Field evaluation of *Prunus* rootstocks for use in dried prune production

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Abstract

The California prune industry has historically utilized five rootstocks, Myrobalan seedling, 'Myro 29C', 'Marianna 2624', 'Lovell' and 'Marianna 40'. The last statewide organized prune rootstock effort was planted in 1987. Since the conclusion of that experiment many more potential rootstocks for prune have been identified. In 2011, a non-replicated screening trial was planted to test 15 experimental rootstocks and 3 standard rootstocks nursery budded to 'Improved French'. This experiment provides an initial evaluation of possible rootstocks that have previously not been tried with prune or have had very little field testing. Our results show a number of rootstocks, including some with moderate size controlling capabilities, hold promise as potential rootstocks for prune production in the future.

Keywords: prune, dried plums, *Prunus domestica*, rootstock, size controlling

INTRODUCTION

California is home to a thriving prune production industry covering 17,800 ha, producing $ 195 million fruit year^{-1} (USDA, 2018). The California prune industry is limited in the number of rootstocks it uses, historically relying on five rootstocks, Myrobalan seedling (*Prunus cerasifera*), 'Myrobalan 29C' ('Myro 29C', *Prunus cerasifera*), 'Marianna 2624' (*P. cerasifera* × *P. munsoniana*), 'Marianna 40' ('M40', *P. cerasifera* × *P. munsoniana*) and 'Lovell' (*P. persica*) (Southwick et al., 2012). However, many of these rootstocks have production limitations and management concerns. Both 'Myro 29C' and 'M2624' have poor anchorage and impart elevated scion vulnerabiliy to bacterial canker (*Pseudomonas syringae*). 'M2624' has high levels of suckering, and 'Lovell' is susceptible to saturated soil conditions but trees on this rootstock are less vulnerable to bacterial canker (Southwick et al., 2012).

In 2011, the University of California (UC) and the California Prune Board set out to test rootstock options that had emerged from across the stone fruit industry since the previous trials of the 1980s. There are a number of challenges in prune production in California that these rootstocks were being evaluated to address. Annual pruning costs to control the size and structure of prune trees and renew fruiting wood are an ever-increasing cost in California (Niederholzer et al., 2018). However, it is important that decreased scion vigor is not accompanied by poor anchorage resulting from decreased root growth vigor or a weak root structure. To stay competitive in the global marketplace, California prune production has begun to focus on producing larger sized fruit (Thompson et al., 2012). This needs to be balanced against total yields for optimal net grower income.

Replicated experiments were set up in commercial orchards with the most promising rootstocks at a typical prune growing site and at a replant-challenged site. An additional experiment, discussed here, was established at the UC Wolfskill experimental orchard in Winters, California. This experiment provides an initial evaluation of possible rootstocks that have previously not been tried with prune or have had very little field testing.

The plot contains 15 experimental rootstocks and three standard rootstocks ('Marianna 2624', 'Lovell', and 'Myrobalan 29C') nursery budded to 'Improved French'. Three size

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controlling peach (*P. persica*) rootstocks from the University of California, 'Controller 6' (HBOK 27), 'Controller 7' (HBOK 32), and 'Controller 8' (HBOK 10) (DeJong et al., 2014) were tested. Two Myrobalan plum (*P. cerasifera*) rootstocks were tested, 'Puente' ('Adara'), a Spanish rootstock touted for its tolerance for heavy and poorly-drained soil (Moreno et al., 1995), and 'WRM2', an experimental open pollinated red leaf type *P. cerasifera*. Three European plum (*P. domestica*) rootstocks were tested: size controlling 'Empyrean 3' (De Salvador et al., 2014a), 'Imperial California' and 'Own Rooted French'. Additionally, a number of inter-species *Prunus* hybrids were tested: 'Controller 9', a California size controlling hybrid (*P. salicina* × *P. persica*), 'Empyrean 1' ('Barrier') (*P. persica* × *P. davidiana*), 'Fortuna' (*P. cerasifera* × *P. persica*), 'Ishtara' ('Ferciana') (*P. cerasifera* × *P. salicina*), 'Krymsk 99' ('Evrika') and 'Speaker' ('Spicer') (both (*P. pumila* × *P. salicina*) × *P. cerasifera*), and 'Krymsk 2' (*P. incana* × *P. tomentosa*).

MATERIALS AND METHODS

The experiment was planted near Winters, California (38°51'N, 121°97'E), in the Central Valley of California. The site was previously planted to peaches, removed in 2008, and the field left fallow for three years with annual winter wheat plantings. The soil is Yolo loam (USDA Soil Survey). This is a deeper, better drained soil than the finer textured, more poorly drained soils on which many California prune orchards are planted.

The majority of the trees were planted on January 19, 2011. Bare-root trees were planted directly after transportation from the nursery's sawdust box. Controller 7 and Controller 8 were potted trees planted on April 25, 2011. 'Improved French' on its own root were grown in the nursery for two years. Own rooted trees do have a graft union because 'Improved French' was budded on top. Trees were planted 5.18 m (17 feet) across the row and 4.27 m (14 feet) down the row, resulting in approximately 452 trees ha^{-1} (183 trees $acre^{-1}$). One set of five trees of each rootstock were planted, grouped together down the row. At the time of planting, trees were headed at 36 inches. Trees were trained and pruned following the long prune method (Krueger et al., 2012), balancing some canopy management with the desire to see the inherent growth potential of the tree. As such, they were not all pruned to the same size.

Tree size and structure

Trunk circumference was taken each winter. In 2016, measurements shifted from being taken at 18 inches above the soil line to 12 inches above the soil line. On July 12, 2020, photosynthetically active radiation (PAR, %) was measured using light bars mounted on a small four wheel vehicle (Lampinen et al., 2012). Tree anchorage was measured in February 2021 as the degree of deviation of the trunk from straight upright (i.e., deviation from a 90° angle with the soil line). The measurement was taken once with no force applied and once with the trunk being pushed.

Yield

The weight of the fruit from five adjacent trees (except 'Puente' and 'Controller 6', n=4) was taken when °Brix and fruit pressure were in the range of production harvest timing practices. A 1.8-kg (4 lb) sub-sample was taken and dried to adjust total field fresh weight to estimated dry weight. This same sub-sample was separated by size class after drying. Subsample fruit were classified as A (≤137 fruit kg^{-1}), B (148-168 fruit kg^{-1}), or smaller (≥170 fruit kg^{-1}), using size screens (Thompson et al., 2012).

Crop set conditions varied from year to year, influencing yield measurement practices. Crop sets were so low in 2014 and 2016 due to unfavorable spring conditions that the trees were not harvested; rather, the numbers of fruit $tree^{-1}$ were counted. These numbers have been adapted to estimate dry weight per tree using the average dry weight per fruit of all the 2020 subsamples. Set was very high in 2017, but trees were not thinned, in order to gauge performance with heavy set. Set was modest in 2018 and 2020, so trees were not thinned. Set was very heavy in 2019 so trees were thinned of fruit by shaker thinning in May, according to standard production practices (Buchner et al., 2012).

RESULTS

Because this trial was not replicated, mean separation was not conducted. Though we cannot say statically how rootstocks differ, we can make initial observations. Averages given are for five trees (except ‘Puente’ and ‘Controller 6’, n=4).

Tree size and structure

The trees that were vigorous and had the largest trunks in the first few years remained the leaders in trunk size in the following years (Figure 1). Seven rootstocks produced trees that were distinguishably larger on average than the remaining 11. In order of size, these were ‘Empyrean 1’ > ‘WRM 2’ > ‘Fortuna’ = ‘Puente’ > ‘Myro 29C’ > ‘Controller 9’ = ‘Lovell’. Ten remaining rootstocks produced trees that were of similar size and growth rate (in no particular order): ‘Controller 7’, ‘Controller 8’, ‘M2624’, ‘Empyrean 3’, ‘Speaker’, ‘Krymsk 99’, ‘Own Root’, ‘Ishtara’, ‘Imperial California’, ‘Controller 6’. ‘Controller 8’ began as the smallest trees, but grew into a mid-sized tree, indecipherable from a large group of other rootstocks. ‘Krymsk 99’ produced trees that grew well in the first four years but then slowed in growth to become one of the smaller-trunked set of trees in the trial. ‘Krymsk 2’ produced the smallest tree by the third year and remained the smallest throughout the trial.

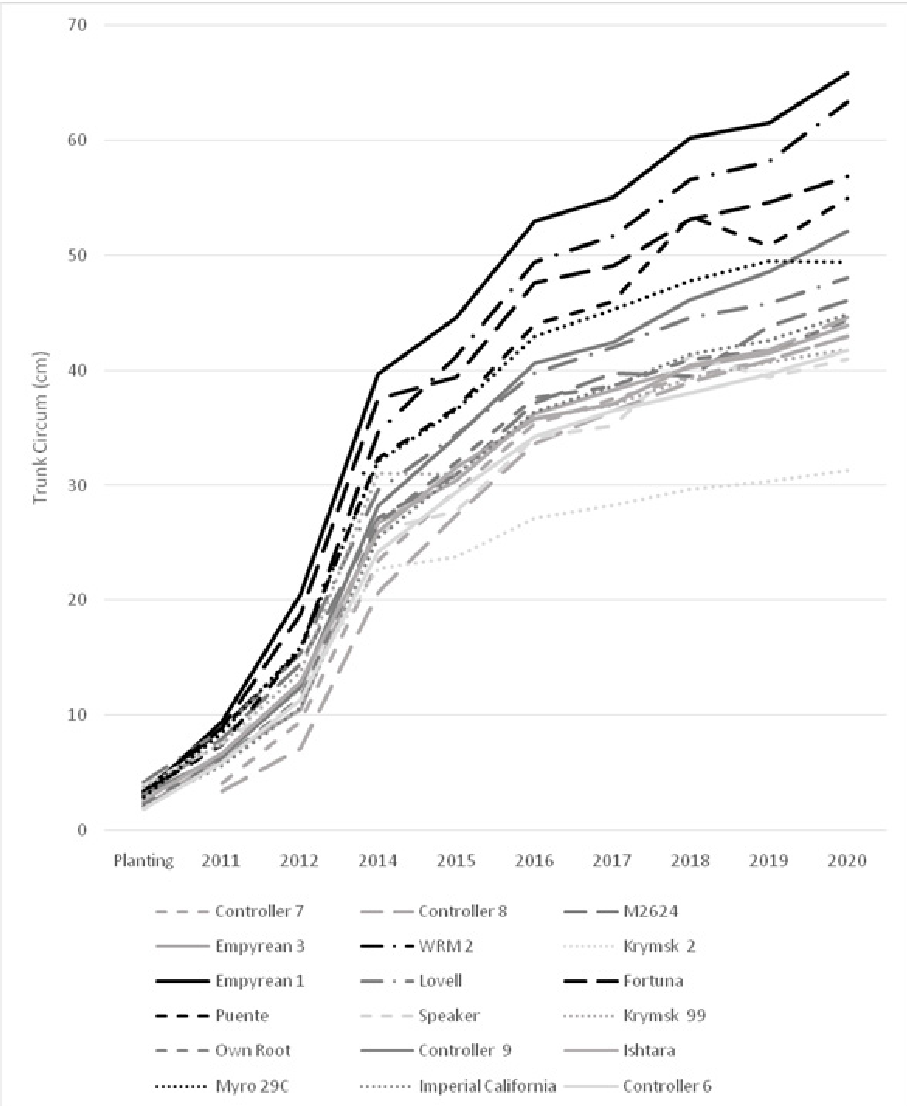

Figure 1. Trunk circumference in centimeters.

The ranking of tree size data when using PAR (Table 1) was similar but not identical to the ranking when using trunk circumference, with more (admittedly subjective) grouping when size falls below that of the largest trees. 'Empyrean 1' and 'WRM 2' produced very large trees, with PAR ranging from 69 to 74% of the orchard floor. 'Puente', 'Myro 29C', 'Lovell', 'Fortuna', 'Controller 9', and 'M2624' all produced large trees with PAR ranging from 51 to 55% PAR. 'Controller 8', 'Ishtara', Controller 7', 'Contoller 6', 'Empyrean 3', and 'Own Root' rootstocks produced medium-sized trees with PAR ranging from 42 to 48% PAR. 'Imperial CA', 'Speaker' and 'Krymsk 99' produced small trees with PAR ranging from 31 to 37% PAR. 'Krymsk 2' produced distinctly smaller trees, with 24% PAR.

Table 1. Measurements of tree size and structure in 2020-2021: Photosynthetically active radiation (PAR), trunk circumference, and anchorage as measured by deviation from upright.

Rootstock	PAR (%)	Circumference (cm)	Deviation from upright (degrees)
Empyrean 1	74	66	8.5
WRM 2	69	63	10.9
Puente	55	55	5.5
Myro 29C	55	49	4.9
M2624	55	46	6.5
Lovell	52	48	5.8
Fortuna	52	57	17.1
Controller 9	51	52	6.8
Controller 8	48	43	13.5
Ishtara	46	45	6.2
Controller 7	45	43	11.4
Controller 6	45	42	6.1
Empyrean 3	45	44	4.8
Own Root	42	44	5.8
Imperial CA	37	45	7.8
Speaker	34	41	11.1
Krymsk 99	31	42	35.0
Krymsk 2	24	31	11.0

Tree anchorage values ranged from 4.8 to 35.0 (Table 1). 'Empyrean 3', 'Myro 29C', 'Puente', 'Own Root', 'Lovell', 'Controller 6', 'Ishtara', 'M2624', 'Controller 9', 'Imperial California' and 'Empyrean 1' all had leaning values in the single digits, whereas 'WRM 2', 'Krymsk 2', 'Speaker', 'Controller 7', 'Controller 8', 'Fortuna' and 'Krymsk 99' all had leaning values in the double digits. 'Fortuna' and 'Krymsk 99' were particularly egregious in their poor anchorage.

Yield

Yield data for 2017 through 2020 were gathered in Figure 2 into stacked bar graphs. These stacked bar graphs give the cumulative yield over four prime production years (7^{th} to 10^{th} leaf). Yields from 2014 and 2016 were excluded from these figures because their values were so small. Total yield from 2015 has been excluded because we did not do size classification that year. In addition to per tree total yield, to the right of each bar of cumulative total yield is an additional bar presenting the subset cumulative yield of Class A and B fruit. No yield data was gathered for 'Krymsk 2' or 'Krymsk 99' after 2016 based on industry feedback that the trees were too small and unhealthy-looking to merit further tracking. Thus, no yield data are given for these trees.

Reporting yield solely on a per-tree basis in a rootstock trial can create a bias in the data toward larger trees. To account for this it is valuable to examine yield relative to canopy size. Figure 2 also shows PAR in 2020 above the bar graphs. Trees on 'Empyrean 1' yielded the most fruit tree^{-1} (104 kg) and most large fruit (59 kg), and also produced the largest trees. Trees on 'Imperial California' produced the least fruit (40 kg) and the least large fruit (21 kg), despite not producing the smallest tree. From this approach, one can decipher how yields of similarly sized trees compare. For example, trees on 'Controller 6' had lower total yields compared to similarly sized trees, but higher A+B fruit yields.

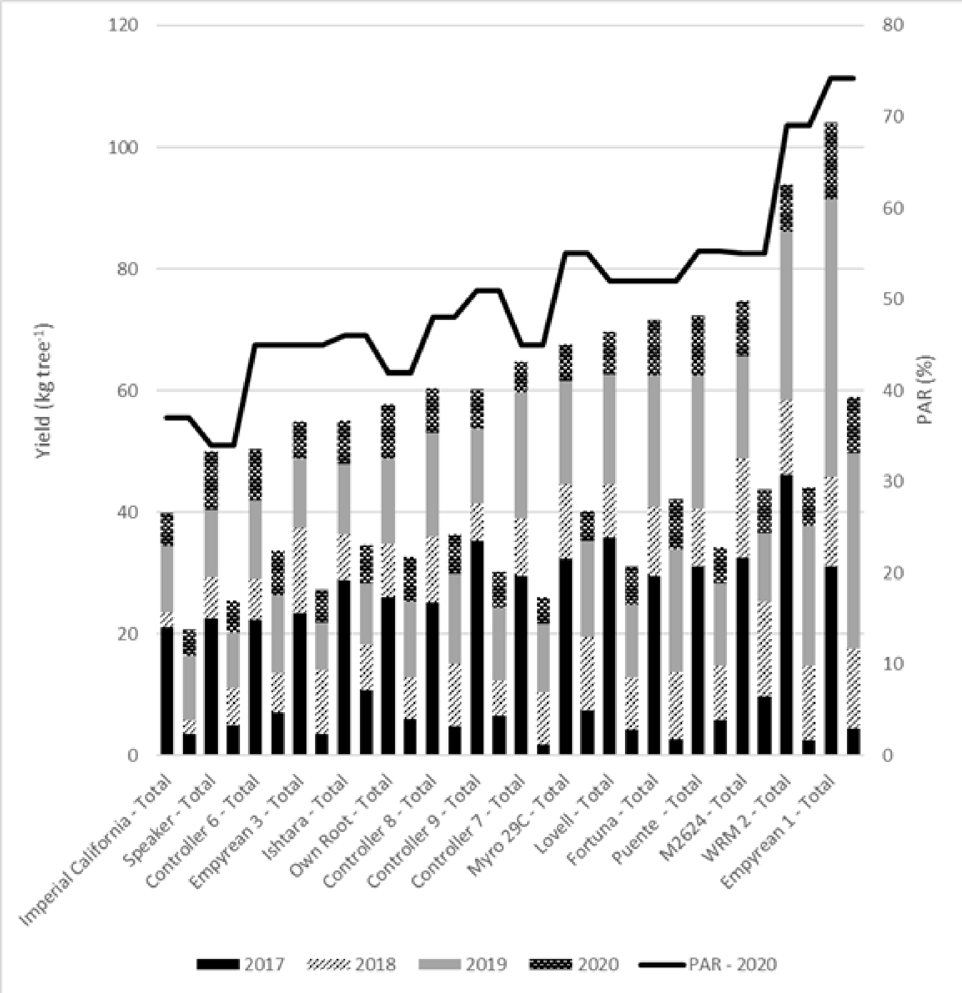

Figure 2. Dry yield from 2017 to 2020 by rootstock. The tall bar stack for each rootstock, "Total", shows stacked average dry yield tree^{-1} each year. The next bar stack, "AB", shows the yield tree^{-1} in A and B sized fruit. The line above the yields shows PAR in 2020 as a representation of canopy size.

DISCUSSION

Tree size and structure

'Myro 29C', 'Speaker', and 'Own Root' have smaller canopy sizes that one might expect based on their trunk circumference. In 2015, tree structure was rated for canopy spread (data not shown). 'Myro 29C' and 'Own Root' were both rated as 2 out of 5, with 1 being most upright, and 'Speaker' was rated 2.5. This upright canopy structure may help explain why the tree trunks are large but the canopy size is small. 'Controller 8' and 'Controller 7' are, as their names imply, size-controlling rootstocks in peach production. They have also done an adequate job here for controlling size, though 'Controller 9' has not conferred as much dwarfing capacity.

Yield

Depending on the market for the produced fruit, total yield or large fruit yield may be more of a production concern. In California, pricing structures are moving more and more toward favoring large fruit (Thompson et al., 2012). Thus it is important to consider both total yield and large fruit yield when evaluating rootstocks. For example, despite the fact that trees on 'WRM 2' produced almost 29 kg more fruit per tree than 'M2624' from 2017 to 2020, 'M2624' produced just as many kg of Class A and B fruit. 'Empyrean 1' generally produced a large proportion of large fruit, despite its overall high yields. 'Fortuna', 'M2624' and 'M29C' produced more large fruit than 'Puente' and 'Lovell' despite the comparable total yields. 'Controller 7's cumulative A and B yield was lower than trees on rootstocks with comparable total yields. 'Controller 6', 'Controller 8', and 'Ishtara' produced large cumulative yields of A and B fruit compared to trees of similar total yield. DeJong et al. (2014) found that under low-to-moderate fruit load, 'Controller 7' and 'Controller 8' produced comparably sized fruit to trees on vigorous rootstock. At high fruit load, there was a small but significant difference.

When yields are considered relative to tree size, a few aspects of the results are worth noting. 'Empyrean 1' is both the largest and the highest yielding tree. For example, although it is twice as large in terms of canopy cover as the smallest productive trees in the trial (on 'Imperial California' and 'Speaker'), in 2019 it yielded about three times as much large fruit. Trees on 'Fortuna' produce much higher or comparable yields (depending on the year) relative to similar-sized trees on 'Puente' and 'Controller 9' rootstocks. Trees on 'Imperial California' and 'Speaker' produced comparable yields to trees that were ~30% larger. This observation was seen in 2019, but not 2020.

The purpose of this trial was to screen potential rootstocks for future replicated trials. Looking back at the data that has been gathered, some rootstocks can be immediately dismissed, some performed adequately but no better than current standards, and some showed promise for use in future trials and eventually perhaps large scale prune production.

'WRM 2' trees at other sites have been found to be very susceptible to bacterial canker, making them a poor choice for future use. 'Krymsk 99' produced a tree that was too miniscule for California prune production. The poor anchorage of trees on 'Krymsk 2' make them a poor choice for future use. In 'South Carolina' grafted under peach, leaning problems were not noted, but 'Krymsk 2' trees were noted to be among the least vigorous with the lowest yield (Reighard et al., 2006). 'Fortuna' is appealing based on its high yields for its size, however, leaning measurements and consistently low mid-summer leaf potassium point (not shown) to anchorage and root vigor issues. In peach production trials, 'Fortuna' showed symptoms of graft incompatibility, had high mortality across multiple states, and had the smallest fruit across all 13 sites (Reighard et al., 2020). 'Imperial California' and 'Speaker' both produced small trees relative to the rest of the trial, with comparable yields to larger trees. In peach production trials, 'Imperial California' showed high susceptibility to bacterial canker (*Pseudomonas syringae*), a significant concern in some areas of prune production in California, as well as some of the smallest fruit among 18 rootstocks (Reighard et al., 2020). Additionally, 'Imperial California' trees were somewhat variable in their size.

'Controller 9' created a tree that was comparable in size and performance to the industry standards of 'Myro 29C', 'M2624' and 'Lovell' without any new exciting attributes aside from delayed bloom. 'Controller 6' did not excel in yields or fruit size relative to similar sized trees and had consistently lower leaf potassium than similar yielding trees (data not shown). 'Own rooted' did not stand out in any way and is reported to be difficult to produce, so may not be worth the trouble of testing for commercial use. 'Empyrean 3' had no particular drawbacks, but it did not excel at anything. It generally slightly under-produced relative to trees of similar size and produced less large fruit compared to similar yielding trees. De Salvador et al. (2014b) also found that on average 'Empyrean 3' produced fresh *P. domestica* fruit that was significantly smaller than fruit from trees on 'Myro 29C'. In peach production trials, 'Empyrean 3' showed high susceptibility to bacterial canker (*Pseudomonas syringae*), a significant concern in some areas of prune production in California (Reighard et al., 2020). 'Puente' also did not excel at anything to make it compelling for future research. Among the five trees, its size was more variable than other sets of trees. Though strictly defined graft incompatibility was not observed with multiple *P. domestica* scions(Moreno et al., 1995), Reig et al. (2018) observed differing coefficients of variation by scion. Thus, while 'Puente' may not be a good match for 'Improved French', it may have utility with other prune cultivars. However, 'Puente' is *P. cerasifera*, like 'Myro 29C' and 'M2624', making it undesirable in a replant situation for many prune orchards. 'Ishtara' had comparable yield to trees of similar size and produced as much or more large fruit than trees of similar cumulative yield. However, there was a fair amount of variability in tree size, even among just five trees at the trial site, indicating it may not produce a uniform commercial orchard. This was not noted in other *P. domestica* scion trials (Grzyb et al., 2010).

'Controller 7' and 'Controller 8' seemed to yield adequately for their size without any serious management or production limitations. One potential exception to this is the somewhat small fruit on 'Controller 7', which was also exhibited at 13 sites in a multi-state peach rootstock trial (Reighard et al., 2020). Given that these rootstocks produce trees that are as small or smaller than trees on the industry's standard rootstocks, these may be worth replicated testing. 'Empyrean 1' makes an undeniably large tree, but also yielded much higher than might be expected even for their size. It may be worth investigating whether these trees might be smaller when grown on more traditional heavy prune-growing ground.

CONCLUSIONS

'Controller 7' and 'Controller 8' rootstocks provide promise for future use in prune production for smaller size resulting in reduced pruning cost, while maintaining economic levels of yield. More trialing of 'Empyrean 1' in traditional California prune growing conditions would provide more information as to whether this could be a valuable rootstock option for future production.

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