MODELING HERBICIDE INSTALLATION FOR THE TREATMENT OF PEACH PLANTATIONS
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МОДЕЛИРАНЕ НА ХЕРБИЦИДНА УРЕДБА ЗА ТРЕТИРАНЕ НА НАСАЖДЕНИЯ ОТ ПРАСКОВИ

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DOI*: https://doi.org/10.35633/inmateh-60-34*

Keywords: *modelling, herbicide installation, spraying, peaches*

ABSTRACT

An approach to modeling herbicide installation for the treatment of peach plantations is proposed. The height of the stem was determined for 4 varieties of peaches. Considering this parameter, the maximum height of the herbicide system and the nozzles on it are indicated. Simulated modelling of the sprayed fluid along the working width of each nozzle was performed. The irregularity of spraying was determined depending on the distance between the nozzles. On the basis of the analysis, the optimal parameters of the spreader system were determined: height - 0.35 m, distance between the spreaders - 0.40 m.

РЕЗЮМЕ

Предложен е подход за моделиране на хербицидна уредба за третиране на прасковени насаждения. Определена е височината на стъблото при 4 сорта праскови. Съблюдавайки този параметър е посочена максималната височина на хербицидната уредба и на разпръсквачите, разположени върху нея. Извършено е имитационно моделиране на изпръсканата течност по работната широчина на всеки разпръсквач. Установена е неравномерността на пръскане в зависимост от разстоянието между разпръсквачите. Въз основа на направения анализ са определени оптималните параметри на разпръсквателната уредба: височина – 0,35 m, разстояние между разпръсквачите – 0,40 m.

INTRODUCTION

The problem with pesticide spraying in agriculture is in the conflict of increasing their deposition on the target crops on the one hand and reducing losses beyond the targets on the other (*Escolà A. et al., 2013*). Very often, treatment conditions impede both. Environmental pollution due to the deposition of pesticide droplets outside the target can be minimized by using optimum design and operating parameters of the sprayers (*Delele M. et al., 2007*). A three-dimensional model has been developed that is used to adjust the spread in orchards to reduce drift without reducing bio-efficiency. It has been established that the spatter quality is influenced by the steady speed, fan speed (airflow rate), number, type, size, position and orientation of the nozzles and the fluid pressure. The authors (*Ramsdale B. and C. Massersmith, 2001*) conducted field experiments to determine the effect of sprayer type, spray rate and additives in herbicide efficacy.

Herbicide applications are complex processes, and as such, few studies have been conducted that consider multiple variables that affect the droplet spectrum of herbicide sprays (*Creech C. et al., 2015*). The objective of this study was to evaluate the effects of nozzle type, orifice size, herbicide active ingredient, pressure, and carrier volume on the droplet spectra of the herbicide spray. The laboratory study was conducted using a Sympatec laser diffraction instrument to determine the droplet spectrum characteristics of each treatment combination. When averaged over each main effect, nozzle type had the greatest effect on droplet size. The effect on droplet size of the variables examined in this study from greatest effect to least effect were nozzle, operating pressure, herbicide, nozzle orifice size, and carrier volume.

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In 2008 and 2009, *Kempenaar C. et al. (2011)* tested 11 machines from three categories of herbicide application technology: weed wipers, controlled droplet applicators (CDA) and sensor sprayers. Weed wipers used the least amount of herbicide, less than 0.05 L product ha^{-1}. Sensor sprayers applied between 0.1 and 0.4 L product ha^{-1} depending on level of weed presence and configuration of the machine. The double number of nozzles and sensors on the spray bar reduced herbicide use by about 50%.

To control weeds, a pneumatic sprayer was developed to apply herbicides dissolved in oil or water with a volume of 2.3 L/ha (*McWhorter Ch. et al., 1988*). The working fluid is fed through a tube into an air stream that sprays it. The number of drops varies from 16 to 54 drops/cm^2 at an air jet pressure of 3.4 to 62 kPa and an outlet diameter of 2 mm. The number of droplets obtained at 34 kPa increased from 7 droplets/cm^2 at 0.8 mm of the hole to 48 droplets/cm^2 at the 2.4 mm diameter hole. The sprayer is designed primarily for treatment with oil-dissolved herbicides at rates of 2.3 to 4.7 L/ha.

Novel spray nozzles with high penetration efficiency and low drifting rates have been developed in recent years and exists on nozzle market (*Bolat A. et al., 2018*). To determine efficiencies of these new products on weed control the authors tested standard flat fan nozzle, air induction nozzle, with standard flat fan nozzle at three different herbicide application volume of 200 l/ha, 300 l/ha and 400 l/ha. Efficiency levels of each method was determined via pesticide coverage rates, weed control efficiency. Wiper applicators allow herbicides to be directly transferred onto the surface of target plants, thereby avoiding application to nearby desirable plants of shorter stature (*Harrington K. and H. Ghanizadeh, 2017*). This form of herbicide application can greatly reduce costs of weed control and risks of environmental contamination. The risk of drift to susceptible plants in areas adjacent to the weed control operations can also be eliminated by using wiper applicators. Despite the huge potential for using wiper applicators to improve weed control in agricultural and non-agricultural sectors, there has been only limited research into the factors that might affect their performance and efficacy. These factors include the growth stage of weeds at the time of application, types of herbicide used, design of wiper applicator and the quantity of herbicide deposited on plants.

An interesting field study was conducted in 2015 and 2016 to compare particle drift of glyphosate using a fluorescent tracer dye applied with hooded and open sprayers at four spray qualities (*Foster H. et al., 2018*). It is current agronomic practice to estimate the average weed density throughout the field and to use this information to decide whether or not to spray and at what dose to apply the herbicide used (*Paice M., P.Miller, W. Day, 1996*). Significant long-term economic and environmental benefits are expected to accrue if the herbicide dose changes according to spatial variations in weed density. The high availability and relatively low cost of information technology and electronic control systems make this concept more practical, but its implementation places a number of limitations on the specification of the sprayer. Chemical weed control is, and will continue to be, essential in high-yield agriculture (*Biller R., 1998*). However, economic and environmental considerations call for a further reduction in herbicide use in the future. One method of achieving this is the localized application of herbicides to weeds. The detection of weeds against the background of soil or plant debris is possible using optoelectronic sensors. The application of such a system results in herbicide saving between 30 and 70%, with a weed control efficiency of 100%.

Precise weed control uses ultrasound recognition and guidance (*Andújar D.et al., 2012*). Site-specific weed management requires sensing of the actual weed infestation levels in agricultural fields to adapt the management accordingly. However, sophisticated sensor systems are not yet in wider practical use, since they are not easily available for the farmers and their handling as well as the management practice requires additional efforts. The ultrasonic readings permitted the separation between weed infested zones and non-infested areas with up to 92.8% of success. This system will potentially reduce the cost of weed detection and offers an opportunity to its use in non-selective methods for weed control.

An aggregated distribution pattern of weed populations provides opportunity to reduce the herbicide application if site-specific weed management is adopted (*Hamouz P. et al., 2013*). The weed infestation was estimated immediately before the post-emergence herbicide application. Treatment maps for every weed group were created based on the weed abundance data and relevant treatment thresholds. The herbicides were applied using a sprayer equipped with boom section control. The herbicide savings were calculated for every treatment and the differences in the grain yield between the treatments were tested using the analysis of variance. The site-specific applications provided herbicide savings ranging from 15.6% to 100% according to the herbicide and application threshold used.

The author *Lei Tian (2002*) develops and tests an intelligent sprayer for accurate pesticide application based on local vision. The aim is to develop new technologies to evaluate the density and size of weeds in real time and to effectively reduce the amount of herbicide applied to crops. The machine vision system is specially designed to operate under variable outdoor lighting conditions. Multiple vision sensors have been used to cover the target area. Weed infestation conditions in each control zone (control area) were detected instead of trying to identify each individual plant in the field. To increase the accuracy of delivery, each individual spray nozzle is controlled separately. The integrated system was tested to evaluate performance and productivity under different conditions.

Site-specific application of pesticides has so far focused mainly on herbicides (*Ørum J.E. et al, 2017*). The purpose of precision farming technologies in relation to herbicide use is to reduce herbicide cost and environmental impact from spraying, but at the same time to achieve acceptable weed control. Another purpose is to increase the spraying capacity, to reduce the number of sprayer refills, and finally to minimize time spent on weed monitoring.

The authors *Beckie H., K. Harker (2017*) recommend several effective practices for weed control with reducing herbicide treatment. Another way to control weeds is to apply alternative methods *(Rifai M., M.Bartošová, P.Brunclík, 2000)*. The authors compare 3 alternative methods with traditional chemical in terms of efficiency and cost. 1) Gas treatment is carried out at 7-day intervals, 3 times. Low speed gives good results in the early stages of growth. In order to achieve higher efficacy in emergent weeds, perennials, weeds in later stages of growth and weeds with higher germination intensity, repetition of treatments is required. 2) Hot steam treatment at a travel speed of 1 km/h over an interval of 7 days. This technology is less effective in perennial weeds. For greater reduction of emergent weeds and for a longer period of time, re-treatment is required, maximum 2 weeks after the first one. 3) Mulching with sawdust results in 99.4% reduction of weeds. Only one treatment with chemical preparations was performed. The results are extremely good 2-3 weeks after treatment. Later, new weeds emerge and emerge, and repeating the treatment is inevitable.

The analysis shows that the chemical method is fundamental in the control of weeds in cultivated crops. The purpose of the presented study is to propose an approach for modeling an herbicide installation for the treatment of peach plantations under specific conditions.

MATERIALS AND METHODS

The observations in this work were carried out in a young peach plantation established 5 years ago with a total area of 1.0 ha. The field is of irregular geometric shape conditionally divided into 2 parts: a rectangle 80x75 m in size and a trapeze with a large base 80 m, a small base - 30 m and a height of 75 m. Four varieties are grown: Laskava, Ufo, Femina and Cassiopeia. Each of the varieties has an area of 0.25 ha. The trees are planted 5 m between rows, and inside the row the step is 4 m. 50 trees are grown in 0.1 ha, with a distance of 3 m from the adjacent fields.

The problem with this planting is the presence of many weeds. Attempts to mechanically destroy them by cultivation do not produce the desired effect. Destroying them requires spraying with an herbicidal bar spraying system, as treatment with a fan sprayer can cause stress or destruction of the trees by inaccurately directing the jet from the working solution.

An important condition for herbicide spraying is not to treat the leaves of fruit trees. The spraying system must be below the crowns of the trees, at a certain distance from their lowest spaced parts. The height of the stem and the limits of its variation have a significant influence on this limitation. Taking this into account, this determines the height at which the spraying system is to be positioned without the risk of spraying on the leaf mass of the trees grown. This data shows us the overall height of the spraying system. During spraying, the movement takes place in pre-treated row spacing. This implies a lot of bumps along the way. There is a danger that its frame will come into contact with some of the lower branches of the trees and damage or destroy them.

For the correct selection of the working height of the spraying system, a dimensional characteristic of the peach tree varieties from the observed plantation is made. For this purpose, 10 seedlings from each of the cultivated varieties are randomly selected and the height of the stem of each of them is measured. The data obtained from the measurements are processed with the software Statistica version 13.3.

By working with bar spraying system, they are required to provide very good transverse uniformity throughout the working width.

The simulation of the bar spraying system at a certain height is performed by varying the distance between the nozzles. The main objective of the changed distances is to determine the optimum distance, with the smallest transverse irregularity in the amount of fluid sprayed (the smallest CV coefficient).

The experimental studies were performed with a Lechler IDK 120-03 injector nozzle at the Department of Agricultural Mechanization at the Agrarian University, Plovdiv at the stand (*Trifonov A. et al., 2000*) shown in Figure 1.

The stand consists of a tank, a piston diaphragm pump with a flow rate of 105 l / min and a pressure of 2 MPa, a boom spray system composed of 5 separate sections with 3 nozzles each. In the first section it is possible to change the height of the nozzles above the collecting platform in the range from 0.20 to 1.00 m and the distance between them from 0.30 to 0.70 m. Below the sections is a collecting platform measuring 1.20 x 2.00 m and consisting of 40 channels with a width of 0.05 m, 0.07 m depth and a slope of 5^0. Below each channel is a measuring cylinder with a volume of 200 cm^3.

The stand is controlled by the onboard controller for controlling the TeeJet 884-E sprayers. Under its control are the main shut-off valve, 5 section shut-off valves, the pressure regulator. The controller allows selecting the proper sprayer operating mode and controlling this mode by displaying the solution pressure, speed, nozzle size, solution consumption rate and spray area up to date.

The stand has a flowmeter, a turbine type with a magnetic induction sensor and a speed simulator consisting of a pneumatic wheel and an induction sensor. The speed of the wheel is steadily controlled by an induction motor and a frequency converter.

Changing the managed variables involves the following basic steps: adjusting the height above the collecting plane 0.35 m; distance between the tips of the triangular chutes from the collecting plane 0.05 m; pressure in the discharge line 0.3 MPa; The experiment was carried out in 3 repetitions, measuring the amount of fluid entering the collecting chutes by measuring cylinders.

Fig. 1 - Experimental stand of spreader boom system

The amount of working fluid in each measuring cylinder is equal to the amount sprayed at 0.05 m from the working width of the nozzle, depending on the distance to its axis. The results of the experiment are given in the first row in an Excel table. In the next row, the same data is plotted, offset by 0.35 m (from 8 columns to the right). In the third row, the same data is offset by another 0.35 m (from 15 columns). In this way the work of 3 adjacent nozzles is imitated. The results of the three rows are collected by columns (each corresponds to the amount of spray solution from the nozzle 0.05 m from its working width). A histogram for the distribution of the working fluid is constructed. A variational analysis of the obtained results was made - average, variance, root mean square deviation and coefficient of variation were found. Using the obtained values for the coefficient of variation, a curve is constructed and, by its nature, the distance between the nozzles is determined, where the agrotechnical requirements (CV≤10%) are maximum satisfied.

The second series of calculations is made at a displacement of 0.40 m, and the third - at a displacement of 0.45 m.

RESULTS

- Stem height

In this indicator, the results are strongly grouped. The average value for all varieties is about 0.63 m. Almost complete overlap of stem height scattering was observed in the individual varieties (Figure 2).

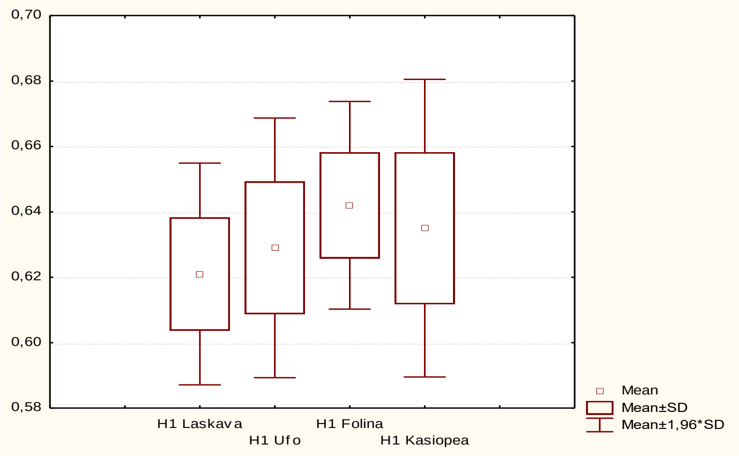

Fig. 2 - Stem height

This leads to the claim that this indicator has no proven statistical difference between the cultivated peach varieties.

Table 1

Stem height

Descriptive Statistics						
	Valid N	**Mean**	**Minimum**	**Maximum**	**Variance**	**Std.Dev.**
H1 Laskava	10	0,621000	0,600000	0,650000	0,000299	0,017288
H1 Ufo	10	0,629000	0,600000	0,660000	0,000410	0,020248
H1 Folina	10	0,642000	0,620000	0,660000	0,000262	0,016193
H1 Kasiopea	10	0,635000	0,600000	0,660000	0,000539	0,023214

The expected lowest placement of twigs and leaves on them may be about 0.59 m. Between the nozzles, the machine frame on the one hand and these twigs on the other, a buffer zone of about 0.25 m is required. It follows that the height of the frame and the spraying system cannot be more than 0.35 m.

σ

- Unevenness in working width

The following results were obtained for the distribution of the working fluid spread over the width of the torch (Table 2)

Table 2

Distribution of the working fluid along the width of the torch, ml

Indicators	**Distance from the nozzle axis, m**																
	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05	0	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4
Amount of working fluid	6	12	17	27	45	63	76	88	110	88	76	63	45	27	17	12	6

The results obtained are plotted in an Excel table and processed according to the procedure described in the Materials and methods section.

The results for each distance between the bar nozzles are statistically processed and presented in the following figures:

- for a distance of 0.35 m

Figure 3 shows that there is a rather large unevenness in the working width. As a rule, two adjacent nozzles must 100% overlap (with their left and right half torches) the torch of the nozzle located between them. When the distance is not optimal (small spread height or small / large distance between the nozzles) there is no possibility to provide this overlap and the distribution of the sprayed liquid is obtained with large irregularities as is the case here.

- for a distance of 0.40 m

Figure 4 shows that as the distance between the nozzles increases, the irregularity observed above (Figure 3) decreases substantially, being below the standard threshold of 10% for the coefficient of variation.

The results obtained in this embodiment are better than the previous one with deviations along the axis and at a distance of 0.35 m to the left and right of the axis. In the other positions, a relatively good levelling of the sprayed liquid is observed.

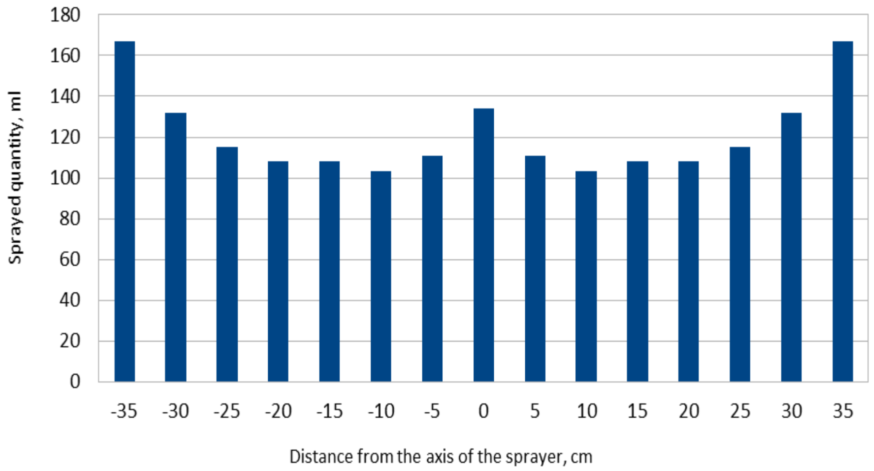

Fig. 3 - for a distance of 0.35 m between the nozzles

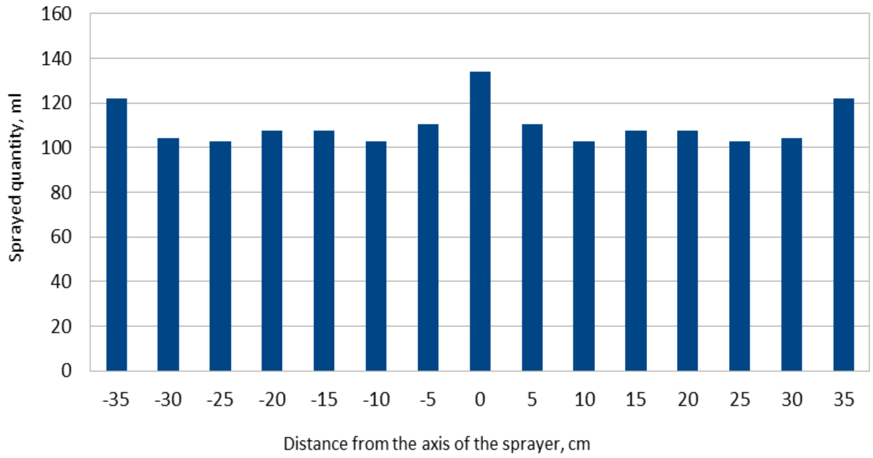

Fig. 4 - for a distance of 0.40 m between the nozzles

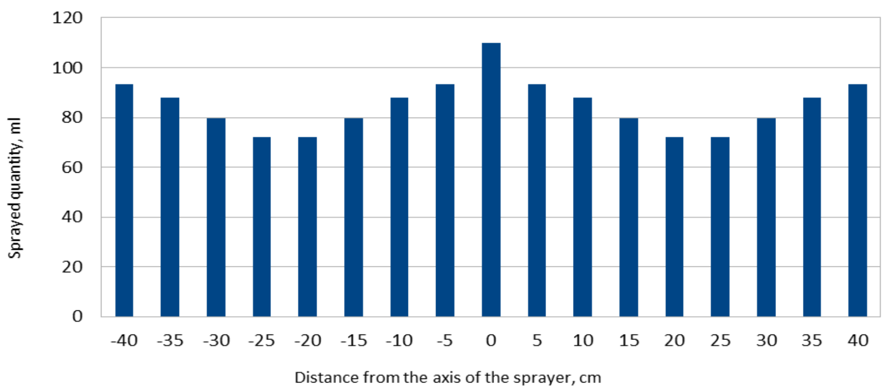

Fig. 5 - for a distance of 0.45 m between the nozzles

At this distance between the nozzles, there is an increase in unevenness. To determine the optimum distance of the bar at which there will be minimal unevenness in the working width, a variational analysis was performed with the data obtained for the sprayed amount of fluid across the bar width.

The end result of this analysis is to obtain the so-called coefficient of variation. A regression curve is constructed with the coefficient of variation data. The minimum in this curve gives us the answer for the optimum distance between the nozzles at a fixed spray height of 0.35 m

Table 3

Variational analysis of the quantities of liquid injected

Indicators	**Spacing between nozzles, [m]**		
	0.35	**0.40**	**0.45**
Average value, X	137	110	91
Dispersion, σ^2	717	82,9	130
RMS, σ	26.77	9.05	11.38
Coefficient of variation, *CV %*	***19.49***	***8.22***	***12.68***

The limit on the coefficient of variation must not exceed 10%. To determine the limits of variation of the spray height at which this condition is met, the graph of Figure 6 is plotted.

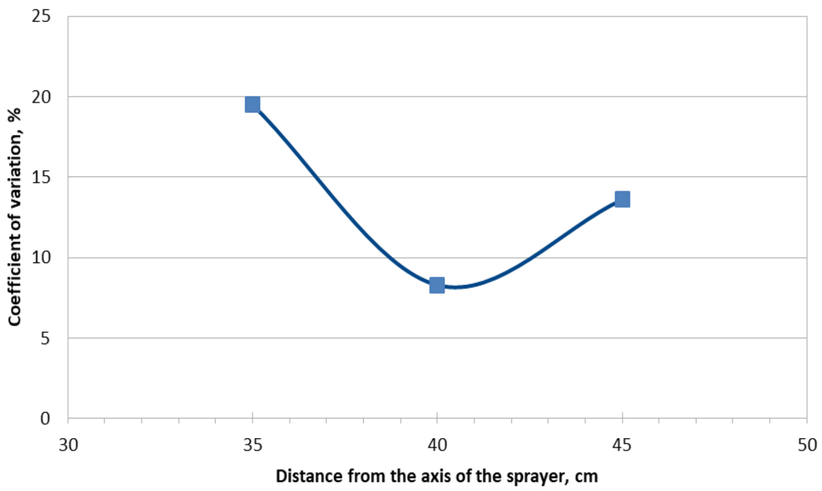

Fig. 6 - Coefficient of variation

The graph shows that the (CV) % coefficient of variation with the nozzle of 0.40 m has the lowest value and meets the agro-technical requirements as follows:

The width of the frame will be 3.5 m so that the treated trees will not be damaged during the movement. It will be pivotally secured with 2 deflecting sections each 1 m long for interior space treatment. At the ends of the deflection sections, 2 free rotating wheels with rubber sheath are mounted. On contact with the stem, they push the sections back and forth in the aisle so that there is no damage. After passing the obstacle, the sections return to the starting position under the influence of springs attached to the frame and each section.

CONCLUSIONS

An approach to modelling the herbicide installation for the treatment of peach plantations is proposed, including the following herbicide spraying parameters for a particular plantation: 1) height of the spraying system and the frame – 0.35 m; 2) distance between nozzles – 0.40 m; 3) frame width – 3.5 m.

ACKNOWLEDGEMENT

The article reflects the results of the work on the project 2020-AIF-01.

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