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Agriculture

APPLICATION OF DRONE USED FOR RICE PRODUCTION IN CENTRAL THAILAND

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ABSTRACT

The aims of this study were to study the application of drone used for rice production in Central Thailand. The research was conducted by collecting data from 60 farmer who used drone for rice production in central of Thailand. The samples were selected by purposive sampling methods. The data were analyzed by frequency, percentage and mean. The results showed that most of farmers are 51 years old and have experience for rice cultivation is approximately 21 years. Most of farmers graduated from elementary school and own farmland. The farmers grow rice on approximately 45 rai per farm. The popular rice's varieties were RD43 and Thai Pathumthani Pragrant Rice. Farmers have problem of high cost of fertilizer and equipment. Moreover, they lack of marketing knowledge. They used drone roughly 1.5 years for chemical spraying (fertilizer, insecticide herbicide and plant hormone). The advantage of using drone are safe working time, safety for farmer, comfortable since farmer do not need to carry the chemical, reduce the loss according to stepping in the field of labor while spraying by human, reduce amount of chemical and higher efficiency. Drone can increase the productivity of rice by 15% and reduce chemical by 35%. However, drone had the disadvantages as follows the efficiency is not stable. The efficiency will be depended on the experience of service provider.

Keywords: drone, rice production, agricultural management

Introduction

Agriculture in Thailand was worth $31.6 billion and accounted for 8.5% of national GDP, in 2016. In 2016, Thailand was initiative introduced Thailand 4.0 policy by government which aim to transform the economy target growing farmer's income to be higher than before. One of the major cash crops in Thailand is rice. Also, rice is the main dish for Thai. Moreover, rice is important for Thailand's economy, since it is the major agricultural export product of Thailand. The cultivation area for rice in Thailand occupies 45.2% of all farm land for a total of 43 million rai. Thailand ranks 6th in the world in terms of the total production of milled rice. The rankings of the countries producing rice are China, India, Indonesia, Bangladesh, Vietnam, and Thailand. The percentage of global production is 29.3%, 23.1%, 7.5%, 7.1%, 5.6%, and 4.2%, respectively. However, in terms of exports, Thailand is in 2nd place. The number one in exports is India, which has a 25.2% market share, Thailand has a 21.0% market share. The competitors for export markets are Vietnam, Pakistan, the United State, and Myanmar. (Krungsri Research, 2020)

In Thailand, drone's company was pioneered introducing by DJI in 2015, which is Chinese company. Then, other manufacturers followed suit (Chiangraitimes, 2019). Thailand is the first country in Southeast Asian that use agricultural drones to sue the machines to deal with the worker shortage in the farming sector. Agricultural in Thailand mostly are small-scale farms (half-hectare or 3.125 rai). Drone for agricultural in Thailand could be interesting option because Thailand is transfer to era of Agricultural 4.0 that is marked by the deployment of advanced technologies and innovations to enhance production efficiency. If Thailand adopts drone technology together with Thai government policy of

Big Farm, the production costs nationally can be reduced by THB 1.1 billion. This estimate is based on an assumption that there will be 1,512 rice farms taking part in “Big farm” pilot program (Kasikorn research, 2017). Today, Thai farmers are increasingly using agricultural drones to sow seed, spray fertilizers and pesticides and survey fields. In order to adopts the technologies, the cultivation efficiency and be improved and the production cost can be reduced. Thailand’s rice production efficiency is quite low compared to other countries including Vietnam, Pakistan, Myanmar, China, and India (SCB Economic Intelligence Center, 2020). Moreover, the farming demographic is ageing. Therefore, drone is a crucial tool to solve the labor shortage, increase the efficiency, reduce production cost, and possible to get attention from the new generation to work in agricultural sector (Bangkok Post, 2018). Therefore, this research aims to study the application of drone use for rice production in central which is the main area for rice production in Thailand. The results of this research can be used to determine the guideline for drone application in Thailand.

Objectives

The purpose of this study was to study the application of drone used for rice production in Central Thailand.

Literature Review

Drones for small scale agriculture

There are several types of drones that apply for agriculture for example fixed wing and multi-rotor as shown in Figure 1 and Figure 2. Mostly, drone application for rice production in Thailand used multi-rotor. The price of drone is start from 200,000 – 500,000 baht, depending on branding and series.

In Thailand, there were several drone’s service providers for rice production. Each service provider has difference service charge rate and shows difference efficiency. Drone service for rice production in Thailand can be reduce mixing water and fertilizer 20-25%. Drone can increase production up to 20-40% and can reduce working time up to 85%. The price of service is 80-100 Baht per rai. It takes time for service about 3-5 minute per rai (Sati-platform, 2020)

Figure 1: Fixed wing

Figure 2: Multi-rotor

The advantages of agriculture drone

Agricultural drone was used in several country for multi purposes as follows (Rolf A., 2020).

1. Field phenotyping: drone can help bleeders accelerate selection of genotypes tolerant to different stress factors. Drone can generate the quantitative data on the dynamic responses of plants to the environment.
2. Identified the drought tolerant varieties: the data collected from drone can show identify the drought tolerant varieties of interested plant.
3. Irrigation scheduling: drone can set the schedule for low-intensity agriculture area.
4. Monitoring plantations: drone can use to monitoring plantation to assess health and pruning quality
5. Chemical spraying: drone can be use for spraying chemical and fertilizer which can reduce time and labor.

Methods

The research was conducted by an interview survey of rice farmers who used drone in central Thailand. Data collection was done by face-to-face interviews and a questionnaire during December 2019 and January 2020. The research was conducted by collecting data from 60 farmer who used drone for rice production in central of Thailand. The samples were selected by purposive sampling methods.

Results and Discussion

General information of farmer

The interviewees were male and female equally. The average age is 51 years old. Most of farmer had graduated from elementary school. Most own the farmland and do not need to pay rental costs. The farmers grow rice on approximately 45 rai per farm. For farmers renting farmland, the rental is approximately 1,155 baht per rai. The farmers have experience to grow rice for approximately 21 years. Income of most of them came from rice production. The famous varieties which the farmer selected were RD43 and Thai Pathumthani Pragrant Rice.

Problems of rice production

The problems of production are high price of fertilizer, high price of seed and disease, respectively. The problems of production cost are high price of equipment, high price of labor hiring and high price of new technology, respectively. Those problems can affect to the cost of production. The problems of marketing are lack of the knowledge of marketing, lack of market and low bargaining power, respectively.

Drone used for rice production in Central Thailand.

The drone use in Central of Thailand was used for approximately 1.5 years. It is still new for farmer. Some of farmers have less information about drone. Drone use in Central of Thailand mostly for spraying chemical such as fertilizer, insecticide, herbicide, plant hormone. The advantage of using drone are safe working time, safety for farmer, comfortable since farmer do not need to carry the chemical, reduce the loss according to stepping in the field of labor while spraying by human, reduce amount of chemical and higher efficiency. However, drone had the disadvantages as follows the efficiency is not stable. The efficiency will be depended on the experience of service provider.

In order to provide the drone service, normally, service provider will assign 1-2 staff to service each time (Figure 4). Staff1 will control drone for spraying with drone controller (Figure 5). The staff will be safe from chemical because the staff will not need to directly touch the chemical. Staff2 will prepare chemical by mixing the chemical in the proper ratio and also, he will prepare battery to change during flight. Figure 6 shows drone's battery and battery charger for using during the service. Drone can carry 10 L of chemical per flight. The drone speed during service is approximately 3.5 minute per rai that much faster than labor. The maximum service area is approximately 132 rai per day. The average price of service is 74 baht per rai which similar to the conventional process (using labor). The famous brand of drone for rice field is DJI which is Chinese brand (Figure 7)

Figure 4: Drone service provider

Figure 5: Drone controller

Figure 6: Drone equipment (battery and charger)

Figure 7: Example of agricultural drone applied in Central of Thailand

The factors affecting making the decision of using a drone of farmer is the result which can be seen from the neighbors' field. Because drone is new technology, then effective result is desired for making decision. Nowadays, there are several service providers in the area. However, the quality of service is not equivalent depending on experiences of the provider. Drone controlling requires multi-skills since in the rice field will be many difficulties such as big tree, windy condition and unshaped of rice field. Moreover, in order to provider the effectiveness result, the providers should have chemical mixing skill in appropriate ration.

Efficiency of drone application in rice field

The result showed that the application of drone in rice field can enhance the productivity of rice up to 15% and can reduce the chemical by 35%. Moreover, this technology can help to provide the healthy life for the farmer since the farmer will not need to touch the chemical and carry the heavy tank of chemical.

Conclusions

This research paper reveals the results of the study of the application of drone use for rice production in central Thailand. Data was collected from selected farmers who use a drone, in central Thailand. The results showed that the average age of farmer is 51 years old. Most of farmer had graduated from elementary school. Most of farmer own the farmland resulted in low production cost. The farmers grow rice on approximately 45 rai per farm. For farmers renting farmland, the rental is approximately 1,155 baht per rai. The farmers have experience to grow rice for approximately 21 years. The famous varieties which the farmer selected were RD43 and Thai Pathumthani Pragrant Rice.

The problem of production is high price of fertilizer. The problem of production cost is high price of equipment. The problems of marketing is lack of the knowledge of marketing.

The drone use in Central of Thailand was used for approximately 1.5 years. Drone use in in Central of Thailand mostly for spraying chemical such as fertilizer, insecticide, herbicide, plant hormone. Drone service, the service provider will assign 1-2 staff to service each time. Staff1 will control drone for spraying with drone controller. Staff2 will prepare chemical by mixing the chemical in the proper ratio and also, he will prepare battery to change during flight. Drone can carry 10 L of chemical per flight. The drone speed during service is approximately 3.5 minute per rai. The maximum service area is approximately 132 rai per day. The average price of service is 74 baht per rai. The famous brand of drone for agriculture is DJI.

The results reveal that drone can increase the productivity of rice by 15% and reduce chemical by 35%. This is resulted in reduction of production cost.

Recommendation

Drone application for rice production has more advantages than conventional method including higher efficiency, lower cost and can be solve labour shortage problem. Therefore, the government should determine the guideline for support the farmer in order to apply drone for rice production. Moreover, the government should provide the seminar to educate farmers about drone for rice production because most of farmers still lack of knowledge about drone application.

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PHYSICAL, CHEMICAL PROPERTY AND ANTIOXIDANT CAPACITY OF INDIAN POMEGRANATE (*Punica granatum L.*)

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ABSTRACT

Pomegranate is one of high nutrients fruits that is widely consumed as fresh fruit and juice. The purpose of this study is to analyze the physical (color), chemical (total soluble solid, pH, contents of sugar, anthocyanin, total phenolic) and antioxidants activity of Indian pomegranate using colorimeter, HPLC, pH difference, Folin-Ciocalteu and DPPH technique, respectively. The results showed that the lightness (L*), red color (a*) and yellow color (b*) values of the Indian pomegranate seeds and juice were 20.77 ± 1.19, 10.28 ± 1.98, 2.69 ± 0.75 and 9.03 ± 0.40, 15.73 ± 0.23, -0.96 ± 0.27, respectively. The total sugar content was 14.53 ± 0.57 g/100g dried weight (DW), which was fructose and glucose. For the anthocyanin contents, freeze dried seed gave the highest level as 293.68 mg C3G/100g DW compared with freeze dried peel, fresh seed, peel and juice. Furthermore, freeze dried seed had higher level in total phenolic compound (451.04 ± 3.61 mg Gallic acid/100g DW) and antioxidant activity (1110.11 ± 12.96 mg Trolox/100g DW) compared with juice. The results showed positive correlated between antioxidant activity with anthocyanin and phenolic contents.

Keywords: Pomegranate, Total sugar, Anthocyanin, Total phenolic compound, Antioxidant.

Introduction

Pomegranate (*Punica granatum L.*) is one of popular fruits that is widely consumed in various cultures for thousand years. They were planted in many countries (such as; Iran, India, Turkey, Tunisia, Morocco, Spain, USA and China) and exported more than 100000 ton (Holland D. and Bar-Ya'akov I., 2008, Ozgen M., *et al*., 2008, Ercisli S., *et al*., 2011, Hasnaoui N., *et al*., 2011, Li X., *et al*., 2015, Hmid I., *et al*., 2017). Nowadays, there is the increasing consumption of pomegranate fruit because its beneficial effects on human health. Many studies have reported anti-inflammatory, anti-cancer, anti-diabetic, anti-microbial and cholesterol lowering effects of pomegranate in the use of *in vivo* and *in vitro* studies (Adams L., *et al*., 2006, Esmaillzadeh A., *et al*., 2006, Gould S. W., *et al*., 2009, Kahya V., *et al*., 2011, Lansky E. P., *et al*., 2005, Larrosa M., *et al*., 2010, Lei F., *et al*., 2007, Park S., *et al*., 2016, Xu K. Z. Y., *et al*., 2009).

The nutrients of pomegranate are carbohydrate, sugar, protein, fat, minerals and vitamins. The two main sugars found in pomegranate juice are fructose and glucose which were reported in various level between 3.50-9.36 g/100 ml and 3.40-11.20 g/100 ml, respectively (Fadavi A., *et al*., 2005, Ozgen M., *et al*., 2008, Tezcan F., *et al*., 2009, Hasnaoui N., *et al*., 2011, Legua P., *et al*., 2012). In addition, the phenolic compounds including anthocyanin, flavonoid and tannin are the health-promoting phytochemicals which were also reported in various level from different cultures (Elfalleh *et al*., 2011). The anthocyanin contents which are the major pigment of pomegranate were reported in range 64-369 mg cyanidin-3-glucoside /100g (Çam M., *et al*., 2009 and Hmid I., *et al*., 2017). Whereas, the total phenolic contents and antioxidant activities were 676 to 3436 mg gallic acid/L and 4.38-7.70 mM Trolox/L, respectively (Ozgen M., *et al*., 2008, Sepúlveda E., *et al*., 2010, Jing P. U., *et al*., 2012 and Alighourchi H. R., *et al*., 2010). Moreover, the anthocyanin and phenolic contents have shown positive correlative effect on antioxidant activities (Prior R. L., *et al*., 1998, Proteggente A. R., *et al*., 2002, Youssef K., *et al*., 2016, Derakhshan Z., *et al*., 2018).

Interestingly, the nutrient differences of various pomegranate cultivars were depended on cultivar, growing region, harvest practices, maturity and storage (Melgarejo *et al*., 2000; Al-Maiman and Ahmad, 2002, Fadavi A., *et al*., 2005). Moreover, the various factors such as pH, temperature, light, sugars, ascorbic acid, metal, hydrogen peroxide and processing process also affect to the phytonutrient level (Jaiswal V. *et al*., 2010, Turfan Ö., *et al*., 2011, Youssef K., *et al*., 2016, Da Silveira T. F. F., 2019). Therefore, the aim of this study was to analyze the total and individual sugar contents, anthocyanin contents and total phenolic contents, also antioxidant activities of Indian pomegranate.

Objectives

1. To determine the pH, total soluble solid and color of Indian pomegranate.
2. To investigate the total and individual sugar in Indian pomegranate juice, using high performance liquid chromatography (HPLC).
3. To determine anthocyanin content in seed, peel and juice of Indian pomegranate.
4. To determine total phenolic content and antioxidant capacity of Indian pomegranate juice and freeze dried Indian pomegranate seed extract.

Literature review

Pomegranate (*Punica granatum L.*) is an ancient fruit that is widely cultivated over the world such as Iran, India, Turkey, Tunisia, Morocco, Spain, USA and China (Ozgen M., *et al*., 2008, Ercisli S., *et al*., 2011, Hasnaoui N., *et al*., 2011, Li X., *et al*., 2015, Hmid I., *et al*., 2017). Iran and India are the most planted area as showed in Table 1 (Holland D., Bar-Ya'akov I., 2008). Pomegranates are popular fruit which are consumed as fresh fruit, juice, jelly, jam, and including processed for flavoring and coloring products (Fadavi and others 2005; Mousavinejad and others 2009). The nutrients of pomegranate 100 g base on united states department of agriculture (USDA) contain 77.93 g of water, 18.73 g of carbohydrate, 13.67 g of sugar, 1.67 g of protein, 1.17 g of fat, 287.85 mg of minerals and 11.30 mg of vitamins. In addition, various pomegranate cultivars had the difference of nutrients depend on growing region, harvest practices, maturity and storage. The researchers have been reported that pomegranates had variation in proteins, sugars, vitamins, and mineral contents (Melgarejo *et al*., 2000; Al-Maiman and Ahmad, 2002, Fadavi A., *et al*., 2005). For example, A variety of sugar content of pomegranates were reported from different countries are 3.50-9.36 g/100ml for fructose and 3.40-11.20 g/100ml for glucose (Tezcan F., *et al*., 2009, Ozgen M., *et al*., 2008, Legua P., *et al*., 2012, Hasnaoui N., *et al*., 2011, Fadavi A., *et al*., 2005).

Table 1: The world pomegranate production and export based on research done by Yael Kachel, Department of Market Research, Israeli Ministry of Agriculture

Country	Planted area (ha)	Production (t)	Export (t)
Iran	65000	600000	60000
India	54750	500000	22000
China	Unknown	260000	Unknown
USA	6070	110000	17000
Turkey	7600	90000	Unknown
Spain	2400	37000	14000
Tunisia	2600	25000	2000
Israel	1500	17000	4000

Modified from Holland D. and Bar-Ya'akov I. (2008)
Source: Holland D. and Bar-Ya'akov I. (2008). The pomegranate: new interest in an ancient fruit. *Chronica Horticulture*, 48 (3), p. 12–15.

As is widely known, the color of pomegranate is affected by anthocyanins which is the one of phenolic group. They also give the orange, purple and blue color of many fruits and vegetables. The different in cultivars gave various anthocyanin contents such as California pomegranate had 162-387 mg/L while Chile, Morocco and Turkey pomegranate had 168-1328 mg CyE/L, 64.16-188.7 mg/100 g and 81 - 369 mg/100g, respectively (Gil *et al*., 2000, Sepúlveda E., *et al*., 2010, Hmid I., *et al*., 2017, Çam M., *et al*., 2009). The six major anthocyanins, including delphinidin-3,5-diglucoside, cyanidin-3,5-diglucoside, delphinidin-3-glucoside, pelargonidin-3,5diglucoside, cyanidin-3-glucoside and pelargonidin-3-glucoside are commonly found in plant as showed in figure 1 (Turfan Ö., *et al*., 2011). Various factors effect on the stability of anthocyanin such as pH, temperature, light, sugars, ascorbic acid, metal, hydrogen peroxide, processing and storage (Jaiswal V. *et al*., 2010, Turfan Ö., *et al*., 2011, Youssef K., *et al*., 2016, Da Silveira T. F. F., 2019).

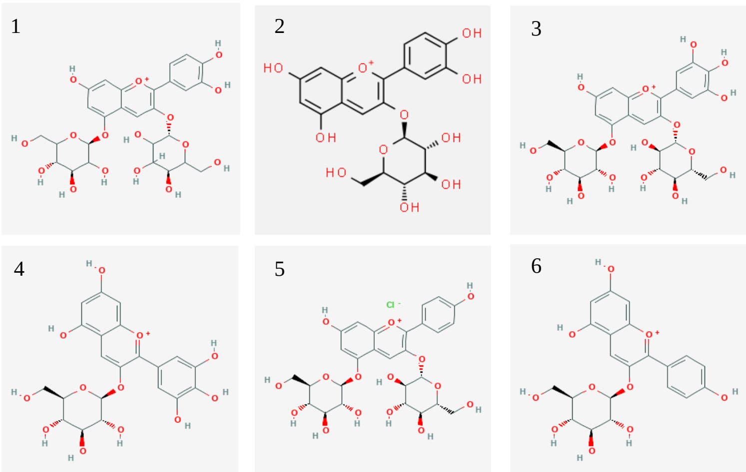

Figure 1: The structure of anthocyanins; 1: delphinidin-3,5-diglucoside, 2: cyanidin-3,5-diglucoside, 3: delphinidin-3-glucoside, 4: pelargonidin-3,5diglucoside, 5: cyanidin-3-glucoside and 6: pelargonidin-3-glucoside

Source: National Center for Biotechnology Information (2020). Retrieved April 16, 2020, from https://pubchem.ncbi.nlm.nih.gov/compound/

Despite of anthocyanins, pomegranate contains other phenolic compounds such as flavonoid and tannins (Elfalleh *et al*., 2011). The total phenolic contents of the different pomegranate cultivar were reported as 208.3-343.6 mg/100 ml from Turkey (Ozgen M., *et al*., 2008), 676-1280 mg gallic acid/L (Sepúlveda E., *et al*., 2010), 1.29-2.17 mg Gallic acid/g from China (Jing P. U., *et al*., 2012) and 204.6-290.7 mg Gallic acid/100 ml from Iran (Alighourchi H. R., *et al*., 2010). These phenolic compounds showed antioxidant activities which their redox properties which depended on the concentration, the structure and the interaction of phenolic compound (Elfalleh *et al*., 2011, Djeridane *et al*., 2006). Sepúlveda E., *et al*. (2010) reported that the total phenolic contents and total anthocyanin contents of the Chilean pomegranate juices were significantly correlated with antioxidant activities similar to the studied in pomegranate seed juice and peel of other researches (Prior R. L., *et al*., 1998, Proteggente A. R., *et al*., 2002, Youssef K., *et al*., 2016, Derakhshan Z., *et al*., 2018). However, the pomegranate antioxidant activities were ranged from 4.38-7.70 mM Trolox/L with different level of phenolic contents and cultivar place (Ozgen M., *et al*., 2008).

Seeram N. P., *et al.*, (2008) studied the antioxidant and total phenolic content in red wine, grape juice, blueberry juice, black cherry juice, acai juice, cranberry juice, orange juice, iced tea beverages, apple juice and pomegranate. The results showed that pomegranate juice had higher antioxidant and total phenolic content than other fruit juices. In addition, the high antioxidant capacities of pomegranate could have prevention potential on injury caused by free radicals. The reactive oxygen species (ROS) such as superoxide ($O_2^{\bullet-}$), hydroxyl ($\bullet OH$), peroxyl ($RO_2\bullet$), and alkoxyl (RO^-) and the reactive nitrogen species (RNS) such as nitric oxide ($NO^{\bullet}$) peroxynitrite ($ONOO^{\bullet}$), nitrogen dioxide (NO_2), are highly reactive free radical molecules that affected to damage all types of bio-molecules-lipid, proteins, carbohydrates and DNA. These damaging effects could relate to some diseases such as coronary heart disease, inflammation and cancer (Wolfe K. L., *et al.*, 2008).

Moreover, pomegranate showed beneficial effects on anti-inflammation, anti-cancer, anti-diabetic, anti-microbial and cholesterol-lowering *in vitro*, *in vivo* and clinical studies (Adams L., *et al*., 2006, Esmaillzadeh A., *et al*., 2006, Gould S. W., *et al*., 2009, Kahya V., *et al*., 2011, Lansky E. P., *et al*., 2005, Larrosa M., *et al*., 2010, Lei F., *et al*., 2007, Park S., *et al*., 2016, Xu K. Z. Y., *et al*., 2009). The term *In vitro* studies, phytochemicals in pomegranate reduced inflammatory cell signaling in colon cancer cells as same as in vivo studies, inhibited the invasion of human PC-3 prostate cancer cells (Adams L., *et al*., 2006, Lansky E. P., *et al*., 2005). Kahya V., *et al*., (2011) reported that pomegranate extract 100 µl/day significantly decreased the acute inflammation due to myringotomy in thirty healthy Sprague–Dawley rats. Similar to the study by Larrosa M., *et al*., (2010), they reported pomegranate also decreased colon inflammation in colitis rat model. Moreover, the clinical study on diabetic type 2 patients with hyperlipidemia of Esmaillzadeh A., *et al*., (2006) showed that pomegranate significantly decreased blood cholesterol, LDL and LDL:HDL ratio which are the heart disease risk factors.

Furthermore, the other parts of pomegranate such as peel, leaf, flower and seed oil benefits were reported in several studies. The pomegranate peel 100 µg/ml decreased ROS production and pro-inflammatory cytokine expression in THP-1 cells stimulated with PM10 (Park S., *et al*., 2016). On the other hand, pomegranate leaf extracts at 800 mg/kg/day significantly decreased body weight on high-fat-diet-induced obese and hyperlipidemic mouse model whereas pomegranate seed oil and flower showed similar effects (Lei F., *et al*., 2007, Vroegrijk I. O., *et al*., 2011 and Xu K. Z. Y., *et al*., 2009).

Materials and methods

1. ***Chemicals and reagents***

D(-)Fructose, D(+)Glucose, D(+)Sucrose, D(+)Maltose, 2,2 diphenyl-l-picrylhydrazyl (DPPH) were purchased from sigma Chemical Co. Ltd. (Steinheim, Germany). Folin-Ciocalteu reagent, gallic acid, potassium chloride, ethanol and methanol were purchased from Merck (Darmstadt, Germany). Sodium acetate and acetonitrile were purchased from RCI Labscan Co. Ltd (Bangkok, Thailand). Sodium carbonate was purchased from KEAMUS (New South Wales, Australia).

2. ***Preparation of pomegranate seed, peel and juice.***

Indian pomegranates from local Indian market were washed, drained, separated peel and seed into two groups. First, seed and peels were freeze dried. Second group was frozen with quick freezing process. Frozen seed were grinded, centrifuged at 3000 rpm for 15 minutes, filtrated and collected as juice. All sample were stored at low temperature (-20^{o}C) before testing.

3. ***Colorimetric measurements***

The color of pomegranate seed and juice were measured and represented as L* (lightness), +a* (redness), -a* (greenness), +b* (yellowness) and -b* (blueness) by using the colorimeter with ten and three times, respectively (Ultrascan pro, Hunterlab, Reston, VA, USA). The color intensity (C*) of pomegranate samples were calculated as $C^* = (a^{*2} + b^{*2})^{0.5}$ and the hue angle (h_{ab}) were calculated as $h_{ab} = \tan^{-1}(b^*/a^*)$, where $h_{ab} = 0^o$ and 90^o for a red and yellow hue, respectively (RØrå A. M. B. and Einen O. 2003).

4. ***Compositional Analysis***

The total soluble solid (TSS, %Brix) of pomegranate juice was measured by an automatic digital refractometer (Atago PAL-α, Tokyo, Japan). The pH value was determined by using pH meter (Seven compact S220K, Mettler Toledo, Switzerland). The samples were measure at 25°C and replicated three times.

5. ***Determination of sugar contents***

Pomegranate juice was centrifuged at 3000 rpm for 10 minutes and filtered through a 0.45-µm Millipore filter. Sugar contents were analyzed using High performance Liquid Chromatograph (HPLC; Model Prominence LC20 series, Shimadzu, Kyoto, Japan) equipped with a refractive index detector for sugars detection. The injection volumes were 10 µl. Sugars analysis was performed on a Shim-pack Gist column (5µm NH_2, 4.6×150 mm, Shimadzu, Kyoto, Japan) using acetonitrile/water (85:15, v/v) as the mobile phase.

6. ***Determination of total anthocyanin contents***

Anthocyanin contents were measured by spectrophotometry method following Lee J. *et al.* (2005). This method was determined under pH differential method using buffer system: pH 1.0 buffer (potassium chloride, 0.025M) and pH 4.5 buffer (sodium acetate 0.4M). The absorbance was measured at 520 and 700 nm using Shimadzu UV-1800 spectrophotometer. The anthocyanin contents were calculated and expressed as cyanidin-3-glucoside using the equivalents as follows:

$$\text{Anthocyanin content (mg/L)} = \frac{(A_{520} - A_{700})pH1.0 - (A_{520} - A_{700})pH4.5 \times MW \times DF \times 1000}{\varepsilon \times 1}$$

Where A = absorbance, MW = 449.2g/ml for cyanidin-3-glucoside, DF = dilution factor, 1 = pathlength in cm, ε = 26900 molar extinction coefficient, 1000 = factor for conversion from g to mg.

7. *Determination of total phenolic contents*

Total phenolic contents in pomegranate were determined by the Folin-Ciocalteu method reported in Bhawamai S. *et al.* (2016). From each sample, 0.1 ml of solution to 0.5 ml of 10% Folin-Ciocalteu's reagent was added and vortex the solution. Then, added 2 ml of a sodium carbonate solution (7.5% w/v) and incubated at room temperature for 30 minutes. After that, added 1.4 ml distilled water and incubated at room temperature for 2 hours. The absorbance was measured at 755 nm using a Shimadzu UV-1800 spectrophotometer. Total phenolic content in pomegranate samples were converted into mg gallic acid equivalents per 100 g sample (mg Gallic/100g).

8. *Determination of Antioxidant activities*

The 2,2 diphenyl-l-picrylhydrazyl (DPPH) method was used to analyze the antioxidant activities of pomegranate. An aliquot of DPPH solution was added to sample and incubated at room temperature for 30 minutes in the dark. The absorbance of the mixture was measured at 515 nm using (Shimadzu UV-1800, Kyoto, Japan). Antioxidant activities were converted into mg trolox equivalents per g sample (mg Trolox/g).

9. *Statistical analysis*

All Sample were performed with three independent replications for compositional measurement, total phenolic contents and antioxidant activities and two independent replications for the measurement of sugar contents. A comparative among anthocyanin contents of difference Indian pomegranate source (seed, peel and juice) and process (fresh and freeze dry) was performed using one-way ANOVA with the Duncan post hoc comparison test. P-values of < 0.05 were considered significant for a confidence interval of 95%.

Results and Discussion

1. *Compositional measurements*

The lightness (L*), red color (a*) and yellow color (b*) values of the Indian pomegranate seeds and juice were 20.77 ± 1.19, 10.28 ± 1.98, 2.69 ± 0.75 and 9.03 ± 0.40, 15.73 ± 0.23, -0.96 ± 0.27, respectively which indicated that these sample had low chroma level (10.63, 15.76) and hue angle (14.66, 3.49). It showed that Indian pomegranate had red tone color. The red color of the pomegranate is attributed to anthocyanins group including delphinidin-3,5-diglucoside, 2: cyanidin-3,5-diglucoside, 3: delphinidin-3-glucoside, 4: pelargonidin-3,5diglucoside, 5: cyanidin-3-glucoside and 6: pelargonidin-3-glucoside (Turfan Ö., *et al*., 2011).

The pH and total soluble solid in Indian pomegranate juice were 3.82 and 15.2 %Brix as seen in Table 2. Similar to the report in Indian pomegranate which had TSS range is 13-15.3 %Brix by Kulkarni and Aradhya (2005). The difference in TSS may be attributed to the hydrolysis of starch to sugar and the ripening stages or maturity stages. According to Fawole and Opara (2013), pomegranate fruit has a significant increasing of TSS during maturation.

Table 2: Total soluble solid (TSS), pH and color parameter of Indian pomegranate seed and juice

Sample	TSS (%Brix)	pH	L*	a*	b*	C*	H_{ab}
Indian Pomegranate Seed	-	-	20.77 ± 1.19	10.28 ± 1.98	2.69 ± 0.75	10.63	14.66
Indian Pomegranate Juice	15.2	3.82	9.03 ± 0.40	15.73 ± 0.23	-0.96 ± 0.27	15.76	3.49

2. *Sugar contents*

Fructose and glucose are main sugar in Indian pomegranate juice as seen from figure 2. Sample was diluted in 1:10 ratio with water and injected two times. Sugar contents were analyzed using HPLC technique and calculated from standard calibration curve with 0.9946 and 0.9943 regression for fructose and glucose, respectively. From table 3, the total sugar (as the sum of individual sugar) of Indian pomegranate juice was 14.53 ± 0.57g/100ml which contained 7.20 ± 0.21 g/100ml fructose and 7.33 ± 0.36 g/100ml glucose. While, the other studies reported individual sugar contents of pomegranate from different countries are range in 3.50-9.36 g/100ml for fructose and 3.40-11.20 g/100ml for glucose (Fadavi A., *et al*., 2005, Ozgen M., *et al*., 2008, Tezcan F., *et al*., 2009, Hasnaoui N., *et al*., 2011, Legua P., *et al*., 2012). From these results implied that, the variety sugar contents may influence by multiple factors such as cultivar, growing region and maturity.

Table 3: Sugar contents in Indian pomegranate juice

Sugar types	Sugar content (g/100mL)
Fructose	7.20 ± 0.21
Glucose	7.33 ± 0.36
Sucrose	ND
Maltose	ND
Total Sugar (g/100 mL)	14.53 ± 0.57

*ND = not detect in this method

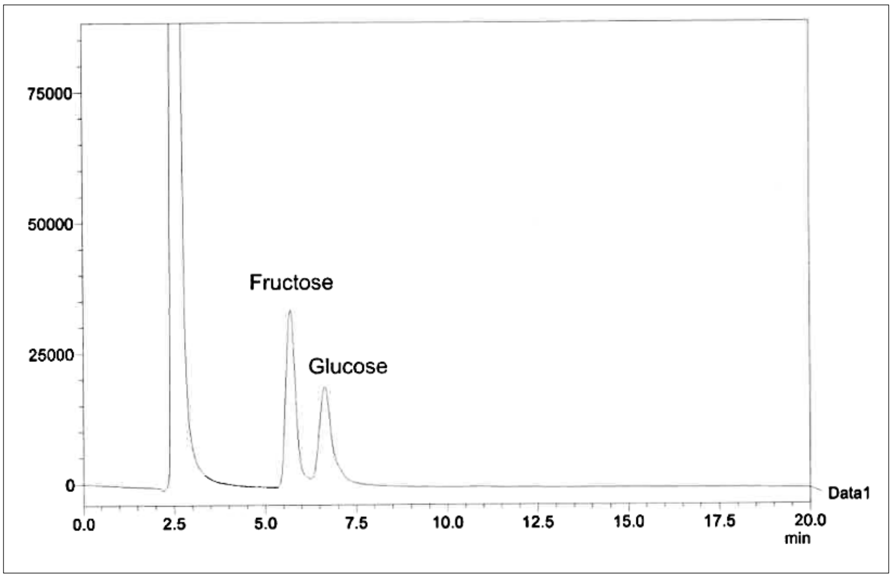

Figure 2: Electropherogram of the Indian pomegranate juice using High-performance Liquid Chromatograph equipped with a refractive index detector

3. Anthocyanin contents

Anthocyanin contents of Indian pomegranate seed, peel and juice, which expressed as cyanidin-3-glucoside, were extracted overnight with methanol acidified (1% HCL). The results showed that freeze dried Indian pomegranate seed gave the highest anthocyanin level as 293.68 ± 11.70 mg C3G/100g whereas peel showed very low anthocyanin level (3.42 ± 0.58 mg C3G/100g). As seen in Table 4, Indian pomegranate seed and juice had no significantly different in anthocyanin level as 91.31 ± 5.33^{b} and 96.30 ± 1.86^{b} mg C3G/100g, respectively. The anthocyanin level of pomegranate juice is similarly to the studied from Morocco and Turkey which are 64.16 -188.7 mg/100g and 81 - 369 mg/100g, respectively (Hmid I., *et al*., 2017, Çam M., *et al*., 2009). In addition, the anthocyanin contents of pomegranate were increased after freeze drying process which similar to the studied of Çoklar H. and Akbulut M. (2017) that the anthocyanin contents in freeze-dried grapes were higher than fresh grapes. Because of freeze drying is one of popular drying methods which the free-water contents are removed without heating. The water in sample is changed to solid form and converted to gas at a vacuum pressure condition. Low temperature process, freeze drying results in high quality product (Oberoi D. P. S. and Sogi D. S., 2015).

Table 4: Anthocyanin contents of Indian pomegranate seed, peel and juice

Type of sample	Anthocyanin (mg C3G/100g DW)
Indian pomegranate seed	91.32 ± 5.33^{b}
Indian pomegranate juice	96.30 ± 1.86^{b}
Freeze dried Indian pomegranate seed	293.68 ± 11.70^{a}
Indian pomegranate peel	3.42 ± 0.58^{d}
Freeze dried Indian pomegranate peel	21.63 ± 7.47^{c}

4. Total phenolic contents and antioxidant activities

The total phenolic contents of Indian pomegranate were calculated with gallic acid standard equivalents. The results in Table 5. showed that total phenolic contents of freeze dried Indian pomegranate seed and juice were 451.04 ± 3.61 and 158.16 ± 3.01 mg Gallic acid/100g. The different level of total phenolic were reported between 676 to 3436 mg gallic acid/L from different pomegranate cultivar (Ozgen M., *et al*., 2008, Sepúlveda E., *et al*., 2010, Jing P. U., *et al*., 2012 and Alighourchi H. R., *et al*., 2010). The major phenolic compounds of pomegranate are flavonoids, anthocyanins and tannins, that affect to their biological and free radical scavenging activities (Elfalleh w. *et al.*, 2011). Whereas the antioxidant activities of Indian pomegranate in both (seed and juice) were 1110.11 ± 12.96 and 671.71 ± 66.74 mg Trolox/100g.

Table 5: Total phenolic contents and antioxidant activities of Indian pomegranate seed and juice

Type of sample	Total phenolic contents (mg Gallic acid/100g DW)	Antioxidant activities (mg Trolox/100g DW)
Indian Pomegranate Juice	158.16 ± 3.01	671.71 ± 66.74
Freeze dried Indian pomegranate seed	451.04 ± 3.61	1110.11 ± 12.96

From the results of this study, the higher level of total phenolic and anthocyanin contents showed a positive correlation with antioxidant activities. Many researchers confirmed that the antioxidant capacity is correlated with the total phenolic and anthocyanin contents. (Prior R. L., *et al*., 1998, Proteggente A. R., *et al*., 2002, Youssef K., *et al*., 2016, Derakhshan Z., *et al*., 2018). Moreover, pomegranate juice had higher antioxidant than red wine, grape juice, blueberry juice, black cherry juice, acai juice, cranberry juice, orange juice, iced tea beverages, apple juice which showed the same trend of total phenolic content (Seeram N. P., *et al*., 2008). The high antioxidant activities of pomegranate attenuate the effect of injury from free radicals. The free radicals both the reactive oxygen species (ROS) and reactive nitrogen species (RNS), are highly reactive molecules that damage all types of bio-molecules-lipid, proteins, carbohydrates and DNA. These damage effects could lead to some diseases such as coronary heart disease, inflammation and cancer (Wolfe K. L., *et al*., 2008). Therefore, the high antioxidant activities could prevent these diseases.

Conclusions

In this study, pomegranate fruit from India had 3.82 of pH and 15.2 %Brix with red color both seed and juice. The total sugar content was 14.53 ± 0.57g/100g, which was fructose and glucose. Freeze dried seed had highest in anthocyanin level following fresh seed, juice, freeze dried peel and peel. Moreover, freeze dried seed extract was higher level in total phenolic contents and antioxidant activities than juice. These results showed positive correlation of antioxidant activity with anthocyanin and phenolic contents of Indian pomegranate which can be used for the raw material selection and value added product development.

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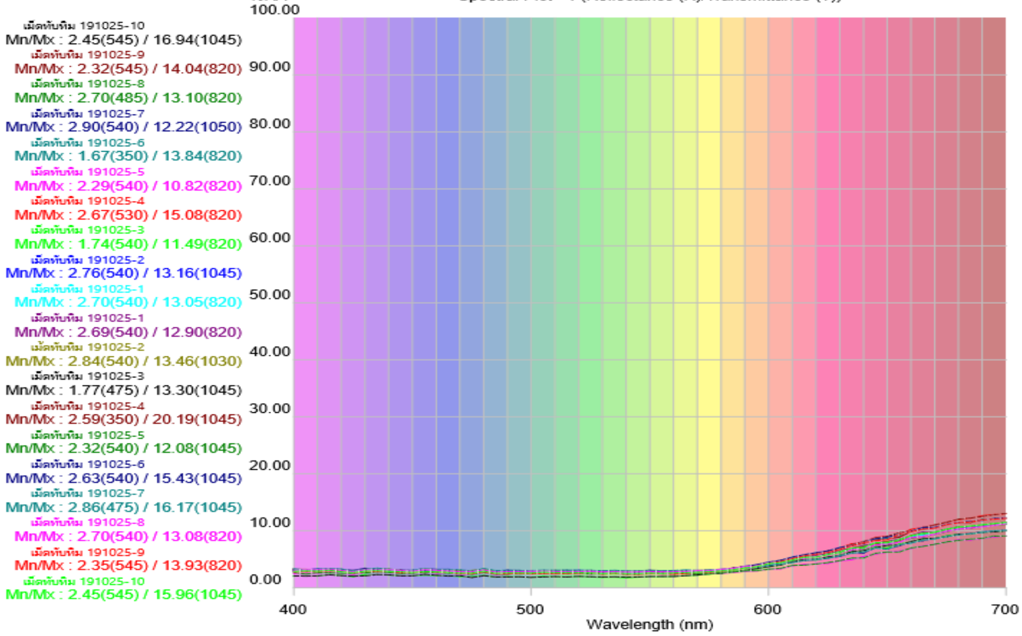
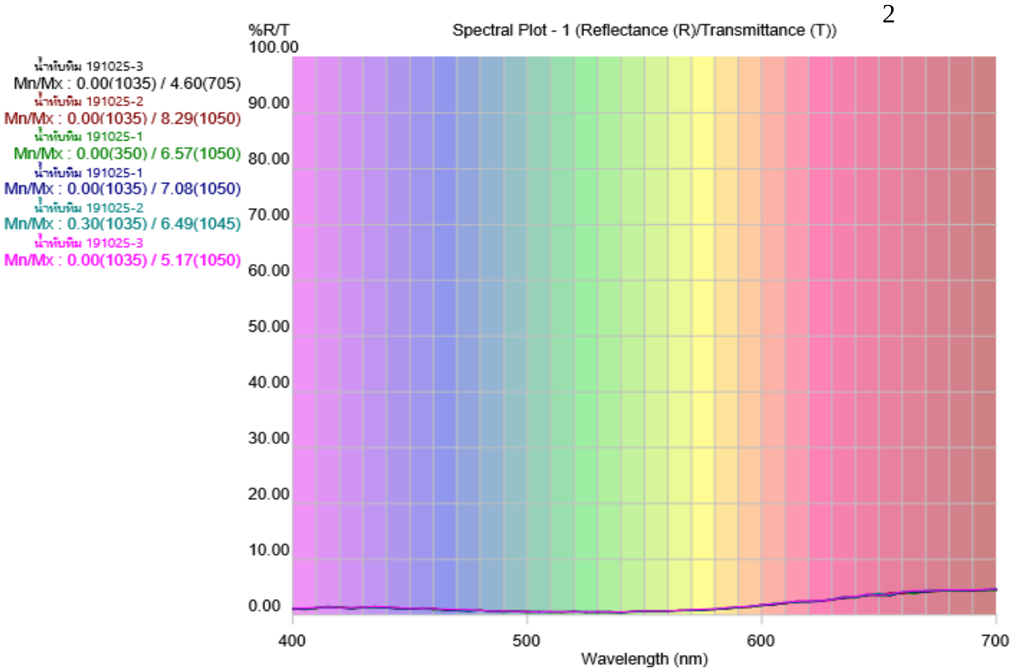
Appendix A - Indian pomegranate

Appendix B – The spectral plot of Indian pomegranate seed (1) and juice (2)

1



2



EVALUATION OF THE SPRAYING DEPOSITION AND SPRAYING DRIFT BY USING UNMANNED AERIAL VEHICLES (UAV) IN PADDY FIELD

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ABSTRACT

An application of unman aerial vehicle (UAV) for chemical spraying had rapidly increased but its dispersion and uniformity had been questioned by the farmers. Therefore, this research was aimed to evaluate the spray dispersion and uniformity of UAV in 50 days old RD 43 rice at Suphan Buri province under a completely randomized design involving three treatments and four replications as spraying by knapsack sprayer (MSK) at application rate of 25 L/rai, spraying by unman aerial vehicle (UAV) at application rate of 4 L/rai and spraying by UAV enhanced with novel adjuvant (UAV+ Adjuvant) at application rate of 4 L/rai. Kingkol tartrazine color was utilized at rate of 400 g/rai instead of chemical substances to determine the average number of droplet deposition, concentration of droplet deposition, loss and drift outside the target. The results showed that the number of droplet deposition of MSK was the greatest and significantly different from other treatments while the ones of UAV + Adjuvant were 35.05 and 34.50 droplet/cm^2 at upper and lower part of paddy rice which was suitable for spraying. However, concentration of droplet deposition was displayed no significantly differences among all treatments. The highest loss was found in UAV with significantly different compared to other treatments. Moreover, the results also indicated that the loss and drift outside targeting area could be reduced by assisting of UAV + Adjuvant. Nevertheless, the spraying by using UAV should concern about characteristics and speed of the wind due to theirs great effects to loss and drift of spraying.

Keywords: spraying by UAV, droplet deposition, spray drift, paddy rice, novel adjuvant.

Introduction

Rice (*Oriza sativa*) is a staple food crop in Thailand and Asia. In the year of 2019, total rice cultivation land was about 11.4 million hectares that accounted for almost 45.2 % of the total agricultural area in Thailand and involved around 4.3 million households of rice-growing farmers. In global market, Thailand had an approximately market share of 21.0 percent of world rice exports (Office of Agricultural Economics, 2020; Krungsri research, 2019). However, the characteristic of rice farming in Thailand was categorized as high risk but low return because agricultural products were depended on erratic weather conditions. When droughts or floods occurred, many farmers would be unavoidable to face the loss of their products and money. On the contrary, the returns form rice farming were very small even in the year when there was no weather problem according to the low selling price and the high production cost that had mainly consisted of labor cost, fertilizer and pesticides (Ngammuangtueng et al., 2019; Puapongsakorn et, al., 2013).

Pesticide intoxication has become one of the important public health issues to concern in Thailand that caused by the intensive use and exposure to pesticides. Generally, 49,000 to 61,000 cases of pesticide intoxication were reported every year. During 2007-2013, the reported cases were found predominantly in the Central region of Thailand. Moreover, the reported cases had the tendency to increase during the growing season and farmer was the most frequently reported occupation in term of high risk for pesticide intoxication due to Thailand relied heavily on the pesticide use for crop protection in order to elevate production level, product quality and product appearance. An import of pesticides to Thailand was extremely increased from 30,971 tons on 1990 to 70,000 tons on 2010 (Tawatsin et al., 2015; Panuwet et al., 2012, Poramacom, 2001). Rice farmers were found to have higher prevalence of hazardous working when compared to vegetable and flower farmers according to misuse or overuse of pesticides during the crop growing season that highly affected the environment and human exposure (Kongtip et al., 2018; Panuwet et al., 2012).

By the late of 20th century, Thailand had moved from subsistence agriculture to agribusiness and industrializing economy. For rice production, agricultural machinery has been intensively employed throughout the entire process to improve yield and productivity (Puapongsakorn and Chokesomritpol, 2017). Recently, agricultural unmanned aerial vehicles (UAV), so-called agricultural drone, have been dramatically increased and adopted around the world including Japan, South Korea, China and Thailand (He et al., 2017; Lan and Chen, 2018). Many agricultural activities have been performed by using UAV such as aerial image capturing, soil and water sampling and pesticides spraying (Lou et al., 2018; Radoglou-Grammatikis et al., 2020). In Thailand, agricultural UAV had been introduced to farmers since 2016. The agricultural UAV were bought by farmers and UAV service providers for monitoring plant health and spraying pesticides (Bhandhubanyong and Sirirangsri, 2019). For rice production in Thailand, agricultural UAV is frequently applied for spraying pesticides and fertilizer according to greater effectiveness compared to conventional spraying method (Maikaensarn and Chantharat, 2019). However, the adoption of agricultural UAV application in rice production is still limited in some regions because of the lack of farmers' confidences on the spraying efficiency especially spraying dispersion, spraying uniformity and drift. Generally, the spraying dispersion and uniformity are the important technical concerns for farmers to choose to spray the pesticides in their paddy fields by using agricultural UAV. Spray drift usually occurs during the application of pesticides spraying by agricultural UAV during the field operation by aerial spraying and leads to the insufficient dosage of pesticides on the target area. Adjuvants are recommended to minimize the spray application problems including spray drift by agricultural UAV and improve the pesticide performance (Celen, 2010; Wang et al., 2018, Lan et al, 2008). Since the research on application of agricultural UAV incorporate with adjuvants for pesticide spraying in rice production has not been reported in Thailand, the technical information on the spraying efficiency by using UAV and UAV with adjuvant is needed for farmers to understand and adopt the aerial spraying by using agricultural UAV.

Objectives

The purpose of this study was to conduct a test for determining the spraying efficiency, namely for number of droplet deposition, concentration of droplet deposition, loss in the ground and drift outside the target of aerial spraying by UAV with and without novel adjuvant in comparison with conventional spraying by using knapsack sprayer. This study also expected to provide an information and recommendation of spraying efficiency by means of UAV for the spraying operation in the paddy field to enhance the sustainable rice production in Thailand.

Literature Review

Unmanned aerial vehicle (UAV) or remotely piloted aircraft (RPA) is an aircraft which can flight without a pilot and can be controlled by using a radio channel (He et al., 2017). In general, UAVs are equipped with cameras and sensors for crop monitoring and pesticides spraying. Currently, UAVs were mainly developed by military and rest 15% by civilian for various applications (Puri et al., 2017). For agriculture, the first UAV model was developed by Yamaha as unman helicopter Yamaha model RMAX for agricultural pest control and crop monitoring (Mogili and Deepak, 2018). The rapid development of agricultural UAV is mainly due to its advantages including: (1) UAV does not require any dedicated airport and navigation station and it can land on the edge of cultivation land; (2) the short turning radius of UAV could help it hover and turn round flexibly in the air; (3) the high rate of climb of UAV could help it to fly vertically and have good performance of super low flight; (4) low rate of no-load flight of UAV and filling fuel and liquid on the ground of working area could reduce invalid working time; (5) UAV is suitable for working in rough terrain and small plots with high efficiency, and (6) high automaticity, less flight crew, low labor intensity and simple to use and maintain in comparison with traditional manned aircraft (He et al., 2017).

Generally, UAV often classifies by using various criteria. Watt et al. (2012) explained that a classification of UAV could be classified by using its characteristics such as size, flight endurance and capacities into 8 categories as MAVs (Micro or Miniature Air Vehicles), NAVs (Nano Air Vehicles), VTOL (Vertical Take-Off & Landing), LASE (Low Altitude, Short-Endurance), LASE Close, LALE (Low Altitude, Long Endurance), MALE (Medium Altitude, Long Endurance), and HALE (High Altitude, Long Endurance). Radoglou-Grammatikis et al. (2020) categorized UAV by using technical features such as aerodynamic features, level of autonomy, size and weight and power source. Mogoli et al. (2018) used number of rotors to classify type of UAV as fixed wing, single rotor, quad copter, hexa copter and octa copter. Mukherjee et al. (2019) also described the class of UAV by using aerodynamic characteristics into 3 types as fixed wing, wingless and bio-mimicry as shown in Figure 1. Therefore, the aerodynamic features seem to be the most frequent criteria that utilize to identify the class or characteristic of UAV.

Crop spraying is very common for ground-based sprayer and agricultural aviation. Nowadays, UAV has become a most promising technology that is suitable for this task and it has been adopted in many countries around the world. In Japan, 40% of all rice fields are sprayed with the assistance of UAV and this spraying method is cheaper than regular agricultural aviation because of lower fuel consumption (Pederi and Cheporniuk, 2015). In China, 95% of Chinese agricultural aviation technology was intensively applied in aerial plant protection. Moreover, over 10,000 units of UAV were used for pest and disease control and fertilization. These UAV are mainly employed in Heilongjian, Inner Mongolia, Xinjian, Henan and other major grain producing area (He et al., 2017). For Thailand, there were approximately six hundred to eight hundred units of UAV in Thailand in 2019 (Bhandhubanyong and Sirirangsri, 2019). Maikaensarn and Chantharat (2019) reported that the application of agricultural UAV in the rice production can reduce the production loss around 10-15% and decrease the amount of pesticides usage by 40%. Therefore, agricultural UAV has become an emerging technology for crop protecting on rice production in Thailand. For rice production, many studies were done to determine the efficiency of UAV spraying. The studies implied that the UAV's spray deposition did not differ from that of conventional spraying by using motorized knapsack sprayer. This may imply that the performance of UAV spraying is not differ from conventional method (Punyawattoe et al., 2019; Su et al., 2018). However, recent studies revealed that there were still some impractical issues of UAV spraying for plant protection that needed to be improved such as ambiguous optimal work parameters and poor penetrability into crop canopy, low droplet coverage ratio, heterogeneous droplet distribution and spray drift (Qin et al., 2018, Celen, 2010). Thus, the current researches on the application of plant protection by using UAV were mainly focused on the effect of operation parameters of aerial spraying on droplet deposition and spraying drift. Various types of adjuvants were developed and tested to reduce the spray drift that occurred during application of aerial spraying.

There are many types of spray adjuvants such as surfactants, spreaders, stickers, deposition aids, activators, humectants, antifoamers, wetting agents and drift reduction agents. Soap and oils were the first materials that used as spray adjuvants for specific purposes for many years. For drift reduction adjuvants, they have become a significant issue with the introduction and use of phenoxy herbicides and the associated off-target damage to sensitive vegetation. Spray drift continues as an industry issue with enhanced concerns about environmental trespass (Mulkey, 2001). Initially, water soluble synthetic polymers were the dominant components of most of the adjuvants that were first designed and marketed for spray drift control (Bouse et al., 1988). These materials were generally effective in increasing the average spray droplet size and in reducing the content of fine droplets that are possible to drift from the application site. Then, dry materials have been marketed for spray drift reduction. Guler et al. (2006) found out that both nonionic colloidal and polyvinyl polymer could reduce the drift potential compared to the spray carrier containing water only.

Many studies reported that the adding of adjuvants could decrease the spraying drift during the aerial spraying according to the adjuvants were control the physical and chemical properties of sprays (Wang et al. ,2018; Wang et al., 2020; Celen ,2010).

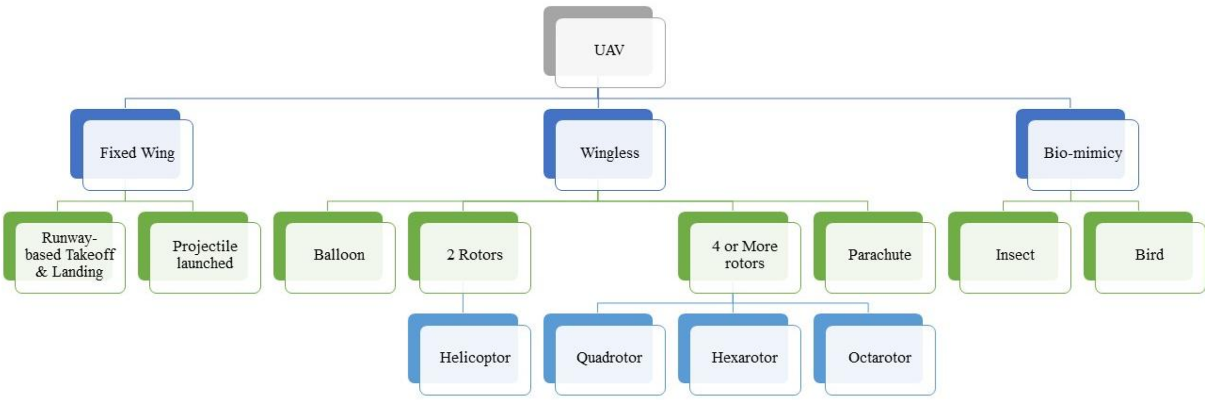


Figure 1: Classification of UAV (Mukherjee et al., 2019)

Methods

Experimental Site

This study was carried out at Doem Bang Nang Buat district, Suphanburi province (14.905750°E, 100.087945°N) on 21 January 2020 with the meteorological conditions of field temperature 28.5-30.0 °C, wind speed 0.2-0.9 m/s. The tested crop was 50 days old of RD43 rice variety with an average height of 60 cm. Rice was planted by using broadcasting method and it grew well and consistently in the whole tested area.

Experimental Design

The experiment was under a randomized complete block design (RCBD) involving three treatments and four replications as spraying by knapsack sprayer (MSK) as shown in Figure 2 at application rate of 25 L/rai, spraying by unman aerial vehicle (UAV) as shown in Figure 3 at application rate of 4 L/rai and spraying by unman aerial vehicle enhanced with 1.5% of Beidatong (SPM Biosciences (Beijing) Co., Ltd., Beijing, China) which was the vegetable oil adjuvant for UAV application (UAV+ adjuvant) at application rate of 4 L/rai. Each treatment was conducted on an area of 2,240 m^2 (28 m×80 m) field with 10 m between each treatment as a buffer zone.

The UAV platform is a multi-rotor UAV. This UAV has a Global Navigation Satellite System (GLONASS) fully autonomous flight function, which can plan the flight area in the mobile application, set the flight speed and height. The UAV was operated at working height of 2.0 m above the canopy as shown in Figure 4. The specification and technical parameters were demonstrated as in Table 1.

Figure 2: Knapsack sprayer (RTS-767F)

DJI MG-1S

Figure 3: Unmanned Aerial Vehicle ()

Figure 4: UAV at working height of 2.0 m above the canopy

Table 1: Technical parameters of knapsack sprayer and UAV

Specification	Sprayer	
	Knapsack sprayer	UAV
Model	RTS-767F	DJI MG-1S
Rotor	-	8
Nozzle type	Adjustable cone Ø 1.2 mm installed with spray lance	Fan type (XR11001VS)
Numbers of nozzle	1	4
Pressure (bar)	5	5
Flow rate nozzle (L/min)	2.1	1.86
Spray angle	45^0 on horizontal direction	0^0 on vertical direction
Swath width (m)	4	4
Working height (m)	0.5	2
Travelling speed m/min	26.67	160
Tank capacity (L)	25	10
Application rate(L/rai)	25-60	3.5-4.5
Application technique	Medium volume application	Very low volume application

Characterization of Spraying Deposition

The three treatments described above were conducted to determine the characterization of spray deposition including the average number of droplet deposition, the concentration of droplet deposition and loss in the ground by using the sampling scheme as in Figure 5. Kingkol tartrazine color was utilized as a tracer at rate of 400 g/rai in all treatments. To determine the average number of droplet deposition and the concentration of droplet deposition, 20 samplings of chromolux card and 20 samplings of filter paper were attached at upper layer and lower layer of the rice canopy while 5 samplings of the petri dishes were also placed between the rice canopy at the ground level to collect the loss in the ground as shown in Figure 6. In the laboratory, the chromolux card was counted the average number of droplet deposition by using image processing method (Figure 7). The chromolux cards were scanned at a resolution of 600 dpi with a scanner. Then, the image processing software (Halcon 7.0, MvTec Germany) was used to determine the number of droplets. For the filter paper and petri dish, they were evaluated the concentration of droplet deposition and loss in the ground by analytical method suggested by Punyawattoe et al. (2019). Colorimetric method was applied to measure the concentration at 470 nm with colorimeter (Jenway model 6051, Spectronic Camspec Ltd., UK).

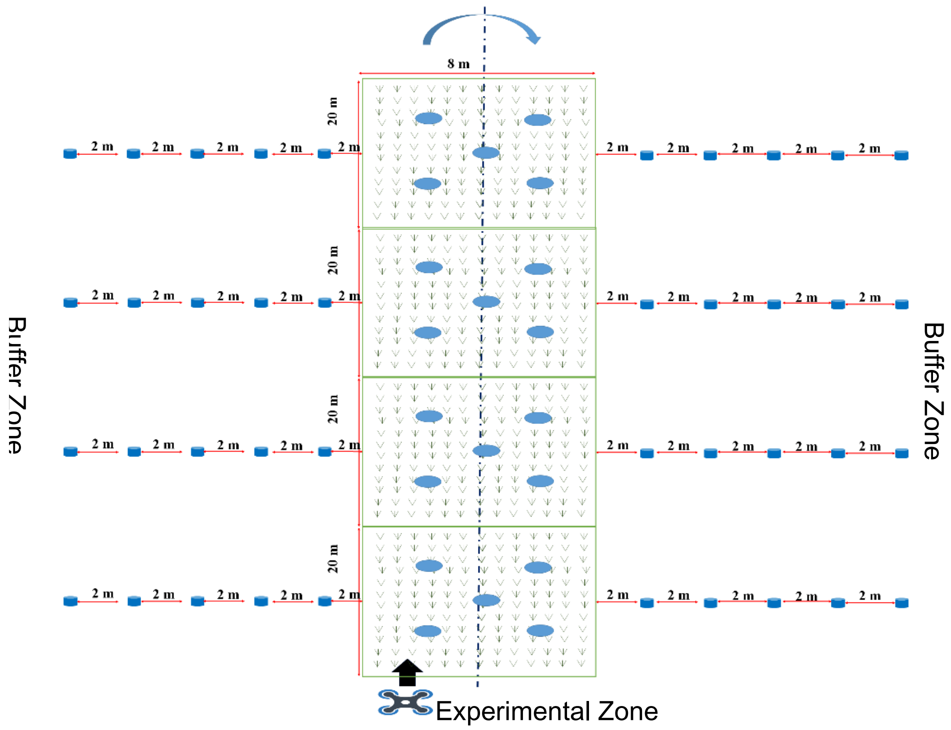


Figure 5 Experimental layout of each treatment

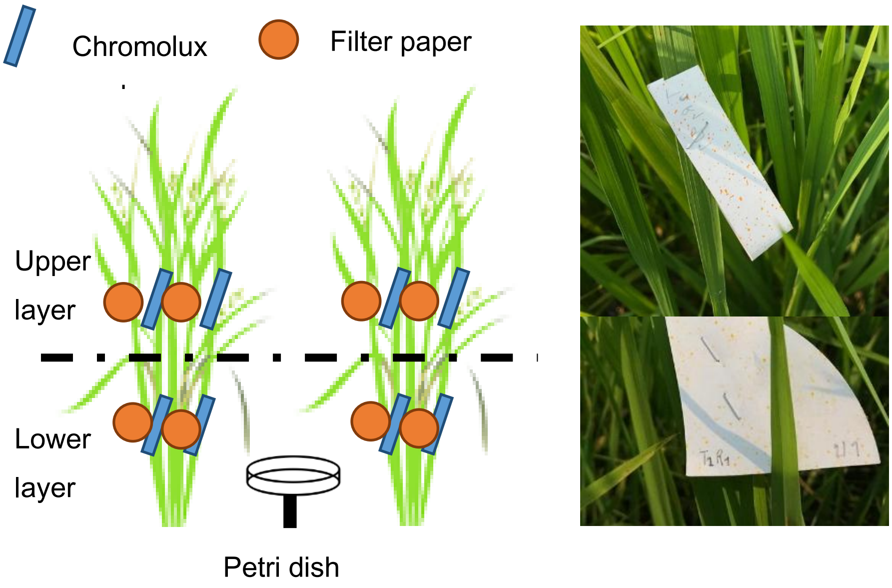


Figure 6: Placement of chromolux card, filter paper and petri dish at each sampling position within the rice canopy

Figure 7: Counting of the average number of droplet deposition in chromolux card

Characterization of Spraying Drift

For measurement of spray drift, the petri dishes were also placed at every 2 m interval from upwind edge and downwind edge of the last spraying swath of each side at the ground level as shown in Figure 5. Then, the same analytical technique as determination of loss in the ground was employed to determine the concentration of drift.

Statistics analysis

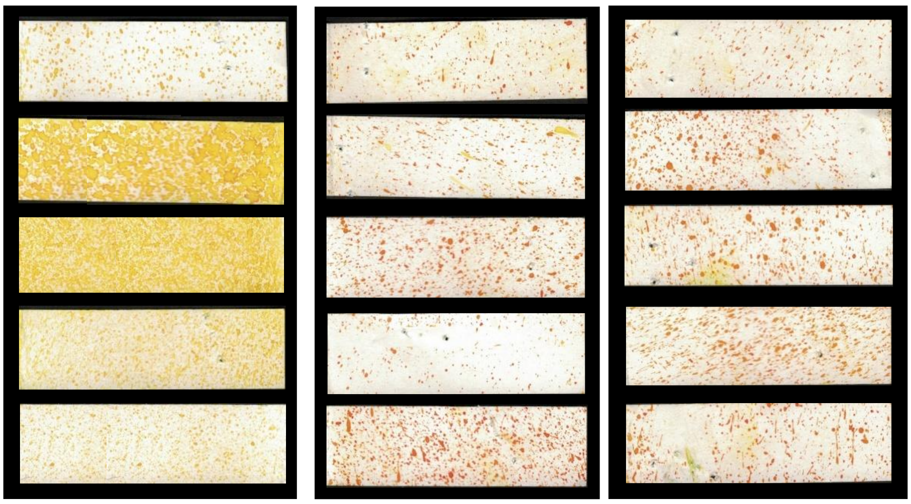
The data of the average number of droplet deposition the concentration of droplet deposition and loss in the ground from each treatment were submitted to analyze analysis of variance (ANOVA) by using SPSS version 24 (SPSS, Inc., Chicago, IL). Duncan's Multiple Range Test was used for multiple comparisons and significance level was $\alpha = 0.05$.

Results and Discussion

Characterization of Spraying Deposition

As the number of droplet deposition in target plant, the results indicated that number of droplet in the lower layer was greater than upper layer in all treatments and MSK was the method that had the highest number of droplet when compared to the one of UAV and UAV+ Adjuvant as shown in Table 2. As the comparison between UAV and UAV+ Adjuvant, the results showed no significant different between these methods. However, studies of Punyawattoe et al. (2013) recommended that it was required more than 30 droplet/cm^2 of the average number of droplet deposition to control *Niaparvata lugens* in paddy field. Since *Niaparvata lugens* Stal is one of important insect in paddy field in Thailand, the adding of adjuvant may be beneficial for spraying by using the UAV if the recommendation was taken in to account. Moreover, since the uniformity of droplet played an important role for pesticide spraying, the variation of the average number of droplet in Table 2 was extremely high in MSK when compared to UAV and UAV + adjuvant. This high variation of droplet deposition in MSK may affect the efficiency of spraying and this may imply that the unequal dosage of pesticides was applied on the target area when using knapsack sprayer. The main factor of this high variation caused by the unsteady travelling speed of operator in the paddy field that clearly illustrated on non-uniformed pattern of droplet deposition in MSK compared to the ones of UAV and UAV + Adjuvant as shown in Figure 8.

For the concentration of droplet, the upper layer of the plant showed the superior concentration than lower layer in all treatments. Moreover, there was no significant different of concentration of different method in the same layer of target plant (Table 3). Since UAV spraying is a spraying technique which uses very low volume application, the concentration of droplet deposition of UAV and UAV+ Adjuvant would be equivalent with the one of MSK even if smaller number of droplet deposition was detected. Therefore, this may confirm that the spraying efficiency in terms of concentration by UAV and UAV+ Adjuvant were equivalent to the conventional spraying method by using knapsack sprayer. However, when it came to the spraying loss, spraying by using UAV demonstrated the greater loss on the ground than MSK. On the contrary, the results of loss on the ground of UAV+ Adjuvant illustrated that the spraying by UAV could be mitigated the loss by adding the adjuvant in the mixture of pesticide and water.



(a) MSK (b) UAV (c) UAV+ Adjuvant

Figure 8: Spraying dispersion on the target area with different spraying method

Table 2: Number of droplet deposition in target area by using different spraying method

Treatment	**Average number of droplet (droplet/cm^2)**	
	Upper layer	**Lower layer**
MSK	71.28 ± 52.83[1/] a	83.91 ± 57.04 a
UAV	25.44 ± 4.36 b	28.91 ± 3.58 b
UAV+ Adjuvant	35.05 ± 4.00 b	34.50 ± 4.13 b

[1/] Mean in the same column followed by a common letter are not significantly different at 5% level by DMRT

Table 3: Concentration of droplet deposition in target area and loss in the ground by using different spraying method

Treatment	**Concentration of droplet (µg/cm^2)**		**Concentration of loss in the ground (µg/cm^2)**
	Upper layer	**Lower layer**	
MSK	0.5278 ± 0.4074	0.3103 ± 0.1506	0.212 ± 0.122 a
UAV	0.5309 ± 0.0345	0.4015 ± 0.1374	0.346 ± 0.090 b
UAV+ Adjuvant	0.5340 ± 0.0401	0.3866 ± 0.2354	0.187 ± 0.039 a

[1/] Mean in the same column followed by a common letter are not significantly different at 5% level by DMRT

Characterization of Spraying Drift

For spraying drift, the experimental results as shown in Table 4. For MSK, there was no spraying drift deposition in upwind zone while the drift in downwind zone was lower than 4 m. On the contrary, the spraying drift was found both upwind zone and downwind zone in UAV and UAV+ Adjuvant. The results of spraying drift indicated that the potential of spray drift took place by spraying with UAV was farer than other methods. This The similar result was described by Punyawattoe et al. (2019) that spraying drift by using UAV in the paddy field was greater than knapsack sprayer. According to the UAV spraying, the droplet size was smaller than the one of knapsack sprayer. Therefore, the drift ability of UAV spraying was higher than conventional spraying by using knapsack sprayer. In the test of UAV and UAV+ Adjuvant, we found out that the spray drift deposition was reduced in the treatment that adjuvant was added even if the wind speed of UAV+ Adjuvant was higher than the one of UAV around 40%.

Table 4: Average spray drift deposition among spray application techniques at different evaluation zone

Treatment	Evaluation zone (m from last swath width)										Wind speed (m/s)
	Spray drift deposition (µg/cm^2)										
	Upwind (m)					Downwind (m)					
	2	4	6	8	10	2	4	6	8	10	
MSK	-[1/]	-	-	-	-	0.10	0.01	-	-	-	0.2
UAV	0.06	-	-	-	-	0.08	0.07	0.03	-	-	0.5
UAV+ Adjuvant	0.02	-	-	-	-	0.03	0.01	0.02	-	-	0.9

[1/] Not detected.

Conclusions

In this study, the UAV spraying by using multi-rotor type UAV was tested to compare the characterization of spraying deposition and spraying drift with conventional spraying by using knapsack sprayer in 50 days old paddy rice. The conclusions are shown as follows:

(1) The average number of droplet deposition from UAV spraying was lower than the conventional one but it had more spraying uniformity.

(2) The concentration of droplet had no significant different between UAV spraying or UAV enhanced with novel adjuvant and the conventional spraying method. However, the loss in the ground of UAV spraying was higher than the one of knapsack sprayer. To mitigate the loss, an adding of adjuvant may be recommended for UAV spraying.

(3) The spraying drift of UAV spraying was definitely greater than knapsack sprayer. The droplet had a possibility to float outside the target area including neighboring plantations or public reservoir. Therefore, the adding of adjuvant with UAV spraying is strongly recommended to increase the spraying efficiency and to avoid the effect of the pesticides that causes by the drift to the environment.

(4) Further research should be done to confirm the efficacy of pesticide spraying by using UAV in the paddy field in different stage of growing to provide more information about the applicability of UAV for farmer.

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