Shahid Bahonar University of Kerman

Biomechanism and Bioenergy Research

Online ISSN: 2821-1855
Homepage: https://bbr.uk.ac.ir

Iranian Society of Agricultural Machinery Engineering and Mechanization

Assessing and Prioritizing Agricultural Drone Sprayers in Kerman Province: an Analytic Hierarchy Process (AHP) Approach

Zinat Eskandari Nasab[1], Hossein Maghsoudi[1]

[1] Biosystems Engineering Department, Faculty of Agriculture, Shahid Bahonar University of Kerman, Kerman, Iran.

Corresponding author: h.maghsoudiuk.ac.ir

ARTICLE INFO

Article type:

Research Article

Article history:

Received 26 January 2024

Received in revised form 29 April 2024

Accepted 26 May 2024

Available Online 30 June 2024

Keywords:

Drone sprayers, sprayer evaluation criteria, Expert Choice software.

ABSTRACT

Given the limited awareness among farmers regarding agricultural spraying drones, the Analytic Hierarchy Process (AHP) method serves as a valuable tool to assist farmers in systematically selecting the most high-performing drone from the available options. This research employed the AHP method, utilizing Expert Choice software, to evaluate and prioritize several drone sprayers in the southern region of Kerman province, specifically Pelikan1, T16, T20, and MG-1P. Various parameters, including coverage percentage, spraying quality coefficient, spraying uniformity, device price, amount of pesticide consumption, and droplet diameter, were thoroughly examined to establish distinct priorities for each parameter. Within the AHP framework, the coverage percentage was accorded the highest weight of 0.340, while spraying uniformity received the lowest weight of 0.100. The spraying quality coefficient, cost, and amount of pesticide consumption were assigned weights of 0.222, 0.185, and 0.153, respectively. Consequently, the T16 drone sprayer emerged with the highest rank, carrying a weight of 0.277 in comparison to other drone sprayers. In contrast, Pelikan1 attained the lowest rank with a weight of 0.225. The prioritization of spraying drones based on their performance is as follows: T16, T20, MG-1P, and Pelikan1, respectively. This study provides valuable insights for farmers seeking to optimize the utilization of drone sprayers in the southern region of Kerman province.

Cite this article: Eskandari Nasab, Z., & Maghsoudi, H. (2024). Assessing and Prioritizing Agricultural Drone Sprayers in Kerman Province: an Analytic Hierarchy Process (AHP) Approach. *Biomechanism and Bioenergy Research*, *3*(1), 36-45. https://doi.org/10.22103/BBR.2024.22817.1075

Publisher: Shahid Bahonar University of Kerman

DOI: https://doi.org/10.22103/BBR.2024.22817.1075

INTRODUCTION

Every year, a vast expanse of farmland requires spraying due to prevalent pest infestations. In such instances, the spraying operation must be executed accurately, employing suitable equipment to ensure cost-effectiveness and efficiency, all while minimizing environmental impact and risks to human health. This necessity has prompted comprehensive research into the advancement of contemporary spraying equipment (Safari & Gerami, 2020).

Spraying constitutes a vital operation in upholding the quality of trees and crops. The utilization of chemical pesticides has prompted agricultural policymakers to reassess production patterns and management systems, aiming to enhance spraying quality while concurrently mitigating environmental damage through the development of innovative sprayers (Jafari Malekabadi et al., 2016).

As the size of farms increased, environmental concerns, and the labor force have all expanded, accompanying challenges have likewise intensified. Nonetheless, contemporary agricultural technologies can provide innovative solutions to tackle these issues. In recent years, agricultural robotics has introduced novel approaches to enhance efficiency through automation and mechanization (Shahrooz et al., 2020).

The utilization of agrochemical products yields benefits, yet excessive use also gives rise to problems (Parks, 2000). Conventional spraying methods result in the excessive use of chemicals, less uniformity, and elevated production costs. The utilization of drones offers the advantage of rapidly spraying of fields areas. When drones operate at the optimal altitude, they can enhance the effective penetration of pesticides, thereby lowering spraying costs and minimizing pesticide losses (Ghadge et al., 2022).

In recent years, the advancement of unmanned aerial vehicles (drones) has significantly contributed to precision agriculture. The utilization of drones can be particularly beneficial for field operations in smaller areas. Drones have emerged as a remarkable solution for addressing various challenges, providing novel possibilities for product management and surveillance, especially in small farming regions (Shahrooz et al., 2020).

In a study, the efficiency of a drone sprayer for weed control with a tractor-mounted boom sprayer and a turbo liner sprayer compared in terms of technical and functional parameters. The results indicated that the drone sprayer outperformed the other two types in four parameters (field efficiency, pesticide consumption, energy consumption, and spraying quality coefficient), while the turbo liner sprayer exhibited the highest field efficiency. Based on these findings, the use of the drone sprayer was recommended under experimental technical and environmental conditions (Zarifneshat et al., 2022).

Considering various spraying methods, it becomes imperative to establish priorities and criteria for combating weeds and pests. In such instances, the AHP is employed for decision-making and prioritization (Bertolini et al., 2006). AHP stands out as one of the most well-known multi-criteria decision-making techniques. It transcends being merely a selection tool, proving highly suitable for scenarios involving both quantitative and qualitative coefficients in the decision-making process. The AHP operates on the basis of pairwise comparisons. The decision-maker initiates the decision process by constructing a hierarchical tree, encompassing elements for comparison, competing options for evaluation, and consequently, a series of pairwise comparisons (Saaty & Vargas, 2012).

In a study, three methods—drone sprayer, lance sprayer mounted on a tractor, and atomizer sprayer—were investigated in terms of technical and economic aspects for controlling the tuta absoluta pest in tomato fields in the Safadasht Karaj region. The study followed a completely randomized design and was replicated three times. The results demonstrated the superior effectiveness of the drone sprayer method compared to the other approaches. Based on both technical and economic considerations. So, it was recommended to utilize drone sprayers for controlling tomato pests in the Safadasht Karaj region (Safari et al., 2023).

In another research, after conducting a field investigation on the operational conditions of commonly used sprayers for weed and pest control, evaluation forms were developed based on the research findings. These forms incorporated key evaluation criteria, including effectiveness, capacity, wind drift, energy consumption, operational costs, spraying uniformity, pesticide consumption, and various sprayers such as Knapsack micronair, turbo liner, lance, boom, and atomizer. Subsequently, the AHP was employed to identify the most suitable criteria and options (Safari & Gerami, 2020).

Based on a literature review, no prior research has been conducted on prioritizing different types of drone sprayers using the Analytic Hierarchy Process. The majority of sources have primarily focused on comparing conventional spraying methods. In this study, the drone sprayers Pelikan1, T16, T20, and MG-1P were selected, and spraying criteria, including coverage percentage, spraying quality coefficient, spraying uniformity, device price, pesticide consumption, and droplet diameter, were measured. The prioritization of the drone sprayers was then carried out through the use of the AHP with the assistance of Expert Choice software.

MATERIALS AND METHODS

To prioritize the drone sprayers using the AHP, four experiments were conducted in the southern province of Kerman, in the county of Orzuiyeh (Soughan). The experiments were conducted under almost consistent field conditions over a 10-day period, with temperatures ranging from 34 to 35°C, during the hours of 5 to 6 a.m. The wind speed during the experiment was averagly about 7 km/h. The trials were carried out on a quarter-hectare land plot situated at geographical coordinates of 31.411140° N latitude, 48.7554° E longitude, and an elevation of 1547 meters (Figure 1). The drone spraying operations followed a back-and-forth pattern based on predefined coordinates. In Figure 1, white lines indicate the selected agricultural land, and red lines delineate the designated quarter-hectare experimental area from this land. Four drone sprayers, namely Pelikan1, DJI AGRAS T16, DJI AGRAS T20, and DJI AGR MG-1P, were selected from among the active sprayers in the region (Figure 2).

Figure 1. The geographic location of the testing site

Figure 2 presents different drone sprayers used in this study (Pelikan1, T16, T20, and MG-1P) and table 1 shows the specifications of these drone sprayers. All four drone sprayers are outfitted with remote control, obstacle detection sensors, altitude adjustment, and battery management systems.

Figure 2. Drone sprayers used in this study

Table 1. Specifications of different drone sprayers used in this study

Drone sprayers	Number of motors	Tank volume (L)	Capacity of lithium batteries (mAh)	Spraying width(m)
Pelikan1	6	12	16000	7
T16	6	16	17500	6.5
T20	6	20	18000	7
MG-1P	8	10	12000	6

As the spraying width of the drone sprayers is adjustable, it has been set to 3.5 meters. This value was configured using the device's remote-control settings based on the land area. The spraying height for the device from the ground, based on the spraying width, was considered to be 2 meters. Additionally, the output flow rate of these drone sprayers was set to 10.5 liters per hectare using the remote-control of the devices. This capability is feasible when the output flow rate of the drone sprayers is in the link spray mode, allowing the user access to pump and nozzle settings. The forward speed of the device has also been set to 25 kilometers per hour. These conditions were uniformly applied to all four devices, and the drones were placed in automatic mode before takeoff.

To measure the quantity of pesticide utilized, the drone tank was filled with 7 liters of water prior to commencing the flight. Upon the drone's return and landing, the necessary amount of pesticide to achieve a total volume of 7 liters was determined. The device price refers to the purchase cost of the drone as of the experiment date, obtained from the manufacturer's website.

The evaluation of the drone sprayers included particle coverage percentage, spray quality coefficient, spray uniformity, pesticide consumption, droplet diameter, and device price. To assess these factors, 80 water-sensitive cards were employed, with 20 cards designated for each drone sprayer. The water-sensitive cards, with 3x7 cm^2 area, were located horizontally in the direction of the drone's movement, maintaining a 30 cm spacing between each card and placing 10 cards in each direction. The water-sensitive card is a resilient card with a special coating and a yellow surface. Due to immersion in a bromophenol solution, its color changes to blue after coming into contact with water droplets (Özlüoymak & Bolat, 2020). Figure 3 presents the Water- sensitive cards before and after spraying.

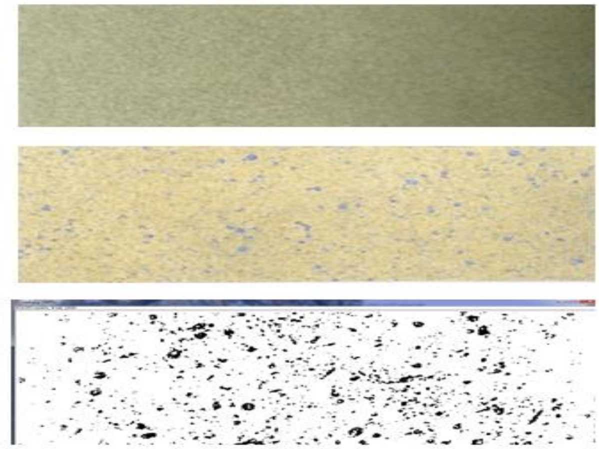

Figure 3. Water- sensitive cards before and after spraying. Third one is binary image

The percentage of particle coverage was obtained using ImageJ image processing software by analyzing water-sensitive cards. The spray quality coefficient is obtained by dividing the volume median diameter (VMD) by the number median diameter (NMD) (Eq. 1). The closer this result is to one, the higher the spray quality. However, in practice and depending on the conditions, and the type of nozzle and spray model, this number is not accessible.

The coverage percentage was determined through the analysis of water-sensitive cards using ImageJ, an image processing software. The spraying quality coefficient is derived by dividing the volumetric median diameter (VMD) by the numerical median diameter (NMD) (Eq. 1). A result closer to one indicates higher spray quality. Nevertheless, in practical scenarios, accessibility to this value is contingent upon varying conditions, nozzle type, and spraying method (Zarifneshat et al., 2022). The volumetric median diameter and numerical median diameter are also obtained from the analysis of water-sensitive cards using ImageJ software.

$$Q_c = \frac{VMD}{NMD} \quad (1)$$

VMD= the volumetric median diameter (in micrometers), is the diameter of the droplets whit 50% of the total volume of the sprayed liquid is smaller than this diameter. $D_{0.5}$

NMD= the numerical median diameter (in micrometers) is considered a diameter where half of the numbers are smaller than this number and the other half are larger than this number. Spraying uniformity is a direct indicator of the distribution range of the droplet size proportional to the volume median diameter, which is obtained from (Eq. 2) (Zarifneshat et al., 2022).

$$\Delta = \frac{(D_{0.9} - D_{0.1})}{VMD} \quad (2)$$

$D_{0.1}$ A diameter of drops that is 10% of the total volume of sprayed drops is smaller than this diameter.

$D_{0.9}$ A diameter of drops that is 90% of the total volume of sprayed drops is smaller than this diameter.

VMD= the volumetric median diameter (in micrometers), the diameter of the droplets that 50% of the total volume of the sprayed drops is smaller than this diameter. $D_{0.5}$

The foundation of the hierarchical method relies on pairwise comparisons. The decision-maker initiates the analysis by constructing a decision hierarchy tree. In the first level, the decision goal is positioned, followed by criteria in the second level, and options in the third level. In accordance with the nature of the problem, the number of main and sub-criteria may vary. (Safari & Gerami, 2020).

One of the important activities to prioritize the methods is the sensitivity analysis, which has several methods provided by the software. This analysis shows the sensitivity of the analysis results according to the change of priority values of criteria and sub-criteria. In Expert Choice software, there are five types of sensitivity analysis, including dynamic, efficiency, gradient, breakeven, and two-dimensional. In this research, efficiency-type sensitivity analysis was used. The total of priorities, taking into account the weight of each parameter, reaches the final result.

One crucial step for prioritizing methods is sensitivity analysis, which encompasses various methods available within the software. This analysis illustrates the sensitivity of the results in response to changes in the priority values of criteria and sub-criteria. Expert Choice software offers five types of sensitivity analysis: Dynamic, Performance, *Gradient*, Head-to-Head and Two-Dimensional (2D Plot). In this research, a Performance-type sensitivity analysis was employed. The sum of priorities, considering the weight of each parameter, contribute to the final outcome.

In this research, the spraying methods and criteria were compared through paired tables, and the corresponding weights were determined. The first level was the goal, the prioritization of different drone sprayers, and the second level was criteria includes the percentage of coverage, spraying quality coefficient, spraying uniformity, price of device, and pesticide consumption. The options (Pelikan1, T16, T20, and MG-1P) constituted the third level in the hierarchy. Figure 3 presents the hierarchical tree for prioritizing of different drone sprayers.

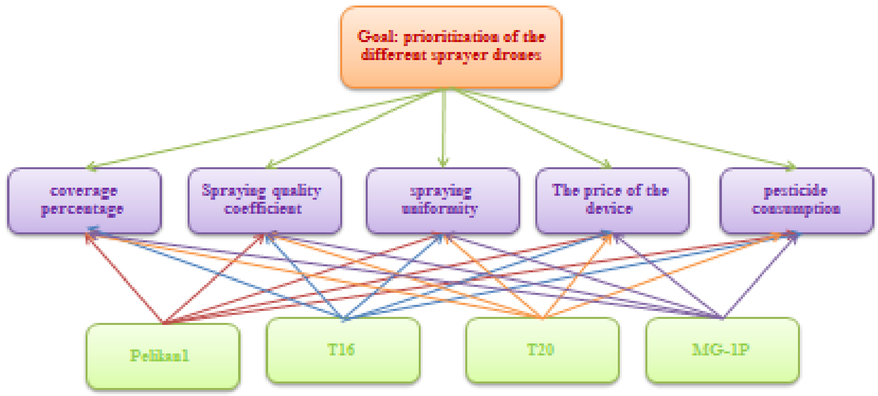

Figure 3. Hierarchical tree for prioritizing of different drone sprayers in Expert Choice software

Following the analysis of data using Expert Choice software, the weights for each of the drone sprayers and criteria were determined. Subsequently, a sensitivity analysis was conducted based on the performance method.

In this study, the Pelikan1, T16, T20, and MG-1P drone sprayers were prioritized and evaluated based on coverage percentage, spraying quality coefficient, spray uniformity, the price of device, pesticide consumption, and droplet diameter. The statistical method employed for comparison was Duncan's multiple range test using SAS software. The obtained data were considered, and realistically analyzed with the assistance of expert farmers' opinions in the Expert Choice software.

Results And Discussion

The results of the statistical analysis indicate that there is no significant difference between the parameters of the different drone sprayers (Table 2). However, as Table 1 illustrates, the T16 drone sprayer exhibits the highest mean values for both percentage of coverage and spraying quality coefficient, while the Pelikan1 drone sprayer has the lowest value.

The T20 drone sprayer exhibits the highest spraying uniformity with a value of 1.84, while the other drone sprayers show nearly identical spraying uniformity values. Additionally, the T20 drone sprayer has the highest actual droplet diameter, averaging 121.16, whereas the Pelikan1 drone sprayer exhibits the lowest value.

According to the statistical results, despite the absence of significant differences among the investigated parameters, and with all the spraying drones exhibiting similar conditions, the criteria of coverage percentage and droplet diameter demonstrate superior performance compared to other criteria. Subsequently, the criteria of spraying quality coefficient and spraying uniformity occupy the subsequent ranks, respectively.

Table 2. Mean value of investigated parameters in different drone sprayers

Drone sprayers	Coverage percentage	Spraying quality coefficient	Spraying uniformity	Droplet diameter
D1	9.58[a]	3.29[b]	1.67[a]	110.09[a]
D2	17.45[a]	11.90[a]	1.56[a]	115.52[a]
D3	14.64[a]	7.19[ab]	1.84[a]	126.16[a]
D4	15.71[a]	9.78[ab]	1.53[a]	113.17[a]

D1, D2, D3, and D4 represent Pelikan1, T16, T20, and MG-1P drone sprayers, respectively.

In research conducted by Zarifneshat et al. (2022) the performance of drone spraying was evaluated in comparison to conventional methods for controlling wheat weeds. One of the measured criteria was the spraying quality coefficient, with the drone sprayer demonstrating a coefficient of 1.8, in contrast to the turbo liner sprayer, which registered 4.2 (Zarifneshat et al., 2022). As can be seen from the table, the spraying quality coefficient for the Pelikan1 drone (3.29) is superior to that of the other drone sprayers.

The results obtained from the analysis in Expert Choice software are illustrated in Figure 4. This figure depicts the relative weights and ranks of each drone. By considering the weighted criteria, the prioritization of the drones can be inferred from this figure. The weights assigned to Pelikan1, T16, T20, and MG-1P are 0.225, 0.277, 0.248, and 0.250, respectively. In terms of the options (drone sprayers), the priority order is T16, T20, MG-1P, and Pelikan1. The inconsistency value is 0.08, which is considered an acceptable result.

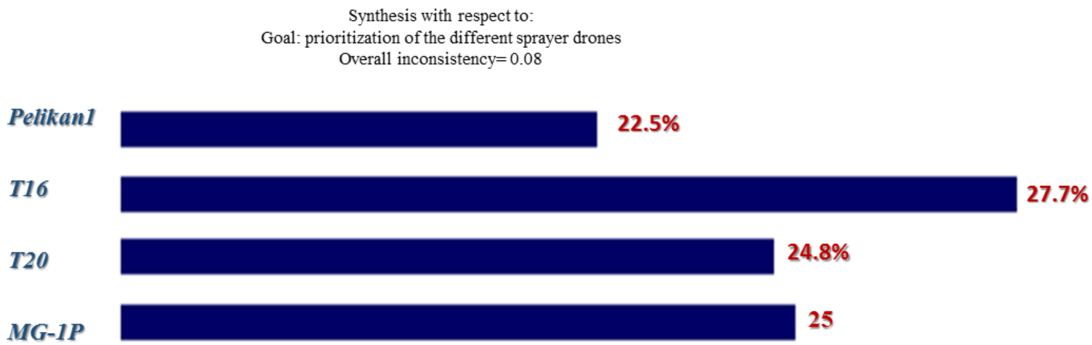

Figure 4. Relative weight of drone sprayers according to criteria

Figure 5 illustrates how to prioritize an option in comparison to other options based on the criteria and overall conditions. The coverage percentage is nearly 35% higher than other criteria. The Pelikan1 drone exhibits the lowest coverage percentage at about 49%, while the other three drones have almost the same coverage percentage, ranging between 65% and 70%.

The spraying quality coefficient is weighted at 25%, with the Pelikan1 drone having the lowest weight at about 28%, and the T16 drone having the highest weight at about 85%. The spraying uniformity, which carries the least weight among other criteria, indicates that all four drones have the same percentage. The price of device constitutes about 15% of the weighting, with the MG-1P drone having the lowest weight, the Pelikan1 having the highest weight, and the other two drones having similar percentages.

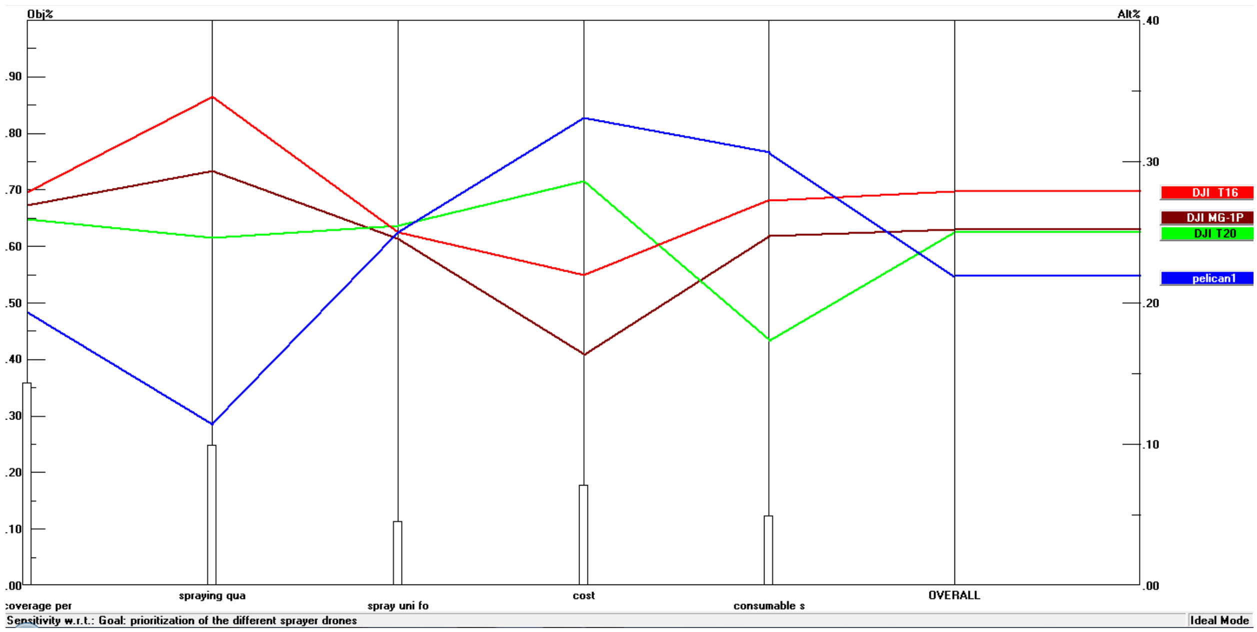

Figure 5. Performance-type sensitivity analysis. The right vertical axis represents the weight of the options (spraying parameters), while the left vertical axis indicates the weight of the criteria.

The T20 drone sprayer has the lowest weight percentage in pesticide consumption, which is nearly equal to the weight of spraying uniformity. The Pelikan1 drone has the highest weight, while the T16 and MG-1P drones have the same percentage, placing them in the middle. Overall, the Pelikan1 drone has the lowest weight, the T16 drone has the highest weight, and the T20 and MG-1P drones have equal weight.

The results of Safari and Grami's research on the scoring of spraying methods in wheat fields indicated that the weights for Knapsack micronair, Tractor boom, Turboliner, Knapsack atomizer, and Tractor Lance sprayers were 0.337, 0.223, 0.175, 0.170, and 0.078, respectively. The Knapsack micronair and Tractor lance sprayers were deemed the best and worst sprayers, respectively, based on the obtained weights. The inconsistency coefficient of weights was 0.08, which is less than 0.1. Similarly, in the present research, drone sprayers (Pelikan1, T16, T20, and MG-1P) were prioritized with weights of 0.255, 0.277, 0.248, and 0.250, respectively. The T16 drone sprayer had the highest weight (0.277), and the inconsistency coefficient was 0.08, which compares favorably with the results obtained from the aforementioned research (Safari & Gerami, 2020).

Figure 6 represents dynamic sensitivity analysis, displaying the weight of each criterion, options, and the change in the importance of the criteria. The weight values for coverage percentage, spraying quality coefficient, spraying uniformity, device price, and pesticide consumption are 34%, 22.2%, 10%, 18.5%, and 15.5%, respectively. In this scenario, the weight of Pelikan1, T16, T20, and MG-1P drone sprayers is 22.5%, 27.7%, 24.2%, and 25%, respectively. According to this diagram, the weights of the options can be altered. If we modify the weight of the criteria, the weight percentages of the options will also change.

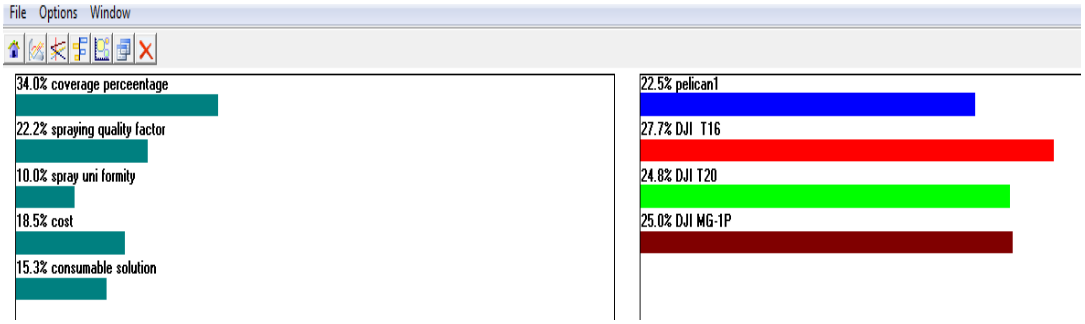

Figure 6. Dynamic sensitivity analysis

Loghmanpour Zarini et al. employed the AHPto determine the proper sprayer in Citrus gardens. Four commonly used sprayers in the region (Motorized Backpack sprayer, Atomizer sprayer, Wheelbarrow sprayer, and Air blast sprayer) were evaluated based on criteria such as tank capacity, costs, spray quality, field capacity, and the amount of consumable solution per hectare. The weights obtained through Expert Choice software were 0.481, 0.302, 0.102, 0.073, and 0.042 for these criteria, respectively, with the atomizer sprayer receiving the highest final value of 0.504 and identified as the most suitable option. The inconsistency coefficient was obtained as 0.04, which is an acceptable value. (Loghmanpour Zarini et al., 2021).

CONCLUSIONS

In this study, four drone sprayers used in the south of Kerman province, namely Pelikan1, T16, T20, and MG-1P drones, were investigated and prioritized using the (AHP) and statistical analysis. Various parameters, including coverage percentage, spraying quality coefficient, spraying uniformity, device price, pesticide consumption, and droplet diameter, were examined, and distinct priorities were assigned to each parameter. In the hierarchical method, the coverage percentage held the highest weight, with a value of 0.340, while the spraying uniformity criterion, with a weight of 0.100, had the lowest. The criteria of spraying quality coefficient, device price, and pesticide consumption had weights of 0.222, 0.185, and 0.153, respectively. In the statistical analysis, the criteria of droplet diameter and coverage percentage demonstrated superior performance, whereas the spraying uniformity criterion exhibited lower performance. Consequently, T16 and Pelikan1 drone sprayers received the highest and lowest weights, respectively (0.277, 0.225). T20 and MG-1P sprayers were ranked equally, each with weights of 0.248 and 0.250. The inconsistency coefficient was 0.08, deemed an acceptable result. Therefore, drone sprayers can be prioritized in the order of T16, T20, MG-1P, and Pelikan1. Investing in an appropriate pesticide sprayer is a crucial aspect of pest control, directly impacting crop production and protection. Thus, these results can significantly aid farmers in making informed decisions when selecting the appropriate drone sprayer.

REFERENCES

Bertolini, M., Braglia, M., & Carmignani, G. (2006). Application of the AHP methodology in making a proposal for a public work contract. *International Journal of Project Management*, *24*(5), 422-430. https://doi.org/10.1016/j.ijproman.2006.01.005

Ghadge, A. S., Shahare, P., Dhande, K., Khandetod, Y., Pathak, S., Haldankar, P., & Patel, S. (2022). Orchard spraying systems for unmanned aerial vehicles: A review. *The Pharma Innovation*, *11*(12), 1438-1443.

Jafari Malekabadi, A., Sadeghi, M., & Zaki Dizaji, H. (2016). Comparing Quality of a Telescopic Boom Sprayer with Conventional Orchard Sprayers in Iran. *Journal of Agricltural Science and Technnology (JAST)*, *18*(3), 585-599.

Loghmanpour Zarini, R., Kalantari, D., Akram, A., & Mollapour, S. (2021). Selecting the Proper Sprayer in Citrus Gardens of Mazandaran Province by Analytical Hierarchy Process. *Iranian Journal of Biosystems Engineering*, *52*(1), 119-129.

Özlüoymak, Ö. B., & Bolat, A. (2020). Development and assessment of a novel imaging software for optimizing the spray parameters on water-sensitive papers. *Computers and Electronics in Agriculture*, *168*,105104. https://doi.org/10.1016/j.compag.2019.105104

Parks, W. J. (2000). *Mapping weed ground cover using a weed-activated sprayer* University of Georgia].

Saaty, T. L., & Vargas, L. G. (2012). *Models, Methods, Concepts & Applications of the Analytic Hierarchy Process* (Second Edition ed., Vol. 175). Springer Science & Business Media. https://doi.org/10.1007/978-1-4614-3597-6

Safari, M., Bagheri, N., Sheikhi Garjan, A., & Zarifneshat, S. (2023). Evaluation and comparison of sprayer drone to control Tuta pest in tomato crop. *Agricultural Mechanization and Systems Research*, *23*(84), 1-16.

Safari, M., & Gerami, K. (2020). Prioritization of Methods and Criteria of Spraying for Wheat Fields by Analytical Hierarchy Process (AHP). *Iranian Journal of Biosystem Engineering*, *51*(1), 139-148. https://doi.org/https://doi.org/10.22059/IJBSE.2019.287967.665217

Shahrooz, M., Talaeizadeh, A., & Alasty, A. (2020). Agricultural spraying drones: Advantages and disadvantages. 2020 Virtual symposium in plant omics sciences (OMICAS),

Zarifneshat, S., Saeidirad, M. H., Safari, M., Motame AlShariati, H. R., & Naseri, M. (2022). Technical Evaluation of Agriculture Drone Sprayer for Control of Wheat Weeds and Compare with Conventional Methods. *Agricultural Mechanization and Systems Research*, *23*(82), 53-70. https://doi.org/10.22092/amsr.2022.360045.1427