DJI AGRICULTURE

DJI AGRICULTURE DRONE INSIGHT REPORT

Aug, 2023

-Introduction-

In 2022, global agriculture faced numerous challenges including geopolitical tensions, economic uncertainties, and extreme weather events. These factors led to a rapid increase in global food prices and highlighted the pressing issue of food security. However, amidst these challenges, there were also opportunities for growth and development. Agriculture drones emerged as a promising technological advancement, with significant progress made in research and development, expansion of crop applications, and the promotion of ecological practices within the industry.

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I. Industry Events

After a decade of extensive efforts, DJI agriculture has successfully expanded its presence across six continents, encompassing over 100 countries and regions.

As of the conclusion of 2022, the global deployment of DJI agriculture drones has surpassed 200,000 units, facilitating operations on a cumulative area exceeding 200 million hectares.

This widespread adoption has benefitted millions of agricultural practitioners by significantly enhancing their productivity and efficiency.

In addition, through dedicated flying training programs, a considerable number of pilots and instructors have been trained, encouraging the participation of young entrepreneurs in the field of science and agriculture.

These efforts have not only fostered the advancement of intelligent agriculture but also provided crucial talent support for its continued development.

Jan 30 obtained the safety approval of the spraying system by JKI in Germany, and opened up new application possibilities for the T30 in the country, particularly in vineyards.

Feb The DJI Academy was established in Mexico to provide more professional pilots training in the country.

Mar DJI agricultural drones assisted in various plant protection activities in Brazil.

Apr T30 obtained the spraying certification and the approval of the Civil Aviation Administration in many European countries, and carried out spraying operations.

May The T40 droplet size research and drift test were launched in China.

Jun The "Agricultural Drone Industry Insight Report" was released for the first time, proposing that agriculture should not only focus on efficiency, but also take ecological and environmental protection into consideration.

Jul DJI Agriculture donated 15 DJI agricultural drones to the China Rural Development Foundation. These drones will be used in all forests and grasses including the Ant Forest Project in Zhangxian County, Gansu Province and Inner Mongolia Autonomous Region to help prevent pests and diseases, contributing to sustainable development of forest and grass industry.

Aug An American user replaced seven of his helicopters with seven DJI agricultural drones.

Sep T20P sprayed durian trees in Malaysia, opening up new the application possibilities of agricultural drones.

Oct The T40 was officially released globally at AirWorks-2022 in the United States. In November, the world witnessed the launch of the first-ever DJI agriculture global branded Video centered around the theme of "Better Growth,Better Life."

Dec The T50 was officially released and put on sale in China.

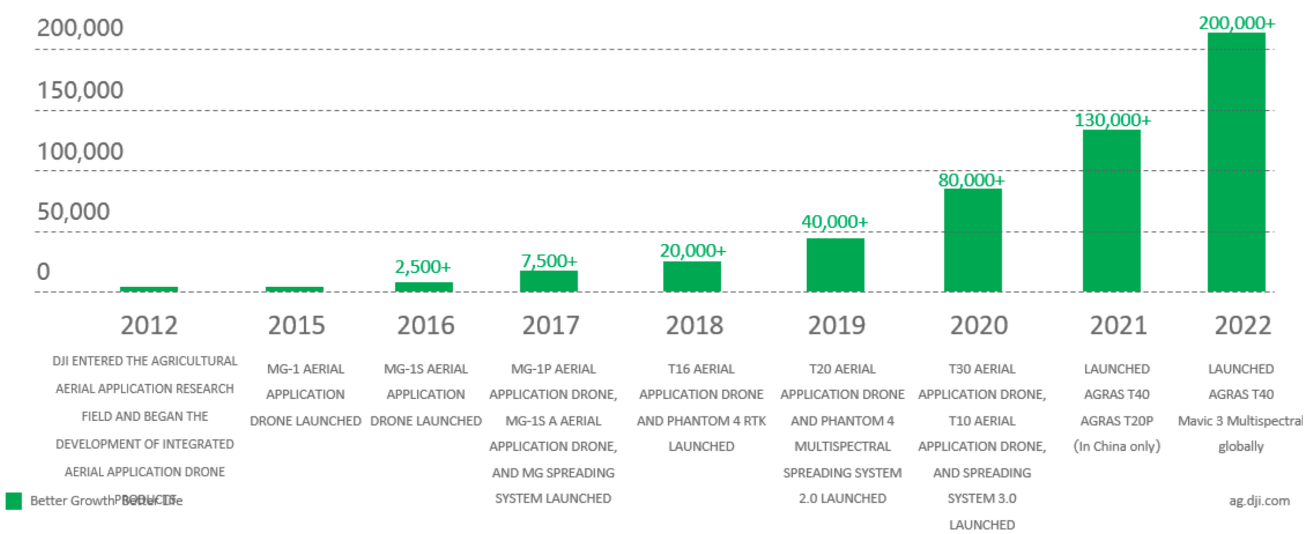

Figure 1 DJI Agricultural Drone Market Size in 2022

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II. Global Policy Trends

The global acceptance of agricultural drones has led to a shift in perspective among government management departments. They have embraced a newfound understanding and openness towards agricultural drones, both in terms of management ideas and processes.

1. Gradual Opening up of Europe

1.1 Proposal to Revise SUD Regulations

On June 22, 2022, the European Commission issued “Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the sustainable use of plant protection products and amending Regulation (EU) 2021/2115”.In the draft, the EU proposes to amend the content of aerial spraying, written in (26):

(26)*It is however likely that certain unmanned aircraft (including drones) will allow for the targeted aerial application of plant protection products. Such unmanned aircraft are likely to help reduce the use of plant protection products due to targeted application and consequently help reduce the risks to human health and the environment compared to use of land-based application equipment. It is therefore appropriate to set criteria in this Regulation for an exemption of certain unmanned aircraft from the prohibition of aerial application. It is also appropriate to defer the application of this exemption for 3 years given the current state of scientific uncertainty.*

The draft has added a description of the conditions for the drones that can be used in Article 21.

“Article 21

Use of plant protection products in aerial application by certain categories of unmanned aircraft

1. Where certain categories of unmanned aircraft fulfil the criteria set out in paragraph 2, a Member State may exempt aerial application by such unmanned aircraft from the prohibition laid down in Article 20(1) prior to any aerial application of plant protection products.

2. An aerial application by an unmanned aircraft may be exempted by the Member State from the prohibition laid down in Article 20(1) where factors related to the use of the unmanned aircraft demonstrate that the risks from its use are lower than the risks arising from other aerial equipment and land-based application equipment.

These factors shall include criteria relating to:
(a) the technical specifications of the unmanned aircraft, including in relation to spray drift, number and size of rotors, payload, boom width and overall weight,
operating height and speed;
(b) the weather conditions, including wind speed;
(c) the area to be sprayed, including its topography;
(d) the availability of plant protection products authorized for use as ultra-low volume formulations in the relevant Member State;
(e) potential use of unmanned aircraft in conjunction with real time kinematic
precision farming in certain cases;
(f) the level of training required for pilots operating an unmanned aircraft;
(g) potential concurrent use of multiple unmanned aircraft in the same area.
3. The Commission is empowered to adopt delegated acts in accordance with Article 40 supplementing this Regulation to specify precise criteria in relation to the factors set out in paragraph 2 once technical progress and scientific developments allow for the development of such precise criteria."

And also in Article 45 "Entry into force" of the draft, the application of Article 21 is three years after the draft regulations come into force.

Article 21

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   (a) the technical specifications of the unmanned aircraft, including in relation to spray drift, number and size of rotors, payload, boom width and overall weight, operating height and speed;

   (b) the weather conditions, including wind speed;

   (c) the area to be sprayed, including its topography;

Figure 2 Provisions on permitting the use of drones

Although this proposal is at a draft stage, and the implementation planning for drone spraying takes a long time, it still reflects that the European Commission has changed from a comprehensive ban on drone spraying, individual users apply for exemption, to approval of specific aircraft types and changes that can apply for exemptions by aircraft type.
We hope that this proposal can be discussed more widely, speed up the legislative process, and help more European users realize the use of agricultural drones in a faster way.

1.2 EASA releases new PDRA for agricultural drones

Since the application and evaluation of agricultural drones using SORA will take an average of 4-6 months or even 1 year, EASA has released 5 PDRAs to help users and civil aviation departments shorten the application and approval time. Four of the five PDRAs involve agricultural drones, and operators can fill in and apply for PDRAs according to their own needs.
At the same time, EASA will also launch SORA 2.5 in 2023. Compared with SORA 2.0, the new version hopes to be clearer and easier for users to use.
In view of the fact that both PDRA and SORA have some design content for drone design, DJI will try its best to help users complete the material proof in these aspects.

1.3 Germany approves agricultural drones below 50kg for operations

On November 4, 2022, the German Federal Ministry for Digital and Transport issued the National Standard scenario for ground deployment of drones on Agricultural Land (hereinafter referred to as "National scenario") (Nationales Standardszenario zum bodennahen Einsatz von unbemannten Flugger ä ten auf landwirtschaftlichem Grund (DE.STS.FARM)), which approves the application of agricultural drones under 50kg.
The German Federal Ministry for Digital and Transport believes that the use of drones for agriculture and forestry is very common in Germany, and the experience of the authorities in such operations has been positive. The bureau takes into account not only the liquid spraying operation of agricultural drones, but also some biological control situations, such as using drones to control European corn borer with Trichogramma[1]. Therefore, when Germany publishes the "national standard scenario", it is not enough to consider the open category below 25kg, and the drone originally classified as specific category under 50kg is also open to a certain extent according to the open category. Operators have to comply with certain flight altitude, speed, drug spraying and geographic information requirements when carrying out agricultural operations, but they only need to send a very simple application form when making an application. This application form includes the applicant's name, contact information, starting time and ending time. After confirmation in writing by the Bureau, the applicant can use the drone to spray.

[1]See: https://en.wikipedia.org/wiki/Trichogramma

1. Angaben zum Betrieb des unbemannten Fluggeräts durch den Betreiber:

Name, Vorname:	
E-Mail:	
Anschrift (Straße, Hausnummer, Postleitzahl, Ort):	
Telefonnummer:	
e-ID:	
Identifikationsnummer Kompetenznachweis A1/A3	
Startdatum des Betriebs:	
Enddatum des Betriebs:	

Figure 3 Application form for agricultural drones under 50kg in Germany

1.4 T30 obtains Agroscope's[2]Certification in Switzerland: drones can use the same chemicals as ground machineries

European countries have very strict management of the use of pesticides, coupled with the ban on aerial spraying for many years, there are few pesticides labeled "used for aerial spraying".
After a certification test of the DJI T30 aircraft, Agroscope in Switzerland believes that the environmental impact, especially in terms of drift, is similar to that of ground equipment. At the same time, considering that the spraying height of the T30 is basically similar to that of some large ground sprayers when flying, Agroscope believes that in Switzerland, the T30 can be used for pesticides that can be used in ground equipment. In terms of pesticide management and use, the move regards drones as similar to ground-based equipment and is flexible under a strict legal framework.

2. Licenses and Exemptions in North America

2.1 United States

In 2022 and 2023, DJI users in the United States have obtained exemptions from the FAA authorization for the T30 and T40, respectively. According to the requirements of the FAA, if the spraying of agricultural drones meets the jurisdiction of part137, an exemption application can be made according to 44807. Specific applications can be made in accordance with the guidelines of the FAA on its official website.

[2]See: https://www.agroscope.admin.ch/agroscope/en/home.html

The FAA's Decision

The FAA has determined that good cause exists for not publishing a summary of the petition in the *Federal Register*. The FAA has determined that good cause exists because the requested amendment to the exemption would not set a precedent and any delay in acting on this petition would be detrimental to Elevated.

Although you requested to operate the T-40 at a weight no more than 222.67 lbs., the 49 U.S.C. § 44807 determination for the DJI Agras T40 UAS is limited to no more than 222.66 lbs. Therefore, T-40 operations under this exemption are limited to a maximum take-off weight not to exceed 222.66 lbs.

The FAA has determined that the justification for the issuance of Exemption No. 19037 remains valid with respect to this exemption and is in the public interest. Therefore, under the authority provided by 49 U.S.C. §§ 106(f), 40113, 44701, and 44807, which the FAA Administrator has delegated to me, I hereby grant Elevated Ag LLC an exemption from 14 CFR §§ 61.3(a)(1)(i), 91.7(a), 91.119(c), 91.121, 91.151(b), 91.403(b), 91.405(a), 91.407(a)(1), 91.409(a)(1), 91.409(a)(2), 91.417(a), 91.417(b), 137.19(c), 137.19(d), 137.19(e)(2)(ii), 137.19(e)(2)(iii), 137.19(e)(2)(v), 137.31, 137.33, 137.41(c), and 137.42 to the extent necessary to allow Elevated to operate the DJI Agras T-16, DJI Agras T-20, and DJI Agras T-40 for the provision of commercial agricultural-related services, subject to the following conditions and limitations.

Figure 4 DJI T40 obtained the FAA's operational exemption

2.2 Canada

According to the requirements of Transport Canada, those who operate drones over 25kg need to apply for SFOC.

The content of SFOC includes the manufacturer's situation, product safety design and reliability test situation, operator's ability certificate, pilot's ability certificate, etc. Although the ultimate responsibility of SFOC is the operator, considering that it is difficult for the operator to prove the product safety design and reliability test of the drone, DJI will provide the aircraft design and reliability test that the manufacturer needs to prove. Unified certification to the bureau.

DJI's T10 series has passed the Standard922 audit according to the requirements of TC. Operators can fly drones in controlled airspace or fly drones close to people (operation distance 5 to 30 meters.) [3]

[3]See: https://tc.canada.ca/en/aviation/drone-safety/learn-rules-you-fly-your-drone/choosing-right-drone#approved

Filter items T10 Show 10 entries

Manufacturer name	Model	Type	Manufacturer RPAS safety assurance		
			Controlled airspace	Near people	Over people
DJI	Agras T10	Rotary wing	Yes	Yes	

Figure 5 T10 passed the 922 standard

DJI's T30 and T40 have passed the audit of the authority, and the operator does not need to prove the content related to the aircraft design again when applying for SFOC.
In the future, DJI will further assist agricultural machinery users at the compliance level, making the process simpler and saving precious time for intensive agricultural operation preparations.

3. Airworthiness Certification in China

On March 15, 2023, the China Civil Aviation Central and South Regional Administration and the China Civil Aviation Shenzhen Safety Supervision and Administration Bureau visited Shenzhen Dajiang Innovation Technology Co., Ltd. to hold the "DJI Model Certificate and Production License Issuing Ceremony" ".
The Civil Aviation Central and South Regional Administration issued Type Certificates and Production Certificates for T16, T20, T10, and T30 agricultural drones to DJI on the spot.

Figure 6 The Airworthiness Certification Office of the Central South Bureau issued t he first agricultural drone PC to DJI

According to Article 34 of the Civil Aviation Law of China, the design of civil aircraft and its engines, propellers and equipment on civil aircraft shall apply to the competent department of civil aviation under the State Council for a type certificate. If it passes the examination, a model certificate will be issued. As an emerging industry, drones have the characteristics of novel design and diverse operating scenarios, which are significantly different from traditional civil aircraft. It also brings huge challenges to the exploration of its airworthiness management mode, which is an internationally recognized problem.

DJI actively cooperates with the Civil Aviation Administration of China to explore the airworthiness management of drones, and actively participates in the research and formulation of various airworthiness technical standards and special conditions. In May 2020, the Airworthiness Department of the Civil Aviation Administration of China issued the "Management Procedures for Airworthiness Certification of Civilian drone Products (Trial)", and DJI became the first company in China to apply for the approval letter for the design and production of plant protection drone systems. Among them, actively cooperate with the various certification work of the inspection team of the bureau, and accumulated a lot of practical experience for the airworthiness management of low-risk civilian drones. The Airworthiness Department of the Civil Aviation Administration of China issued the first domestic plant protection drone system design and production approval letter to DJI T16 and T20 models on December 21, 2020, and completed the DJI T10 and T30 on May 31, 2021. The final review meeting of the design and production approval letter approval project.

In December 2022, in accordance with the Civil Aviation Regulations of China "Civil Aviation Products and Parts Qualification Certification Regulations" (CCAR-21), the Civil Aviation Administration officially issued the "Civil Unmanned Aircraft System Airworthiness Certification Management Procedures" (AP-21-AA -2022-71). According to the requirements of this procedure, the medium-sized agricultural unmanned aerial vehicle system can carry out type certification, production license certification and airworthiness certification according to the requirements for restricted civil unmanned aircraft systems, and obtain the type certificate and its modification and supplement Design approval is obtained through the type certificate, production approval is obtained by obtaining a production license, and airworthiness approval is obtained by obtaining a special airworthiness certificate for civil unmanned aircraft. DJI actively carries out certificate conversion and application in accordance with regulations and procedures. After completing the conversion and application review of the four model certificates of DJI, the Central and South Regional Administration of Civil Aviation will issue the DJI T16 and T20 agricultural drone model certificates on January 31, 2023; on February 10 On February 22, the production licenses of DJI T16, T20, T10 and T30 were issued.

中国民用航空局
CIVIL AVIATION ADMINISTRATION OF CHINA
生产许可证
PRODUCTION CERTIFICATE

中国民用航空局
CIVIL AVIATION ADMINISTRATION OF CHINA
许可生产项目单
PRODUCTION LIMITATION RECORD

Figure 7 PC of DJI T16, T20, T10, T30 drone

The DJI Model Certificate and Production License Issuing Ceremony represents that DJI's T16, T20, T10, and T30 agricultural drones have successfully passed the bureau's model certification and production license approval, and successfully completed the evidence collection work.

Figure 8 DJI T30 agricultural drone, one of the first models to receive PC from Civil Aviation Administration of China

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III. Agriculture Drone Tests

1. Droplet Size Test for T40

From August to October 2022, the Central Laboratory of China Agricultural University's Pharmaceutical Equipment and Application Technology will conduct analysis and testing on the droplet spectrum characteristics of the LX8060SZ centrifugal nozzle of DJI T40. The test methods and results are as follows:

1.1 Droplet Size Spectrum Test of Centrifugal Sprinklers Under No Wind Field Condition

1.1.1 Test process

Test equipment: laser particle size analysis, LX8060SZ centrifugal nozzle and its control

Test method: Install a single LX8060SZ centrifugal nozzle directly above the laser line of the laser particle size analyzer, set the angle between the nozzle turntable and the horizontal line to be 45° and 0°, and when the nozzle is installed obliquely, the near-ground end of the nozzle is within 0.3m of the laser beam Inside, the fog surface passes through the midpoint of the laser beam. When the nozzle is installed horizontally, the distance between the near-ground end of the nozzle and the laser beam is within 0.2m. The distance between the two instruments should be such that all the droplets can fall accurately within the range of the laser beam. The recommended distance is 3m. Use standard hard water as the spray liquid.

Test the droplet spectrum data at different nozzle atomization disk speeds under the nozzle flow rate of 2.70L/min.

Set multiple groups of sprinkler speeds, measure 3 times for each treatment, and record DV50, DV10, DV90, relative droplet distribution span RS, and the proportion of droplets smaller than 100 and 200 μm, and find out the volume median diameter DV50 at 50-500μm not less than 5 levels of nozzle speed or other control indicators.

1.1.2 Result analysis

The test results show that due to the influence of gravity, the droplet spectrum Dv50 and Dv90 low-speed areas of the spray nozzles at a 45° inclination angle are significantly higher than those at a 0° inclination angle. Continue to increase the speed of the nozzle, the difference between DV50 and DV90 of the droplet spectrum of the two nozzle inclination angles disappears. The reason is that the centrifugal force generated by high-speed rotation is much greater than gravity, which can eliminate the influence of gravity. However, the DV10 value of 0° inclination angle is higher than that of 45° inclination angle in most speed ranges.

According to the above analysis, the atomization effect of this type of centrifugal nozzle placed horizontally is better than that placed obliquely. Placing the nozzle horizontally is more conducive to producing a more uniform droplet spectrum. When working in the field, it is recommended to place the nozzle horizontally to obtain the best spray effect.

1.2 Droplet Size Spectrum Test under the Single Rotor Downwash Airflow Field

1.2.1 Test process

A test platform for the droplet size distribution of the LX8060SZ centrifugal nozzle droplet size distribution based on the T40 motor and the rotor is built, and the nozzle is located directly below the rotor.

Adjust the position of the instrument so that the center of the nozzle is above the laser beam, keep the position of the nozzle horizontal, change the movement direction of the droplets with the help of the wind field, and increase the proportion of droplets passing through the laser section.

Use OP-10 non-ionic surfactant to prepare a spray liquid with a concentration of 0.1% to simulate the physical and chemical properties of pesticide liquid.

Turn on the rotor motor to adjust the speed to the working speed of the drone flight state, turn on the spray system, adjust the spray flow rate to 2.7L/min and the spray head speed to stabilize and start measuring the droplet spectrum.

Test the droplet spectrum data under different nozzle atomization disc rotation speeds under the flow rate to be tested, set multiple nozzle rotation speeds, measure 3 times for each treatment, and record DV50, DV10, DV90, relative distribution span RS of droplets .

Figure 9 Spray test site

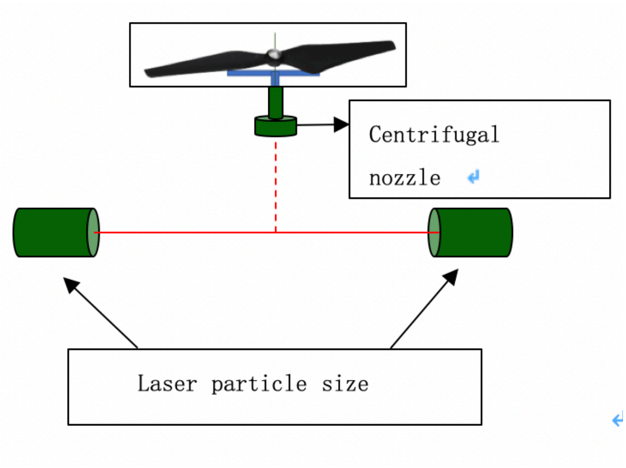


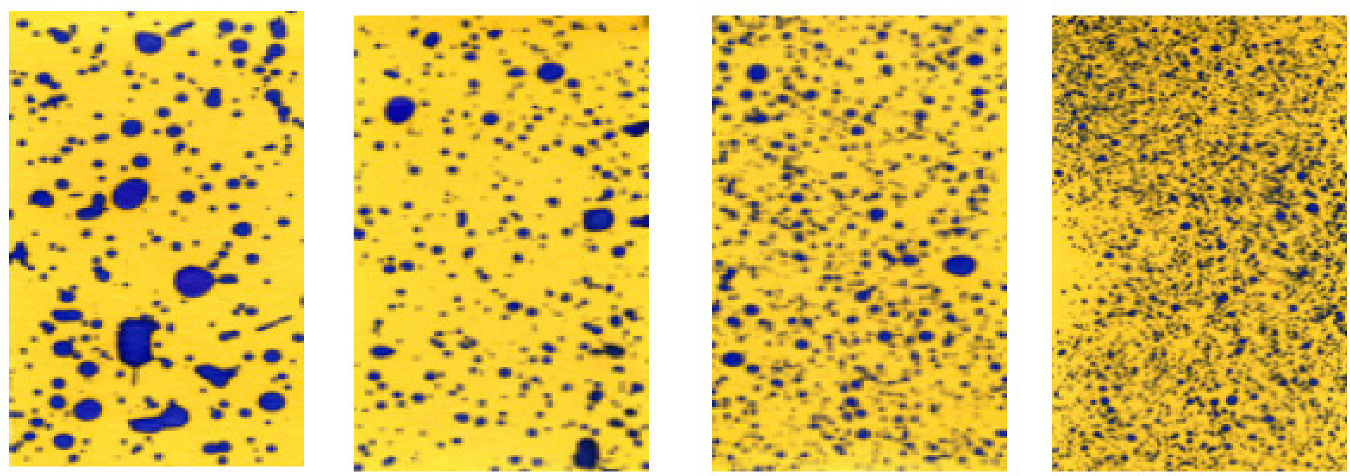
Figure 10 Schematic diagram of particle size test

1.2.2 Results and analysis

Compared with the results of measuring the particle size of droplets in the state of no wind field, under the same nozzle speed condition, there is an interaction between the rotor downwash airflow and the fog field, resulting in the following results:

1) In the speed range of 5500-14000 r/min, compared with the static measurement, the downwash flow field will increase the droplet size by 10%-60%. In this range, the lower the nozzle speed, the more obvious the increase effect.

2) Affected by the downwash flow, according to the above content, it is speculated that the droplet particle size transition effect under the static wind field increases from the 3000-4000r/min nozzle speed range to 4000-6000r/min, that is, the transition effect develops to a higher nozzle speed.



Dv50:751μm Dv50:486μm Dv50:273μm Dv50:110μm

Figure 11 Water-sensitive paper test results

Figure 12 Test site of droplet size spectrum under the action of single rotor downwash flow field

1.3 Droplet size spectrum measurement under four-rotor downwash flow field

1.3.1 Test process

Two LX8060SZ centrifugal nozzles were installed on a self-built simulated drone spray test bench to simulate the interaction process between the four-rotor drone downwash airflow field and the droplets.

The nozzle is installed directly under the rotor, adjust the horizontal position of the laser particle size analyzer, the laser beam is parallel to the advancing direction of the drone, and the spraying part of the nozzle is located 2m above the laser beam, and the position of the nozzle is kept horizontal to test the overall wind field of the drone and the droplets interaction.

Use OP-10 non-ionic surfactant to prepare a spray liquid with a concentration of 0.1% to simulate the physical and chemical properties of pesticide liquid.

Turn on the rotor motor to adjust the speed to the working speed of the drone flight state, turn on the spray system, adjust the spray flow rate and the nozzle speed to stabilize, and then start measuring the droplet spectrum. The initial measurement point is located at the centerline of the simulated drone.

Test the droplet spectrum data at 1.6L/min flow rate under different nozzle atomization disc rotation speeds, measure 3 times for each treatment, record DV50, DV10, DV90, relative droplet distribution span RS and droplet ratio smaller than 100, 150μm V100, V150 to evaluate the atomization effect.

In the horizontal direction along the vertical laser line, three measurement points are selected, which are respectively located at the midpoint of the drone simulation platform, directly below the nozzle and outside the radius of the rotor, and move the position of the laser particle size analyzer to measure the droplet size distribution in the horizontal direction.

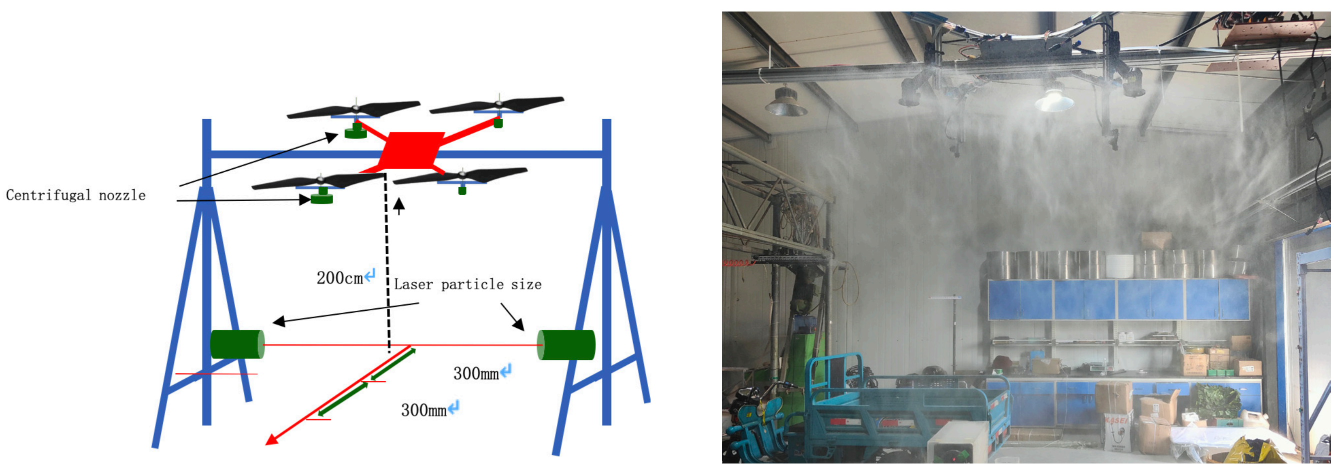


Figure 13 Test of droplet size distribution in drone wind field environment

1.3.2 Results and analysis

The test results are shown in Figure 14. In the extremely low rotational speed range, large droplets are easy to break free from the range of the downwash airflow field, which is not conducive to the uniform distribution of pesticide droplets.

Figure 14 Test site of droplet size distribution in drone downwash flow field

2. Drift Tests

In order to clarify the spray drift rules of agricultural drones under different influencing factors, guide agricultural drones to carry out plant protection operations safely and efficiently, and ensure the safety of non-target organisms and the environment, a drift field test was carried out on T30 and T40.

2.1 T30 Drift Test

2.1.1 Test process

The test was carried out in the experimental field of the Chinese Academy of Agricultural Sciences. The T30 agricultural drone was used. The terrain of the farmland was flat and the surrounding area was open and unobstructed.

The flight speed of T30 selected as 3 m/s, 4 m/s, 5 m/s and 6 m/s, and the flight height can be selected as 2.0, 3.0 and 4.0 m. Choose between normal and coarse droplet sizes. Each parameter combination was used to measure the droplet deposition and drift of multi-rotor agricultural drone spray under three different crosswind speeds.

The test was carried out in an area of 128 m x 125 m (length x width). Six sampling strips were arranged in the sampling area, with an interval of 5 m between each sampling strip. The first and last sampling strips were respectively 50 m away from the edge of the test area.

The sampling area includes 0-20 m in the operation area and 0-50 m in the downwind drift area.

According to the ISO 22866 spray drift field test standard, under the condition of ensuring the accuracy of the sampling results as much as possible, the sampling points are set as follows: one every 1 m between the edge of the downwind operation area and the 10 m downwind drift area The droplet collection device (supported by the mylar sheet at the bottom, the droplet test card and the filter paper with a diameter of 9 cm are fixed on the mylar sheet, based on this design, the cross-contamination between test personnel and a single collection device can be reduced to the greatest extent problem), and place a fog at 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 45 and 50 m from the downwind edge of the work area drop collection device.

At the same time, the sampling device was placed 1 m above the ground to avoid the influence of the ground effect on the droplet deposition.

Wait for 5-10 minutes after the spraying, confirm that the droplets on the filter paper are all dry, put them into ziplock bags in order, and store the samples in dark and cool conditions, and then process and measure the samples.

The agricultural drone is set to multi-spray automatic operation mode, and the flight route of the drone is 125 m long to ensure that the agricultural drone keeps flying at a constant speed in the sampling zone area.

Before the test, a 5 g/L Rhodamine B aqueous solution was prepared, and the prepared Rhodamine B aqueous solution was added to the medicine box to ensure that the agricultural drone's drug loading was 50% of the full load. Check the working status of the drone nozzle and calibrate its flow before the test.

After the wind direction meets the requirements and stabilizes, take off the drone with one button to spray automatically, use the RTK that comes with the drone to ensure the accuracy of the route, and return to the take-off point from the upwind direction after spraying, and use the dark centrifugal tube to collect the spray after each spray Mother liquor to clarify the change of solution concentration during the spraying process.

Figure 15 T30 test scene recording diagram

2.1.2 Analysis and Conclusion

1) The influence of crosswind speed on fog droplet drift: The crosswind speed is the most important factor affecting the drift distance and drift amount, and the best operating condition is that the crosswind speed is less than 3.4 m/s.
2) The effect of flying height on droplet drift: when the crosswind wind speed is within 0-3.4 m/s, and the flying height is 2 m, 3 m and 4 m, the deposition amount of spray droplets in the operation area gradually decreases, The uniformity of droplet distribution becomes worse, and the distance of droplet drift increases gradually. When the crosswind speed is greater than 3.4 m/s, changing the working height has almost no effect on the droplet deposition and drift, and the crosswind speed is the main influencing factor.
3) The influence of ambient temperature and humidity on drift: Under the premise of ambient temperature 15-30°C, side wind speed less than 3.4 m/s, and air humidity between 20-80%, the impact of humidity on droplet drift is most significant. As the ambient humidity increases, the amount of mist drift and the drift distance both decrease. The optimal range of ambient humidity to reduce mist drift is: the ambient humidity is above 60%. When the ambient wind speed reaches above 3.4 m/s, changing the ambient temperature and humidity has no significant effect on the droplet drift.

2.2 T40 Drift Tests

Because the T40 uses a newly designed centrifugal nozzle system, we adopted a "one year two places" drift test for the T40, that is, in the same year, the drift test was carried out simultaneously in two places in Henan Province and Hebei Province.

2.2.1 T40 Drift Test in Henan

A. Test process

The test was carried out in an area of 128 m x 125 m (length x width). Six sampling strips were arranged in the sampling area, with an interval of 5 m between each sampling strip. The first and last sampling strips were respectively 50 m away from the edge of the test area.
The sampling area includes 0-20 m in the operation area and 0-50 m in the downwind drift area. According to the ISO 22866 spray drift field test standard, under the condition of ensuring the accuracy of the sampling results as much as possible, the sampling points are set as follows: one every 1 m between the edge of the downwind operation area and the 10 m downwind drift area
The droplet collection device (supported by the mylar sheet at the bottom, the droplet test card and the filter paper with a diameter of 9 cm are fixed on the mylar sheet, based on this design, the cross-contamination between test personnel and a single collection device can be reduced to the greatest extent problem), and place a fog at 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 45 and 50 m from the downwind edge of the work area drop collection device.

At the same time, the sampling device was placed 1 m above the ground to avoid the influence of the ground effect on the droplet deposition.
Wait for 5-10 minutes after the spraying, confirm that the droplets on the filter paper are all dry, put them into ziplock bags in order, and store the samples in dark and cool conditions, and then process and measure the samples.
The agricultural drone is set to multi-spray automatic operation mode, and the flight route of the drone is 125 m long to ensure that the agricultural drone keeps flying at a constant speed in the sampling zone area.
Before the test, a 5 g/L Rhodamine B aqueous solution was prepared, and the prepared Rhodamine B aqueous solution was added to the medicine box to ensure that the agricultural drone's drug loading was 50% of the full load. Check the working status of the drone nozzle and calibrate its flow before the test.
After the wind direction meets the requirements and stabilizes, take off the drone with one button to spray automatically, use the RTK that comes with the drone to ensure the accuracy of the route, and return to the take-off point from the upwind direction after spraying, and use the dark centrifugal tube to collect the spray after each spray Mother liquor to clarify the change of solution concentration during the spraying process.

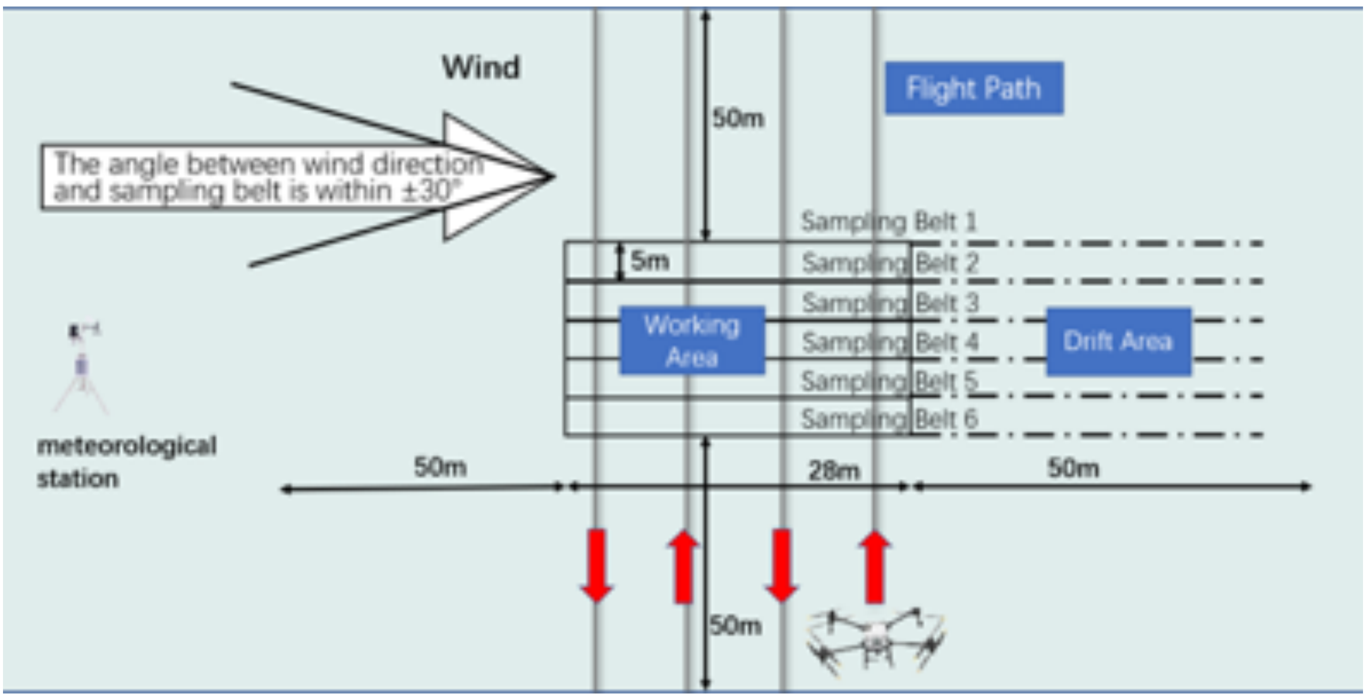


Figure 16 Schematic diagram of the test

B. Analysis and Conclusion

1) The influence of crosswind speed on fog droplet drift: The crosswind speed is the most important factor affecting the drift distance and drift amount, and the best operating condition is that the crosswind speed is less than 3.4 m/s.

2) The effect of flying height on droplet drift: when the crosswind wind speed is within 0-3.4 m/s, and the flying height is 2 m, 3 m and 4 m, the deposition amount of spray droplets in the operation area gradually decreases, The uniformity of droplet distribution becomes worse, and the distance of droplet drift increases gradually. When the crosswind speed is greater than 3.4 m/s, changing the working height has almost no effect on the droplet deposition and drift, and the crosswind speed is the main influencing factor.

3) The influence of ambient temperature and humidity on drift: Under the premise of ambient temperature 15-30°C, side wind speed less than 3.4 m/s, and air humidity between 20-80%, the impact of humidity on droplet drift is most significant. As the ambient humidity increases, the amount of mist drift and the drift distance both decrease. The optimal range of ambient humidity to reduce mist drift is: the ambient humidity is above 60%. When the ambient wind speed reaches above 3.4 m/s, changing the ambient temperature and humidity has no significant effect on the droplet drift.

2.2.2 T40 Drift Test in Hebei

A. Test settings

In order to explore the droplet drift of T40, we use three kinds of droplet collection devices (ground droplet deposition collector, ground drift collection device, air drift collection device) to evaluate the distribution of fog droplets in the operation area and the downwind area of the operation Condition.

Ground droplet deposition collector: In order to collect the deposition distribution of the agricultural drone operation area, a PVC card support device belt is arranged in the operation area of the agricultural drone to collect the deposition droplets, and the deposition droplet collection belt is perpendicular to the flight of the drone Direction, the width of the deposition collection area is 30m (3 spray widths), each group has a total of 13 points from the upwind direction to the downwind direction edge, with an interval of 2.5m, a total of 3 groups, 39 points, during use, ensure that the plane of the PVC card is parallel to the ground .

Ground drift collection device: In order to collect the drift distribution of agricultural drones on the ground in the downwind direction, 9 plastic culture plants with a diameter of 15cm are arranged at 3, 5, 10, 15, 20, 30, and 50m downwind from the edge of the agricultural drone's spraying width. The dishes were placed on three metal plates, and the petri dishes were on the same straight line and parallel to the direction of travel of the drone. A total of 63 petri dishes were tested in each group.

Air drift collection device: In order to collect air drift droplets in the downwind direction, 3 sets of air drift collection frames are placed 2m downwind from the edge of the spray width. On the frame, one frame with a length of 2m in diameter is arranged every 50cm from the ground at a distance of 0.5m. 1.98 mm polytetrafluoroethylene line, up to 5.0m; at the same time, three groups of 2.0 m × 2.0 m aerial drift collection frames were placed at 15 m downwind, and polytetrafluoroethylene lines were also arranged at an interval of 50 cm, and each group tested a total of 42 pieces. The Teflon wires are clamped at both ends to the vertical frame and stretched to ensure no bends.
Weather station: YG-BX portable field weather station is used to record the wind speed, wind direction, temperature and humidity during the outdoor drift test, with a frequency of 0.2Hz.
Fluorescence instrument: Hitachi F-2700 fluorescence spectrophotometer. Other equipment also includes: bottle-top dispenser, decolorization shaker, etc.

B. Test plan and venue

The test site is arranged as shown in Figure 17, the drift test device is completely perpendicular to the flight line, and the weather station is turned on during the test to collect wind speed and direction.

When the wind speed and direction meet the requirements and are stable, the operator is notified to prepare before take-off, and the simulated liquid with the concentration of ABF fluorescent tracer and OP-10 non-ionic surfactant is both 0.1% added to the liquid tank. A collector is arranged on each collecting device.

The drone flew three routes with an interval of 6.5m. Using the fully automatic flight mode, the pre-set routes were called for operations. Each treatment was repeated 3 times to ensure 54 effective tests. The test can withstand the natural crosswind parameters: the wind speed range is 1.0-3.0m/s or >3.0m/s, and the wind direction is ±30° perpendicular to the flight line. After the test is completed, the samples are collected and stored in the dark, and sent to the laboratory for subsequent testing. After each set of tests is completed, no less than 10ml of mother liquor is collected in a 50ml centrifuge tube for analysis of sedimentation.

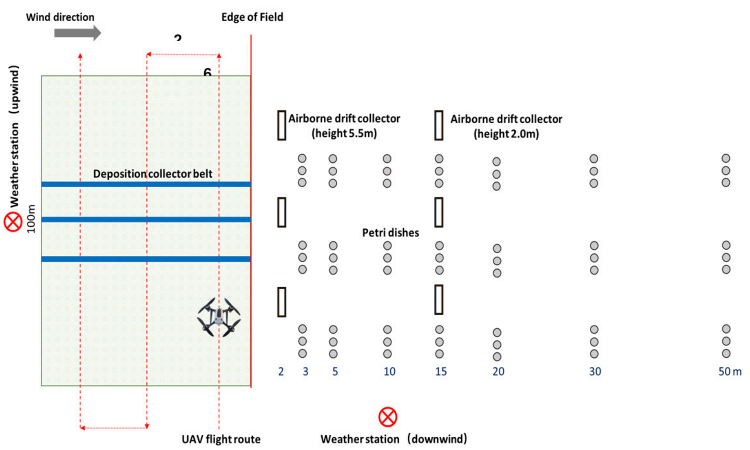


Figure 17 Schematic diagram of the test

C. Test results and recommendations

During the test, the ambient temperature was between 13-29°C, the average humidity was 22-69%, and the ambient wind speed of the low wind speed treatment group was distributed at 0.7-3.4m/s. The ambient wind speed distribution of the high wind speed treatment group was 1.9-4.2m/s. The test is currently carried out under the conditions of high ambient wind speed (≥3m/s) and low ambient wind speed (1-3m/s). Three different flight speeds are selected for the T40 model drone; three nozzle speeds; three flight altitudes A total of 14 test treatment groups were set up for the droplet drift related tests of operating parameters. Based on the above test results and analysis, the following suggestions are obtained:

a. When spraying with different parameters in a low wind speed environment, the ground drift is not obvious. It is recommended to work in a low wind speed environment.

b. Under the condition of high wind speed (≥3m/s), the drift rate in the air is positively correlated with the flight speed, nozzle speed, and flight height. Choosing a flight height of 1.5m or a low nozzle speed can significantly reduce the droplet drift rate.

c. The flight height of agricultural drone operation is the main factor affecting the drift of droplets. When the flight height is 4m, its potential drift index is much higher than that of other treatment groups. During field plant protection operations, the flight height should be controlled at 2-3m within a reasonable range.

d. Except for individual treatment, the increase of wind speed from 1-3m/s to above 3m/s will lead to an increase in the air drift rate at the same location. The fog droplet drift caused by high-speed flight is most sensitive to changes in wind speed. Under ambient wind speed conditions, the operating speed of agricultural drones should be reduced as much as possible.

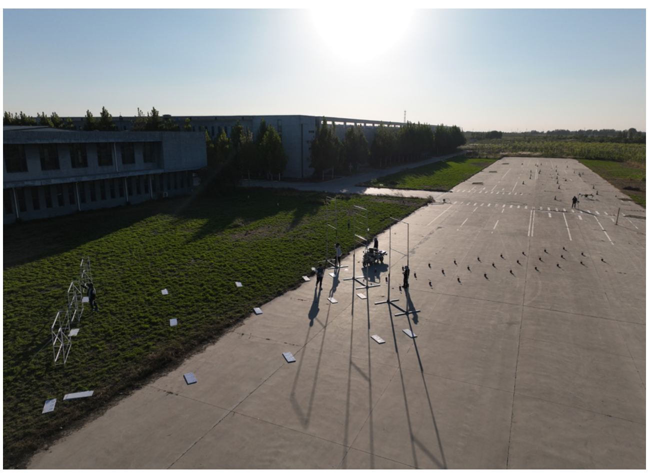


Figure 18 T40 Hebei Drift Test Record

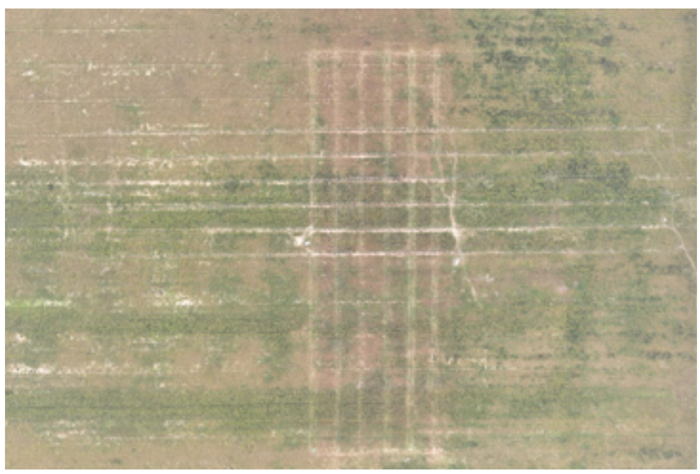


Figure 19 Schematic diagram of layout of sensitive crops and test cards

3. T40 Herbicide Test

Among pesticides, herbicides are the most likely to cause damage due to drift. There are generally two reasons for herbicide drift. One is that the wind speed is too high during the spraying process; the other is that the herbicide is easy to evaporate when the temperature is high. The gaseous herbicide re-condenses on the plant foliage on the crop or under the action of a temperature difference.

Therefore, in addition to the drift test, we also specially carried out the drift test of herbicides. The experiment was carried out to simulate the herbicide spraying operation scene carried out by the agricultural UAV T40, and to study the influence of herbicide spray drift on the growth of sensitive crop rape in non-target areas under different wind speed conditions.

4. Model Exploration

Among pesticides, herbicides are the most likely to cause damage due to drift. There are generally two reasons for herbicide drift. One is that the wind speed is too high during the spraying process; the other is that the herbicide is easy to evaporate when the temperature is high. The gaseous herbicide re-condenses on the plant foliage on the crop or under the action of a temperature difference.

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IV. Innovations of Drone Application

4.1 Pest and Disease Control

As a world-renowned tourist destination, the resorts in the Maldives are constantly plagued by "caterpillars" (Euproctis fraterna[4]). The caterpillars' bristles contain a toxin that can cause severe rashes and blisters on human skin when in contact, and in severe cases, medical attention is required. Resorts need to set up special medical rooms to provide medical services for guests.

Figure 20: Ground spraying in progress

Traditional pest control methods involve manually spraying trees with pesticides using a handheld sprayer. This spraying is not only heavy and difficult to carry and move, but also has extremely low efficiency. Due to the inability to accurately target pests, hundreds of liters of pesticides are wasted when spraying from the ground. In some resorts, trees have to be cut down when the caterpillar infestation is severe, but since most islands in the Maldives are coral islands, the roots of trees play a significant role in the stability of the islands. Cutting down trees can cause a terrible impact on the ecology.

Compared to manual spraying, using a DJI agricultural drone, such as the T30, can be more effective and accurate. Dr. Bart Knols, a medical entomologist led a team to use the T30 agricultural drone for precision spraying in the Maldives.

[4]See:https://en.wikipedia.org/wiki/Euproctis_fraterna

To achieve better pest control result, it is necessary to monitor trees at an earlier stage with multispectral technology, and to perform precision point spraying as soon as the risk is identified. This not only avoids affecting healthy trees but also prevents potential harm in the early stages.

Figure 21: Dr. Knols and his team

This method of using drones for multispectral monitoring and precision spraying was welcomed by local tourists as it not only solves the problem but also aligns with their environmental protection awareness.

In the future, this method may be promoted to more countries and regions to help people control pests and diseases.

4.2 The Integration of Drone Applications with Farming Techniques

The integration of agricultural drones with farming techniques is another trend in agriculture, where traditional farming is transformed with the arrival of new technologies. Taking grape cultivation as an example, traditional grape cultivation involves growing the grapes on horizontal trellises with concrete posts and nets, allowing the grapes to grow naturally on the trellises. In South America, the grapes can even form a "roof-like" growth structure.

Figure 22: Traditional grape farming in Chile

Figure 23: Grape farming in Henan, China

For traditional grape cultivation, pesticides are often applied manually using backpack sprayers or ground mist machines. During the leafy growth period, manual spraying exposes the sprayers to the chemical environment, potentially causing toxicity.

In China, many grape gardens adopt new grape cultivation techniques, pruning the grape branches into shapes that are easier for drones to work with. These branches are pruned into a "Y" shape, with pruning taking place in March after the buds sprout, leaving only 15-16 bunches of grapes on each tree. Agricultural drones will perform three sprayings during the growth cycle of the grapes: the first spraying to kill eggs, insects, and bacteria; the second spraying to kill insects and bacteria; and the third spraying to kill insects and bacteria. After the three sprayings, a tent will be set up over the grapes, and a mist machine will be used to spray a nutrient solution, without involving pesticides.

For a 40-mu (6.67 acres) grape garden, a mist machine typically takes about 2 hours to complete a spraying job, while a drone can finish the task in less than 30 minutes.

4.3 Case Study of Smart Agriculture

4.3.1. Application and Development of Agricultural Drones in Potato Cultivation

Potatoes are grown in 158 countries and regions worldwide, with the highest concentrations in Asia and Europe. The top 5 countries with the largest potato planting areas are China, Russia, India, Ukraine, and Bangladesh, while the top 5 countries with the highest potato yields per hectare are New Zealand, the United States, Belgium, the Netherlands, and France. The top 5 potato-producing countries are China, India, Russia, Ukraine, and the United States.

According to FAO statistics, China is currently the world's largest potato producer. In China, potatoes have a planting history of over 400 years. By 2020, the potato planting area had expanded to over 100 million mu (6,666,666 hectares). In terms of spatial layout, according to the advantageous regional layout planning, China's potato cultivation is divided into four advantageous areas: the Northern Single-Crop Zone, the Central Double-Crop Zone, the Southern Double-Crop Zone, and the Southwestern Mixed-Crop Zone. The Northern Single-Crop Zone accounts for 50% of the total planting area, including the majority of Heilongjiang, Jilin, and Liaoning provinces in Northeast China; the northern parts of Hebei, Shanxi, and Shaanxi provinces; and the eastern parts of Ningxia, Gansu, and Qinghai provinces. The region boasts favorable climate characteristics, including extended daylight hours, significant variations in temperature throughout the day, a tuber-forming phase occurring primarily in July and August, and a cool, humid environment. These conditions make it an essential hub for the production of seed potatoes and commercial potatoes. At the same time, individual planting scales are large, planting levels, mechanization levels, and those of developed countries in Europe and America are comparable, with an average yield of over two tons per acre, and full-process mechanized management was achieved in 2008.

Figure 24: Spraying vehicle operation in potato fields

The main diseases affecting potatoes include late blight, early blight, viral diseases, and ring rot. The number of pesticide applications throughout the growing cycle ranges from 8 to 12, with late blight affecting the leaves, stems, and tubers of potatoes, being a typical epidemic disease. It rapidly breaks out and spreads within two weeks from the onset of symptoms to the complete wilting of the field, requiring a humid and cool climate, with relative humidity not lower than 85%, being a devastating disease. Early blight also affects the same parts as late blight, but the damage is less severe than late blight. In the Northern Single-Crop Zone, with continuous planting for many years, the pathogen base is large, and the pressure for late blight control is increasing. In addition, the special climatic conditions mean that during the potato plant's closure and tuber bulking period, the weather also enters the rainy season, and the concentration of planting is high, and the terrain is mostly hilly and sloping, which is prone to waterlogging, and the cold and humid natural conditions are conducive to the rapid spread of late blight.

Figure 25: Planting lane of vehicles in potato fields

DJI Agriculture began experimenting with the application of agricultural drones on potatoes in 2017. Initially limited by payload and wind field size, the operation effect was generally unsatisfactory. And the application development area was relatively small. However, with the increase in payload and the improvement of wind field penetration after 2019, the number of farmers using agricultural drones in the northern area have increased. The following advantages can be summarized as below:

1.Rapid response ability: Agricultural drones can enter the field immediately after rain to execute spraying tasks, and can work at night;

2.Agricultural drones can achieve equal speed, equal height, equal row spacing, and equal flow during spraying operations in farmland, without over-spraying or under-spraying, more uniform, and more efficient;
3.Agricultural drone operations are not restricted by terrain, and the terrain-following flight mode can perform operations in various complex plots;
4.Agricultural drone spraying has good atomization, and crops can absorb the effective components of pesticides faster. When using agricultural drones for plant protection, pesticide utilization can be provided, and the situation of pesticide falling to the ground can be reduced;
5.Agricultural drone operations do not crush the ground, which can effectively avoid damage to crops by large machinery, so that increased yield can be achieved, and also avoid damage to pipes and avoid the spread of pathogens through machinery;
On the basis of aerial application of potatoes conducted by agricultural drones, combined with high-resolution multispectral field scouting drones, it is also possible to realize the monitoring of potato field leveling, seedling recognition, pest and disease monitoring, precise variable nutrient solution, and accurate spot spraying of insecticides.
Uneven field terrain can cause uneven irrigation and fertilizer distribution, increasing management difficulty. By using a drone to conduct aerial surveys of potato planting plots, a digital elevation model of the plot can be generated to measure the height difference within the plot, identify local high and low areas, and promptly rectify them. Or the land leveling project can be accepted to ensure that the land levelness reaches the acceptance standard.

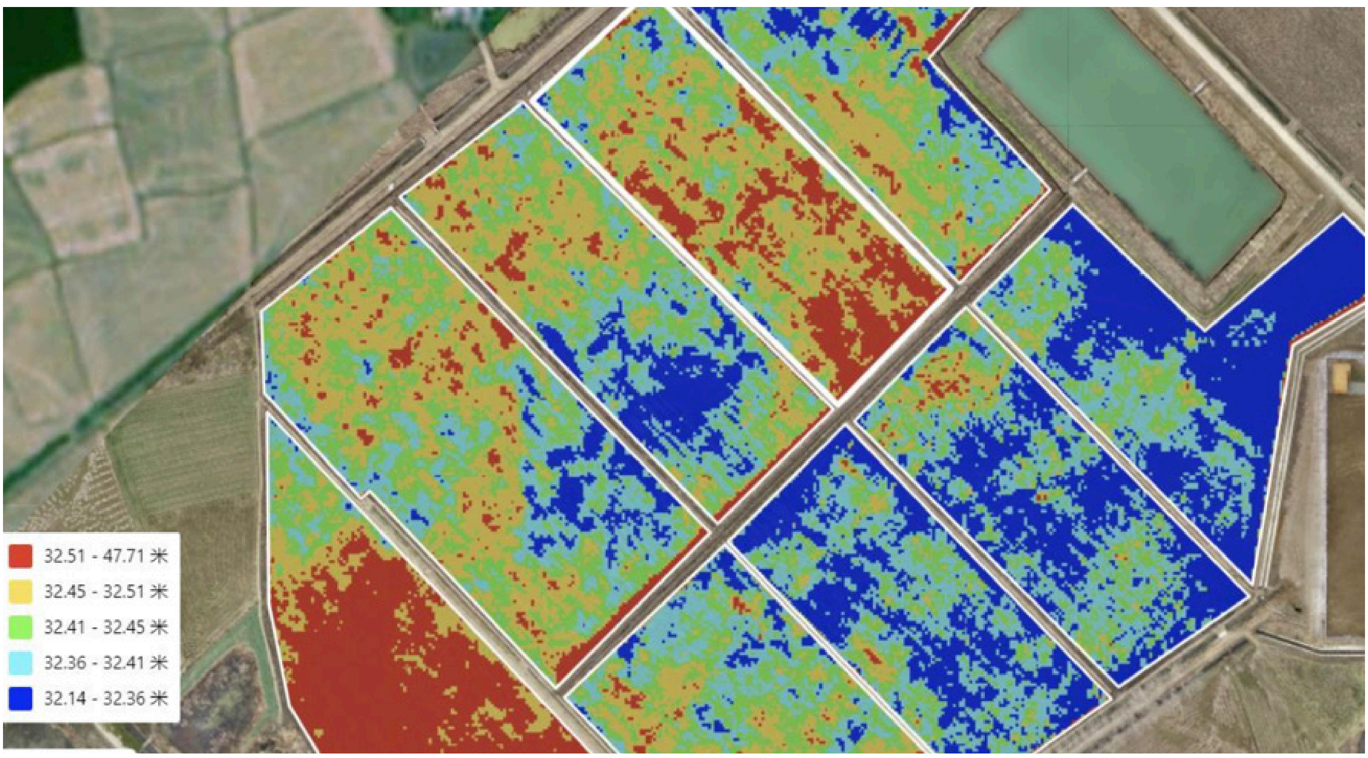


Figure 26: Field prescription map generated by multispectral drone

Uneven field terrain can cause uneven irrigation and fertilizer distribution, increasing management difficulty. By using a drone to conduct aerial scouting of potato planting fields, a digital elevation model of the field can be generated to measure the height difference within the field, identify high and low areas, and promptly rectify them. Or the land leveling project can be examined to ensure that the land levelness reaches the acceptance standard.

In the past, pest and disease surveillance in potato fields highly relied on manual field inspections by selecting sample points for inspection. However, this method has limitations as the inspected area is limited, making it easy to overlook affected areas. Additionally, manual field inspections are time-consuming and can also lead to the spread of diseases and pests during the inspection process. Conversely, drone surveillance of potato fields can capture the canopy without contact, flying at a much higher speed than manual inspections and covering the entire field, significantly increasing the chances of early disease detection. For high-risk diseases such as late blight and early blight, early detection and prevention can reduce yield losses. The method for drone detection of pests and diseases involves setting up automatic flight and shooting routes for the entire field, conducting high-density sampling and photography, and inputting the photographs into a pest and disease recognition AI model to automatically monitors diseases and pests, and presents their locations and severity levels to the management team through the software.

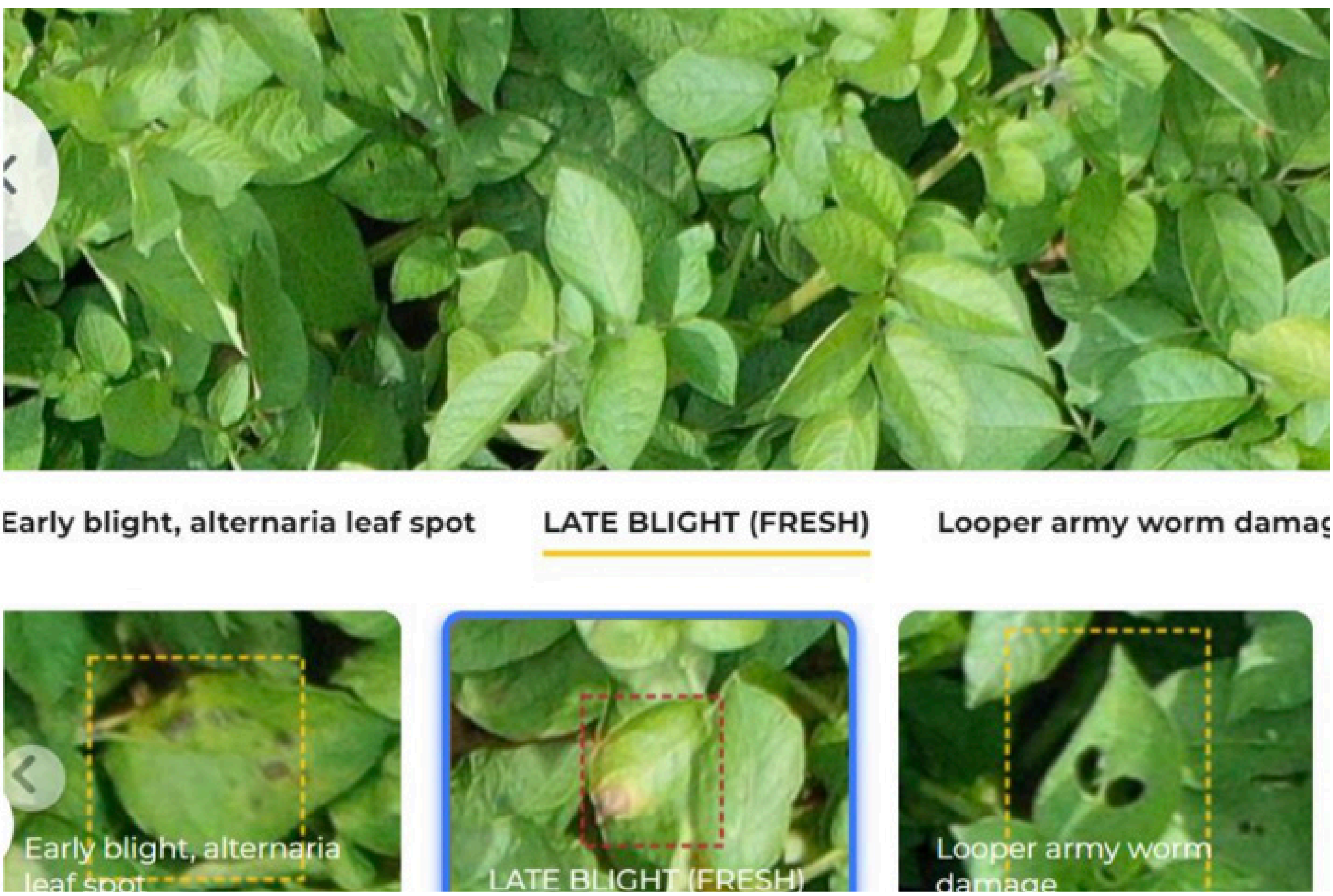


Figure 27: Pest and disease monitoring photo by drone field surveillance

Combining the hotspots of pests and diseases detected by the drone, a spot-spray prescription map can be generated and sent to the agricultural drone for spot spraying. Compared to traditional full-field spraying practices, significant savings in pesticide use can be achieved while still ensuring effective disease control. In 2022, a large-scale potato farmer in Washington State utilized the DJI Mavic 3 Multispectral Drone and AgroScout's[5] pest and disease monitoring and prescription map software to monitor and spot-spray Colorado potato beetles. By conducting spot spraying on a 60-hectare field, an 80% reduction in insect damage was achieved while maintaining the same level of disease control.

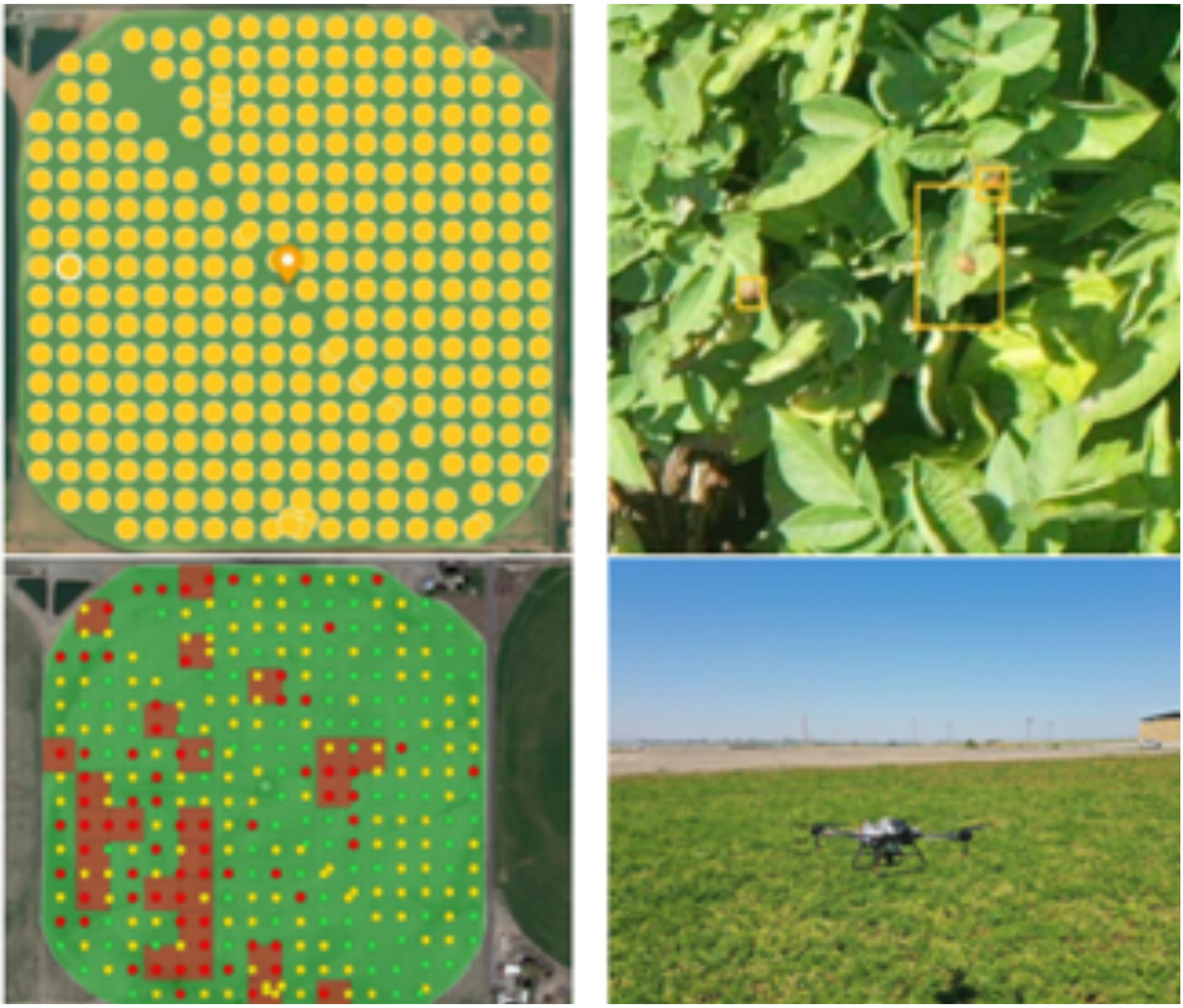


Figure 28 Spot-spray prescription map generated by
DJI Mavic 3 Multispectral Drone

[4]See:https://agro-scout.com/

In addition to precise spot spraying for pests and diseases, drones can also monitor the overall growth of potato fields and conduct variable spraying of nutrient solutions. By using a multispectral drone for aerial surveillance, a full-field vegetation index map, such as the NDVI (Normalized Difference Vegetation Index), can be generated, reflecting the overall growth of the field and in-field variations. Based on the NDVI index, a variable nutrient solution prescription map can be generated, targeting specific areas for treatment, adjusting growth variations, saving costs while increasing yields.

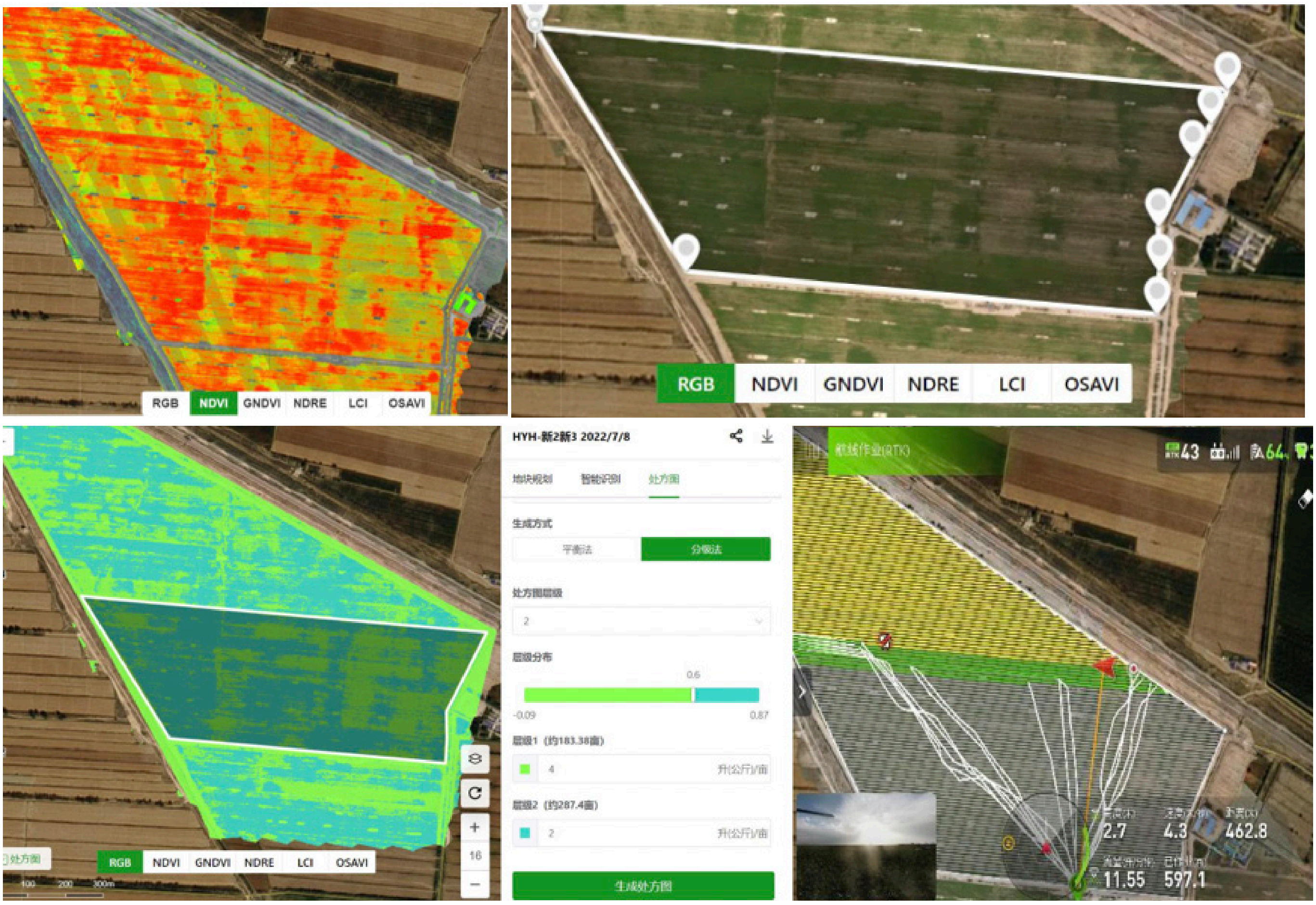


Figure 29 Full-field vegetation index map and NDVI prescription map

4.3.2. Precision Farming in Rice Cultivation

When it comes to rice in Japan, the super-premium Koshihikari rice is considered the best representation of authentic Japanese food culture. However, Koshihikari rice is a low-yield rice variety which easily suffers from lodging and diseases. As an affordable alternative to Koshihikari rice, Hoshijirushi rice has higher resistance to diseases as well as higher yield.

[6] 见：https://agro-scout.com/

One of the important producing areas of Hoshijirushi rice is Kaizu Town of Kaizu City in Gifu Prefecture, which is located in the central part of Japan. With the majority of rice producers within the area being agricultural corporations, the annual revenue of local agricultural produce is estimated to be 5.2 billion yen (37.9 million USD), of which rice accounted for a quarter.
As the fertilizer is usually sprayed evenly on a large scale, rice producers often encounter the following pain points:
1.Over-fertilization occasionally happens when fertilizer is spread evenly on the entire field, which might cause nitrogen burns on seedlings, crop lodging in later stage, decrease in rice quality, and waste of fertilizer.
2.If conducting variable-rate fertilization with prescription maps generated from satellite imagery, the quality of operation will be highly dependent on quality of satellite imageries, which is unpredictable due to weather conduction, revisit frequency, and low resolution.
3.During the mature period of crops, top-dressing with traditional agricultural machinery like tractors could cause severe damages to the plants when moving in the fields.
4.Traditional agricultural machineries might be trapped by the muddy soil during or after the rain.

Figure 30: Japanese Koshihikari rice

Figure 31 Japanese plant protection team using DJI agricultural drones

To solve the aforementioned pain points, DJI Agriculture Japan teamed up with Yanmar and a local rice producer to conduct variable-rate fertilization from July to November of 2022, which proved that variable rate fertilization conducted by agricultural drones can reduce 6332.5 yen/hectare (46.25 USD/hectare) of fertilizer cost and increase 1942.5kg of yield per hectare. With the average price for rice in Japan being 559 yen/kg (4.1 USD/kg), the total savings and earnings per hectare exceed 775,000 yen/hectare (5425 USD/hectare).

The successful fertilization consists of the following procedures: land survey with DJI Phantom 4 Multispectral drone, image processing and reconstruction with DJI Terra and variable-rate precision spraying with T30 agricultural drone. The next sections will introduce the operation and parameter settings from an all-around scope.

a.The Pain-point Killer: DJI Multispectral Drone & T30

By preparing two fields with similar size, DJI agriculture team partnered with Yanmar to conduct fertilization operation on fields provided by local rice producers. To validate the effectiveness of land surveying conducted by DJI multispectral drone and variable-rate fertilization with the agricultural drone, fertilizer amount and yield of two experimental fields after the operation were to be compared.

In terms of how the drones work in the specifically, the first step was to conduct a land survey with the DJI P4M drone. After uploading the land survey data to DJI Terra, a prescription map was generated. Based on the prescription map, Yanmar operated the DJI T30 drone to conduct fertilization operations. We will walk through the entire experiment in the next section.

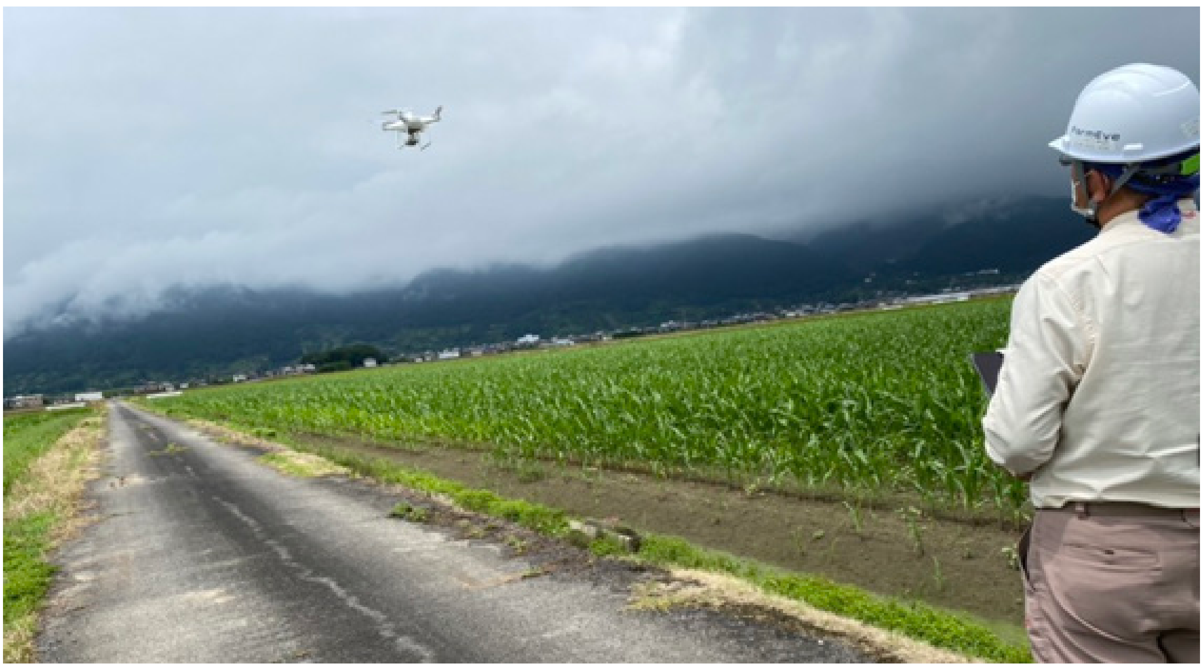


Figure 32 Field survey with DJI multispectral drone

b.Experiment Procedure Overview

DJI Agriculture Japan set up two experimental fields. The size of the variable-rate fertilization field was 3.11 hectares while the size of the fixed-rate fertilization field was 3.43 hectares. Both fields were spread with MIX20, a compound fertilizer with 20% of nitrogen contained. The top-dressing process was conducted with an agricultural drone at an operation height of 2 meters at the speed of 18-22 km/h, with a width of furrows for sowing of 7 meters.

Step 1: Land Survey with DJI multispectral drone and Image Reconstruction with DJI Terra
The first step was to collect multispectral images with a DJI P4M drone. Then, upload the image to DJI Terra for image reconstruction, prescription generation, and flight mission planning for agriculture drone.

Figure 33 Image Reconstruction with DJI Terra

Step 2: Precision top-dressing with DJI T30 Agricultural Drone
Upon completion of image reconstruction and route planning, start the precision top-dressing operation with T30 agricultural drone for both pieces of fields after setting up the parameters below.
Variable-rate fertilization operation parameters (Field A):

Variable spray rate	Good growth rate: 75 kg/ha Average rate: 100 kg/ha Poor growth rate: 125 kg/ha As a result, the application rate will be in the range of [75, 125]kg/ha with an average of 100kg/ha
Flight speed	13.8 km/h
Spinner speed	700 rev/min
Flight altitude	2 m

Table 1 Variable-rate fertilization operation parameters

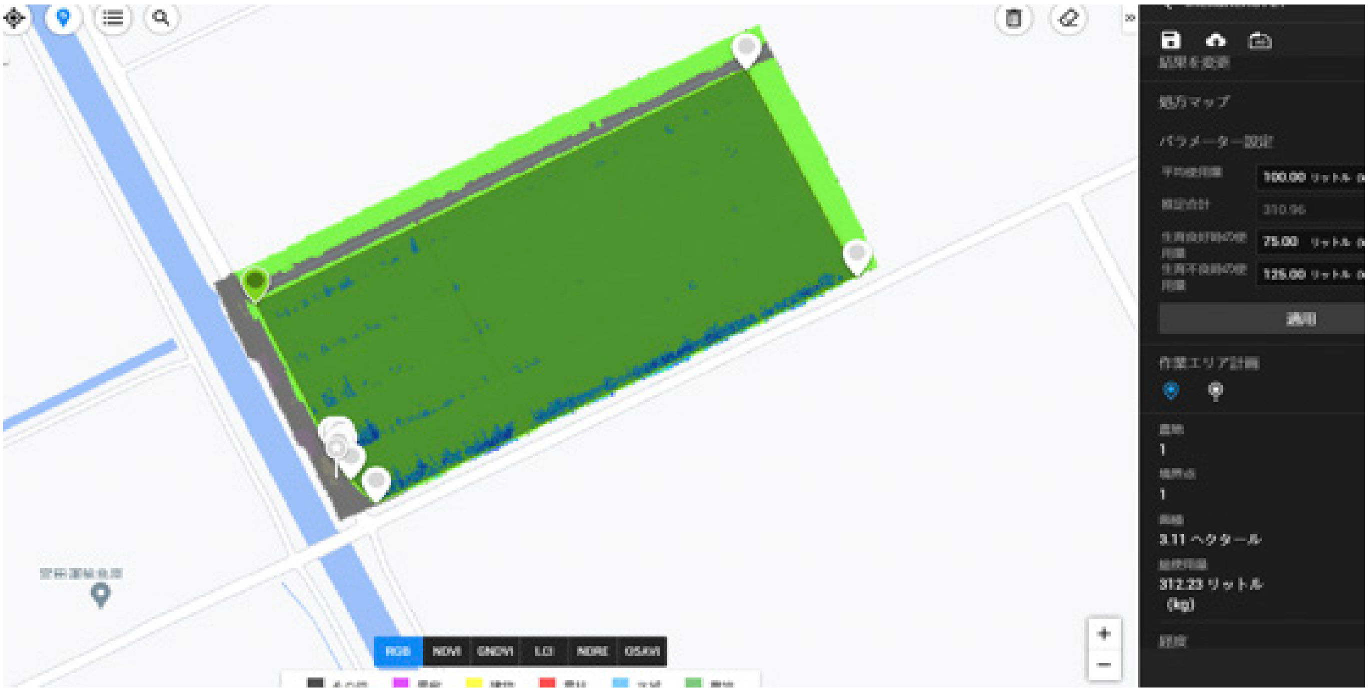


Figure 34 Variable-rate fertilization field

Maximum spray rate	100.1 kg/ha
Flight speed	25.2 km/h
Spinner speed	700 rev/min
Flight altitude	2 m

Table 2 Fixed-rate fertilization operation parameters (Field B):

Figure 35: Fixed-rate fertilization field

As the initial prescription map shows, the rice grown in the variable-rate field (Field A) is in a poorer and more uneven condition compared to its fixed-rate counterpart (Field B).

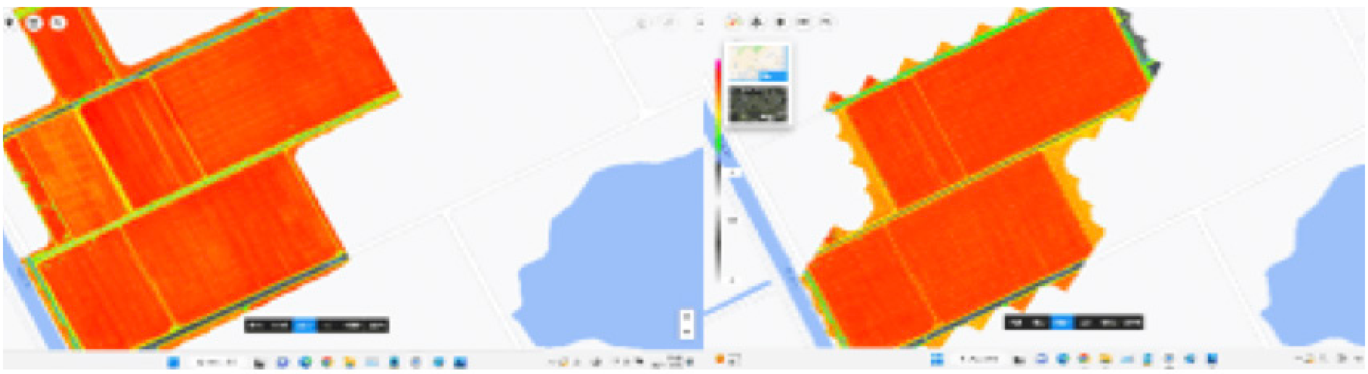


Figure 36 Left:Variable-rate fertilization field,Right:Fixed-rate fertilization field

However, the data collected on the harvest date shows that Field A produced 8% more rice than Field B, while Field A was applied with only 80% of the fertilizer amount used in Field B.

Parameters	Field A	Field B
Actual Fertilizer Amount	(Variable-rate fertilization)	(Fixed-rate fertilization)
Actual Fertilizer Cost	302.8 L	371.9 L
Yield	22296 JPY/ha	24829 JPY/ha
Harvest Date	31591 KG → 10157.88kg/ha	32176 KG → 9380.76kg/ha

Table 3 Multi-Indicator Comparison Table

Therefore, the variable-rate fertilization method proved to be effective, not only fixing the previously existing problems of Field A, but also significantly increased yield with less fertilizer, even exceeding that of Field B, which was in better condition in the beginning.

Two weeks after the variable-rate top-dressing operation, it can be observed that colors in the field on the RGB light, NDVI and GNDVI images tend to distribute more evenly. The reason behind is that the P4M identified the growing difference in the field accurately, thus providing guidance for the T30 to conduct precision top-dressing to enhance the growing uniformity and yield of rice in the same paddy field.

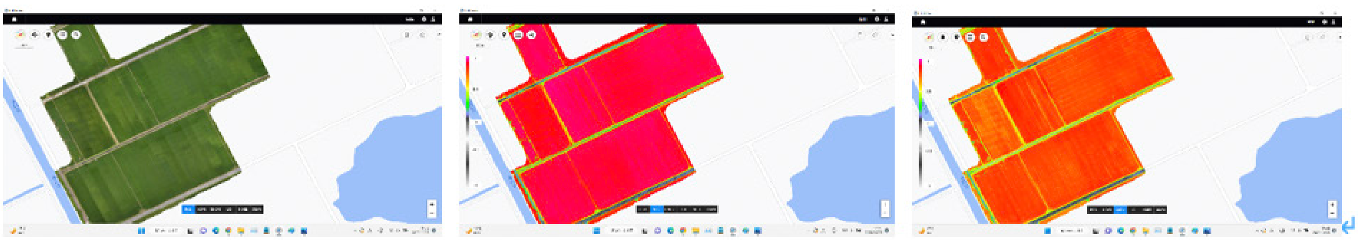


Figure 37 Before the operation

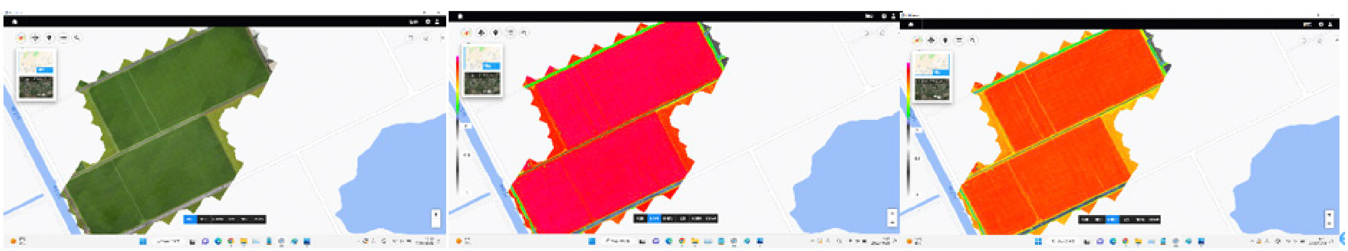
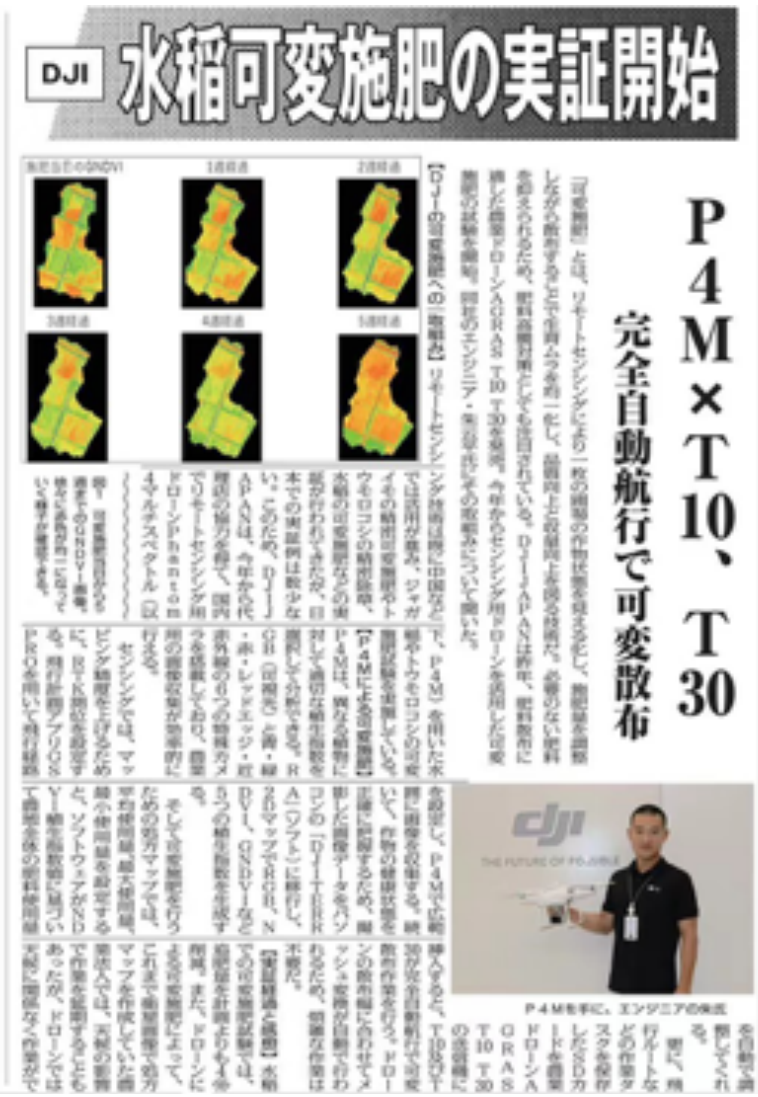


Figure 38 Two weeks after the operation

From an economic perspective, the actual fertilizer amount used in variable-rate fertilization fields is less than the estimated amount, which improves the utilization rate of fertilizer and lowers the potential loss due to over fertilization. While saving 6332.5 yen/hectare (46.25 USD/hectare) of fertilizer cost, the yield increased by 1942.5 kg/hectare.

"Less is more" should not be considered merely an interpretation of minimalism in Japanese culture. As a matter of fact, the ideology now thrives in agriculture by bringing more actual outcomes with less input. The application of technologies like agricultural drones makes it possible to grow more with less, which have been demonstrated by a growing number of successful case studies.

The application of DJI agricultural drones in top-dressing for paddy fields can lower the use of fertilizer and prevent loss caused by over fertilization. As population aging becomes a prevalent phenomenon in the country, agricultural drones can minimize physical strength required in daily operations, making agriculture an industry with higher inclusivity for the senior group. Meanwhile, agricultural drones can solve problems existing in traditional agricultural machinery operation, including crop damage during mature periods of crops and spatial limitations in rainy days.


DJI 水稲可変施肥の実証開始

P4M×T10、T30

完全自動航行で可変散布

Figure 39 Report from local newspaper

4.3.3 Improving Soybean Yield with Spot Weed Treatment [6]

Agriculture could be the most inefficient industry, but still with a trend of an increasing number of innovations. A farm in the Midwest, USA, adopted a spot spraying solution this season with DJI drones and Agremo AI weed detection to precisely target weed infestation.

Weed management is an almost mandatory part of a farmer's life. On a normal corn soybean rotation farm, studies show that controlling volunteer corn could prevent a 15% and 60% yield loss from individual and clumped volunteer corn, respectively. Furthermore, the farmer saved money by opting for spot treatment instead of a blanket treatment. By using drone imageries and Agremo's weed detection function, 3.75 acres of individual volunteer corn and 6 acres of clumped corn infestation was found in this 64-acre soybean farm. The farmer then flew DJI's spraying drone, T30, to spot treat these volunteer corn. As a result, he only used 60% of herbicide, and his crops were spared losses due to driving. In the end, the farmer saw a 68.39% boost to his income by opting for spot treatment over flat treatment.

These results validated the technical feasibility and economic return of mapping + AI analyses + spot spraying for precise treatment in agriculture.

Corn, followed by soybean, is a standard crop rotation in many parts of the US. However, corn kernels dropped during harvest can germinate in the next season and compete with soybean. Volunteer corn is problematic as it robs soybean of nutrients, sunlight, and water and can reduce yield. Volunteer corn is more competitive than any other weed, and more and larger plants increase soybean yield losses. One volunteer corn plant per 10 square feet reduces yield by 8% to 9%, and one corn per square foot reduces yield by 71%.

If growers allow volunteer corn to grow large, they require more herbicides to control them. Volunteer corn also attracts rootworms, which can become a problem for the next season's corn crop. If untreated with additional herbicides, glyphosate-resistant volunteer corn can't be controlled by Roundup used for soybean weeds, and the chances of resistance buildup can increase.

Figure 40 Volunteer corn in the soybean field

[6] Improving Soybean Yield with Spot Weed Treatment https://www.agremo.com/improving-soybean-yield-with-spot-weed-treatment/ (Agremo official website: https://www.agremo.com)

Traditionally, growers used tractors fitted with sprayers for whole-field post emergence spraying, swelling the cost of treatment. Moreover, the tractor's movement caused soil compaction, reducing yield per acre. Since it is necessary to travel in opposite directions to avoid shadows of sprays and improve herbicide application around and on weeds, growers were driving more, resulting in more damage to their crops.

3.1 How DJI and Agremo Approached the Challenge

Drones offer solutions for both field scouting and spraying. As a result, not only crop loss due to soil compaction and crop destruction can be avoided, weed infestation can be treated precisely with spraying drone's spot spraying capability. DJI's partner, Agremo, offers a key function in this precise spraying solution – Weed Detection Analysis. This analytical tool can precisely identify the exact location, extent, and degree of weed infestation, and prepare an AGRAS drone spraying map, using the crop insights from the analysis, allowing drones to make spot Variable Drone Spraying (VDS) applications of herbicides where the weeds are present, instead of the entire farm.

Figure 41 DJI Phantom 4 multispectral drone for field scouting

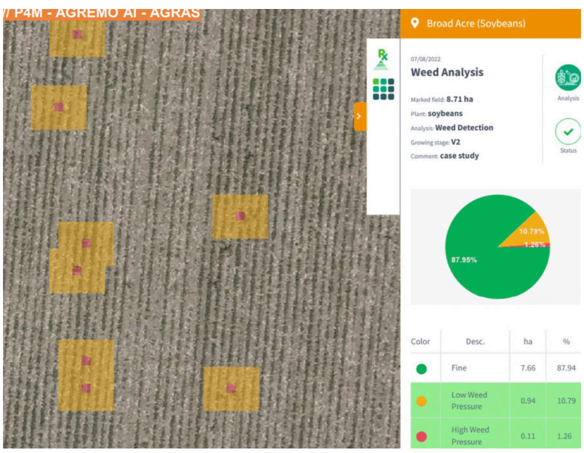


Figure 42: The volunteer corn weed detection result

Figure 43 The DJI T30 AGRAS drone for herbicide spraying

3.2 Farmer’s gains from the Agremo & DJI Service

A farmer agreed to try the VDS application to help in validating the new Agremo-DJI technology. The DJI Agras drone flew and sprayed only the spots where the farmer had volunteer corn in soybean. Of the total 65 acres of farmland, the farmer had 3.75 acres of individual corn and six acres of clumped corn, and if the farmer had not controlled the volunteer corn, they would have suffered a loss of 15% and 60% yield, respectively. See Table 4.

Weed	Weed area (acre)	*Yield reduction %	Yield	Soybean prices (per bushel)	Yield losses
Individual volunteer corn	3.75	15%	(bushels per acre)	$15	($)
Clumps of volunteer corn	6	60%	50	$15	$422
Total yield losses			50		$2,700
Avg yield losses per acre					$3,122

Table 4:Weed infestation areas and possible losses if volunteer corn were not controlled

The expected farm yield is 50 bushels per acre sold at $15 per bushel. The farmer would have incurred a total loss of $3122, $422 due to individual corn, and $2700 due to clumped corn. That would have been a loss of $48 per acre.

With the new technology from Agremo and DJI, the farmer treated only 9.75 acres instead of treating the entire farm with flat spraying rates, saving considerable money. So the increased yield that the farmer obtained by treating the crop was not the only benefit of the new technology.

3.3 Returns on Investment

Using the spot treatment increased the farmers' ROI in two ways:

1. Reducing the amount and cost needed for herbicide treatment.
2. Eliminating crop losses due to driving.

Spraying	Area (ac)	Herbicide cost per acre	Yield lost to driving	Yield loss if not sprayed	Weed	Profits	Profit per acre
FLAT	65	$7.00	$15.00	$3,122	$1,430.00	$1,692	$26
AGREMO & DJI AGRAS	65	$4.20	$0.00	$3,122	$273.00	$2,849	$44

Table 5:Comparison of flat and Agremo-DJI spot treatment costs

The cost of flat spraying the entire field at $7 per acre would have cost the farmer $455, and the yield losses due to soil compaction caused by driving would have been $975 (or $15 per acre). So the total cost to the farmer from flat spraying would be $1430.

AGRAS sprays only those places that Agremo AI identified, so the farmer had to spend only 60% of the herbicides. The cost for the chemicals was only $4.20 per acre or $273 for the entire weed management. Moreover, the yield was higher as there were no crop losses due to driving. So their ROI from spot treatment is significantly higher than from flat treatment.

With a savings of $17.80 per acre, the farmer's ROI from the Agremo-DJI spot treatment was 68.39% higher than the flat treatment! And that is a bottom line hard to beat.

4.4 Spreading Case

4.4.1 Crayfish Feeding

In the process of raising crayfish, the most time-consuming and labor-intensive task is feeding. Crayfish have a large daily feed intake, with feed consumption reaching 5%-10% of their body weight. During the most vigorous growth season, daily feeding per mu can reach 4 kilograms. Crayfish are usually fed twice a day, with feeding times in the morning and evening. When water temperatures are lower during early spring and late autumn, only one feeding per day is required in the afternoon.

The traditional feeding method mainly involves walking in the crayfish pond or rowing a boat into the pond to feed. This method can only cover about 5 acres per hour, and the feed is not distributed evenly.

Figure 44 Crayfish feed

Figure 45 Traditional feeding method

After the T-series spreading system 2.0 was launched, farmers in various regions purchased it to feed their own crayfish ponds, saving time, effort, and money.

Mr. Fang from Zhejiang Province and his 160 acres crayfish paddy:

Mr. Fang lives in Shaoxing City, Zhejiang Province, and has been raising crayfish for 4 years. He is a well-known large-scale crayfish farmer in the area. Feeding crayfish has always been a headache for him. In the past, he hired workers to feed his 160-acre crayfish paddy, and it took 10 people a whole afternoon to complete the task. During the rice planting season, feeding speed is even slower, and rice is easily damaged. Not only does it consume a lot of labor costs, but it's also difficult to find people during the busy farming season.

Figure 46 Crayfish paddy

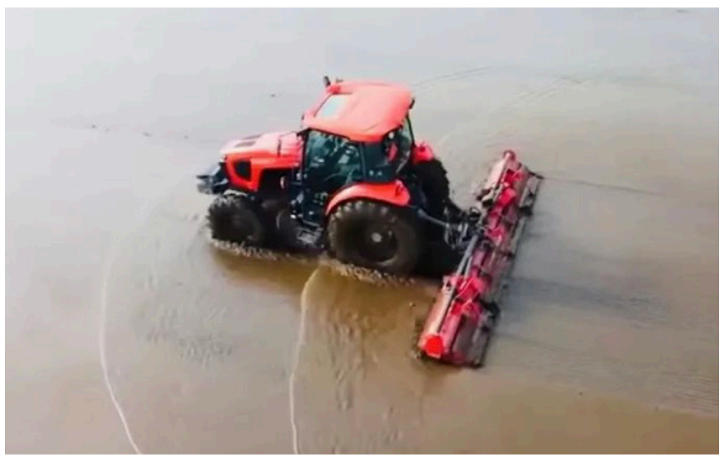


Figure 47 Flattening field operation

Drone spreading has changed his original production method. Mr. Fang spreads feed in his crayfish paddy using a drone. For the first time, he powered up the drone and completed 50 acres of work in just one hour. After that, two spreading machines worked simultaneously every day, and it took less than 4 hours to feed 160 acres.

4.4.2 Aerial Spreading Application for Rice

The application of aerial spreading for rice requires high standards for fields, such as rice fields to be directly spread must be flat, without water accumulation, and the height difference of the field surface should not exceed 3-5 cm. For the rice seed spreading in the fertile black land in Northeast China, it is particularly important to pay attention to the softness of the mud, to avoid the rice seed sinking into the mud after being spread from 3 meters in the air. After the field is flattened, if the rice seed sinks completely into the mud after falling from 3 meters in the air, the field should be sun-dried for 3-5 days until it meets the requirements for aerial broadcasting of rice seeds.

Seed Soaking and Germination Acceleration

Before germination acceleration, rice seeds need to be coated, bagged, and sealed, then soaked in chemicals to kill pathogens carried by the seeds, which increases the germination rate and disease resistance of the seeds. After the soaking and germination process, it only takes about 7 days for the seeds to stay in an intelligent temperature-controlled and water-controlled box, greatly improving the germination efficiency.

Figure 48 Drying Germinated Seeds

After germination acceleration, rice seeds should be spread flat in a cool, ventilated place to dry until no obvious moisture can be felt when holding them in your hand. You can also leave a gap between your fingers, and if the seeds can fall one by one through the gap without sticking to each other, it indicates that they have been dried. If the seeds are not dried after germination acceleration, they are prone to clumping and uneven discharge during template calibration, leading to inaccurate spreading.

In early May, the temperature on the day of sowing operation reached 15°C. The selection of suitable temperature is extremely important for live broadcasting in cold paddy fields, which will affect the survival rate of seeds.

The seeds sowed with T40 on May 12th were evenly scattered on the soil.

Figure 49 The left is 23 days after sowing on June 2 the right is 44 days after sowing on June 24

Figure 50 The 60th day after sowing

23 days after sowing on June 2, each seed can clearly see green shoots starting from the broken chest and white. 44 days after sowing on June 24, the seedlings have begun to thrive.

Farmers said that in the past, artificial sowing was uneven and inefficient, and manual work could reach up to 75 mu of land a day. However, after using agricultural unmanned aerial vehicles to broadcast live, the operating efficiency is 10 times that of traditional machine transplanting, and there is no need to purchase equipment such as sheds and seedlings. , greatly reducing labor and production costs.

4.5 Pollination Application

1. Heading and flowering period of rice

The female parent and the male parent of seed production rice are planted alternately. During the critical period of rice flowering, it is necessary to promote the pollen exchange between the male parent and the female parent through external means. In the past, the work was done manually with bamboo poles, and the daily work efficiency was only 2-3 mu; however, the "catch flowers" operation through the wind field of agricultural drones can reach 100 mu, which is the highest efficiency of manual work. more than 30 times.

2. Pear Tree Pollination

Pear trees are fruit-bearing crops through cross-pollination, that is, they need pollen from different plants to pollinate each other to produce fruit. Therefore, pollination has become an important link in the production of pears. During the flowering period, how to pollinate pear trees with high efficiency and high quality is particularly critical.

In the past, pollination of fruit trees was mainly completed with the help of bees and natural wind. However, with the development of large-scale planting, natural measures alone cannot meet the pollination needs of large-scale planting. In Guang'an City, Sichuan Province, in addition to using bees for pollination, workers were also hired for artificial pollination in the past.

Nowadays, drone liquid pollination is generally used. First, the pollen is dissolved in a special solution, and after stirring evenly, the drone is sprayed at a low altitude to help the pear flower (pistil) complete pollination and fruit setting. Adopting drone liquid pollination technology, the integrated pollination cost is reduced by 2/3 compared to before, which is welcomed by fruit farmers.

Figure 51 drone pollination operation

3. Use drone to shake flowers for fruit trees

In the later stage of concentrated flowering of citrus, withered flowers will accumulate on the leaves and cause botrytis to occur frequently, so the remaining flowers need to be cleaned out of the leaves in time. The current common rocking methods include:

1) Artificial flower shaking, manually grasping the main pole of the fruit tree and shaking it quickly, it is relatively hard, and about 0.66 hectares can be completed every day;

2) Backpack shaking flower blower, with high wind speed and flexible operation, one machine can process 2 hectares per day;

3) Use the drone to shake the flowers, and use the wind field generated by the drone to blow the fruit trees, thereby blowing off the flowers on the leaves, and can treat 10 hectares per day. It can be seen that the use of drones to shake flowers is high in efficiency and low in cost, and it is currently used more and more widely.

Figure 52 Citrus

Figure 53 Artificial shaking flowers

Figure 54 Drone Shaking Flowers and Preserving Fruits

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DJI T50 agricultural drone fruit tree set with 50 kg load and 4 nozzles can solve the problem of fruit growers during the flowering period. During the flowering period, it can be sprayed to prevent thrips, spider mites, botrytis and foliar fertilizers, etc. At the same time, it can also shake the flowers very well, which can be said to kill two birds with one stone, and it is easy to shake the flowers and preserve the fruit.

With the help of drones, fruit growers will choose to shake the flowers 1 or 2 times during the flowering period, during which thrips and spider mites can also be treated. At the same time, it can also save pesticides and labor costs for the control of botrytis cinerea. Since citrus botrytis is one of the main reasons for fruit enlargement and fruit peeling, shaking flowers in the early stage with drones can also improve the appearance of mature fruits and increase income.

By comparing the effects of artificial flower shaking and drone shaking flowers, drone shaking flowers is not only much more efficient than manual shaking, but also has the same or better shaking effect as artificial ones, because the large wind field of drones sticks to the leaves The petals can also be blown off, but it is difficult to shake off the petals stuck to the leaves by artificial shaking.

Figure 55 Comparison of shaking flowers, the left is before shaking flowers and the right is after shaking flowers

Figure 56 The effect of spraying sunscreen on drones

4.6 Spraying of antifreeze and sunscreen for fruit trees

In Guangxi in July and August, the weather is relatively hot. At this time, the citrus is also in the period of rapid expansion, and it is very easy to have fruit cracking. If it encounters high temperature, sun fruit and fruit cracking are very easy to appear, which seriously affects the fruit and the income of fruit farmers.

Orchards usually require workers to work, but workers are hard to find, work efficiency is low, and workers are prone to heatstroke and poisoning in hot weather. Orchards often fail to hire workers or work efficiency cannot keep up, resulting in untimely sun-dried protection and a large number of sun-dried fruits and cracked fruits. The spraying method of agricultural drones is vertical spraying. The sunscreen film formed after spraying the whitening agent can well cover the sun-irradiated surface of the citrus, which can greatly reduce the number of sun-dried fruits and cracked fruits and ensure the income of fruit farmers.

Figure 57 sun-dried fruit

Figure 58 Schematic diagram of two routes

V. Best Practices

5.1 Personnel Training

DJI has established the DJI ACADEMY training brand and has carried out agricultural drone operation training in Thailand, Mexico, Brazil, and Turkey. The healthy development of agricultural drones cannot be separated from the outstanding quality of personnel. It is not only necessary to have a correct understanding of equipment, but also to master comprehensive knowledge of crops, pests, and operation risk control.

In Mexico, training instructors from DJI Academy have promoted standardized agricultural drone operation training for cooperating companies and have conducted multiple technical training sessions themselves. Meanwhile, in terms of user operation safety, they have also conducted multiple online safety operation training sessions, covering drug safety, electric safety, flight safety, and safety regulations.

In Turkey, DJI Academy selected capable instructors from major partners and authorized them as local instructors. They will work with the headquarters to train more qualified instructors, allowing these experienced instructor teams to train more users to operate agricultural drones in a standardized and efficient manner, further deepening the DJI Academy standard training system.

Figure 59 DJI Huifei Academy Training in Turkey

5.2 New Technology Development

Agricultural drones are revolutionizing agricultural production methods in a smarter, more efficient, and safer way.

On November 23, 2022, DJI Agriculture released the T50, T25 agricultural drones, and the Mavic 3 multispectral drone. Two brand new agricultural drones have undergone comprehensive upgrades, with optimizations for large-field spraying, fertilizer spreading, fruit tree spraying, and other application scenarios. They work together with the Mavic 3 Multispectral drone to take agricultural production management to a new height in terms of intelligence, efficiency, effectiveness, and safety.

1.Smarter

Based on crop growth conditions, combined with field prescriptions, agricultural drones can achieve precise variable operations, such as variable fertilization for rice, variable growth regulation for cotton, variable nutrient solution for soybeans and corn.

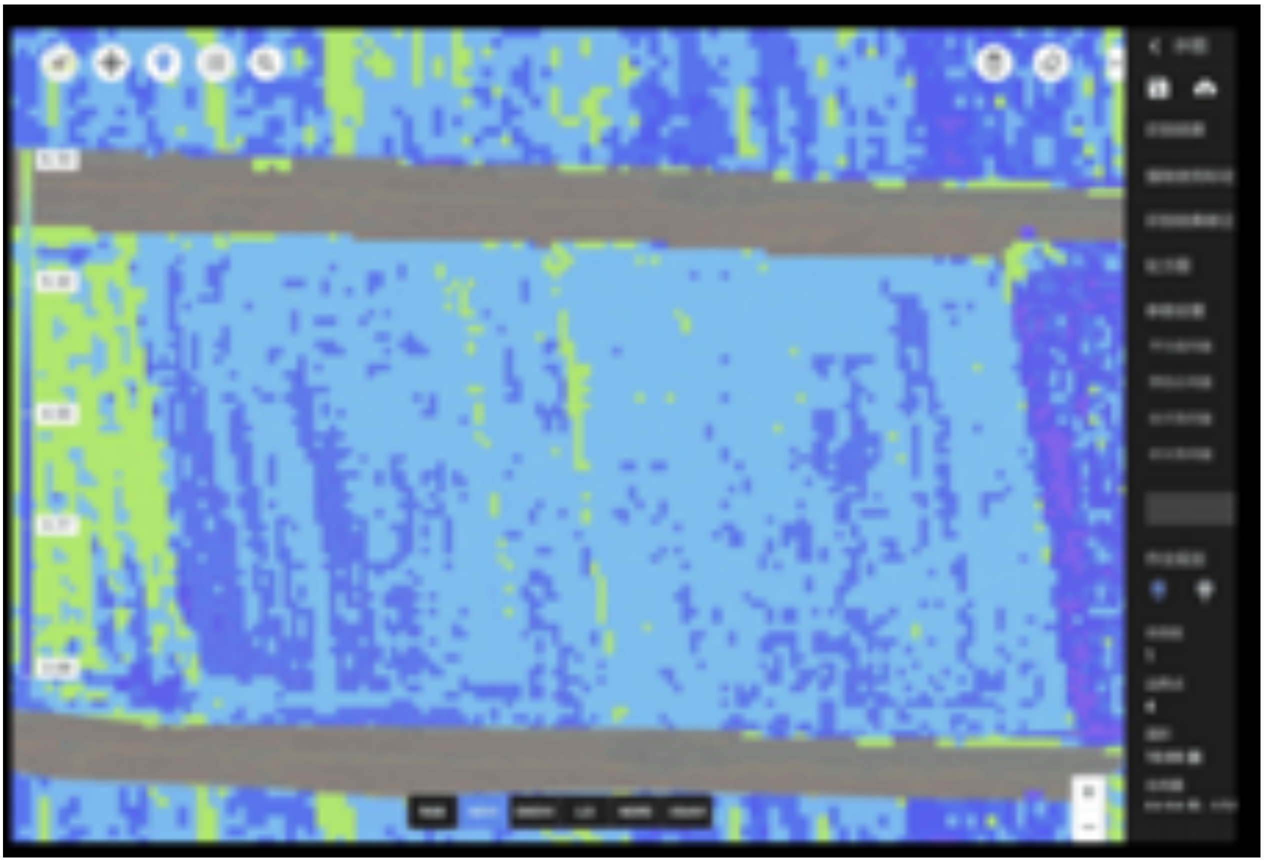

Figure 60 Prescription map for farmland

Through DJI's Smart Agriculture Platform and the new Mavic3M aerial mapping drone, automatic fields patrolling, land levelness monitoring, seedling recognition, and growth analysis can be realized as smart agricultural solutions. The Mavic 3M aerial mapping drone's new imaging system integrates a 20-megapixel visible light camera and four 5-megapixel multispectral cameras (green, red, red edge, and near-infrared). It can achieve high-precision aerial mapping, crop growth monitoring, and natural resource surveys.

Figure 61 Mavic 3M aerial surveying operation

Utilizing the Mavic 3M's terrain mapping of mountainous orchards, combined with DJI's Smart Agriculture Platform or DJI Terra, the orchard high-definition maps can be reconstructed. This method can also automatically identify tree numbers, distinguish trees from obstacles, and generate agricultural drone three-dimensional operation routes, making operations smarter.

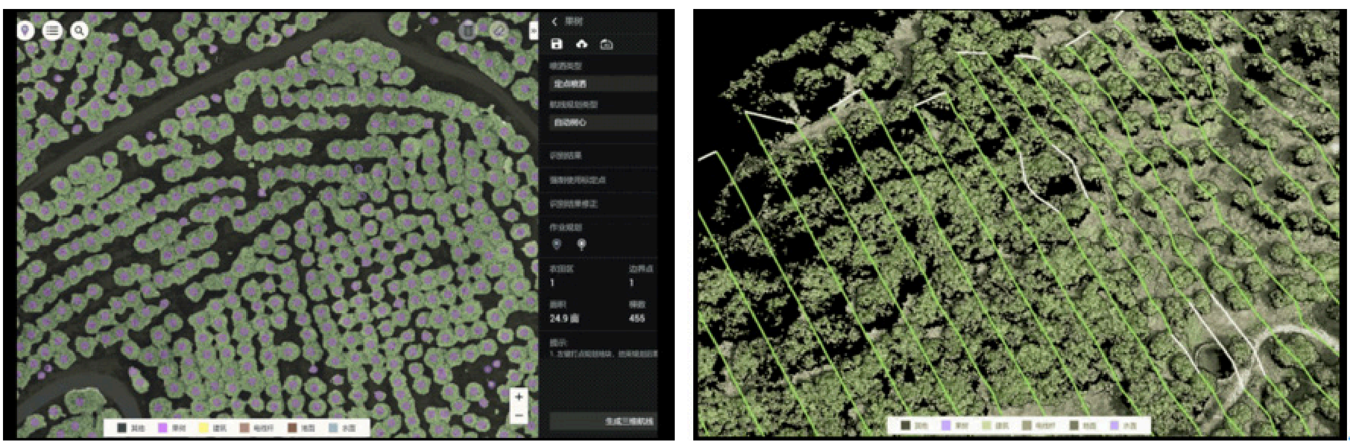

Figure 62 Mavic 3M aerial surveying operation

Since 2018, DJI Agriculture has launched the fruit tree mode. As of 2022, DJI drones have flown over 15 million mu of fruit trees, with equipment holdings exceeding 3,000 units. After years of technological accumulation, DJI Agriculture has provided a fruit tree solution that combines "drone aerial mapping + AI recognition + fully automatic operations" and has verified the effectiveness of drone fruit tree spraying in crops such as oranges, mangoes, and pears.

2.More Efficient

As agricultural drone R&D technology evolves, issues that affect efficiency, such as low load capacity, low flow rate, and slow charging, are constantly being addressed. The T50 agricultural drone has a maximum effective load of 50kg, a maximum water pump flow rate of 24L/min, and a maximum fertilizer spreading flow rate of 108kg/min. In large-field scenarios, it achieves a maximum spraying efficiency of 320 mu/hour and a maximum fertilizer spreading efficiency of 1.5 tons/hour. In fruit tree scenarios, it achieves a maximum spraying efficiency of 72 mu/hour. The power system allows for a 9-minute ultra-fast charge, with two batteries enabling cyclic operation, and a battery warranty cycle of up to 1,500 times.

3.Safer

DJI T50 has been upgraded with 2 sets of active phased array radars and 2 sets of binocular vision systems. The number of radar RF transmission and reception channels has been doubled, extending the detection distance and improving detection accuracy, ensuring safety even in complex and variable operating environments. With the assistance of the two binocular vision systems, the terrain and obstacle details can be accurately depicted. With two sets of phased array radars in the front and rear, 360-degree full-directional obstacle avoidance and intelligent detours are achieved, allowing for fully automatic terrain following operations in steep orchards.

The T50 combines aerial surveying and crop protection into one, equipped with an adjustable super high-definition FPV gimbal camera that can collect real-time images of farmland and orchards. With the intelligent remote control, high-definition maps and flight routes can be generated, obstacles can be automatically recognized, and the drone can take off with one key, enabling safe automatic operations at all times.

5.3 Combination of Pesticide Application Techniques with Drones [7]

1. Proper tank mixing of pesticides

Generally, used water volume on drone application is 15 – 45 Liters / hectare for row crops and some small canopy vegetables. And it is 75 – 300 Liters / hectare for fruit trees. So, drone application belonged to low or very low water volume application. See table 1 for detail classification of spraying volume of pesticides in China. Under such low water volume, it is important to know how to proper tank mixing using pesticides, foliar fertilizers, plant growth regulators and adjuvant. Due to lacking professional knowledge and irresponsibility, every year drone service providers or pilots come across tank mixing issue. In general, the problem is related with physical incompatibility and instability of mixing solution under low water volume [8].

Classification of spraying volume	Spray Volume/Ha (Litter)		VMD (μm) (droplet size)	Nozzle Type
	row crops	Orchard or Forests		
High volume spraying (HV)	>600	>1000	400~1000	Hollow cone nozzle with orifice larger than 1.3mm, or large flow rate of fan nozzle
Middle volume spraying (MV)	200~600	500~1000	225~400	0.7~1 mm small orifice, fan nozzle with middle or small flow rate
Low volume spraying (LV)	50~200	200~500	150~250	0.7 mm orifice, centrifugal nozzle
Very low volume spraying (VLV)	5~50	50~200	80~150	0.7 mm orifice, centrifugal nozzle, twin fluid nozzle
Ultra low volume spraying (ULV)	<5	<50	15~75	Centrifugal nozzle, ULV nozzle

Table 9 Classification of spraying volume for pesticides

Figure 63 Phytotoxicity of citrus leaves caused by tank mixing using (Difenoconazole, thiacloprid, deltamethrin, plant growth regulator and foliar fertilizer)

Figure 64 Poor tank mixing using pesticides

[7]Pamela Wang，Application Technology Group Lead of Drone Task Force of Crop Life Asia; APAC CPDD Drone Application Technology Leader, Corteva
[8]Hui zhu, Yuan Plant Protection Mechaine and Standardization of Application Technology, https://www.gengzhongbang.com/article-194340-1.html

So general understanding of chemicals which you used is necessary for any good drone application practice. Such as, tank mixing requirement and taboo for each pesticide, fertilizer or plant growth regulator and adjuvant, pH value of above chemicals, tank mixing solution stability under extreme weather conditions such as when temperature is higher than 35℃ , whether the products you used are qualified or not, etc. For examples, some inorganic coppers are relative more alkaline, and some antibiotics are more acidic chemicals. Tank mixing these pesticides with other chemicals should be very careful. Calcium fertilizer tank mixing with potassium dihydrogen phosphate (KDP) should not be recommended. In aqueous solution the stability of the two mixture is very poor, and foliar calcium fertilizer is easy to react with potassium dihydrogen phosphate to produce calcium phosphate which is insoluble in water.

To ensure safely and effectively using of pesticide by drone application, there are several good practices you can follow:

1)Always check label and MSDS of the products to ensure you have better understanding of the used chemicals.

2)It is always recommended to do physical compatibility study and physical/chemical stability test before using chemicals on drone application if possible. For example, big companies will do such kind of tests for their pesticides by tank mixing using with representative tank mixing partners in the market. Such test is simple and cheap and would be executable for service providers and pilots. Using proper method to dilute, to tank mixing or to prepare pesticide solution {Source: Drone Operator Toolkit of Crop life Asia}.

3)Proper tank mixing order and procedure are very important to ensure good tank mixing compatibility of pesticides, plant growth regulator, foliar fertilizer, and adjuvants. But many farmers, retailers and service providers did not grasp this basic knowledge and caused some problems. Proper tank mixing order and procedure are:
Fill 1/4-1/3 water and shake evenly. Follow following order to add different kind of formulations. Please make sure the mixtures on-hand are mixed evenly and sufficiently before adding the next chemical. When an application must be postponed, normal agitation is required to re-suspend any material that may have settled before application can be performed. Pesticides need to be used immediately after tank mixing. Do not leave the pesticide solution overnight. Observe the most restrictive of the labeling limitations and precautions of all products used in the mixtures.

SIt is good practice to follow product tank mixing sequence, maintain agitation and spray on the same day. Proper tank mixing order is [Source, Corteva]:
Dry Formulation - Water Soluble Packets (WSP); Water Dispersible Granules (WG, DP); Water soluble granules (SG); Wettable Powders (WP)

uspension Concentrates (SC); Capsule Suspensions (CS); Suspo-emulsion (SE); Oil-in-water emulsions (EW)
Liquid Drift Retardants (polymers, dehydrate)
Emulsifiable Concentrates (EC); Oil Dispersion (OD); Soluble Liquids (SL).
Add Adjuvants (COC, MSO etc.) if needed
Add Micronutrients & Liquid Fertilizers if needed

4)Water quality is critical to the performance of pesticides. There are four main water quality indicators related to pesticide performance. In general, clean water with small hardness and neutral pH are suggested to be used. Such as pond water or ditch water rather than deep well water.
A.Water hardness is caused by positively charged minerals and cations which can bind to some herbicides (glyphosate is the best-known example, also 2,4-D amine) and reducing its performance.
B.Water with pH values between 4 and 7 are considered acceptable. But some herbicides have specific pH needs to dissolve properly. Label directions are important, sometimes calling for specific adjuvants. Some pesticides, particularly insecticides, can break down rapidly in higher pH water.
C.Cleanliness/turbidity. Water may contain suspended solids such as clay. Some chemicals are sensitive to this, as they are readily adsorbed to soil particles, and so turbid water can reduce their effectiveness.

2. Pesticide Formulation and its technical feasibility on drone application

Understanding the attribute of different pesticide formulations is very important to realize safely and effectively using of pesticides. Products with qualified formulations are recommended to be used on drone application. Feasible formulation for crop protection DRONE is chosen for application. Small scale pre-test of spray performance of any new products is necessary.

1)Registration status of pesticides formulation in Japan
1)Japan has well established regulation for drone application. It has more than 30 years development history of radio control helicopter and it changed its well-established RCH regulation to drone application quickly. In Japan, 316 pesticides have been registered by the end of 2020 November, the main dosage forms are: Granule, EC, SC, WDG. And South Korea has also registered 110 kinds, the main formulations are: SC, EC, OD, ME, WDG by 2017.

2)Japanese industry did not proceed herbicide application for broadacre crops except rice due to concerns of drift to surrounding farmland and areas. Only exceptional uses are for burndown of weeds in forest and abundant non-agricultural land. Drift risk and potential phytotoxicity to neighbor fields cannot be avoidable in consideration of normal spray drift risk of spray application by drone. Thus, Japan industry players developed herbicide application with drone only for rice where Into-water application with ready-to-use formulation is the most common method and is unlikely cause drift issue.

3)Herbicide drone application registration is mostly given to rice herbicides. Total 204 herbicide products obtained drone application registration for rice (Granular formulation: 141 products, SC formulation: 61 products, EC formulation: 1 product, EW formulation: 1 product.

4)There are only 2 drone registration is granted for herbicide outside of rice. Exceptional drone application registration is given to Glyphosate (Round-up MxLoad) for weed burn down in non-agricultural area after North-east Japan Great Earthquake. Another formulation of selective herbicide (fine granule) is registered for weed control in forest.

5)There are 2 types of ready-to-use rice herbicides:
A.Granule (solo or mixtures up to 4 components) to be broadcasted into water. 10 kg/ha is most common product dose per ha. Drone machine can equip a special attachment to spread or drop granules without too much drift risk
B.Liquid (SC, EC, EW etc) to be dripped or spilled into water without dilution. Formulation is developed specifically to improve spreadability in water. All liquid formulations may not be adaptable to such into-water application due to phytotoxicity risks or performance issue caused by poor spreadability. This application method requires fully flooded condition (3-5 cm submerged condition). Herbicidal performance may not be achieved if paddy field is not fully flooded. Drone application can be done by special nozzle to splash gently into water without dilution.
C.For both GR and Liquid formulations, drift risk can be minimized as fine particle may not be applicable during application.
D.You can see actual demonstration of 2 different kinds of formulation/application by drone[9]:
a.Demo of drone application of granule rice herbicide: https://www.youtube.com/watch?v=bQOe_x-YJZI
b.Demo of drone application of liquid rice herbicide: https://www.youtube.com/watch?v=l9WoZT89N9k

[9]Source: Hashino Yoji SGSG from Syngenta and CLA, https://www.youtube.com/@syngenta-japan, https://www.youtube.com/@HaradaFarm

2) Feasibility of pesticide formulation is closely related with different spray nozzle of drone application.

A.Types of Atomization System

There are two different kinds of spray system in general: hydraulic energy nozzle and pump and centrifugal nozzle and related pump like peristaltic pump or magnetic drive impeller pump. XAG and EAVISION are all using centrifugal nozzle and related pump. But DJI using both two kinds of atomization system. At the beginning of several years, DJI equipped hydraulic nozzles on their drones, while DJI changed to centrifugal nozzle on their new generation drones such as T40, T50. Nowadays, centrifugal nozzle dominant China market.

B.Rotated Centrifugal nozzle

The droplet size of centrifugal nozzle can be adjusted, it can realize very coarse droplet size like T50 with droplet size can be adjusted from 50μm to 500 μm. So, you can choose coarse droplet size to do herbicide application by adjusting the rotating speed. It is more appropriate to be used on herbicide application compared with hydraulic nozzle because the size of the droplets was relatively uniform.

C.Hydraulic energy nozzle

Hydraulic atomization is especially suitable for spraying water-soluble preparations and is the most used atomization method. The atomized particle size is mainly affected by the nozzle pressure, nozzle type and orifice.

Droplet size is a broad range for such kind of nozzles. For example, it is ranged from 100-250μm for commonly used XR11001VS and XR110015VS. The commonly used hydraulic energy nozzle are flat fan nozzle and hollow cone nozzle in China. AIXR, AI, TF, TT such anti drift nozzles can create coarser droplet size compared with XR nozzles. But these nozzles like IDK has much narrower spray swath that is meant low work efficiency. So, IDK or related anti-drift nozzle are not commercially used due to its low work efficiency. Work efficiency is the big barrier to limit anti-drift nozzles to be used by service providers. Narrow spray swath caused low work efficiency of anti-drift nozzle, that is why flat fan and hollow cone hydraulic nozzle, and centrifugal nozzle are broadly used in China.

VI. Detailed explanation of wrong application

1. Mistake 1: Spraying herbicides in unsuitable areas

Many chemicals have some drift characteristics, especially herbicide products. Therefore, when spraying herbicides, attention should be paid to whether there are sensitive crops around, so as to avoid drifting and affecting the growth of surrounding crops. For example, from February to March, winter wheat and rapeseed co-existed on the arable land of the capitals of Hubei and Sichuan provinces in China. If the wheat was weeded, the liquid would drift onto the rapeseed, which would cause the rapeseed to wither or even die completely.

2. Mistake 2: Spraying pesticides near bees and mulberry trees

Chemical pesticides have a certain impact on the activity of bees. In particular, the widely used neonicotinoid insecticides (imidacloprid , thiamethoxam[11] , etc.) have a strong killing effect on bees, and special attention should be paid to whether there are bee breeding activities around the spraying of such pesticides. Other chemicals should also be based on the product label requirements, after confirming the degree of impact on bees, and then formulate the application plan and the window for the timing of bee release.

In 2022, the insecticide imidacloprid was sprayed in a banana orchard in Guangxi, causing the loss of 246 boxes of bees to nearby mobile bee farmers.

In areas where there is a bee breeding industry, before operation, you should check with the person in charge of the cultivated land whether there is bee breeding within 3 kilometers around, and if there is, operation is prohibited. Or confirm with the beekeepers, and then work after transferring in advance. For areas where mulberry trees are planted downwind, spraying pesticides is strictly prohibited.

3. Mistake 3: Use high speed or coarse droplets for fruit tree operations

Fruit trees are characterized by taller plants, thicker canopies, and less penetration. Therefore, when using drone operation parameters, the principle of "higher dosage per hectare, lower speed, and finer droplets" should be adhered to. The faster an agricultural drone is, the less penetrating the fog droplets will be to the crop.

[10] See:https://en.wikipedia.org/wiki/Imidacloprid
[11] See:https://en.wikipedia.org/wiki/Thiamethoxam

The common operating speed should be around 1.5-3 m/s. Some pilots who are accustomed to working on field crops often do not know the specific requirements for fruit tree operations, and use the common field operation per mu and the speed of 6-7 m/s to work on fruit trees. This kind of operation not only has poor effect and reduces the reputation of drone spraying, but also makes it difficult for pilots to follow up with commercial promotion.

Figure 65 Fruit tree operations require higher dosage and finer droplets to ensure the effect

At the same time, fruit trees are luxuriant and need more mist droplets to improve the operation effect, so finer mist droplets should be selected. For T20/T30 and other models with standard pressure spraying system, the standard nozzle should be selected, and it is not recommended to replace the 015 and 02 nozzles. For T40/T20P models with centrifugal nozzles, the droplet size can be adjusted, and it is generally recommended to use finer droplets to improve the operation effect.

4. Mistake 4:The obstacle area adopts a flying height of more than ten meters

here are many wires in some areas, and some pilots fly directly to a height of more than ten meters for safer flying. After the liquid is sprayed, it takes a few seconds to reach the crop surface. If the ambient temperature is high and the wind speed is high, then this operation method will cause problems such as a large amount of liquid evaporation and drifting with the wind. In the end, most of the liquid cannot be effectively deposited.

Therefore, it is not advisable to fly too high for safety, and the operation effect is not guaranteed.

5. The line spacing of weeding or chlormequat[10] is set too wide

When using foliage herbicides and growth regulators, the requirements for operating parameters are relatively high, and it is easy to cause problems of heavy spraying or missed spraying. If the line spacing is set too wide, the phenomenon of stem and leaf herbicides will be that the killing effect of weeds at the junction of the routes will be poor. From the observation of the field, it is easy to produce high undulations for chlormequat spraying operations.

Figure 66 Wavy growth caused by uneven spraying of chlormequa

[12] See:https://en.wikipedia.org/wiki/Chlormequat

For herbicide or chlormequat operations, the recommendations are as follows:

For T20 models, the recommended height is 2.2-2.5 meters, and the row spacing should be controlled within 5.5 meters;
For T20P models, the recommended height is 2.5-3 meters, and the row spacing should be controlled within 5.5 meters;
For T30 models, the recommended height is 2.5-3 meters, and the row spacing should be controlled within 6 meters;
T40 model, the recommended height is 3-3.5 meters, and the row spacing should be controlled within 7 meters.

-Epilogue-

In the thousands of years of human civilization, the spirit of agriculture has always been present.

The emergence of the agricultural drone industry signifies the continuation of this agricultural spirit.

Today, agricultural drones are gaining popularity worldwide.

We believe that agricultural drones can enhance agriculture through the integration of technology, revolutionizing agricultural practices and ultimately embrace Better Growth and Better Life.