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Genetic Origin Affects the Reduction of Fruit Load in Young Grapevines Sprayed with an Organosilicone Surfactant and Ethephon

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Genetic origin affects the reduction of fruit load in young grapevines sprayed with an organosilicone surfactant and ethephon

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Abstract: Combinations of Dilwet, an organosilicone surfactant, and ethephon, a hormonal compound often applied to fruit trees to thin the crop, were applied at full bloom to prevent fruit development in two young vineyards differing in elevation by 600 m. Each vineyard was planted with the same 19 red and 10 white grape cultivars from a range of countries of origin. Vineyard elevation did not affect response to treatment. A combined spray of 0.5% Dilwet with 0.04% ethephon reduced cluster number by an average of 85%, while weight of the remaining clusters was reduced by 63%, compared to unsprayed controls. Increasing the concentration of Dilwet to 1% reduced cluster number by 93% and cluster weight by 76%. There were significant differences in the response of cultivars to the treatments, depending on country of origin, with grapes originating in France responding better to higher concentrations of Dilwet. White grapes were more responsive than red grapes. These results highlight the need to test different cultivars and genetic origins of crops when examining the effects of new agricultural chemicals.

Keywords: Dilwet, full bloom, red and white grapes, Spain, France, Germany, Egypt, Italy, Portugal

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1. Introduction

Young fruit trees in the nursery and in the first few years after transfer from the nursery to the field often produce minor non-commercial yields that can reduce the development of the full scaffold necessary for maximal commercial production (1). Growers often manually remove fruitlets or mature fruit from young trees and vines to allow further development of the fruit scaffold for increased commercial yields (2,3,4). Surfactants have been used to thin fruit crops in mature trees (5-10) , but their use in young (less than three years old; Leviticus 19:23) trees for total removal of the crop has not been thoroughly examined. Dilwet (Adama Inc., Ashdod, Israel) and other organosilicone surfactants have been applied at concentrations of 0.5-1.0 percent to open flowers of grapes (11), apples (12), almonds (Klein and Cohen, unpublished), loquats (13), plums (14,15) and peaches and nectarines (16), and can reduce this undesirable yield significantly. Spraying Dilwet during full bloom, with or without the addition of ethephon (11), significantly reduced the number of Cabernet Sauvignon and Merlot grape clusters, but it has not been tested on other red grapes and not at all on white wine grape varieties.

In 2012, two experimental vineyards were planted in the Negev desert at Ramat HaNegev (elevation 300 m) and at the outskirts of Mitzpe Ramon (Kerem Ramon, elevation 900 m), in order to investigate the effect of hot dry climates on grape production and wine quality (Eran Harcabi, personal communication). Each vineyard included 19 red wine grape varieties and 10 white wine grape varieties. Most originated from the Mediterranean region, with the exception of Riesling and Gewurztraminer, which originate in Germany (17). We examined the effectiveness of Dilwet spraying, with and without the addition of 0.5 and 1 percent ethephon, as a means of reducing fruit yield of young vines in a wide range of wine grape varieties.

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2. Materials and Methods

In preliminary experiments (11), spraying combinations of Dilwet, an organosilicone surfactant also known as Silwet 408, and ethephon, reduced both number and size of Merlot and Cabernet Sauvignon grape clusters. The two cultivars responded differently to combinations and concentrations of the two compounds. Although effects of the treatment on Cabernet Sauvignon were noticed after 3 weeks, effects on Merlot were noted only much later (11).

In order to examine the effects of Dilwet with ethephon on reducing number and size (weight) of grape clusters in a wider range of wine grapes, we tested combinations of Dilwet and ethephon on 19 red wine cultivars and 10 white wine cultivars in two separate vineyards. The cultivars originated in Germany, Italy, France, Portugal, Egypt and Israel. The grapevines were grafted on Ruggeri rootstock and planted in four replications for each variety, with 8 (Ramat Hanegev) or 9 (Mitzpe Ramon) vines per replication. The central two (Ramat Hanegev) or three (Mitzpe Ramon) vines of each of three replications were treated. In late April (Ramat HaNegev) and early May (Mitzpe Ramon) 2014, we sprayed 0.5 and 1.0 percent Dilwet with or without 0.04 percent ethephon during the peak bloom of each variety at each site. Since the growers in both vineyards were eager to remove the grapes to allow development of the young vines, we counted and weighed clusters 5-6 weeks after spraying. We also examined the effect of ethephon alone, as well as an 'overdose' of 2 percent Dilwet with 0.08 percent ethephon on five white varieties and four red varieties in the Mitzpe Ramon vineyard.

All sprays were applied using a mechanical Solo backpack sprayer (15 liters). Based on preliminary experiments, we lightly pruned foliage in the flowering area of the vines before treatment. This allowed optimal penetration of the spray. We applied 0.5 liters of solution per vine, which is equivalent to 1000 liters of spray per hectare. Six to eight weeks after the treatments, we counted all the clusters on the middle vine in each triplet of vines/repetition and weighed five of them. At the same time, we rated leaf damage on a scale of 1 to 4, where 1= no damage,2= minor, 3= moderate and 4 = severe damage.

3. Results

Despite the differences in elevation, there were no significant differences between the Ramat HaNegev (300 m.a.s) and the Mitzpe Ramon (900 m.a.s.) vineyards in yield or in response to spray treatments. Data from the two vineyards were combined.

Number of clusters

The number of clusters per vine ranged from 46 (Muscat Alexandria) to 86 (Dolcetto) and averaged 66 (Table 1). Geographic origin of the grapes did not usually affect cluster number, although in the case of white grapes the two Muscat cultivars from Egypt and the Riesling from Germany all had relatively few clusters. Application of 0.5% Dilwet was mostly ineffective in reducing cluster number, except in French-origin white grapes and in 2 of 3 Spanish red cultivars. Doubling the Dilwet concentration to 1% further reduced the overall number of clusters by more than 20% only in French-origin red grapes and in Muscat cultivars. The addition of 0.04% ethephon to 0.5% Dilwet reduced cluster number to an average of 12 and 18% of control in red and white varieties. Adding 0.04% ethephon to 1.0% Dilwet further improved cluster removal in both red and white grapes of French origin, as well as in Temperanillo (ES) and Argaman, which is a cross derived from the Spanish cultivar Carignan (18), but did not substantially improve cluster removal in the other cultivars. However, the number of clusters over all cultivars was reduced to 6% of controls as a result of spraying 1% Dilwet with 0.04% ethephon (Figure 1). The effect was more pronounced in red wine grape varieties than in white wine grape varieties.

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Table 1. Clusters per vine in red and white wine grape cultivars sprayed with 0.5 or 1.0 percent Dilwet, alone or combined with 0.04% ethephon. Vines were sprayed in late April or early May 2014; clusters were counted 5-6 weeks later. Means of three replicate vines in two vineyards (n=6). + = added 0.04% ethephon Grape variety origins: EGY-Egypt; ES-Spain, FR- France; GE-Germany; IL-Israel; IT-Italy; PO-Portugal. .

	Origin	Clusters per vine	Dilwet treatment (Percent of control)			
Red grapes	_	**Control**	**0.5**	0.5+	1	1+
Toreiga Nacional	PO	70	64	10	92	3
Tinta Cao	PO	67	110	9	67	14
	Average	68.5	87.0	9.5	79.5	8.5
	SD	2.1	32.5	0.7	17.7	7.8
Barbera	IT	60	86	6	114	2
Dolcetto	IT	86	91	5	97	10
Sangiovese	IT	51	144	4	82	11
	Average	65.7	107.0	5.0	97.7	7.7
	SD	18.2	32.1	1.0	16.0	4.9
Malbec	FR	70	137	2	90	2
Merlot	FR	63	124	15	64	10
Syrah	FR	67	68	6	66	5
Petit Verdot	FR	67	103	18	72	6
Pinot Noir	FR	61	98	23	69	9
Pinotage	FR	76	72	15	75	6
Cabernet Sauvignon	FR	81	34	3	62	5
Cabernet Franc	FR	78	85	10	77	2
Ruby Cabernet	FR	65	95	14	84	12
	Average	69.8	90.7	11.8	73.2	6.3
	SD	7.0	30.8	7.1	9.3	3.4
Temperanillo	ES	52	97	27	81	3
Carignan	ES	79	66	12	64	11
Grenache Noir	ES	71	48	0	92	2
	Average	67.3	70.3	13.0	79.0	5.3
	SD	13.9	24.8	13.5	14.1	4.9
Argaman	IL	61	124	23	82	14
Zinfandel	CRO	49	88	29	97	15
Overall	Average	67.1	91.3	12.2	80.4	7.5
	SD	10.2	29.0	8.6	14.1	4.6
White grapes	_	Control	0.5	0.5+	1	1.0+
White Muscat	EGY	56	89	4	67	2
Muscat Alexandria	EGY	46	114	0	74	4
	Average	51.0	101.5	2.0	70.5	3.0
	SD	7.1	17.7	2.8	4.9	1.4
Pinot Gris	FR	74	79	31	103	4
Sauvignon Blanc	FR	85	67	16	68	5
Colombard	FR	67	119	5	84	7
Chenin Blanc	FR	69	85	69	95	3
Chardonnay	FR	61	71	44	87	23
Semillon	FR	66	50	7	98	2

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	Average	70.3	78.5	28.7	89.2	7.3
	SD	8.3	23.2	24.7	12.5	7.9
Gerwurztramminer	GE	77	62	2	103	0
White Riesling	GE	56	87	3	105	11
	Average	66.5	74.5	2.5	104.0	5.5
	SD	14.8	17.7	0.7	1.4	7.8
Overall	Average	65.7	82.3	18.1	88.4	6.1
	SD	11.5	21.7	23.0	14.7	6.7

Figure 1. 'Barbera" grapevine at Ramat HaNegev at end of season (11.14). Grape clusters on the ground in the red circle are from control (untreated) vines, and were removed to help the young vines grow. Vines in the foreground were sprayed at full bloom with 1% Dilwet plus 0.04% ethephon, on 14.4.14. No grape berries developed.

Cluster Weight

Grape cluster weight ranged from 68 grams (Cabernet Sauvignon) to 133 grams (Tempranillo) and averaged 88 grams (Table 2). On average, Dilwet alone at either 0.5 or 1.0% reduced cluster weight by less than 20% compared to control. Adding 0.04% ethephon to 0.5% Dilwet reduced cluster weight by more than 60%, while adding it to 1.0% Dilwet further reduced cluster weight by another 10-20% (Table 2 and Figures 2 and 3).

Table 2. Weight per cluster (g) in red and white wine grape cultivars sprayed with 0.5 or 1.0 percent Dilwet, alone or combined with 0.04% ethephon. Vines were sprayed in late April or early May 2014; clusters were counted 5-6 weeks later. Means of three replicate vines in two vineyards (n=6). + = added 0.04% ethephon Grape variety origins: EGY-Egypt; ES-Spain, FR- France; GE-Germany; IL-Israel; IT-Italy; PO-Portugal .

	Origin	**Cluster weight (g)**	**Dilwet treatment**			
			(Percent of control)			
<u>Red grapes</u>		Control	0.5	0.5+	1	1+
Touriga Nacional	PO	79	38	35	85	18
Tinta Cao	PO	78	97	79	86	51
	Average	78.5	67.5	57.0	85.5	34.5
	SD	0.7	41.7	31.1	0.7	23.3

Barbera	IT	123	99	60	83	24
Dolcetto	IT	131	65	20	60	25
Sangiovese	IT	100	89	10	95	25
	Average	118.0	84.3	30.0	79.3	24.7
	SD	16.1	17.5	26.5	17.8	0.6
Malbec	FR	102	63	32	78	8
Merlot	FR	80	62	30	100	37
Syrah	FR	70	139	57	118	32
Petit Verdot	FR	91	56	29	72	29
Pinot Noir	FR	77	102	37	97	33
Pinotage	FR	78	57	23	87	32
Cabernet Sauvignon	FR	68	149	39	113	17
Cabernet Franc	FR	76	59	29	101	26
Ruby Cabernet	FR	87	160	61	94	16
	Average	81.0	94.1	37.4	95.6	25.6
	SD	10.7	44.0	13.1	15.0	9.7
Grenache Noir	ES	124	91	--	115	15
Tempranillo	ES	133	105	19	62	17
Carignan	ES	92	84	63	61	50
	Average	116.3	93.3	41.0	79.3	27.3
	SD	21.5	10.7	31.1	30.9	19.7
Argaman	IL	101	114	44	74	50
Zinfandel	CRO	129	95	23	81	54
Overall	Average	95.7	90.7	38.3	87.5	29.4
	SD	22.1	33.3	18.6	17.6	13.7
White grapes	_	Control	0.5	0.5+	1	1+
White Muscat	EGY	102	97	8	74	8
Muscat Alexandria	EGY	99	116	0	83	22
	Average	100.5	106.5	4.0	78.5	15.0
	SD	2.1	13.4	5.7	6.4	9.9
Pinot Gris	FR	86	47	15	64	19
Sauvignon Blanc	FR	101	131	87	77	17
Colombard	FR	82	81	58	95	13
Chenin Blanc	FR	70	38	21	85	39
Chardonnay	FR	69	85	25	84	20
Semillon	FR	97	71	51	86	33
	Average	84.2	75.5	42.8	81.8	23.5
	SD	13.3	33.0	27.6	10.5	10.2
Gerwurztramminer	GE	89	108	54	88	28
White Riesling	GE	93	57	44	78	0
	Average	91.0	82.5	49.0	83.0	14.0
	SD	2.8	36.1	7.1	7.1	19.8
Overall	Average	88.8	83.1	36.3	81.4	19.9
	SD	12.1	30.5	27.0	8.6	11.6

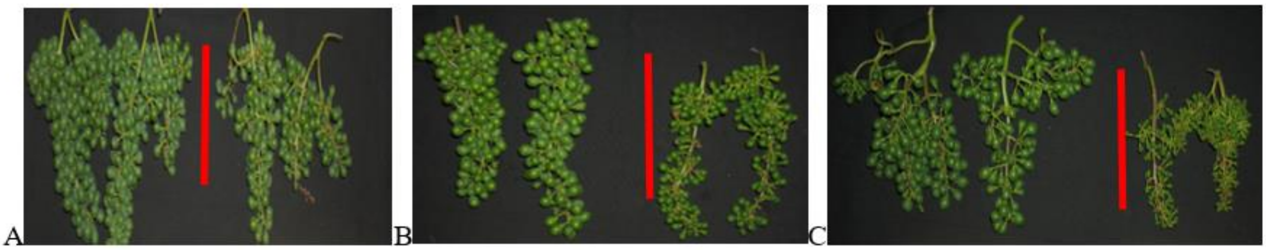

Figure 2. Clusters of control unsprayed (left) and sprayed with 1% Dilwet plus 0.04% ethephon (right) grape varieties (A) Petit Verdot (B) Cabernet Sauvignon and (C) Malbec, 3 weeks after spraying. Bars indicate 12 cm.

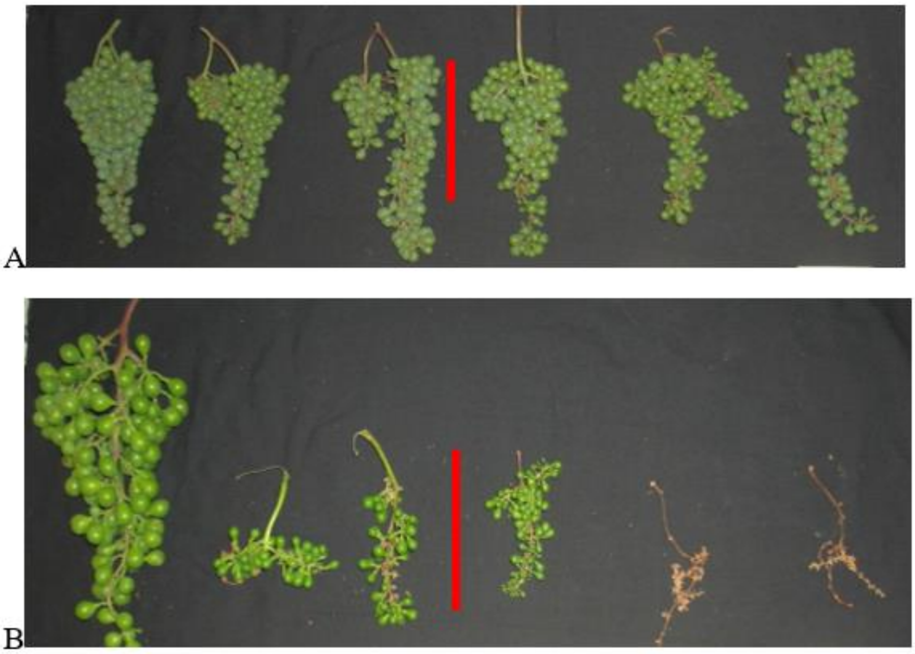

Figure 3. Clusters of A) Cabernet Franc (France, red) and b) Muscat Alexandria (Egypt, white) grapes, three weeks after treatment. Left to right: control unsprayed, sprayed with 0.5% Dilwet, 0.5% Dilwet plus 0.04% ethephon, , 0.5% Dilwet plus 0.08% ethephon, 1.0% Dilwet, 1.0% Dilwet plus 0.04% ethephon. Bars indicate 12 cm.

Leaf and Fruit Damage

Dilwet application, with or without ethephon, did not cause significant leaf damage compared to the control. Leaf damage ratings averaged less than 2 (minor) in all cases. The overdose spray of 2% Dilwet and 0.08% ethephon resulted in severe (average rating 3.5) damage to leaves of white grapes, but did not cause significant damage to leaves of red grapes (Table 3). We could not let clusters remain on the vine until ripe. However, damage to unripe fruit (scarring, browning) was non-existent to minimal.

Spraying grapes with 0.04% ethrel alone had no effect on grapevine flowers, fruit clusters, or leaves (data not shown).

Table 3. Degree of damage on leaves of red and white wine grapes, 5 weeks after spraying in midMay with 2 percent Dilwet plus 0.08% ethephon. Means of 3 replicate vines at Mitzpe Ramon vineyard. Damage scores 1=minor damage to 4=major damage. Grape variety origins: EGY-Egypt; ES-Spain, FR- France; GE-Germany; IL-Israel; IT-Italy.

	Origin	**Leaf damage score**
Red Grapes		

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Argaman	IL	0
Cabernet Sauvignon	FR	0
Temperanillo	ES	0
Dolcetto	IT	0.1
White Grapes		
Chardonnay	FR	3.5
Sauvignon Blanc	FR	4
Gewürztraminer	GE	4
Semillon	FR	3
Muscat Alexandroni	EGY	3

3. Discussion

Dilwet and other organosilicone surfactants are effective alone in reducing the number of fruits set in a number of tree and vine crops (11-16). We have now shown that the effect can be enhanced by adding 0.04% ethrel to 0.5% Dilwet, and that results obtained are similar to those found with 1.0% Dilwet alone (a considerable savings). The combination of 1% Dilwet with 0.04% ethephon reduced fruit load the most, but 0.5% Dilwet with ethephon was also quite effective.

It is important to note that spraying did not significantly affect fruit weight as much as it affected fruit formation. This suggests that the significant reduction in cluster number did not have as substantial an impact on individual fruit size in remaining clusters, at least not early in the season when we removed the clusters for analysis, despite the spray's effectiveness as a selective blossom thinner that reduces the formation and development of fruits (11-16). Unless sprayed at more than twice the recommended concentration, Dilwet did not cause significant leaf damage, as has been noted with apples (12), peaches (16) and almonds (unpublished data).

The many articles about differential effects of wine grape thinning on yield (19-21) and on biochemical (19-21) and organoleptic (24-27) quality indices of grapes and of resulting wine ascribe the contradictory results to varietal differences without further investigation. Recently the contrasting and sometimes contradictory results of variety, yield, and quality indices resulting from wine grape thinning have been ascribed to the interaction of fruit and vine characteristics with varying amounts and timing of irrigation (28). Results presented here were derived from nearly 30 grape cultivars that were grown under identical soil, water, and horticultural conditions, Despite this uniformity of cultivation, we also found that the effectiveness of Dilwet varied among different grape varieties, and that the degree of responsiveness to the treatment could be ascribed at least partially to currently unexamined factors connected to the origin and berry color of the cultivars. French-origin cultivars seemed more resistant to the chemical effect of Dilwet than were Portugese or Spanish-origin varieties (Tables 1 and 2). White grape cultivars were more responsive to the spray treatment than were red cultivars (Tables 1 and 2). This was further highlighted in the much greater sensitivity of leaves of white grape cultivars than those of red cultivars to a Dilwet+ethephon overdose (Table 3). It should be noted that cultivar differences in response to thinning compounds have also been noted for apples (3), peaches (7) and pears (10). These results emphasize the need to test a range of cultivars and genetic origins of a given crop when developing and testing new agrichemicals and combinations.

5. Conclusions

Dilwet applications can reduce the number of clusters in a wide range of wine grape varieties, thus permitting young vines to develop more fully without being burdened in their initial growing seasons. The combination of 1% Dilwet with 0.04% ethephon was most effective in fruit thinning (Table 1). However, in many cases 0.5% Dilwet with ethephon performed similarly to the higher concentration, at a savings in cost and in potential environmental contamination. Dilwet treatment did not reduce remaining cluster weight to the same extent that it reduced cluster number (Table 2) nor did it cause damage to leaves or to the fruit scaffold.

These findings provide valuable information for grape growers and vineyard managers seeking to control fruit yield at an early stage of vine development in a range of wine grape varieties. Further studies are recommended to investigate the long-term effects of Dilwet spray application on return yield, and to evaluate its effectiveness in other grape varieties, particularly those originating in other geographic regions or those that are the result of inter-regional crosses.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. Warmund, M., 2022. Fruit cultivars for home plantings. University of Missouri Extension Bulletin G6005
2. Famiani, F., Cinosi, N., Paoletti, A., Farinelli, D., Rosati, A. and Lodolini, E.M., 2022. Deflowering as a tool to accelerate growth of young trees in both intensive and super-high-density olive orchards. Agronomy, 12(10), p.2319.
3. Radivojevic, D.D., Milivojevic, J.M., Oparnica, C.D., Vulic, T.B., Djordjevic, B.S. and ERCİŞLİ, S., 2014. Impact of early cropping on vegetative development, productivity, and fruit quality of Gala and Braeburn apple trees. Turkish Journal of Agriculture and Forestry, 38(6), pp.773-780.
4. Upreti, R., Shrestha, A.K., Tripathi, K.M., Shrestha, B., Krakauer, N., Devkota, N.R., Jha, P.K. and Thapa, P., 2019. Effect of fruit thinning and defoliation on yield and quality of papaya (Carica papaya) cv. Red Lady in Chitwan. Acta Sci Agric, 3, pp.130-136.
5. Byers, R.E. and Lyons, C.G. 1983. Chemical peach thinning with surfactants and ammonium nitrate. J. Hort. Sci. 58:517-519. Fallahi, E. and Willemsen, K.M. 2002. Blossom thinning of pome and stone fruit. HortScience 37:474-477.
6. Cline, J.A., Bakker, C.J. and Beneff, A., 2022. Multi-year investigation on the rate, timing, and use of surfactant for thinning apples with post-bloom applications of metamitron. Canadian Journal of Plant Science, 102(3), pp.628-655.
7. Fallahi, E., B., McFerson, J.R., Byers, R.E., Ebel, R.C., Boozer, R.T., Pitts, J. and Wilkins, B.S. 2006. Tergitol-TMN-6 surfactant is an effective blossom thinner for stone fruits. HortScience 41:1243-1248
8. McArtney, S.J., Abrams, S.R., Woolard, D.D. and Petracek, P.D., 2014. Effects of S-abscisic acid and (+)-8'-acetylene abscisic acid on fruit set and stomatal conductance in apple. HortScience, 49(6), pp.763-768.
9. Southwick, S.M., Weis, K.G. and Yeager, J.T. 1996. Bloom thinning 'Loadel' cling peach with a surfactant. J. Am. Soc. Hort. Sci. 121:224-228.
10. 10 Stern, R.A. and Flaishman, M.A., 2003. Benzyladenine effects on fruit size, fruit thinning and return yield of 'Spadona'and 'Coscia'pear. Scientia Horticulturae, 98(4), pp.499-504.
11. Klein, J.D. and Cohen, S., 2011. Thinning clusters of 'Merlot' and 'Cabernet Sauvignon' grapes in young grapevines with combinations of Dilwet and ethephon. Alon HaNotea 65:20-22 (in Hebrew)
12. Bound, S.A. and Klein, J.D., 2009. Successful thinning of apples with an organosilicone surfactant. In XI International Symposium on Plant Bioregulators in Fruit Production 884 (pp. 413-417).
13. Schneider, D., Stern, R.A. and Antman, S., 2014, May. Reducing labor costs of hand thinning for 'Akko 1' using an organosilicone surfactant. In IV International Symposium on Loquat 1092 (pp. 273-277).
14. Leece, D.R. and Dirou, J.F., 1977. Organosilicone and alginate adjuvants evaluated in urea sprays foliar-applied to prune trees. Communications in Soil Science and Plant Analysis, 8(2), pp.169-176.
15. Laňar, L., Scháňková, K. and Náměstek, J., 2022. Searching for plum flower thinner. In XIV International Symposium on Plant Bioregulators in Fruit Production 1344 (pp. 93-98).
16. Klein, J.D. and Cohen, S., 2000. Thinning nectarines and peaches at flowering with organosilicone surfactants. HortScience, 35(3), pp.496B.
17. Dong, Y., Duan, S., Xia, Q., Liang, Z., Dong, X., Margaryan, K., Musayev, M., Goryslavets, S., Zdunić, G., Bert, P.F. and Lacombe, T., 2023. Dual domestications and origin of traits in grapevine evolution. Science, 379(6635), pp.892-901.

18. Spiegel-Roy, P., Cohen, S., Baron, I., Assaf, R., Ben-A'haron, S. and Striem, M.J., 1996. 'Argaman': A new, highly colored, productive, vinifera wine cultivar. HortScience, 31:1252-1253.
19. Vaillant-Gaveau, N., Wojnarowiez, G., Petit, A.N., Jacquens, L., Panigai, L., Clement, C. and Fontaine, F., 2014. Relationships between carbohydrates and reproductive development in Chardonnay grapevine: Impact of defoliation and fruit removal treatments during four successive growing seasons. OENO one, 48(4), pp.219-229.
20. Holzapfel, B.P. and Smith, J.P., 2012. Developmental stage and climatic factors impact more on carbohydrate reserve dynamics of Shiraz than cultural practice. American journal of enology and viticulture, 63(3), pp.333-342.
21. Hardie, W.J. and Martin, S.R., 2000. Shoot growth on de-fruited grapevines: a physiological indicator for irrigation scheduling. Australian Journal of Grape and Wine Research, 6(1), pp.52-58.
22. Soltekin, O., Güler, A., Teker, T. and Candemir, A., 2022. Combined Effects of Pruning and Crop Removal Levels on Yield, Quality, and Physiological Properties in 'Merlot'and 'Cabernet Sauvignon 'Grapevines. Erwerbs-Obstbau, 64(Suppl 1), pp.129-140.
23. Wang, W., Liang, Y., Quan, G., Wang, X. and Xi, Z., 2022. Thinning of cluster improves berry composition and sugar accumulation in Syrah grapes. Scientia Horticulturae, 297, p.110966.
24. Wang, Y., He, Y.N., He, L., He, F., Chen, W., Duan, C.Q. and Wang, J., 2019. Changes in global aroma profiles of Cabernet Sauvignon in response to cluster thinning. Food Research International, 122, pp.56-65.
25. Xi, X., Zha, Q., He, Y., Tian, Y. and Jiang, A., 2020. Influence of cluster thinning and girdling on aroma composition in 'Jumeigui'table grape. Scientific reports, 10(1), p.6877.
26. Kok, D., 2011. Influences of pre-and post-veraison cluster thinning treatments on grape composition
27. Cataldo, E., Salvi, L., Paoli, F., Fucile, M. and Mattii, G.B., 2021. Effect of agronomic techniques on aroma composition of white grapevines: A review. Agronomy, 11(10), p.2027.
28. Valdés, M.E., Talaverano, M.I., Moreno, D., Uriarte, D., Mancha, L. and Vilanova, M., 2022. Improving the phenolic content of Tempranillo grapes by sustainable strategies in the vineyard. Plants, 11(11), p.1393.