.09-15.09	03.10-05.10
Golden Delicious	2017-2018	23.03-28.03	07.04-13.04	17.04-23.04	28.04-01.05	06.05-12.05	13.05-18.05	12.09-14.09	03.10-05.10
Mutsu	2018-2019	25.03-26.03	09.04-11.04	18.04-20.04	25.04-27.04	03.05-05.05	11.05-12.05	26.08-28.08	01.10-06.10
Golden Delicious	2018-2019	28.03-29.03	07.04-13.04	17.04-23.04	25.04-01.05	06.05-12.05	13.05-18.05	25.08-27.08	01.10-07.10
Gala	2020-2021	20.03-25.03	01.04-05.04	21.04-25.04	01.05-03.05	12.05-15.05	20.05-22.05	01.09-05.09	15.09
Granny Smith	2020-2021	20.03-23.03	03.04-05.04	23.04-25.04	01.05-05.05	10.05-15.05	19.05-23.05	09.09-13.09	22.09-24.09
Golden Delicious	2020-2021	25.03-27.03	03.04-07.04	25.04-27.04	01.05-04.05	10.05-13.05	22.05-26.05	09.09-15.09	25.09-27.09

Table 8. Yield capacity of the cultivar in Akunk, Karbi and Garni*

Varieties	Years	Yield harvesting period	Harvested yield per tree (kg)		Average fruit weight (g)	Weight of the biggest fruits (g)	Regularly colored fruits	
			yield on a tree	fallen yield			Weight (kg)	%
Granny Smith	2017-2018	08.10-15.10	19.5-20	1-1	285-290	294-300	18.5-19	94.8-95
Fuji	2017-2018	05.10-10.10	14.5-15	1-2	160-165	160-170	12.5-13	86.2-86.6
Jonagold Decosta	2017-2018	03.10-05.10	18.5-20	2-2	250-260	260-270	17.5-19	94.5-95
Golden Delicious	2017-2018	03.10-05.10	21-22	3-3	299-300	299-310	20.5-21.5	97.6-97.7
Mutsu	2018-2019	05.10-07.10	33-41	2.5-4	280-300	350-370	31-37	90.2-93.9
Golden Delicious	2018-2019	02.10-06.10	37-40	3-3	220-250	299-310	33-36	89.1-90
Gala	2020-2021	24.09-30.09	6-6	1-1	150-145	200-200	4.30-5	75-75
Granny Smith	2020-2021	24.09-07.10	13-14	1-1	250-250	300-300	12-14	95-95
Golden Delicious	2020-2021	17.09-30.09	11-12	1-1	200-200	280-300	11-12	95-95

* Composed by the authors.

Picture 3. Growth intensity of of vegetative organs of apple (Garni 2017-2018).

In Karbi swelling was recorded on 23-27.03, bursting – on 01-07.04, single flowering – on 21-27.04, mass on – 01-05.05, end – 12-15.05, fruit formation – on 19-26.05, beginning – on 01-15.09, full – 15-27.09.

LSD_{05} = 3.51 kg /tree, $E\chi_0$%=8.5 % –Akunk,
LSD_{05} = 2.3 kg /tree, $E\chi_0$%=3.2 % – Garni,
LSD_{05} = 14.4 kg /tree. $E\chi_0$%=2.9% – Karbi.

The results of conducted statistical calculations for the yield data on the three studied plots of apple tree plantations using the Student's formula show that their LSD (Least Significant Difference) is at the 5 % significance level (which corresponds to a 95 % probability level) and the data from Karbi and Garni plots do not go beyond ± LSD_{05}, while the data from the Akunk plot have a positive deviation from the average yields of the standard (control) option. In Akunk, the harvest was collected on 03-15.10. The maximum yield was Golden Delicious (25.0 kg/day); the commercial yield was 21.5 kg/day. The minimal yield was in the Fuji variety – 15.0 kg/tree and 11.0 kg/day, while for varieties of Granny Smith and Jonagold Decosta, the yield amount was 21.5 kg/tree and 19.0 kg/tree, respectively. Harvest in Garni took place on 02-07.10.

The maximum yield capacity was recorded in the variety Mutsu – 41.0 kg/tree and 37.0 kg/tree. The minimum index was observed in the variety of Golden Delicious – 40.0 kg/tree and 36.0 kg/tree. In Karbi, the yield was harvested on 17.09-07.10. The maximum yield amount was obtained in the variety of Granny Smith – 14.0 kg/tree and 12.0 kg\tree. Minimum yield was recorded in the Gala variety – 6.0 kg\tree and 4.3 kg\tree. In the variety Golden Delicious, the yield was 11.0 – 12.0 kg\tree. Such a yield amount is accounted for by the fact that the plants haven't yet entered the period of full fruiting. Concerning the key economic indicators, the yield capacity of the control variant of the Golden Delicious variety demonstrated high results in all three communities. In the first community – Akunk, the indices of Granny Smith and Jonagold Decosta varieties approached the control variety data. In the second community – Garni the best indicators were found in the Mutsu variety, and in the third community – Karbi. The variety of Granny Smith even exceeded the control.

Conclusion

Soil analysis indicates that it possible to cultivate apple trees on such soils. The study of apple tree varieties shows a high survival rate, with the Gala variety having the highest survival rate of 90 %. The vegetation period lasts between 233-300 days, with swelling of buds occurring between 02.03-07.04 and leaf fall ending between 15.11-18.12. The developmental stages of vegetative buds occur between April-June, with the formation of green cones and shoot lasting from 7 days (Mutsu) to 21 days (Golden Delicious).

Observations showed that in comparison with the Golden Delicious variety, only the Mutsu variety surpassed the number of shoots on one of its trees and in their length. The Mutsu variety, which has the largest leaf area, has also the highest yield amount per tree.

In Akunk, the maximum yield was in the control option of Golden Delicious amounting to 25.0 kg/day, commercial yield was 21.5 kg/day. The minimal yield was in the Fuji variety – 15.0 kg/tree and 11.0 kg/day, while for the varieties of Granny Smith and Jonagold Dacosta, the yield amount was 21.5 kg/tree and 19.0 kg/tree, respectively. In Garni, the maximum yield capacity was recorded in the variety Mutsu – 41.0 kg/tree and 37.0 kg/tree. The minimum index was observed in the variety of Golden Delicious – 40.0 kg/tree and 36.0 kg/tree. In Karbi, the maximum yield amount was recorded in the variety of Granny Smith – 14.0 kg/tree and 12.0 kg/tree. Minimum yield was recorded in Gala variety – 6.0 kg/tree and 4.3 kg/tree. In the variety of Golden Delicious, the yield amount was 11.0 – 12.0 kg/tree. Such a yield amount is accounted for by the fact that the plants haven't yet entered the period of full fruiting. Concerning the key economic indicators, the yield capacity of the control variant of the Golden Delicious variety has demonstrated high results in all three communities. In the first community – Akunk, the

indices of Granny Smith and Jonagold Decosta varieties approached the data of the control variety. In the second community – Garni – the best indicators were recorded in the variety of Mutsu, and in the third community – Karbi, the variety of Granny Smith even slightly surpassed the control.

We recommend that Granny Smith, Mutsu, Jonagold Decosta, and Fuji varieties can be used for a wide production expertise and in establishing intensive orchards under similar conditions. According to the important data of economic index, i.e. yield capacity, the varieties Granny Smith and Jonagold Decosta have good prospects for further wide industrial testing and distribution.

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