A comprehensive look at the universal self-propelled rice transplanters using analytic hierarchy process (A case of a developing country)

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Abstract: The main aim of the study at the first phase was to rank all common rice transplanters used in Guilan Province, Iran, by relevant experts in the area from technical, social and economic aspects. After the most appropriate rice transplanter was identified, the technical skillfulness of operators to use the selected machine was assessed at the second phase. To this end, analytic hierarchy process (AHP) was applied and the opinions of experts were asked to explore the most appropriate rice transplanter in the study region based on nine criteria including ergonomics, economic advantage, reliability, field capacity, ease of use, ease of repairs and access to spare parts, compatibility with plot conditions, planting density range, compatibility with different soil conditions and planting quality of the rice seedling. A pairwise questionnaire and face to face interview were used to collect data. The statistical sample in this study was 15 experts in the field of agricultural machinery. Among the studied indices, the ease of repairs and access to spare parts criteria had the highest importance score (0.217) in determining the most appropriate rice transplanter, followed by reliability and ergonomics (0.169 and 0.104, respectively). Overall, the 4-row DaeDong rice transplanter (0.194) was the first choice from experts' perspectives. 4-row Kubota walking-type and 6-row DaeDong riding-type rice transplanter (0.167 and 0.154, respectively) were ranked at second and third places. In addition, 4-row TongYang ranked at last place. Respondents' knowledge about 4-row DaeDong as the selected rice transplanter was assessed and the research members were classified into skillful and semi-skillful groups. Results showed that the majority of respondents (51.8%) were in semi-skillful groups. The findings not only aid in selecting the most appropriate rice transplanter, but also it is useful to set appropriate training programs to enhance the required technical skills of the selected rice transplanter operators in the study region.

Keywords: agricultural machinery, mechanization, prioritization, rice transplanter, technical skills

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1 Introduction

Whereas the main resources of agricultural crop production, i.e. water and land, are constant, the global population is steadily growing. Consequently, people are faced with limitations in meeting their food demand and have no way but to resort to technologies that can enhance the performance of labor, land, and water as the main production factors. Agricultural machinery that

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constitutes a category of these technologies is presently regarded as one of the main parameters of the sustainability of the agricultural sector (Goyal et al., 2014; Edgerton, 2009). By managing this technology appropriately, the crop production cost is reduced and then, the farmers' income is promoted; making agriculture more economical (Paudel et al., 2019).

Rice is the second most important food crop after wheat in Iran (Firouzi et al., 2017). It plays a significant role in the livelihood of rice growers in Iran and has crucial strategic importance. Although rice has a long and rich history of cultivation and experience among rice growers of Iran, it is in a poorer condition in terms of the adoption of new technologies for its mechanized planting than other agricultural and horticultural crops (Yaghoubi and Asoudar, 2010). The manual transplanting of rice seedlings in flooded and puddled fields is labor intensive (Thomas, 2002). In addition, unavailability of adequate human resource in rice transplanting season and the resulting delay in transplanting operation, and the non-uniform and inadequate transplanting of rice across fields by manual transplanting are the main motives for the tendency towards rice planting mechanization (Hemmat and Taki, 2002). As well, research has shown that rice yield is higher in mechanized planting than in manual planting (Sing et al., 2006; Chaitanya et al., 2018). Owing to the physiological need of rice plants to saturated soil, its planting machines are different from those of other crops, so its mechanized planting requires special mechanical technologies (Firouzi, 2015).

1.1 Rice transplanter

A rice transplanter (RT) is a specific machine equipped with a special planting mechanism driven manually or by an engine in order to establish young rice seedlings onto paddy satisfactorily (Shahid et al., 2019). Regardless of the power source, RTs are broadly divided into wash root and mat types. In wash root type, 4-6-leaf seedlings are uprooted from the nursery and their roots are washed. Seedling harvesting, washing, and placement in the boxes of the machine are labor-intensive. In mat-type transplanters, rice seedlings are grown in specialized trays. Then, after about one month, they are separated from the tray bed as a piece of mat and are placed on the machine. Mat-type transplanters are more efficient than wash root type so that their labor requirement is one-fourth of that of wash root type. Also, RTs are divided into manually operated, self-propelled walk behind, self-propelled riding, and tractor operated on the basis of power supply and operation (Dixit et al., 2007).

The development of RTs in Iran was practically begun in 1991. First, trials were carried out on wash root-type transplanters and their results turned out to be satisfactory. After mat-type self-propelled walk-behind transplanters were introduced, further experiments were carried out. In 1994, several Korean 4-row transplanters were imported into Iran and distributed among pioneer farmers. Presently, as statistics of Jihad-e Agriculture Organization of Guilan province shows, there are 4620 RTs of self-propelled walk-behind and self-propelled riding types operated in this province (Guilan Organization of Jihad e Keshaverzi, 2017). Seven RTs conventionally used across Guilan Province, Iran includes 4-row Daedong walking-type RT, 4-row Yanmar walking-type RT, 4-row Kukje walking-type RT, 4-row Tongyang walking-type RT, 6-row Daedong riding-type RT, 4-row Kubota walking-type RT, and 6-row Kubota walking-type RT (Figure 1).

The techno-economic and ergonomic performances of various RTs have been assessed in some studies. In this regard, Munnaf et al. (2014) evaluated the techno-economic performance of imported Kukje RTs in Bangladesh. The mechanized method exhibited higher grain yield and lower production cost than the manual method. Dixit et al. (2007) reported about the performance of mat-type transplanters in India that they were more efficient and less labor-dependent. Overall, 6-row manually operated transplanters were found to be the best for India. Singh et al (2006) reported that rice transplanting by a self-propelled wheel-driven transplanter had better field capacity and energy use efficiency and was more economical than direct dry seeding, direct seeding in the puddled field, and manual transplanting. Murumkar et al. (2014) also focused on the performance of a Mahindra self-propelled paddy transplanter in India. The performance of the machine was assessed positively versus user-friendly manual transplanting on the basis of time, cost, and labor-dependence. Patil et al. (2017) tested the performance of a wash root-type paddy transplanter developed in India. They reported the field capacity and efficiency of the transplanter at 0.0445 ha/h and 43%, respectively. Also, paddy transplanting with the developed transplanter was about 39% of the manual method. Firouzi (2015) reported that the mechanization degree of paddy transplanting was about 25 percent in Guilan province, Iran whilst the mechanical weeding with a mechanization degree of <1% fully depended upon row sowing with transplanters.

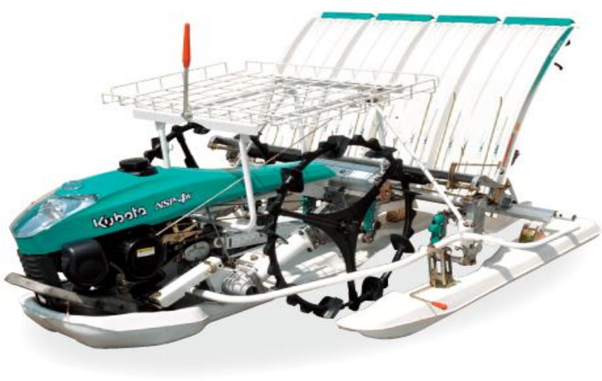
a. Four-row Daedong rice transplanter

b. Four-row Yanmar rice transplanter

c. Four-row Kukje rice transplanter

d. Four-row Tongyang rice transplanter

e. Six-row Daedong riding-type rice transplanter



f. Four-row Kubota rice transplanter

g. Six-row Kubota rice transplanter

Figure 1 Rice transplanters conventionally used in Guilan Province, Iran

1.2 The necessity of study

Given the increasing wage of labor and the loss of labor availability and to contribute to the sustainability of the production of this strategic crop in the north of Iran, it is necessary to explore the technical, social, and economic performance of RTs that have already been introduced into the province of Guilan to use the results in purposeful planning for the support of machinery import and the supply of the conditions for transplanter development in this province. So, the first phase of the study will rank all RTs used in Guilan Province by relevant experts in this province from technical, social and economic aspects. After the most appropriate type is identified, the technical skillfulness of operators to use this specific type will be assessed in the second phase. Obviously, the results can contribute to regional and national planning at a macro level for the importation of suitable machinery that is compatible with the conditions of Guilan province and for the maintenance of sustainability of this strategic crop in the region.

2 Materials and methods

The research was conducted in Guilan province in the north of Iran (Figure 2). The province is the second leading rice producer of Iran in terms of acreage and the leading producer in terms of production rate (Firouzi et al., 2017).

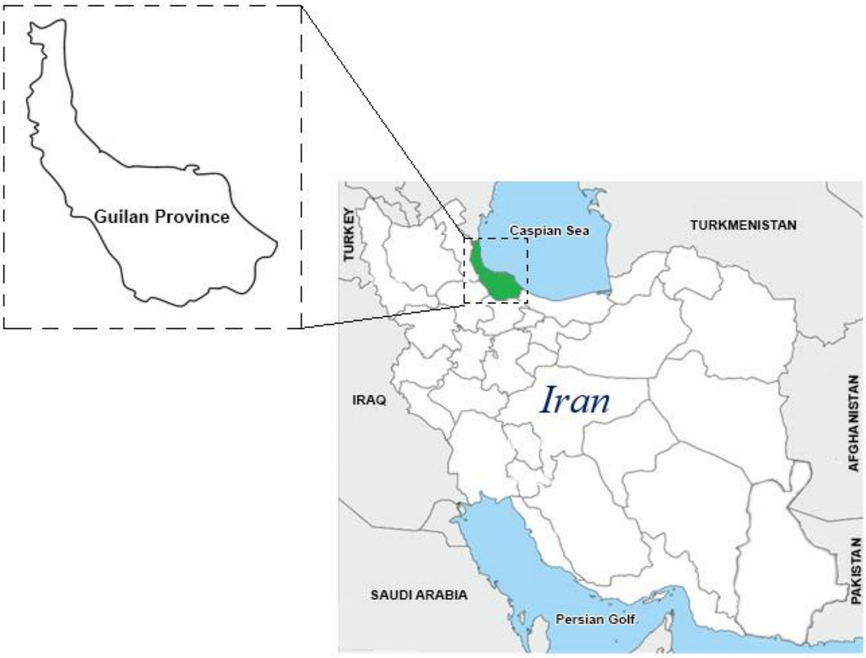


Figure 2 Map of the study area, Guilan Province, northern Iran

2.1 Population and sample

Since the study was carried out in two phases, the statistical population was specified in two phases. In the first phase, the analytic hierarchy process (AHP) was applied to identify the most appropriate RT for the conditions of Guilan Province, north of Iran. Accordingly, fifteen experts including experienced farm machinery researchers, salespeople and repairmen of the RTs (having at least 20 years of relevant background and credibility and recognition in the target community) were selected to fill out the related questionnaire. After the most appropriate RT was specified, the second phase was carried out on 85 RT users sampled by simple randomization from the statistical population to fill out the second phase questionnaire.

2.2 Analytic hierarchy process (AHP)

Tomas El-Saaty in 1980 firstly presented the AHP as an efficient decision-making tool (Saaty, 1990). This technique builds on pairwise comparisons of importance indicators and criteria and enables decision-makers to examine different situations. AHP technique is based on pairwise comparisons and allows examining various scenarios. Due to its simple, yet comprehensive nature, AHP has been welcomed by different managers and users. There are many AHP studies for decision-making on different alternatives and scenarios to execute the agricultural plans and to do agricultural activities (Bagheramiri et al., 2014; Amini and Asoodar, 2016; García-Alcaraz et al., 2016; Tošović-Stevanović et al., 2020; Firouzi et al., 2021). It has also been interested in by the scientific circles in the last 30 years. The technique allows formulating a problem as a hierarchy and considering different quantitative and qualitative criteria for the problem. By this technique, different alternatives are involved in decision-making and the sensitivity can be analyzed on criteria and sub-criteria. Furthermore, it facilitates the pairwise comparison of variables, judgments, and calculations. It also shows the compatibility/incompatibility of decision, which is the overwhelming advantage of this technique in multi-criteria decision-making. A utility function-based theory can express a decision-maker's mood by exchanging the goals of moods and habits and mathematical representation of these habits so that decisions can be adjusted with respect to his/her preferences. The integration of the AHP technique and the theory of utility can lead to more precise decision-making. AHP is a graphical representation of a complicated problem in which the general goal of the problem is placed at the top and the next levels are devoted to criteria and alternatives (Baffoe, 2018, Bagheramiri et al., 2014).

In AHP, the elements in each level are compared with their respective elements in the lower level in a pairwise manner and their weights, called relative weights, are calculated. Next, the relative weights are aggregated to yield the final weight for each alternative, which is called absolute weight. Afterwards, the criteria are weighted against the objective and their aggregation gives the final weight of each individual alternative. All comparisons in AHP are pairwise in which decision makers will use verbal judgments. Saaty (1990) has converted these judgments to quantitative values from 1 to 9 as presented in Table 1, so that when element *i* is compared with element *j*, the decision maker will express the importance/priority of *i* versus *j* as one of those states.

Table 1 Equivalent concepts for pairwise comparison scores in the AHP method

Preferences (oral judgment)	Numerical value
Extremely preferred	9
Very strongly preferred	7
Strongly preferred	5
Moderately preferred	3
Equally preferred	1
Intermediate	8,6,4,2

Consistency ratio (CR) is a tool to specify the consistency and shows the extent to which the priorities derived from the comparisons can be trusted. CR of 0.1 or lower expresses the consistency of the comparisons. Saaty (1990) defined the consistency index (CI) as:

$$CI=(\lambda_{max}-n)/(n-1) \quad (1)$$

where λ_{max} is the maximum eigenvalue and n is the number of factors in the judgment matrix. Accordingly, Saaty (1990) defined the consistency ratio (CR) as:

$$CR = CI / RI \quad (2)$$

where RI is represented by average CI values gathered from a random simulation of Saaty pairwise comparison matrices CIs. The suggested value of the CR should be no higher than 0.1 (Franek and Kresta, 2014).

2.3 Data collection

Based on the AHP methodology, the present study first compared the criteria on a pairwise basis. The criteria were selected by technical interviews with experts of RTs with respect to the agronomic, and socio-economic conditions of Guilan Province. Finally, 10 following criteria were considered for the comparison:

Table 2 Technical specifications of the rice transplanters investigated in Guilan Province, north of Iran

Rice transplanters* / Specifications	Daedong DP480 (Fig 1*a*)	Yanmar AP4 (Fig 1b)	Kukje (Fig 1c)	TongYang pf48 (TYM) (Fig 1d)	Daedong S3-680 (Fig 1e)	Kubota NSP-4W (Fig 1f)	Kubota NSP-6W (Fig 1g)
Driving unit	Walk Behind, 4 rows, 2 tire	Walk Behind, 4 rows, 2 tire	Walk Behind, 4 rows, 2 tire	Walk Behind, 4 rows, 2 tire	Riding Type, 6 Rows, 4 tire	Walk Behind, 4 rows, 2 tire	Walk Behind, 6 rows, 2 tire
Engine type	4 cycle, Gasoline Air-cooled	4 cycle, Gasoline Air-cooled	4 cycle, Gasoline Air-cooled	4 cycle, Gasoline Air-cooled	4 cycle, Gasoline Air-cooled	4 cycle, Gasoline Air-cooled	4 cycle, Gasoline Air-cooled
Rated revolution (kw rpm^{-1})	2.94 / 3200	2.6 / 3000	4.0 / 1800	3.2 / 3200	8.8 / 3600	2.6 / 3000	3.3 / 3200
Transmission level	F:2, R:1	F:2, R:1	F:4, R:4	F:2, R:1	HST type, Sub transmission: 2	F:2, R:1	F:2, R:1
Transplanting speeds Average (m s^{-1})	0.6	0.57	0.5	0.73	0.68	0.56	0.53
Transplanting interval (cm)	13, 15, 17	12, 15, 17, 22	14, 16, 18, 22	14, 16, 18	12, 14, 16, 18	12, 14, 16, 18, 21	12, 14, 16, 18, 21
Working capacity Average (ha h^{-1})	0.100	0.188	0.180	0.209	0.100	0.150	0.212
Weight (kg)	185	155	152	175	620	160	190

Note: * Adapted from the machines manuals. All units were matched.

A.1 *Ergonomics*: Machine structure in terms of access to controls and adjustments, comfortability of the driver's seat in riding type, control over steering and balance of the machine

A.2 *Economic advantage*: the costs of purchase, service, and maintenance of machines

A.3 Reliability: reliability to optimal and uninterrupted performance of the machine (or the minimum failure) in the working season (Almasi et al., 2005).

A.4 Field or machine capacity: an area of the field in m^2 (or ha) worked in one hour. It is a decisive factor in farm machinery management (Grisso et al., 2004).

A.5 Ease of use: the skill level needed to adjust, maintain, and steer the machine during transplanting operation

A.6 Ease of repairs and access to spare parts: the skillfulness of repairmen in repairing the broken machines, easiness, and the time required to overhaul machine components, as well as access to the spare parts in the domestic markets

A.7 Compatibility with plot conditions: matching with diverse geometrical shapes and the size of paddy plots in Guilan province

A.8 Planting density range: the capability to adjust the spacing between the hills with respect to cultivar and paddy field conditions

A.9 Compatibility with different soil conditions: compatibility with soil conditions of paddy fields (depth of soil and its texture) in terms of the steering the machine and its optimal performance

A.10 Planting quality: the capability of planting different rice seedling cultivars in different sizes, appropriate deployment of the rice seedlings in soil, and the optimal growth of the seedlings.

The research alternatives were composed of seven conventionally used RTs across Guilan Province, Iran, i.e. 4-row Daedong walking-type RT (D1), 4-row Yanmar walking-type RT (D2), 4-row Kukje walking-type RT (D3), 4-row Tongyang walking-type RT (D4), 6-row Daedong riding-type RT (D5), 4-row Kubota walking-type RT (D6), and 6-row Kubota walking-type RT (D7) (Figure 1). The technical specifications of the RTs investigated in the study are presented in Table 2. Figure 3 depicts the AHP decision tree for present study. Pairwise comparisons were made on a nine-point range of preferences based on the studied indicators. Table 1 shows the concepts equivalent to the scores of pairwise comparison test in the AHP method.

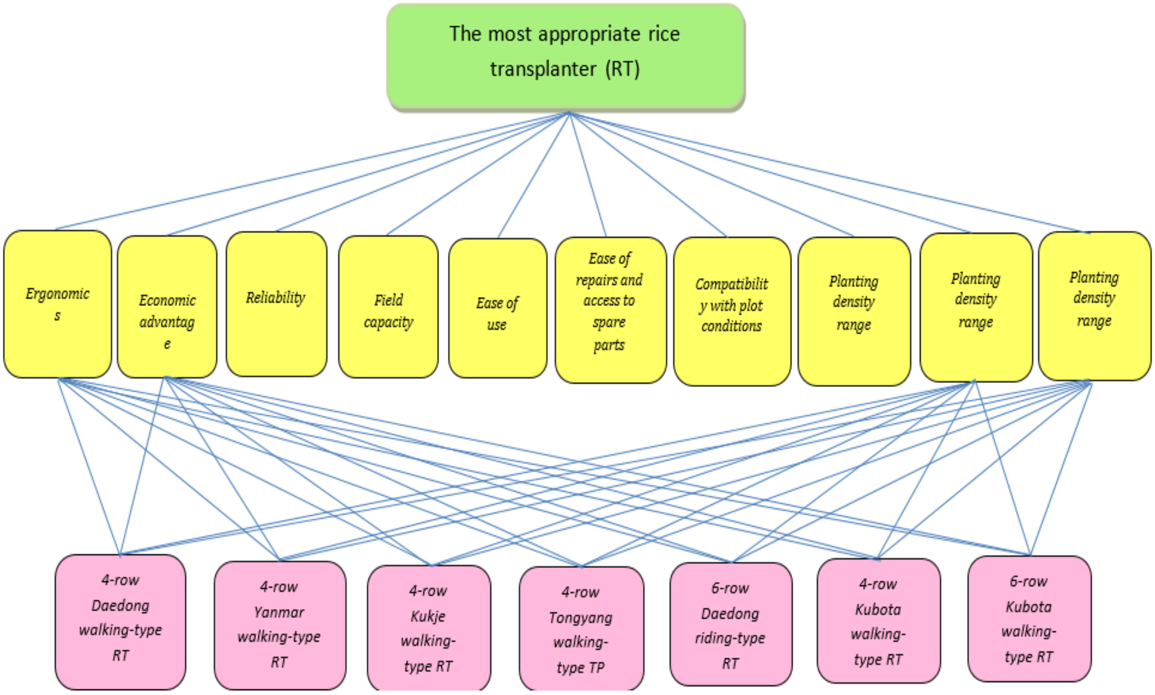


Figure 3 The AHP decision tree for selecting the most appropriate rice transplanter in Guilan Province, northern Iran

The questionnaires of this phase were all filled out through face-to-face interviews in a calm and friendly atmosphere. Since two members of the research team were presented in interviews, all studied criteria were discussed.

The second phase addressed the analysis of technical knowledge of the select RT operators using a researcher made questionnaire that was composed of two sections. The first section was related to the demographics features of the participants i.e. their age, educational level, field of study, work experience, ownership type, attendance in extension courses, membership in cooperatives, the use of bank credits, access to information, the area of paddy fields, the number of farm parcels, farm equipping and rehabilitation, and the ability to perform partial and overall repairs on RTs. The second section included 31 true-falls questions about the repair, maintenance, and use of the RTs for which the manual of how to use RTs and the opinions of agricultural mechanization experts were used. The questions were multi-choice with the answers confined to correct/incorrect or ‘I don’t know’. The face validity of the questionnaire was checked by a panel of experts from academia and Jihad-e Agriculture Organization. The questionnaires were filled out during interviews with operators.

Data of the second phase were analyzed by descriptive statistics including frequency, percentage, mean, and standard deviation used to summarize and categorize the data. The skillfulness of the operators was assessed by 31 true-false questions in which each correct answer was scored one, so the respondents could be scored 0-31. These scores were converted into z-scores in order to categorize the respondents so that individuals with negative z-score (smaller than the sample average) were categorized as the semi-skillful users and those with a positive z-score (greater than the sample average) were categorized as adequately skillful users. The normality of the data was checked by the Shapiro-Wilk test at the 5% error level whose statistic was found to be 0.963 at the $p<0.05$ level, so we used the non-parametric Kruskal-Wallis and Mann-Whitney tests to compare to the studied sub-categories. Given the low number of samples and the unknown distribution of the statistical population, the sample was taken by the bootstrap technique. Bootstrap is a sampling technique relying on a frequent replacement from a major sample. In other words, frequent re-sampling with replacement is performed from a constant sample with limited volume so as to be able to use the results of all samplings to achieve a sample distribution. In the end, the sample distribution forms a basis for estimations, especially the estimation of standard error for different parameters. In bootstrapping, instead of estimating the standard error by a sample (main sample), frequent (often more than 200) re-sampling is performed to achieve an empirical sample distribution that becomes the basis for calculating the standard error. This empirical sample distribution is called bootstrap sample distribution (Härdle et al., 2003).

3 Results

The pairwise comparison of the criteria that were considered for the selection of the most appropriate RT showed that "ease of repair and access to spare parts" (A6) was the first priority. According to Figure 4, A6 had the highest degree of importance (0.217) among all criteria. The inconsistency rate for the pairwise comparisons of this criterion was 7% which was smaller than 10%, implying the acceptable precision of this pairwise comparison. As well, the criteria of "reliability" (A3) and "ergonomics" (A1) were ranked the next with importance degrees of 0.169 and 0.104, respectively.

Figures 5 (5a-5j) illustrate the ranking of RTs in Guilan Province in terms of the 10 criteria studied here. Pairwise comparison of RTs in terms of "ease of repair and access to spare parts" showed that 4-row Daedong walking-type RT (D1) and 4-row Kubota walking-type RT (D6) were the most appropriate RTs in Guilan province with the priority degrees of 0.376 and 0.122, respectively (Figure 5a). These pairwise comparisons exhibited an inconsistency rate of 0.5% for this selection which is smaller than 10%, so these comparisons had an acceptable accuracy.

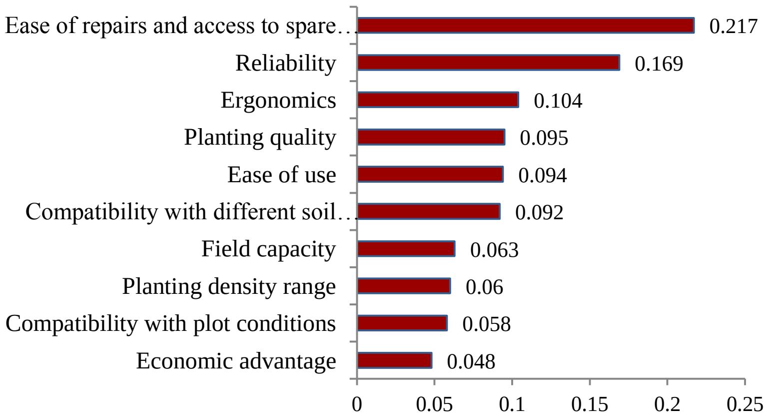
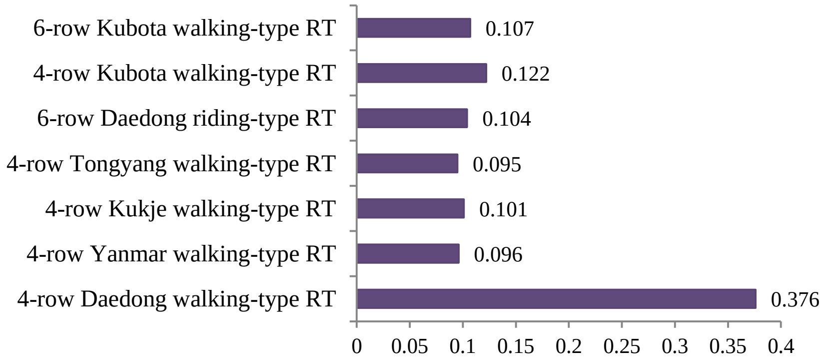
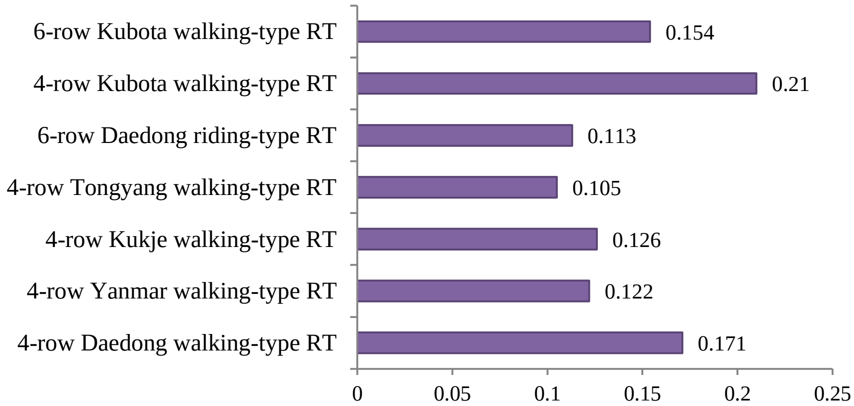


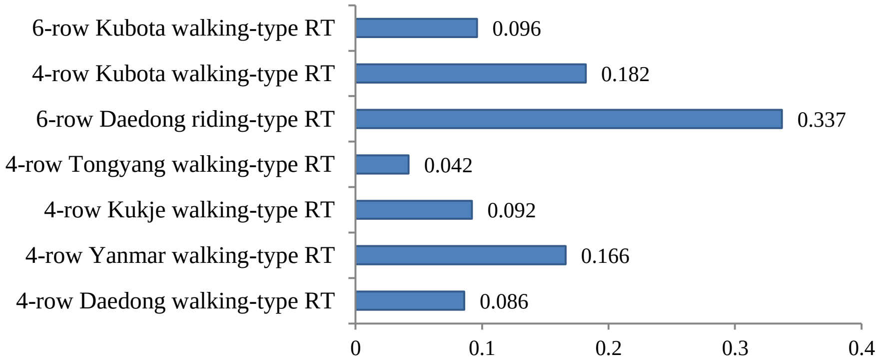
Figure 4 Pairwise comparison of the studied criteria of rice transplanters



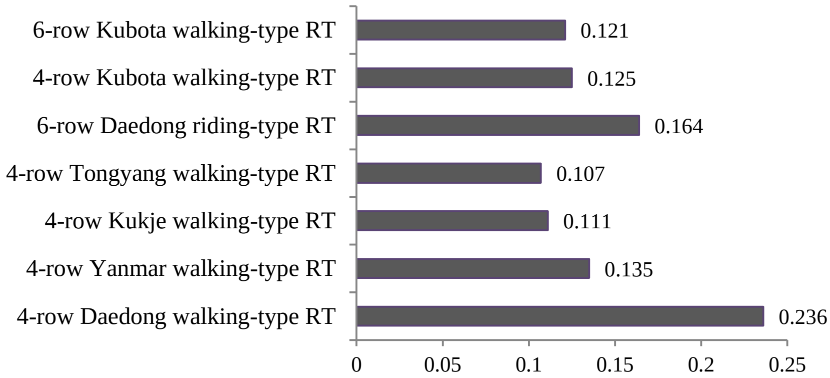
a. Ease of repair and access to spare parts



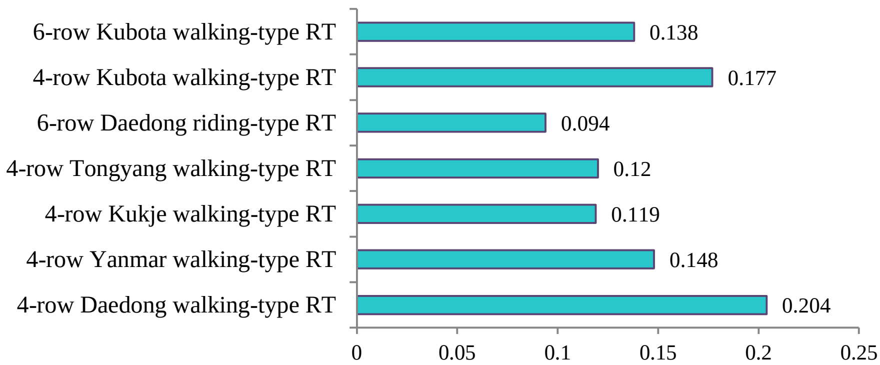
b. Reliability



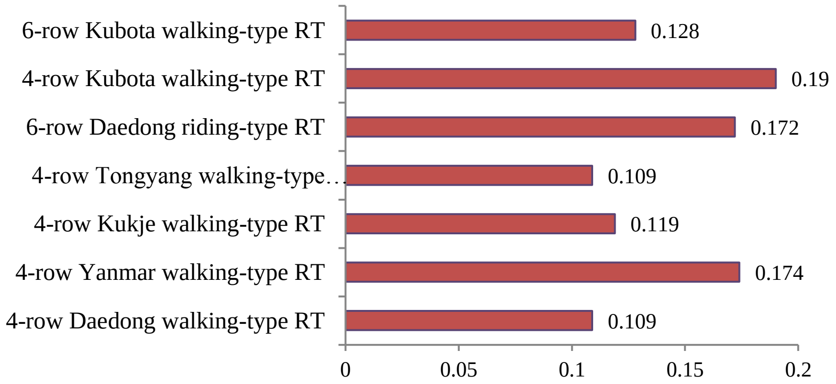
c. Ergonomics



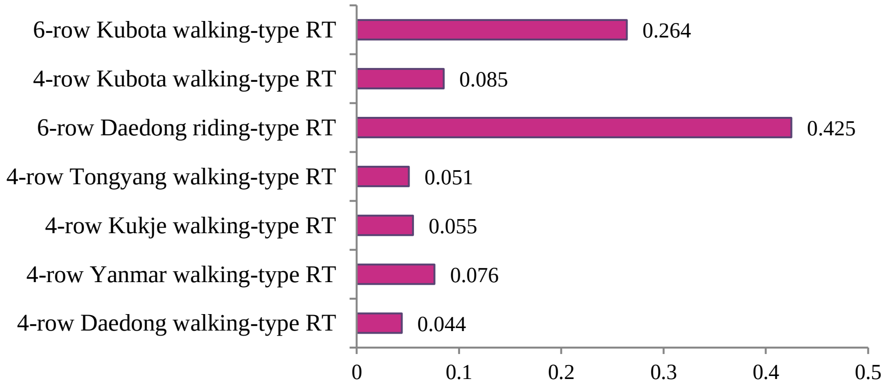
d. Planting quality



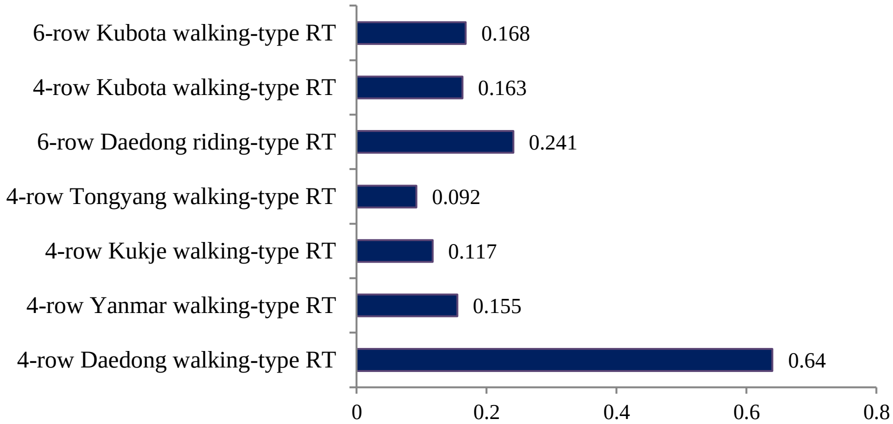
e. Ease of use



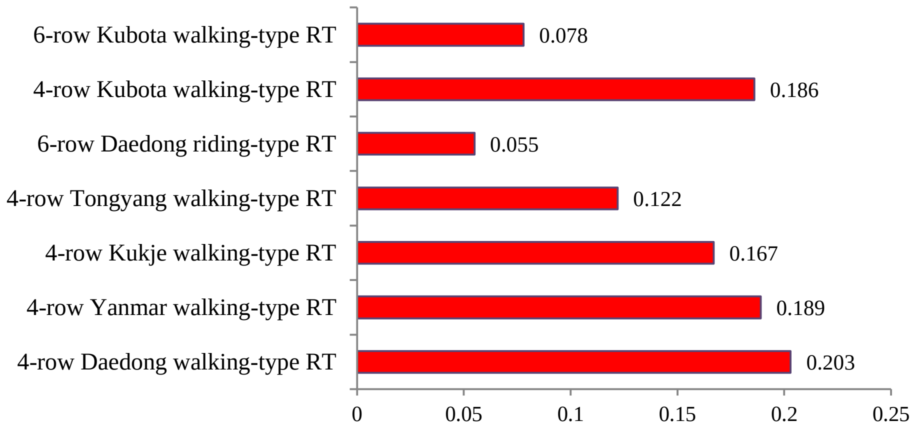
f. Compatibility different soil conditions



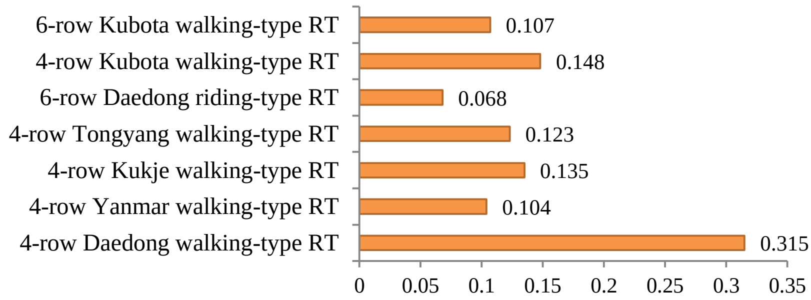
g. Field capacity



h. Planting density range



i. Compatibility with plot conditions



j. Economic advantage

Figure 5 Pairwise comparison of rice transplanters in terms of 10 criteria

The most appropriate RTs in terms of "reliability" were found to be 4-row Kubota walking-type RT (D6) with an importance degree of 0.21 and 4-row Daedong walking-type RT (D1) with an importance degree of 0.171. The inconsistency rate of 7% confirms the accuracy of the comparisons (Figure 5b).

Pairwise comparisons of RTs in terms of "ergonomics" revealed that 6-row Daedong riding-type RT (D5) and 4-row Kubota walking-type RT (D6) were the most appropriate RTs with the importance degrees of 0.337 and 0.182, respectively (Figure 5c). These comparisons had an inconsistency rate of 3%, showing their acceptable accuracy.

Also, 4-row Daedong walking-type RT (D1) and 6-row Daedong riding-type RT (D5) were selected as the most appropriate RTs in terms of "planting quality" with importance degrees of 0.236 and 0.164, respectively (Figure 5d). With an inconsistency rate of 6%, these pairwise comparisons were turned out to have acceptable accuracy.

Pairwise comparison of RTs in terms of "ease of use" as an important criterion for the machine selection indicated that 4-row Daedong walking-type RT (D1) and 4-row Kubota walking-type RT (D6) were the best with importance degrees of 0.204 and 0.177, respectively (Figure 5e). These pairwise comparisons had an inconsistency rate of 1%, implying their good accuracy.

Four-row Kubota walking-type RT (D6) was found to be the best for Guilan Province with respect to "compatibility with different soil conditions" with an important degree of 0.190. Also, 4-row Yanmar walking-type RT (D2) was ranked the second best with an importance degree of 0.174 based on this criterion (Figure 5f). These pairwise comparisons showed an inconsistency rate of 0.3%. Thus, they were accurate enough.

According to Figure 5g and based on pairwise comparisons by the research group experts, 6-row Daedong riding-type RT (D5) was found to be the best for Guilan province in terms of "field capacity" with an importance degree of 0.425. The second best was found to be 6-row Kubota walking-type RT (D7) with an importance degree of 0.264. The rate of inconsistency for these comparisons was estimated at 2%; representing a good accuracy.

According to Figure 5h, 4-row Daedong walking-type RT (D1) and 6-row Daedong riding-type RT (D5) were the first and second best RTs in terms of "planting density range" with priority degrees of 0.640 and 0.241, respectively. The results gave a value of 0.5% for the inconsistency rate of these comparisons and prove their good accuracy.

The results, also, indicated that 4-row Daedong walking-type RT (D1) with an importance degree of 0.203 was the most suitable when selected on the basis of "compatibility with plot conditions" (Figure 5i). The second most suitable was 4-row Yanmar walking-type RT (D2) with a priority degree of 0.189. The inconsistency rate was 0.6% for these comparisons and since this value is smaller than 10%, then it can be claimed that the comparisons were of good accuracy.

Figure 5j presents the results of pairwise comparisons of RTs on the basis of "economic advantage" according to which 4-row Daedong walking-type RT (D1) and 4-row Kubota walking-type RT (D6) were found to be the first and second best for the study region with importance degrees of 0.315 and 0.148, respectively. These pairwise comparisons exhibited an inconsistency rate of 2%, proving their good accuracy.

As is evident in Figures 6 and 7, 4-row Daedong walking-type RT (D1) is the best RT for Guilan province with an important degree of 0.194 and an inconsistency rate of 5% with respect to the studied criteria. The second and third ranks were assigned to 4-row Kubota walking-type RT (D6) and 6-row Daedong riding-type RT (D5) with priority degrees of 0.167 and 0.154, respectively.

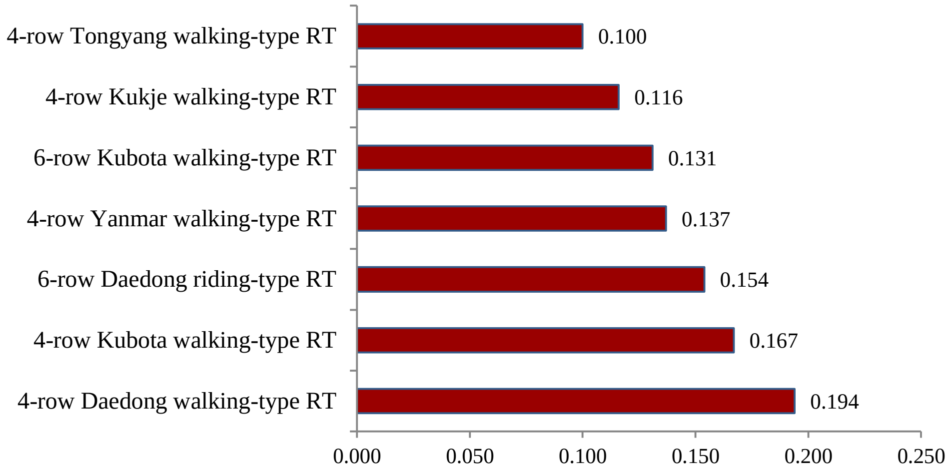


Figure 6 The overall comparisons of rice transplanters using the studied criteria

The results showed that the users had an average age of 41.81 years and almost one-third of them were in the age group of 30-40 years although other age groups had a uniform distribution too (Table 3). Most users of 4-row Daedong TRs had a diploma or lower educational level (81.2 percent) whereas the study field of most users of this type of TRs (84.7 percent of all users) was irrelevant to agriculture. A great part of the users of 4-row Daedong TRs (88.2 percent) were a landowner. Only 6 percent were cooperative members. The results showed that about two-thirds of the respondents had not used bank facilities. About 62.4 percent of 4-row Daedong TR users used the machine on lands that have not been consolidated. It was revealed that 98.8 percent of users themselves took care of the maintenance of their machines. About 84.1 percent took advantage of specialized repairmen to repair their machines. With respect to the number of years using 4-row Daedong TRs, data showed that most users (65.9 percent) had an experience of less than 5 years. What is the impact of demogragraphic characteristics on machine? (the main focus of the second phase was specifically about the training needs assessment of operators on the best identified RT, not on the impact of demogragraphic characteristics on machine).

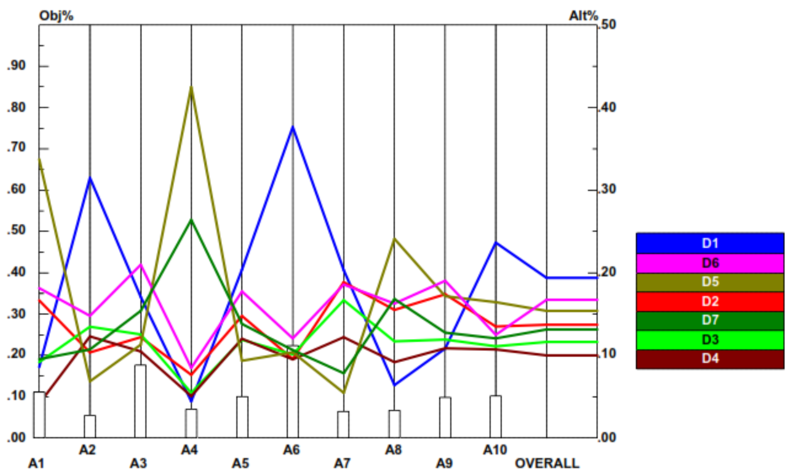


Figure 7 Sensitivity analysis in terms of the studied criteria to select the best rice transplanter

Table 3 Demographics and skill-related characteristics of the users of 4-row walking-type Daedong rice transplanter

Variable		Frequency	Percentage
Age (years)	<30	13	15.3
	30-40	27	31.8
	40-50	25	29.4
	>50	20	23.5
Educational level	Diploma or lower	69	81.2
	Higher than diploma	16	18.8
Field of study	Relevant	13	15.3
	Irrelevant	72	84.7
Land ownership	Personal property	75	88.2
	Non-personal	10	11.8
Having attended training courses	Yes	15	17.6
	No	70	82.4
Membership in a cooperative	Yes	5	5.9
	No	80	94.1
The use of bank facilities	Yes	31	36.5
	No	54	63.5
Is land consolidation done?	Yes	32	37.6
	No	53	62.4
Machine maintenance	I myself do.	84	98.8
	I have a repairman do.	1	1.2
Ability to repair the machine	I myself repair.	5	5.9
	I have a repairman do.	80	84.1
Experience (years)	<5	56	65.9
	5-10	24	28.2
	>10	5	5.9

With respect to the technical skill of 4-row Daedong TR users, 31 true-false questions were developed by using the operational manual of the machine and experts' opinions with each correct answer scoring one. The results showed that the minimum score was 17 and the maximum was 30 with an average of 23.23 (SD = 3.6), showing that the average score was equal to 75 percent of the optimal score. According to Table 4, the respondents gave the least correct answer to the items of "spark plugs should be cleaned once 150 hours", "the standard number of seedlings picked up by the forks is 3-8 per hill", and "In the out-of-working season, the transplanter fuel tank should be fully discharged", with the percentage of correct answers of 5.9, 23.5, and 29.4, respectively (Table 4). Given the standard scores and the range of the scores obtained by the users, they were divided into skillful and semi-skillful groups with the latter group including over half of the respondents (51.8%) as is evident in Table 5.

According to Table 6, the results of Kruskal-Wallis and Mann-Whitney tests show that the variables of study field and attendance in training courses had a significant ($p < 0.01$) effect on the technical knowledge of 4-row Daedong TR users so that the respondents who had attended in training courses and those with relevant study field had higher technical knowledge. Also, the effect of the educational level was significant ($p < 0.05$) on the respondents' technical knowledge.

As well, the results of analysis of variance revealed that there was a significant relationship only between the number of years using TRs and technical knowledge of using 4-row Daedong TRs at the $p < 0.01$ level (Table 7).

Table 4 The correct answers to questions on how to use 4-row Daedong rice transplanters

Item	Percentage of Correct answers
When refueling, the transplanter's engine must be turned off.	77.6
It is OK turning on the transplanter in closed spaces.	78.8
The SAE 85 lubricant oil should be used in the engine's crankcase at the rate of 3.2 liters.	62.4
Spark plugs should be cleaned every 150 hours.	5.9
The transplanter starter rope should not be pulled out more than 65 cm.	94.1
When starting the transplanter's engine in cold weather, the choke valve should be in fully open or semi-open position.	96.5
The main clutch in its upper position moves the transplanter forward and puts the machine in neutral state in lower position.	98.8
The lubricant oil of the engine's crankcase should be cold when it is replaced.	87.1
The gearbox lubricant oil should of SAE 30 used at the amount of 0.55 liters.	62.4
When cleaning the spark plugs, the gap between their tips' should be adjusted at 0.9 mm.	57.6
Transplanting should be done in very soft soils.	94.1
The standard number of seedlings picked up by the transplanter forks is 3-8 per hill.	23.5
In the out-of-working season, the transplanter fuel tank should be fully discharged.	29.4
In the out-of-service seasons, the wheels should be raised by the hydraulic system and the machine should be placed on a plain level.	95.3
At the end of the daily work, the machine should be cleaned from mud and dirt and the metal parts should be lubricated.	94.1
At the end of the transplanting season, the handles on both sides should be filled up with oil.	63.5
When storing the transplanter for the next working season, it should be put in reverse gear.	89.4
Standard transplanting depth is 2-3 cm.	96.5
To clean the air filter, it should be washed with Kerosene or gasoline. Then, it should be placed into lubricant oil for a short time, squeezed well to have the lubricant oil drained.	82.4
To lubricate cylinders, when the machine is off, some lubricant oil is poured into the carburetor, the starter rope is slowly pulled out two or three times to reach the lubricant oil to the cylinder head to prevent the stain of the unused parts.	58.8
To install forks on the transplanter, its plain side should be placed upwardly.	71.8
When starting the engine, the main clutch should be in a neutral position and the transplanter clutch should be in lock state.	96.5
Transplanting is much easier in sandy soils than in clay.	87.1
To go through the border or ridge, the control lever should be placed in body raising state and the transplanting parts should be stopped working.	97.6
The transplanting depth is 3-4 cm for tall seedlings and 1.5-2.5 cm for short seedlings.	97.6
When working in paddy fields with a depth of 25 cm, the forward speed should be set at low rate.	31.8
The adjusting lever of the seedling placement on needles should have a gap of 6-8 cm for small seedlings and 4-5 cm for tall seedlings.	49.4
Planting depth is adjusted by the depth control lever so that the seedlings are planted at deeper depth at its upper position and vice versa.	70.6
To add seedlings, the main and the transplanter clutches should be put in neutral position, then the seedlings will be added to the transplanter.	96.5
Seedlings whose seed substrate in the seedling box has a 2 cm thickness or less are the most appropriate for transplanting.	78.8
Seedlings whose height is 6 cm or less are not appropriate for transplanting.	97.6

Table 5 The statistics of skillful and semi-skillful users of 4-row Daedong rice transplanters in Guilan province, Iran

Group	Frequency	Percentage
Semi-skillful users	44	51.8
Skillful users	41	48.2

Table 6 The relationship between demographic and social characteristics of the users of 4-row Daedong rice transplanters with the technical skill of the respondents

Independent variable	Rank mean	Test	Statistic value	*p*-value	Confidence Interval
Age (year)					
<30	40.12	Kruskal-Wallis (Monte Carlo)	8.35	0.039* 0.018*	0.022-0.15
30-40	52.19				
40-50	84.00				
>50	40.00				
Field of study		Mann-Whitney (Monte Carlo)	-2.67	0.008** 0.006**	0.008-0.004
Relevant	59.77				
Irrelevant	39.97				
Land ownership		Mann-Whitney (Monte Carlo)	1.54	0.462 0.529 -	0.542-0.516
Personal property	42.22				
Non-personal	46.39				
Having attended training courses		Mann-Whitney (Monte Carlo)	-2.75	0.006** 0.005**	0.007-0.003
Yes	58.83				
No	39.61				
Membership in a cooperative		Mann-Whitney (Monte Carlo)	-0.263	0.793 0.802 -	0.812-0.792
Yes	45.80				
No	42.83				
The use of bank facilities		Mann-Whitney (Monte Carlo)	-1.61	0.108 0.111 -	0.120-0.103
Yes	48.66				
No	39.75				
Is land consolidation done?		Mann-Whitney (Mont Carlo)	-1.27	0.204 0.210 -	0.211-0.191
Yes	47.36				
No	40.37				
Ability to repair the machine		Mann-Whitney (Monte Carlo)	-0.351	0.725 0.740 -	0.751-0.729
I myself repair.	46.20				
I have a repairman do.	42.27				

Table 7 The correlation between demographics and agronomic characteristics with the technical skill of the respondents

Score	r	*p*-value		Correlation coefficient range
Age (year)	-0.028	0.798	-	0.190-0.243
Experience (year)	0.297	0.006	**	0.514-0.070
Planting area (ha)	-0.058	0.601	-	0.166-0.263
Number of land parcels	-0.123	0.261	-	0.103-0.320

Note: $^{**}p<0.01$

4 Discussion

There is an optimal time for rice transplanting to achieve the highest crop yield (Singh et al., 2006). Delayed transplanting will impair grain yield (Liu et al., 2015). Indeed, when transplanting is delayed, farmers incur a cost of untimely operation, some of which arises from the coincidence with inappropriate working days (Alamasi et al., 2005). Furthermore, this will aggravate the loss of crop yield due to the late-season water scarcity. This explains the superior rank of the criterion "ease of repair and access to spare parts" in order to ensure the operation of RTs within the optimal time frame. In the meantime, the mechanisms used in different RT systems, including propelling and seedling feeding systems and the deployment of RT components, influence the ease of repair. The number and distribution of after-sale service centers in regions where agricultural machinery is supplied is an effective factor influencing ease of repair and access to spare parts (Alamasi et al., 2005).

As well, if the machines are lowly reliable, it will be more likely to have operation stoppage in the optimal transplanting time frame leading to lose a great part of the planned working hours and incur higher costs due to untimely operation, and consequently, face the coincidence of transplanting with water scarcity period of summer. This explains why reliability was chosen as the second most important criterion. The total reliability of a mechanism/machine is equal to the product of the multiplication of the reliability of its all components. In addition to influencing the quality and efficiency of transplanting, transplanting mechanisms can be a decisive factor in machine reliability (Wen et al., 2018). Also, the quality of the material used in the fabrication of components and their production technology are among the effective factors underpinning the reliability of RTs.

Ergonomics, or the relationship between human and machine, is of crucial importance in the selection of agricultural machinery. Manual transplanting of rice is laborious whilst mechanical transplanting is user-friendly (Kumar et al., 2018). Ergonomics has played a significant role in the process of rice transplanting mechanization (Yadav et al., 2007). The low weight of RTs, their appropriate weight distribution and the resulting maneuverability, ease of adjustments of planting distance, density and depth, and adjustment of the height of RT handles with users' height are among the factors underpinning the ergonomics of RTs. So, this criterion was selected as the third most important criterion by experts for the selection of RT.

Since the criteria of "ease of repair and access to spare parts", "reliability", and "ergonomics" were identified as the three main criteria for the assessment of RTs in Guilan province, this section discusses the ranking of RTs in terms of them.

Four-row Daedong RTs are among the first RTs imported into Iran and were welcomed greatly because of their good after-sale services by the South Korean manufacturer. The different components of the machine are arranged and mounted in such a way that all components are available with no interference with other mechanisms. Thus, they are relatively easier to be repaired than other studied RTs and their components can be accessed faster. This justifies the selection of this transplanter as the best RT in Guilan province in terms of the criterion "ease of repair and access to spare parts". On the other hand, 4-row Kubota was ranked the second in spite of the simplicity of the components of its mechanisms, the simpler installation of its components, and better access to its parts. Given the extension activities of the agricultural mechanization extension services in Guilan province, it seems that the familiarity of RT users and repairmen in Guilan province with Daedong RTs as the first imported transplanter is a reason for its preference over other RTs in terms of this criterion. In this respect, some users and repairmen stated that the lack of specialized repair stores for these machines in the early years of their importation has forced them to fix them experimentally and this has contributed to their familiarity with them and increased their knowledge and skill in fixing them.

Also, the results revealed that 4-row Kubota and 4-row Daedong were the best RTs in terms of reliability. Given the 50-year history of the import of these two brands into Guilan Province and the satisfactory support by the manufacturers and the high quality of their parts, it appears that users and repairmen are more confident to them.

As far as ergonomics was concerned, 6-row Daedong was ranked the first and 4-row Kubota the second. Six-row Daedong riding-type RTs have better ergonomics because of their electronic control systems, hydraulic steering and power transfer systems, and above all, the capability of carrying the users in puddled soils. In addition, 4-row Kubota had better design in terms of weight distribution so that users impose less pressure on this machine. So, it was ranked the second in ergonomics in spite of the fact that it is of walking type. Indeed, most users and repairmen of RTs believe that this machine is lighter and steers better than most competing machines.

Over half of the users of four-row Daedong RTs were semi-skillful so that only a few could repair the device. Even though the device is easier to fix than the other devices, few users could fix it whereas most users had the capability of the device maintenance including adjustments, daily and weekly services, visits, and lubricant replacement and charging.

An important point to consider in the maintenance of four-row Daedong RTs is to check and clean spark plugs after 150 operational hours, but nearly 94 percent of the users gave a wrong answer to this item. The standard number of rice transplanting by a transplanter is 3-8 seedlings/hill, but 23.5 percent of the respondents did not know that. Also, 29.5 percent of the users were not aware of the significance of discharging the fuel tank of transplanters when they were supposed to be out-of-service for a long time.

Land defragmentation contributes to enhancing agriculture efficiency by facilitating mechanization development (Wen et al., 2018; Jürgenson, 2016; Li et al., 2018). As such, Agricultural Jihad Organization of Guilan province has pursued some large-scale plans in the last two decades to defragment paddy fields, thereby developing agricultural mechanization in the province (Aghabeigi and Gholami-Sefidkouhi, 2018). However, our results showed that the use of machinery is presently inevitable irrespective of the shape and size of farm plots so that about 62 percent of the users of four-row Daedong transplanters as the most appropriate and commonplace RT across Guilan province were working on traditional lands (Table 3).

Attending the training courses on transplanter maintenance had a significant impact on the users' knowledge of how to use four-row Daedong transplanters so that these courses were effective in increasing their operational knowledge. Izadi and Hayati (2013) revealed that the training courses held were influential on precision agriculture knowledge. Also, Mohammad-Rezaei and Hayati (2018) found that extension and training services influenced the pistachio farmers' technical knowledge of integrated pest management in Kerman province, Iran. The results in Table 3, also, show that the farmers with higher relevant agricultural education levels had higher levels of knowledge as to how to use RTs. Given the curricula offered in agricultural colleges and vocational schools as to the maintenance of agricultural machinery, the study confirms their impact on the users' technical knowledge.

5 Conclusion

The agricultural sector needs a quick transition from the livelihoods production to the industrial and commercial production stage to fulfill its missions, including providing food security to the community and playing an effective role in food soverginity. Mechanization development is an approach that achieves the agricultural sector for the industrial and commercial production stage. Therefore, it is necessary to develop it by adopting appropriate plans. Problems with the development of agricultural mechanization are the lack of technical skills of agricultural machinery users. For planning in this area, it is imperative to define such issues as the definition of mechanization, the process and the prioritization of the technical skills of the users. This study identified the most appropriate of RT considering ergonomics, economic advantage, reliability, field capacity, ease of use, ease of repairs and access to spare parts, compatibility with plot conditions, planting density range, compatibility with different soil conditions and planting quality perspectives in Guilan Province, Iran using AHP. Overall, 4-row DaeDong transplanter (0.194) was the first choice from experts' perspectives. Also, the majority of respondents (51.8%) were semi-skillful in using 4-row DaeDong transplanter. The findings provide useful aspects on the most appriopriate of RT, but country-specific conditions should be taken into account along with the results of the AHP before practical decisions are made. Overall, AHP can create a solid information basis for a decision, but the final decision needs to be made by the decision maker.

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