RADIO-CONTROLLED HELICOPTER USE FOR DIRECT SEEDING RICE PADDY; FIELD OPERATIONS AND ESTIMATION

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ABSTRACT

The time components of the operations were investigated on the rice paddy field operations by radio controlled helicopter. The net time of operations, seeding and application, were less than a quarter of the required total time in the field of 1 ha. The most interesting is how to decrease the time of hop-off and landing. In this paper the seeding density itself is taken under a new look and its describing method is discussed. Voronoi diagram was introduced to consider individual plant of rice paddy. Extremely wide ranges of the distribution of seeding density are not supposed by the common indexes based on the concept of mean values and discussed on the aggregate of plants.

INTRODUCTION

An aircraft use for rice cultivation in Japan and other regions is not so convenient on account of small size field and something of electric poles as obstacle. Radio controlled helicopter (RCH) use has been considered sometimes. However, RCH lacking gyro-control is not far from actual usage by its unstable hovering. Recent years industrial use RCH has been developed under the design concept for providing same stability to ordinary helicopter and easy operation. By introducing this RCH to all operations after paddling and before harvesting will be able to be free from propelling on muddy field.

The direct seeding requires the enough preparation of paddy field condition by water control and implement adjustment of drill machine. The soil may be well conditioned, but the scattered seeds has not enough terminal speed to penetrate into soil and rifted by extending roots. The seed lifting demands deliberation as shown by Nakamura (1976, 1981). The downwash of helicopter makes seeds easily penetrate into soil of any condition. The study on air jet application to drilling machine by (1996) has same standings.

This paper is divided to two parts; time study on field operations of seeding and application of herbicide and fertilizer, estimation and pesticide of seeding density and hill distribution. The indexes for yield components of rice paddy, generally in crop science, are presented in mean values and discussed on the aggregate of plants. Extreme wide ranges of the distribution of seeding density and variance of seed spacing, like the results of operation by using RCH, are not supposed by such method. We have to establish the estimation methods for RCH introduction to rice paddy growing.

FIELD OPERATIONS

Apparatus and Methods The specifics of employed RCH are presented in Table 1. This RCH on market has the maximum payload 25 kg for practical usage under the permission of Aviation Law in Japan. Total length and width are 3000 mm and 620 mm respectively, and transportable with common wagon car by complicating main rotor. It is significantly deferent from common RCH, most of them for hobby use, that mechanical gyro-stabilizer is systematized; it is easy to keep constant flight height and also hovering height. The equipment mounted are broadcaster (impeller of 240 mm in diameter) for seeding or fertilizer application or a couple of atomizers (disk type rotating at 6800 rpm) for liquid chemicals. The net payload for the application materials, tank or hopper capacities, is 10 litters for liquid and particles. The maximum duration of flight is 30 min. for full charged materials by 4 litters fuel. The general view of employed RCH is shown in Fig.1.

The layout of employed paddy fields is shown in Fig.2. The paddy fields were divided to three parts by seeding methods for comparison; RCH, riding drill and knapsack power applicator. Both fields were paddled on two days before seeding and 1 to 3 cm in watered depth, and their the liquid and plastic limits were respectively 55.1 % and 26.8 % in field A, 62.7 % and 24.1 % in field B. The application of herbicide and top dressing were carried by RCH for the whole area of the fields. The broadcasting width was 5 m, also for the swath width. The flight passes for seeding are shown by dotted arrows, and the other operations were carried by returning in same direction from north to south. In the south part of field A flight direction was changed as shown because some trees are standing as obstacles near to field. The operations for seeding, herbicide application and top dressing were carried out in the condition presented in Table 2. Paddies were coated by CaO_2 for seeding, and coated weight was 80 kg for 25 kg of net paddies.

Time Components and Field Efficiency of RCH Operations The required time and its components for each field operation of seeding, herbicide application, top dressing (2 passes of half application rate and regular rate by 1 pass) and pesticide application are shown in Fig.3 where the required time for adjusting implement and engine is not included; about 15 min. for each operation, non-related to area. Nearly a half of total time was spent for moving between landing point and applying cite, and about 1/3 of this half was the period for observing the engine stability after a hop-off. About a quarter of total time was spent on the ground for loss time for rotor rotation by inertia, charging fuel and feeding application. The net operation time including headland turn was less than a quarter of total time. The highest field efficiency was obtained in pesticide application. It was because large area could be covered by one flight and the time for moving between landing point and applying cite was saved. The lowest field efficiency was in top dressing because the application rate of fertilizer is large in weight, and frequent landing is required. However, its efficiency, about

1 hour per ha, was not so low as common method by a broadcaster of 10 m application width and 2 m/s traveling speed.

Seeding Operation The downwash of rotor has speed of about 8 m/s at the 30 cm height from ground for flight height of 3 – 4 m. The broadcast seed accelerated by the gravity and the downwash passes through water and penetrates into soil. The penetrated depth of the seed was measured by using displacement meter of laser reflection type. The depth was 5 – 10 mm from soil surface. The seed positioned in soil lay on its lateral side, and the penetration had some angles from vertical under the influence of downwash.

The positions of broadcast seeds were measured, for single pass of flight, by grease-dressed board of 50 cm width and 20 m length laid on field–side; grease caught the seeds to fix well against downwash blast. The positions of seeds were calculated from the photographs by using image processor. The result was shown in the histogram for the distance from flight center (Fig.4). The pattern of distribution is seen racking in left side of top or asymmetrical binomial distribution. However, this does not show the characteristics of employed broadcaster itself. The distribution pattern will be changed by the setting of impeller rpm vs. feed rate of material, kind of material or the location of open part of impeller casing. This fact was observed in another seeding operation carried by different condition of lower feed rate. Father details should be defined by experiments.

FIELD ESTIMATION

General Results of Rice Paddy The details of yield components obtained from sampled unit area are presented in Table of appendix with comparison to other direct seeding methods and also transplanting.

Hills Distribution in Field The stump density per sq. meter was counted in each 1 m section along longitude direction from point A to A′ as shown in Fig.2 as AA′, and is shown in Fig.5. Seeding was done by 5 passes of flight upon the center of every 5 m widths for total width of 25 m. Seeding density was estimated from the recorded flight speed of each pass and the density distribution function obtained from Fig.4. The number of seeds swathed in unit length at position x (x=0 – 1, corresponding to position from –6.2 to +6.2 m as the origin at flight center) and for 1 m width for flight direction by single pass of flight is given by

$$S(x) = kp(x) = \frac{1}{B(q,r)} x^{q-1}(1-x)^{r-1} \tag{1}$$

where k is constant (= 55.6), q and r are estimated as 5 and 4 respectively. The estimated values are shown in Fig.5, and some correlation is seen to stump density. The ratio of stumps and seeds was extremely lower than establishment ratio, from 45 to 70 %, in ordinal direct seeding by using drill machine. The desired seeding rate was planed in much higher. However, the establishment ratio was within the range above cited. Two or three seedlings nearly positioned each together gathered like to one stump, and counted as one stump.

Stump distributions after harvesting are shown in Fig.6; an example of sparse distribution (a) and dense one (b). Numbered labels were attached on hills for the calculation of their coordinate as shown in photographs. In each example density has big variance and the randomness of spacing distance between neighboring hills is also large. Those variance and randomness were, as a matter of course, resulted from RCH seeding. The indexes of yield components of rice paddy, generally in crop science, are presented in mean values and discussed on the aggregate of plants. Extreme wide ranges of the distribution of hill density and variance of hill spacing are not supposed by such common method.

Voronoi Diagram Voronoi diagram was introduced for the estimation of a individual rice paddy hill spacing. The concept was developed by G. Voronoi in 1902 (Okabe, 1993), and is frequently applied to optimum spacing problems in urban planning (ex. Okabe, 1988). Voronoi polygon is defined as follows. When any point p_j is connected with another point p_i, let H_{ji} the semi-finite planes given by perpendicular bisectors in the side of point p_j. The interjection V_j

$$V_j = H_{j1} \cap \cdots \cap H_{jj-1} \cap H_{jj+1} \cdots \cap H_{jn} \qquad (2)$$

is the convex polygon of Voronoi diagram. The position of rice paddy hill in field is assumed as point p_j and Voronoi diagram was calculated by using personal computer. An example of calculation results is shown in Fig.7.

We considered the yield components of individual plant for each area of Voronoi diagram. The relation of yield per hill to each area of Voronoi polygon is shown in Fig.8. Many hills were plotted less than 150 cm^2, and the maximum area was 520 cm^2, little larger than that in transplanted field. The correlation curve was estimated as shown in Fig.9, given by curve ①. If the range of the area was taken for more larger, the curve will increase and then be saturated in certain value. The increase of the curve may reach to 700 or 900 cm^2 as shown by broken part of curve ①. When seeds are uniformly distributed in same area of Voronoi diagram, the yield per sq. meter is estimated as shown in Fig.9, given by curve ②. The mean values of yield obtained from the field per sq. meter are plotted for dense, minimum and sparse place, corresponding to 100, 200 and 400 cm^2. The values of plots at medium and sparse parts are higher than that of the estimated curve. It was because the dense part of rice paddies existed in the sampled sq. meter raised the mean value. However, this fact goes for nothing of the grounds that only mean value obtained from the sampled unit area shows whole situation of the yields also for the extremely wide range of distribution of density by RCH seeding. The method of Voronoi diagram applied to the consideration focused on the individual plant presents the grounds of an argument that the higher value of yield obtained from the sampled unit area was caused by the yield in dense part of plants.

CONCLUDING REMARKS

Further diffusion of RCH operations in rice paddy field may be concerned with reducing the time for hopping off and landing. The more lower rate of seeding is not entirely to decrease the yield but increased field efficiency for seeding. The results in practical field will be obtained in this autumn.

ACKNOWLEDGMENT

We wish to express our thanks to Mr. Tsuyoshi KITA and Mr. MATOBA, Yanmer Agricultural Equipment Co. ltd. for providing us with RCH operations in our Experimental Farm, Kobe University, and also to Mr. Hitoshi SAKAMOTO and Mr. Minoru KAMATA, Faculty of Agriculture, Kobe University, for assisting our experiments.

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Table 1 Specifics of employed RCH

Plane	Total length	3000 mm
	Total height	1160 mm
	Main rotor diameter	3250 mm
	Empty weight	58 kg
	Payload	25 kg
Engine	2 stroke-cycle / opposed-horizontal 2 cylinders	
	Max. power	12.5 kW / 8800 rpm
Equipment	payload for application material	10 kg
	Duration of flight	30 min. / fuel 4 l
	Swath width	5 m for liquid and particle
	Propelling speed	10 ~ 20 km/s
	Allowable wind speed	less than 3 m/s

Fig.1 General view of employed RCH

Table 2 Items concerning operations

	unit	Seeding *	Herbicide	Top dressing	Pesticide
Application rate (planned)	kg/ha	25 **	30	100	8 ***
Area applied	ha	0.468	1.17	1.17	1.0
Results of application	kg/ha	21.8 **	30.1	99.2	8 ***
ibid. total	kg (l)	10.2	35.2	116.1	8
Flight speed	m/s	4.0	4.7	4.5	4.6
Flight height	m	3 - 4	3 - 4	3 - 4	3 - 4
Wind velocity	m/s(dir.)	2.4 (SE)	1.9 (SSE)	1.8 (SE)	1.9(SSE)
Particle size (diameter.)	m	5.3	1.2	2.7	-

* 80 kg in CaO_2-coated ** net paddy in dry matter *** l/ha

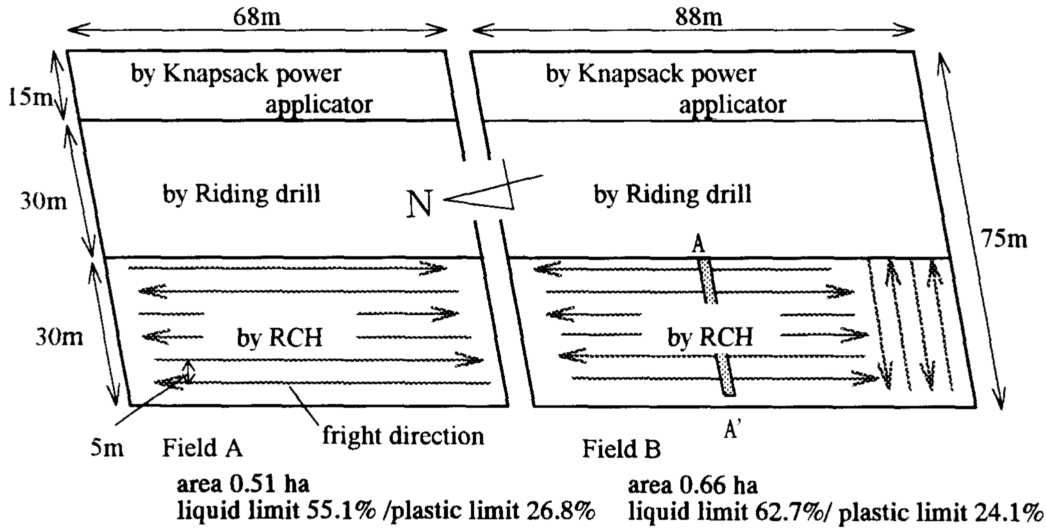

Fig.2 Layout of employed field and soil properties

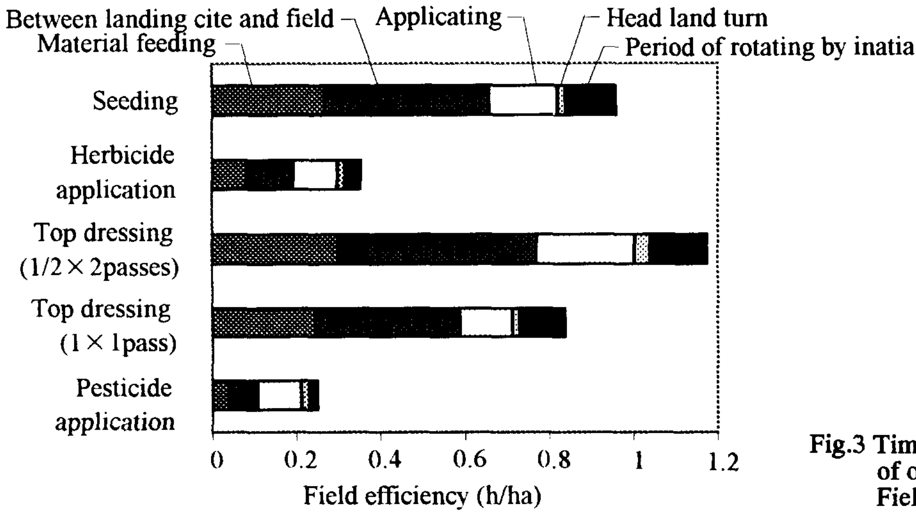

Fig.3 Time components of operations and Field efficiencies

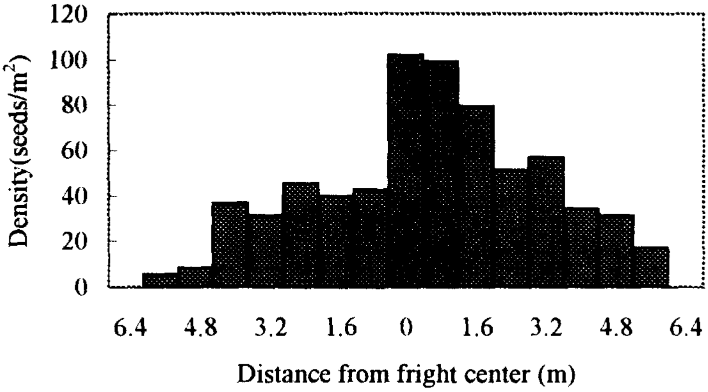

Fig.4 Swath distribution of seed by single pass

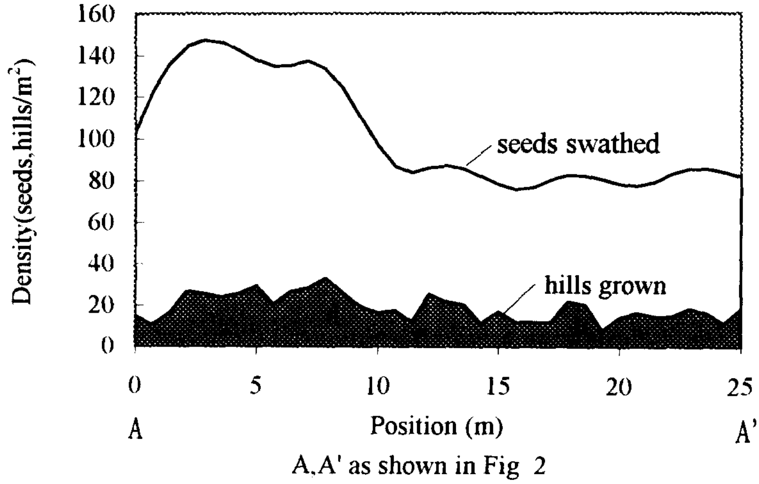

Fig.5 Distribution of seeds and hills

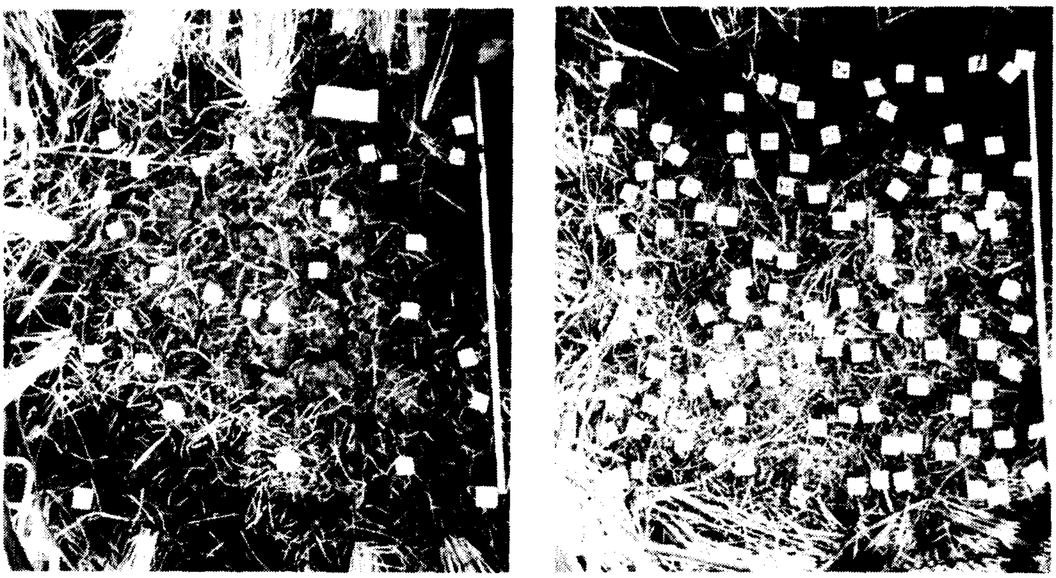

Fig.6 Examples of tumps distributions after harvesting; (a) sparse and (b) dense

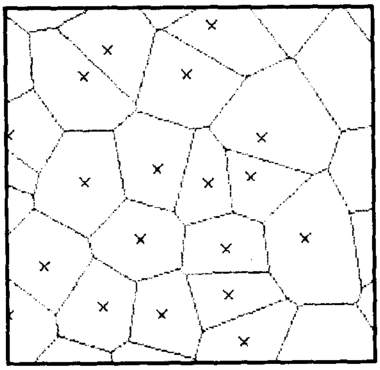

Fig.7 An example of Voronoi diagram applied to hill distribution (hills corresponded to ×)

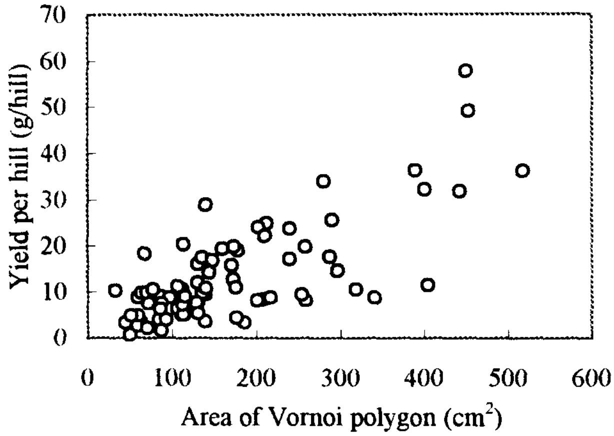

Fig.8 Yield per hill vs. area of Voronoi polygon

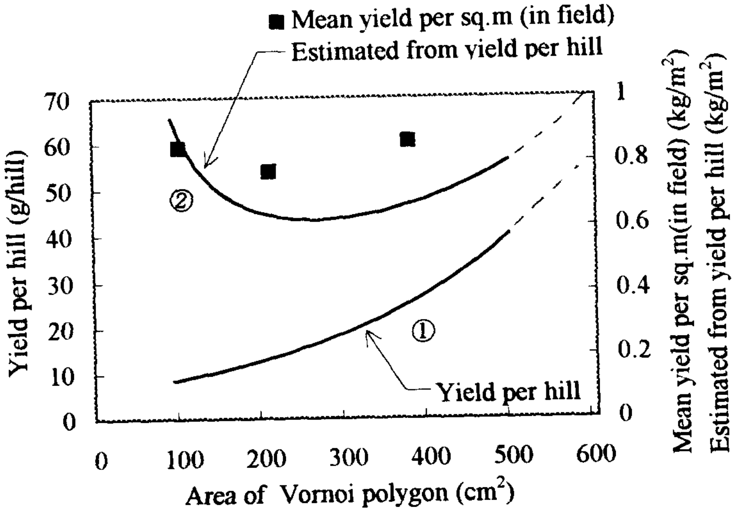

Fig.9 Correlation regression curve obtained from the data the data shown in Fig.8 and yield per sq. meter estimated from the regression curve

APPENDIX

The yield components obtained in the sampled sq. meter of field are presented in Table (next page). The yield components obtained in the other field by riding drill and knapsack power applicator are also presented for comparison. The results in the field by transplanting machine is presented for comparison in yield amount The average yield from the field by RCH was higher than those from the field drill and power applicator. The field was arranged for RCH broadcasting, and not well fit to drilling. The variances for any items in the field by RCH were larger than in the field by another methods. The paddy weight per sq. meter in the field by RCH was larger that that in the field by transplanting machine, but less in brown rice.

Table Yield components of sampled sq. meter in each field by RCH, riding drill, knapsack power applicater and transplanting machine

Variety; *Kimmaze*, grown at Experimental Farm, Faculty of Agr., in 1995

		hills (/m²)	paddy weight (g/m²)	paddies per head	heads (/m²)	ripen -ing (%)	brawn rice (g/m²)
RCH	dense	143	933	70.4	509	84.7	
		114	790	91.5	403	86.4	
		88	905	78.2	434	75.1	
		88	759	82	354	85.9	
		84	830	71.5	414	65.7	
	[average]	[103.4]	[843.4]	[78.7]	[422.8]	[79.6]	
	medium	42	728	83.6	305	89.5	
		47	840	90.6	233	79.8	
		57	842	69.2	359	89.6	527
		45	762	87.9	349	90.3	[total ave]
		42	672	81.5	333	86.3	
	[average]	[46.6]	[768.8]	[82.6]	[315.8]	[87.1]	
	sparse	29	812	113.4	356	69.7	
		22	914	114.3	413	66.2	
		25	756	87.4	316	91.4	
		25	937	87.9	425	86.2	
		30	890	89.7	330	76.9	
	[average]	[26.2]	[861.8]	[98.5]	[368]	[78.1]	
Riding drill		84	779	82.4	361		
		70	563	78	291		
		92	490	92.6	252		
		69	476	82.3	248		
		59	487	76.9	242		
		[74.8]	[559]	[82.4]	[278.8]	[94]	427
Knapsack power applicator		34	651	62.2	337		
		23	479	81.4	244		
		65	689	66.5	366		
		43	694	73.2	298		
		25	693	82.4	364		
		[38]	[641.2]	[73.14]	[321.8]	[93]	447
Transplanting machine			820	85.8	415		
			722	71.7	366		
		[17]	[771]	[78.8]	[390.5]	[94.6]	592

(note) 1000 grains weight was 23.9g in average, no significant variance each together