Research Article

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Preventive Evaluation of Drought Resistance of Apple Varieties and Hybrids and Sources of Late Apple Flowering

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Abstract

In the context of climate change, water scarcity is one of the most pressing threats to global agricultural production, especially the increasing demand for food in connection with the growing population. In recent years, frequent droughts have occurred not only in arid areas but also in regions where this natural calamity was quite rare and short-lived. Thus, in many areas of successful cultivation of apple varieties, droughts have occurred more often and for longer periods. At the same time, global warming causes trees to bloom much earlier, which leads to the exposure of fruit plantations, including apple ones, to the devastating action of late spring frosts and frosts. The Republic of Moldova is also subject to such devastating natural trials more and more frequently. Climate change, leading to global warming, requires the creation of varieties that combine drought resistance in the same genotype and, to avoid late spring frosts, later and longer flowering of trees.

Keywords

Drought, Apple, Resistance, Cultivars, Hibrids, Flovering, Republic of Moldova, France, Romania

Introduction

Drought stress refers to water deficit, when soil moisture is insufficient to support transpiration and photosynthesis. It is also a serious threat to food security not only in arid and semi-arid regions [1]. The prolonged lack of precipitation causes difficulties in the process of supplying plants with substances necessary for normal growth and development. Photosynthesis, the genetic and physiological basis for obtaining high and quality crops, in the absence of water is difficult or can even be stopped with the intervention of plant drying. All plant species, including fruit trees, are subject to the serious consequences of drought. It is expected that many historically productive agricultural regions will face severe water stress, which could lead to yield losses of 4-10% [2, 3]. For apple, improving drought resistance is combined with improving vegetative rootstocks, which must have a high water absorption capacity on a smaller soil surface [4-8]. Reducing the action of drought on apple plants can also be obtained by treating them with betanin. The results showed that, under drought stress conditions, the chlorophyll content of apple leaves pretreated with betanine was significantly higher than that of control plants. Pretreatment with betaine increased the stomatal conductance of apple leaves, reduced the accumulation of reactive oxygen species, and increased the activity of antioxidant enzymes [9]. Different varieties do not react identically to drought stress. In Hungary, it was established that Idared and Jonagold belong to the group of susceptible varieties. In the same group are the varieties Akane, Red Rome van Well and Pink Lady. In terms of changes in carbohydrate content, the varieties Greensleeves and Ozark Gold belong to the moderately water-dependent group [10]. In the Republic of Moldova, annual precipitation, depending on the area, is on average 350-650mm/m2, their distribution during the year is uneven, summers are characterized by dry winds, high temperatures and heat. Under these conditions, the need to create new drought-resistant varieties is obvious [11]. Moreover, in drought conditions, the condition of apple tree varieties worsens due to the excessive development of powdery mildew (Podosphaera lecotricha Salm) [12]. The first drought-tolerant variety Green Delicious was created by crossing the Gold Delicious variety as a maternal parent with the Yellow Transparent variety as a paternal parent in 1966. Planting in the western part of the Qinghai and Caidrmu basin regions of China yielded results of cold resistance and drought tolerance and since 1992 this cultivar has become popular [13]. Along with the creation of drought-resistant varieties and rootstocks, work will be needed to develop a hydro-economic model of water management [14].

Following climate change towards warming, late spring frosts have become increasingly frequent, which are disastrous for fruit plants and bring great economic losses. Late flowering is considered important to avoid disastrous damage caused by spring frost, and the reaction of varieties to frost by damaging flower components is different [15]. A goal of many breeding programs is to create varieties that bloom so late that virtually any danger to the flowers from late frost has passed. Another factor contributing to crop losses due to late frost is the inherent susceptibility of flowers to damage [16-18]. Although there are differences in flower sensitivity to frost damage, selection for this trait does not appear to have been carried out. Tetraploid and triploid apple varieties, such as Jonagold, Mutsu, etc., with larger cells, are more susceptible to damage than diploids. [19] The resistance and damage of apple trees exposed to winter conditions and the resistance of flowers to spring frost damage appear to be independently inherited [20-22]. A major emphasis is placed on testing a selection method that allows indirect selection for late flowering before entering the adult phase. Such a program includes in itself the determination of correlations between the time of bud break of plants in the juvenile stage, genetic analysis of DNA and flowering in the adult phase [23].

Materials and Methods

In 2020, the central area of the Republic of Moldova was subjected to a terrible drought. In order to determine the action of the moisture deficit, the genotypes from the collection and from the selection orchard were subjected to visual evaluation regarding the morphological changes of the leaves due to the attack of the trees by the drought. 210 cultivars, species and elites including 160 genotypes with genetic resistance to apple scab and 50 non-resistant. In parallel, observations were made on 1878 hybrid plants from 49 hybridization combinations. Pollen from the varieties Ariane, Crimson Crips, Goldrush, Opal, Rosyglow obtained from IFO France according to the collaboration agreement was used in the pollinations. The collection was established in the years 2007-2009, M26 rootstocks, and the selection orchard in the years 2009 - 2011 with planting distances of 4 x 1,5 and 4 x 0,75m, respectively. The assessment of the reaction of the plants was carried out by scoring according to the scale 1-6 where:- 1 – no attack..... 6 – very strong attack, over 80% of the leaves have fallen and the rest are yellow, wilted and twisted. Precipitation in 2019-2020, in the months of October-April, was 60% less than normal (Table 1.).

Table 1: Monthly and general temperatures, precipitation and hydrothermal coefficients.

Year	Month	Average temperature, daily monthly	Precipitation, mm	Sum of daily average temperatures above 10oC	Precipitation deviation from the norm, %	Hydrothermal index
2019	October	12,2	19,4	285,8	46	0,68
2019	November	7,4	7,3	175,8	19	0,42
2019	December	2,9	1,2	15,8	54	0,76
2020	January	0,86	8,4	0	24	-
2020	February	3,8	22,8	0	73	-
2020	March	7,7	19,4	119,4	57	1,62
2020	April	11,3	4,4	282,2	11	0,16
2020	May	13,9	65,8	413,6	132	1,59
2020	June	21,3	85,9	638,3	131	1,35
2020	July	23,1	112,2	717,9	170	1,56
2020	August	25,4	4,5	788,7	8	0,06
2020	September	20,26	1	607,8	2	0,02
Average						0,82

Average monthly temperatures between October 2019 and September 2020 were 3-5% higher. The observations were carried out between September 17-23, 2020 until the rains intervened on September 24. For 12 months that have an impact on the resistance of plants to drought, the hydrothermal index was calculated - a relative indicator of the hydration state of the territory proposed by Seleaninov. It is determined by the ratio of the amount of precipitation increased by 10 times for the period with the average daily air temperature higher than 100C and the sum of the average daily temperatures higher than 100C for this period [24].

A hydrothermal index higher than 1 indicates overmoistening, equal to 1 normal humidity and lower than 1 low humidity. Thus, the hydrothermal index for the months of October, November, and the sum of precipitation for the months of December, January and February are well below the norm.

Global warming is causing fruit tree species to flower earlier than multi-year data preceding this effect show. To avoid late spring frosts, it is necessary to create late-flowering varieties. The calendar date of flowering of apple hybrids for those with extra early flowering was observed on April 20 and the flowering period was in the calendar dates starting from April 1. Hybrid plants with extra-early flowering during April 20-21 were evaluated with a score of 1, early during April 22-23 with a score of 2, semi-late during April 24-25 with a score of 3, semi-late during April 26-27 with a score of 4, late during April 28-29 with a score of 5 and very late flowering during April 30 - May 1 were evaluated with a score of 6. Out of the total of 1878 plants, only 1554 hybrids bloomed in 2020. Due to the higher temperatures of March-April, the onset of flowering of trees, varieties, species, elites and apple hybrids with extra-early and early flowering was observed in the interval of April 20-23, which was 8 days earlier compared to the average dates of several years - April 27-28 [25-27]. In genotypes with very late flowering of trees, the onset occurred on May 1 (Table 2).

Table 2: Temperature conditions, t0C, in the months of influence on the flowering of apple trees in 2020

Month	Average of the multiannual norm	Average in 2020	Deviation from the norm
January	-5,6	1,7	-3,9
February	-3,6	1,7	-1,9
March	4,5	6,3	+1,8
April	7,2	9,1	+1,9
May	15,9	16,3	+0,4

Data processing was performed in Excel using one-way analysis of variance without repetitions with the determination of partial differences between hybridization combinations and the level of heritability, H2%.

Results and Discussion

In the collection of varieties, practically without symptoms of attack by water deficit were M. sieboldii, 6 local elites:- 2-46(42), 2-48(35), 2-48(38), 2-48(45), 3-39(78), 3-41(107), the Corevidem variety and the apple form from France, L40.

Very weak attack with a score of 1.1-2 indicated the species:- M. baccata sibirica, M. floribunda, varieties:- Aura, Bistrițean, Corelita, Dalinred, Florina, Golden Lasa, Salva,, 14 local selections:- 2-56(1,2,5), 2-46(31), 2-48(6), 2-98(21), 2-48(31), 3-41(106), 3-60(3), 3-41(77), 3-63(10), 3-39(79), 3-60(74), 3-60(77), 3-40(44), 2-34(19), DL48 from France and PiAs22,17 from Germany.

Weakly attacked determined with a score of 2.1-3 were the species:- M. pumila, M. prunifolia, varieties:- Ariwa, Arlet, Baujade, Cidor, Dacian, Dalinco, Dani, Generos, Golden Orange, Goldrush, Judeline, Iris, Nicol, Nova Easygro, Orlovskoe Polesie, Pimona, Primula, Redfree, Regine, Sir Prize, Starkprim, Svejesti, 28 local elites:- 2-32(28), 2-32(60), 2-32(91-92), 2-35(42), 2-36(26), 2-36(33), 2-36(88-89), 2-38(40), 2-38(105), 2-45(1-4,7), 2-46(37), 2-46(39), 2-47(41), 2-47(99), 2-48(7), 2-48(15), 2-48(16), 2-48(18), 2-48(27), 2-48(43), 2-48(105a), 2-48(105b), 2-49(34), 2-49(45), 3-47(50,54,55), 3-59(120), 3-60(1), DL35, DL33 and PP15 from France, form R12740-7 and selection with red fruits from Central Asia K66. Further, the local apple elites are not listed because they are not of interest for selection according to drought attack.

Medium attacked rated 3.1-4 or proven species:- M. sieversii, and M. niedzwetzkyana, varieties:- Astrahanskoe Krasnoe, Beacon, Bolotovskoe, Coremodet, Dalinbel, Dayton, Doina, Dolgo, Goldprim, Greensleevs, Honey Gold, Jonafree, Jonaprim, Judaine, Kandil Orlovskii, Liberty, Lotos, Pinova, Priam, Rebra, Redix, Regia, Reghistani, Remo, Romus 4, Slava Peremojțiam, Stroevskoe, Svejesti, 20 local elite, DL41 from France and form 9130 x Lobo.

Strong drought attack with grades 4.1-5 were observed on the varieties:- Afrodita, Candil Sinap, Coredana, Coredar, Golden Delicious, Golden Grimes, Hazarinskoe, Judeline, Ingol, Mleevskoe Letnee, McIntosh Geneva, Prima, Reglindis, Relinda, Renet Simirenko, Romus 2, Romus 3, Saturn, Trauton, Voinea, RJK forms, Col24/5P from Romania and 18 local elites.

Very strong drought attack with grades 5.1-6 were observed on the varieties:- James Grieve Red, Imrus, Iubilear, Mutsu, Orange Glass Apfel, Orlovskoe Polesie, Pikant, Pikkolo, Solnâșko, Reka, Start, Stroevskoe, Veniaminovskoe, 12 local elites Col114/P forms from Romania, and V11 from France.

In 2020, the genotypes evaluated according to the time of the onset of tree flowering indicated different calendar dates. In accordance with the purpose of determining sources of genotypes for the creation of varieties with tolerance or resistance to drought and late flowering, hereinafter we will refer only to species, varieties and forms of apple with late and very late flowering. Late flowering, on April 28-29 (corresponding to note 5) under the conditions of 2020, indicated the varieties: - Coremodet, Dalinbel, Dalinred, Generos, Golden Grimes, Goldrush, Golden Lasa, Jonafree, Florina, Pinova, Nicol, Sir Prize, 16 local elites:- 2-32(60), 2-35(102), 2-36(33), 2-36(101-102), 2-37(97-98), 2-38(43), 2-48(56), 2-56(1-2,5), 3-39(78), 3-41(77), 3-41(107), 3-47(50,54,55), 3-60(1), 3-61(15), 3-61(43), 3-61(62), and L40 from France.

Very late on April 30 – May 01 (corresponding to note 6) only the varieties Baujade, Corevidem, Corelita, Dacian, Lotos and Regine bloomed. Thus, the possibility of choosing apple genotypes by plant phenotype according to the trees' reaction to drought and the time of flowering onset for selection can be seen in Table 3.

Table 3: Possible genotypes for hybridizations

No symptoms of drought attack	**Average in 2020**
Corevidem, 3-39(78), 3-41(107), L40.	Very late flowering
Very weak drought attack	Baujade, Corevidem, Corelita, Dacian, Lotos și Regine.
Corelita, Dalinred, Florina, Golden Lasa, 2-56(1,2,5), 3-41(77),	Late flowering
Weak drought attack	Dalinred, Generos, Goldrush, Golden Lasa, Florina, Nicol, 2-32(60), 2-36(33), 2-56(1-2,5), 3-39(78), 3-41(77), 3-41(107), 3-47(50,54,55), 3-60(1), L40.
Baujade, Dacian, Generos, Goldrush, Nicol, Regine, 2-36(33), 2-32(60), 3-47(50,54,55), 3-60(1).	

In the experiments presented in this article, six apple genotypes were crossed as maternal forms with various other paternal genotypes. Thus, the Coredana variety was crossed with 9 paternal parental varieties Ariane, Goldrush, Rosyglow, Hana, Florina, Coredar, Nova Easygro and the compact columnar form KV43. From the monofactorial dispersion analysis it is observed that the paternal parental varieties differ genotypically from each other in their drought resistance, the heritability coefficient (H2) is 54.5%, being also highly significant (Table 4). For the flowering onset period, the heritability coefficient is lower but still significant. This character in the paternal varieties in the given experiment may depend on several factors.In both cases, there may be promising combinations for obtaining hybrids with increased drought resistance and late flowering.

Table 4: Dispersion analysis for the hybridization complex of the maternal variety Coredana

Hybrids attacked by drought						
Source of variability	**Sum of squares, SS**	**Degree of freedom, df**	**Mean squares, ms**	**Heritability, H2%**	**Significant, F**	
					Calculating	**P0,05**
General	327,75	253	-	-	-	-
Paternal variety	171,26	7	24,47***	54,5***	38,5	2,1
Error, mse	156,49	246	0,6362	-	-	-
Flowering onset time for hibrids						
General	262,99	224	-	-	-	-
Paternal variety	78,91	7	11,2727	31,0***	13,3	2,0
Error, mse	184,09	217	0,8483	-	-	-

In this table and the following - *** significant at P=0,001, ** P=0,01, * P=0,05,

In the combinations of the Coredana variety with the Hana, Florina and Nova Easygro varieties, more drought-tolerant hybrids can be expected. The average attack of hybrid plants ($\dot{x}$) in these combinations deviates significantly from the global average ($\dot{X}$) (Table 5). In the hybrid combination Coredana x Ariane, plants are strongly attacked by drought, the average attack scores being much higher than the global average for all analyzed paternal combinations. From the analysis of the flowering period of hybrid plants, it is observed that in the combinations Coredana x Florina and Coredana x Nova Easygro late-flowering hybrids can be formed, and in the combinations Coredana x Hana and Coredana x Coredar, earlier-flowering hybrids. Promising combinations for the selection of late-flowering and drought-tolerant hybrids can be Coredana x Florina and Coredana x Nova Eazygro.

Table 5: The difference between the combinations of the maternal variety Coredana

Hybrids attacked by drought						**Flowering onset time for hibrids**			
Maternal variety, ♀	**Paternal variety, ♂**	**Number of hybrids, ni**	**Amount of data, s**	**Mean date, $\dot{x}$**	**Deviation from the mean, $\dot{X}$**	**Number of hybrids, ni**	**Amount of data, s**	**Mean date, $\dot{x}$**	**Deviation from the mean, $\dot{X}$**
Coredana	Ariane	45	224	4,98	1,70***	41	172	4,10	0,07~
	Goldrush	26	84	3,23	-0,05~	26	109	4,19	0,16~
	Rosyglow	45	166	3,69	0,41*	41	176	4,29	0,26~
	Hana	19	53	2,79	-0,49**	15	37	2,47	-1,56***
	Florina	29	81	2,79	-0,49**	8	40	5,00	0,97**
	Coredar	43	132	3,07	-0,21~	42	143	3,40	-0,63*
	Nova Easygro	29	68	2,34	-0,94**	20	97	4,85	0,82**
	KV43	18	60	3,33	0,05~	32	125	3,91	-0,12~
Sums, global mean $\dot{X}$		254	868	3,28	-	225	899	4,03	-
LD0,05		-	-	-	±0,27	-	-	-	±0,33

In this table and the following- ~ not significant.

The Generos apple variety was crossed with nine paternal varieties: - Lotos, 2584, Rosyglow, Crimson Crisp, Ariane, Opal, Dalinred, Goldrush and Dalinbel. The single-factor dispersion analysis shows that the paternal parental varieties differ genotypically from each other in their drought resistance, the heritability coefficient (H2) is 50.6% and is significant (Table 6). So half of the total variation belongs to the paternal varieties. For the flowering onset period, the heritability coefficient is higher, it is 69.8% and significant. Most of the variability for the flowering onset period belongs to the paternal varieties. In this complex of hybridizations, hybrids with increased drought resistance and late flowering can be obtained.

Table 6: Dispersion analysis for the hybridization complex of the maternal variety Generos

Source of variability	Sum of squares, SS	Degree of freedom, df	Mean squares, ms	Heritability, H2%	Significant, F	
					Calculating	P0,05
Hybrids attacked by drought						
General	318,19	243	-	-	-	-
Paternal variety	160,39	8	20,0489***	50,6***	29,9	2,0
Error, mse	157,80	235	0,6715	-	-	-
Flowering onset time for hibrids						
General	304,29	212	-	-	-	-
Paternal variety	206,62	8	25,8274	69,8***	53,9	1,98
Error, mse	97,67	204	0,4788	-	-	-

Hybrids with increased drought resistance according to the deviations of the averages on combinations ($\dot{x}$) from the general average ($\dot{X}$) can be formed from the pollination of the Generos variety with the varieties Lotos, 2584, Opal and Goldrush. In the combinations with the varieties Rosyglow, Ariane and Dalinbel most of the hybrids are formed not resistant to drought (Table 7). The analysis of the flowering of the hybrids shows that in the combinations Generos x Lotos, Generos x 2584 and Generos x Goldrush, in which the deviation of the averages from the global average is positive and highly significant, segregates hybrids with late flowering and in the combinations of the Generos variety with the varieties Rosyglow, Crimson Crisp, Ariane, Dalinred and Dalinbel segregates many hybrids with early flowering. Promising combinations for obtaining late-flowering and drought-resistant hybrids are Generos x Lotos, Generos x 2584 and Generos x Goldrush.

Table 7: The difference between the combinations of the maternal variety Generos

		Hybrids attacked by drought				Flowering onset time for hibrids			
Maternal variety, ♀	Paternal variety, ♂	Number of hybrids, ni	Amount of data, s	Mean date, $\dot{x}$	Deviation from the mean, $\dot{X}$	Number of hybrids, ni	Amount of data, s	Mean date, $\dot{x}$	Deviation from the mean, $\dot{X}$
Generos	Lotos	32	98	3,06	-0,44*	27	132	4,89	0,63***
	2584	16	50	3,13	-0,37*	7	41	5,86	1,6**
	Rosyglow	25	117	4,68	1,18***	18	63	3,50	-0,76**
	Crimson Crisp	57	190	3,33	-0,17~	54	274	5,07	-0,81**
	Ariane	22	101	4,59	1,09***	18	55	3,06	-1,2**
	Opal	24	58	2,42	-1,08***	22	99	4,50	0,24~
	Dalinred	25	94	3,76	0,26~	24	72	3,00	-1,26***
	Goldrush	28	71	2,54	-0,96**	22	121	5,50	1,24***
	Dalinbel	24	95	3,96	0,46*	21	63	3,00	-1,26***
Sums, global mean $\dot{X}$		244	874	3,50	-	213	920	4,26	-
LD0,05		-	-	-	±0,35	-	-	-	±0,29

The Nova Easygro apple variety was crossed with five paternal genotypes: - Goldrush, Ariane, Rosyglow, Coredar and the compact columnar tree form KV43. The single-factor dispersion analysis shows that the paternal parental varieties differ genotypically from each other after the transmission of drought resistance to the offspring, the heritability coefficient (H2) is 41.4% and is significant (Table 8).

Table 8: Dispersion analysis for the hybridization complex of the maternal variety Nova Easygro

Source of variability	Sum of squares, SS	Degree of freedom, df	Mean squares, ms	Heritability, H2%	Significant, F	
					Calculating	P0,05
Hybrids attacked by drought						
General	143,88	133	-	-	-	-
Paternal variety	54,66	4	13,665***	41,4***	19,8	2.5
Error, mse	89,22	129	0,6916	-	-	-
Flowering onset time for hibrids						
General	60,75	103	-	-	-	-
Paternal variety	3,15	4	0,7881~	0,01~	1,4	2,5
Error, mse	57,60	99	0,5819	-	-	-

So more than half of the total variation does not belong to the paternal varieties but to other factors. After the onset of flowering, the paternal varieties are genotypically identical, the heritability coefficient is almost zero. In this complex of hybridizations, few hybrids with increased drought resistance and late flowering can be obtained.

From the data in Table 9 it can be seen that hybrids with increased drought resistance can be obtained in combinations from the crosses Nova Esygro x Goldrush and Nova Easygro x Ariane. Hybrids with late flowering can only be formed in the combination Nova Esygro x Rosyglow. In this complex of hybridizations there are no combinations in which hybrids are formed that combine drought resistance with late flowering.

Table 9: The difference between the combinations of the maternal variety Nova Easygro

Hybrids attacked by drought						Flowering onset time for hibrids			
Maternal variety, ♀	Paternal variety, ♂	Number of hybrids, ni	Amount of data, s	Mean date, $\dot{x}$	Deviation from the mean, $\dot{X}$	Number of hybrids, ni	Amount of data, s	Mean date, $\dot{x}$	Deviation from the mean, $\dot{X}$
Nova Easygro	Goldrush	34	150	4,41	0,40*	29	109	3,76	-0,22~
	Ariane	21	100	4,76	0,75**	18	72	4,00	0,02~
	Rosyglow	23	94	4,09	0,08~	17	73	4,29	0,31*
	Coredar	26	101	3,88	-0,13~	17	67	3,94	-0,04~
	Kv43	30	87	2,90	-1,11***	23	90	3,91	-0,07~
Sums, global mean $\dot{X}$		134	532	4,01	-	104	411	3,98	-
LD0,05		-	-	-	±0,29	-	-	-	±0,28

The apple form with the columnar tree type KV42 was crossed with 8 paternal genotypes: - Granny Smith Spur, 1-11(6-10), Romus 2, Coredana, Rubinola, Florina and Hana. The data in Table 10 show that in this hybridization block the heritability coefficient for the level of attack of hybrids by drought (H2) is high, making up 60.5% and the paternal varieties are genotypically varied according to their action on the expression of the analyzed characteristic in the offspring. Thus, from this block, prospective varieties for crosses can be chosen. Lower is the heritability index regarding the flowering onset period, 36.4%, but significantly high.

Table 10: Dispersion analysis for the hybridization complex of the columnar apple tree KV42

Source of variability	Sum of squares, SS	Degree of freedom, df	Mean squares, ms	Heritability, H2%	Significant, F	
					Calculating	P0,05
Hybrids attacked by drought						
General	386,88	267	-	-	-	-
Paternal variety	186,14	6	31,0233***	60,5***	40,3	2,1
Error, mse	200,74	261	0,7691	-	-	-
Flowering onset time for hibrids						
General	289,72	229	-	-	-	-
Paternal variety	100,04	6	16,6739	36,4***	19,6	2,1
Error, mse	189,68	223	0,8506	-	-	-

The analysis of hybrid combinations shows different results regarding their perspective of selection of discounted hybrids (Table 11). Drought-tolerant hybrids can be formed in combinations of the maternal form KV42 with the paternal varieties Romus 2, Florina and Hana in which the deviation of the averages of hybrid combinations from the global average is negative and significant. Regarding the time of flowering onset, late-flowering hybrids are formed in the hybridization combinations KV42 x Granny Smith Spur, KV42 x Coredana and KV42 x Florina. At the same time, only from the crossing of the form with the compact columnar tree type KV42 with the apple variety Florina can hybrids be formed that combine both valuable characteristics of weak drought attac and late flowering.

Table 11: The difference between the combinations of the columnar apple tree KV42

Hybrids attacked by drought						Flowering onset time for hibrids			
Maternal variety, ♀	**Paternal variety, ♂**	**Number of hybrids, ni**	**Amount of data, s**	**Mean date, $\dot{x}$**	**Deviation from the mean, $\dot{X}$**	**Number of hybrids, ni**	**Amount of data, s**	**Mean date, $\dot{x}$**	**Deviation from the mean, $\dot{X}$**
KV42	Granny Smith Spur	34	107	3,82	0,57*	30	151	5,03	0,9**
	1-11(6-10)	48	89	3,56	0,31*	43	175	4,01	-0,06~
	Romus 2	29	62	2,82	-0,43*	22	85	3,86	-0,27~
	Coredana	34	47	3,36	0,11~	28	126	4,5	0,37*
	Rubinola	45	81	4,26	1,01***	43	148	3,44	-0,69**
	Florina	26	64	2,46	-0,80**	24	117	4,88	0,75**
	Hana	52	130	2,5	-0,75**	40	126	3,15	-0,98***
Sums, global mean $\dot{X}$		268	580	3,25	-	230	928	4,13	-
LD0,05		-	-	-	±0,31	-	-	-	±0,30

In the hybridization block of the Lotos apple variety crossed with 9 paternal varieties Trident, Priam, Coredana, Corelita, Florina, Dalinred, Coredar, Čampion, Red Idared the heritability coefficient for the level of attack of hybrids by drought (H2) is not high, it is 43.2%, so the parental varieties are genotypically less varied among themselves according to their action on the expression of the analyzed characteristic in the offspring (Table 12). Even lower are the heritability indices regarding the flowering onset time, 14.8%, but significantly high. The genotypic difference between the analyzed varieties is not significantly high for both analyzed characteristics.

Table 12: Dispersion analysis for the hybridization complex of the maternal variety Lotos

Hybrids attacked by drought						
Source of variability	**Sum of squares, SS**	**Degree of freedom, df**	**Mean squares, ms**	**Heritability, H2%**	**Significant, F**	
					Calculating	**P0,05**
General	818.04	601	-	-	-	-
Paternal variety	314,17	8	39,2713***	43,2***	46,2	2,0
Error, mse	503,87	593	0,8497			
Flowering onset time for hibrids						
General	605,63	548	-	-	-	-
Paternal variety	87,46	8	10,93	14,8***	11,4	2,0
Error, mse	518,17	540	0,9596	-	-	-

Of the nine hybridization combinations, after the attack of the hybrids by drought, Lotos x Corelita, Lotos x Florina and Lotos x Dalinred can be mentioned in which hybrids less subject to water stress can be selected. The same hybridization combinations denote the presence of several late-flowering hybrids (Table 13).

Table 13: The difference between the combinations of the maternal variety Lotos

Hybrids attacked by drought						Flowering onset time for hibrids			
Maternal variety, ♀	**Paternal variety, ♂**	**Number of hybrids, ni**	**Amount of data, s**	**Mean date, ẋ**	**Deviation from the mean, Ẋ**	**Number of hybrids, ni**	**Amount of data, s**	**Mean date, ẋ**	**Deviation from the mean, Ẋ**
Lotos	Trident	85	446	5,25	1,15***	69	292	4,23	0,22˜
	Priam	82	348	4,24	0,14~	79	325	4,11	0,1˜
	Coredana	41	160	3,90	-0,2~	40	152	3,8	-0,21˜
	Corelita	64	166	2,59	-1,51***	63	289	4,59	0,58**
	Florina	109	327	3,00	-1,1***	104	449	4,32	0,31*
	Dalinred	36	130	3,61	-0,49**	30	134	4,47	0,46*
	Coredar	92	399	4,34	0,24*	88	336	3,82	-0,19˜
	Čampion	52	267	5,13	1,03***	42	164	3,90	-0,11˜
	Red Idared	41	201	4,90	0,8***	34	98	2,88	-1,13˜
Sums, global mean Ẋ		602	2444	4,10	-	549	2239	4,01	-
LD0,05		-	-	-	±0,23	-	-	-	±0,24

The apple selection OR38T17 was crossed with 11 paternal genotypes:- Generos, 2584, Red Idared, Golden Delicious, KV43, Goldrush, Rosyglow, Ariane, Crimson Crisp, Dalinred, and Opal. In this hybridization block the heritability coefficient for the level of attack of hybrids by drought (H2) is 58.6%. The paternal parental varieties are genotypically varied according to their action on the expression of the attack of the offspring by drought. Thus, from this block the prospective varieties for crosses can be chosen. The heritability indices regarding the time of flowering onset are lower, 22.6%, but significant. According to this character the paternal varieties are more identical compared to the attack by drought (Table 14).

Table 14: Dispersion analysis for the hybridization complex of the apple selection OR38T17

Hybrids attacked by drought						
Source of variability	**Sum of squares, SS**	**Degree of freedom, df**	**Mean squares, ms**	**Heritability, H2%**	**Significant, F**	
					Calculating	**P0,05**
General	676,59	375	-	-	-	-
Paternal variety	386,80	10	38,6802***	58,6***	48,7	1,9
Error, mse	289,79	365	0,7939	-	-	-
Flowering onset time for hibrids						
General	281,75	232	-	-	-	-
Paternal variety	67,29	10	6,7287	22,6***	7,0	1,9
Error, mse	214,46	222	0,9661	-	-	-

The selection of hybrids weakly attacked by drought from this hybridization block can be carried out from several combinations:- OR38T17 x Generos, OR38T17 x 2584, OR38T17 x Goldrush, OR38T17 x Crimson Crisp, OR38T17 x Dalinred and OR38T17 x Opal in which the deviation of the averages of the hybrid combinations from the global average is negative and significant (Table 15). Regarding the flowering onset time, late-flowering hybrids are formed only in the OR38T17 x Golden Delicious combination. At the same time, no hybrid combination was differentiated that would combine both valuable characteristics of weak drought attack and late flowering.

Table 15: The difference between the combinations of the maternal apple selection OR38T17

Hybrids attacked by drought						Flowering onset time for hibrids			
Maternal variety, ♀	**Paternal variety, ♂**	**Number of hybrids, ni**	**Amount of data, s**	**Mean date, ẋ**	**Deviation from the mean, Ẋ**	**Number of hybrids, ni**	**Amount of data, s**	**Mean date, ẋ**	**Deviation from the mean, Ẋ**
OR38T17	Generos	31	86	2,77	-0,83**	20	96	4,8	0,39˜
	2584	62	179	2,89	-0,71**	50	226	4,52	0,11˜
	Red Idared	49	266	5,43	1,83***	38	123	3,24	-1,17**
	Golden Deli-cious	22	116	5,27	1,67***	13	66	5,08	0,67*
	KV43	22	80	3,64	0,04~	12	55	4,58	0,17˜
	Goldrush	41	123	3,00	-0,60*	31	143	4,61	0,21˜
	Rosyglow	23	102	4,43	0,83**	11	52	4,73	0,32˜
	Ariane	34	136	4,00	0,40*	10	46	4,6	0,19˜
	Crimson Crisp	22	65	2,95	-0,65**	12	51	4,25	-0,16˜
	Dalinred	31	77	2,48	-1,12***	18	73	4,06	-0,35˜
	Opal	39	109	2,79	-0,81***	18	73	4,06	-0,35˜
Sums, global mean Ẋ		376	1339	3,60	-	233	1004	4,41	-
LD0,05		-	-	-	±0,32				±0,43

Conclusions

The collection of apple varieties in the Republic of Moldova includes various foreign and locally created genotypes from which initial forms can be chosen in order to create new drought-tolerant or drought-resistant varieties with late flowering of trees.

According to the coefficient of heritability, H2%, which in the analyzed hybrid combinations varies between indices 41.4 and 60.5%, there is the possibility of choosing the most suitable genotypes for the purpose of subsequent hybridizations for the creation of new varieties less affected by drought. Hibrizi slab atacați de secetă se pot forma în combinațiile de hibridare Coredana x Hana, Coredana x Nova Esygro, Generos x Opal, Nova Esygro x KV43, Nova Esygro x Hana, OR38T17 x Generos, OR38T17 x 2584, OR38T17 x Goldrush, OR38T17 x Crimson Crisp, OR38T17 x Dalinred, OR38T17 x Opal.

In the hybrid combinations Generos x Lotos and OR38T17 x Golden Delicious, late-flowering hybrids can segregate. Hybrid plants that combine both characteristics of poor drought resistance and late flowering of trees can be formed in the cross combinations Coredana x Florina, Generos x Lotos, Generos x 2584, Generos Goldrush, KV42 x Florina, Lotos x Corelita, Lotos x Florina and Lotos x Dalinred.

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