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Full Length Research Paper

Assessment of direct seeded and transplanting methods of rice cultivars in the northern part of Iran

Hassan Akhgari[1]* and Behzad Kaviani[2]

[1]Department of Agronomy, Islamic Azad University, Rasht Branch, Rasht, Iran.
[2]Department of Horticultural Science, Islamic Azad University, Rasht Branch, Rasht, Iran.

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A split plot design experiment based on randomized complete block design (RCBD) with three replications was conducted to compare differences between direct seeded rice and transplanting methods. Different cultivars were "Hashemi", "Ali Kazemi", "Hassani", and "Hybrid Spring 1" in the main plots, and cultivation methods were transplanting, direct seeded in wet lands distribution, as linear and hill in the sub-plots. According to analysis of variance, the effects of cultivars on all yield components (panicle/m^2, seed/panicle, and 1000 grain weight), plant height, panicle length, and total tiller were significant, while the effect of cultivation method was significant on the rest of the traits except for grain weight. The largest and least number of seed/panicle was obtained under interaction effect of transplanting method of "Hybrid Spring 1" and direct seeded method as distribution of "Ali Kazemi", respectively. Plant height in hill method of "Hybrid Spring 1" and transplanting method of "Hashemi" appeared to be the highest and lowest, respectively. The largest and least number of tillers and fertile tillers were obtained in direct seeded method of "Hybrid Spring 1" and transplanting method of "Hashemi", respectively. The yield across different varieties was not significant, while different cultivation methods were significant. The most and least yield was seen in transplanting and hill methods, respectively. Yield amount was significant between transplanting and linear methods, but because of 20 to 30% reduction in production cost due to the omission of seedling and transplanting operations, as well as reduction in the length of crop cultivation period in direct seeded method that caused conserved water and energy, a little reduction in direct seeded method will be compensating. Thus, direct seeded method as linear is introduced as an economical method for rice production in this area and "Hybrid Spring 1" has the better compatibility to this method than other varieties.

Key words: *Oryza sativa* L., wet land, labor saving, cost saving, water saving, time saving.

INTRODUCTION

Nowadays, rice cultivation is done in different ways in the world. The most important cultivation ways are direct seeded and transplanting methods. Direct seeding of rice (DSR) refers to the process of establishing a rice crop from seeds sown in the field rather than by transplanting rice (TPR) seedlings from the nursery. There are three principal methods of DSR: dry seeding (sowing dry seeds into dry soil), wet seeding (sowing pre-germinated seeds on wet puddle soils) and water seeding (seeds sown into standing water). Dry seeding has been the principal method of rice establishment since the 1950s in developing countries (Pandey and Velasco, 2005). At present, rice cultivation is as direct seeded in America, Western Europe such as Italy and French, Russia, Japan, Cuba, India, Korea, and the Philippines and in some parts of Iran, due to high technology, high labor cost and shortage of skilled labor (Akhgari, 2004). In northeastern Thailand and many other rice growing areas

*Corresponding author. E-mail: akhgar_h@yahoo.com. Tel: 00981317734034, 00989111351842.

Abbreviations: DSR, Direct seeding of rice; **TP,** transplanting rice.

in Asia, conventional TPR has been replaced by dry seed broadcasting (DSR), mainly because of the higher cost of TPR and a shortage of the labor required (Dawe, 2005; Naklang, 1997; Pandey et al., 2002; Tuong et al., 2005). The final rice cultivation system in the world is affected by water deficient, low suitable land, and shortages of worker (Nguyen and Ferrero, 2006). At present, 23% of rice is direct-seeded globally (Rao et al., 2007). In the United States, Australia and Europe, rice is planted into either a dry-seeded or water-seeded system (Gianessi et al., 2002; Ntanos, 2001; Pratley et al., 2004). In Australia for instance, most rice is aerially sown in water (Pratley et al., 2004), while in Africa, broadcasting and dibbling are common seeding practices for rice sowing (Ampong-Nyarko, 1996). Labor saving of DSR method induced by preparation of nursery and TPR, causes the reduction of 11.2% in total production cost. DSR methods have several advantages over TPR (Singh et al., 2005a). In addition to higher economic returns, DSR crops are faster and easier to plant, less labor intensive and consume less water (Jehangir et al., 2005; Khade et al., 1993; Santhi et al., 1998; Balasubramanian and Hill, 2002; Pandey and Velasco, 1999). DSR has received much attention because of its low-input demand (Farooq et al., 2011). The development of early-maturing varieties and improved nutrient management techniques along with increased availability of chemical weed control methods has encouraged many farmers in the Philippines, Malaysia, Thailand and India to switch from TPR to DSR culture (Farooq et al., 2011). Main method of rice cultivation in Iran is transplanting. The cost of rice worker is two to three times of the other field crop production. It is important to note that the reduction of worker is necessary for rice production. Thus, it is necessary to change the cultivation system from TPR to DSR. In DSR method such as wet bed, seeds are cultivated as distribution, linear and hill. Also, crop management such as weeds management, water management, production cost, the number of labor, yield potential of varieties and seedling establishment method are assessed. Rice cultivation system in the main world areas in response to major world economic and technological factors is changing in the fields. One of the major changes is TPR to DSR method. For extension of the method, there is need for early maturity of rice varieties and better chemical technology for weed control in rice fields (IRRI, 1991; Kim et al., 2000; Pandey et al., 2002; Akhgari, 2004). Basically, trend to DSR and TPR depends on the region and the type of dominant ecosystem. The use of TPR method for increasing the yield became customary. Nowadays, production cost has been decreased using DSR. Weather, economical and society conditions are effective factors for this dominant (Kim et al., 2000). Yield in DSR is often lower than TPR principally owing to poor crop stand and high weed infestation (Singh et al., 2005a). Moreover, cost for weed control is usually higher than TPR. High weed infestation is a major constraint for broader adoption of DSR (Rao et al., 2007). Therefore, assessment of varieties with high yield potential is one of the research requirements (Kim et al., 2000). Efforts to improve grain yield under drought conditions through breeding are continuing (Cooper et al., 1999b; Jongdee, 2001), but progress is limited, mainly because of the large genotype-environment interaction (Cooper and Somrith, 1997; Wade et al., 1999; Cooper et al., 1999a). Extensive researches in Rural Development Administrate (RDA) showed that no significant differences was shown between DSR and TPR methods or even between two methods of direct seeded. Based on the researches, the future progress in increasing of the yield of irrigated rice in DSR will be highly more than TPR, and this value will reach to 10 to 15 tons/ha (IRRI, 1991).

The aim of this study was to evaluate of potential in main cultivars in the region and assessment of the best method of DSR in comparison to conventional TPR method.

MATERIALS AND METHODS

Experimental design and materials

The experiments were done as split plot design in the 1000 m^2 of rice land in Rice Researches Institute of Iran. Cultivars in main plot (15 × 6 m) and cultivation method in sub-plot (3 × 4 m) were considered. Desired varieties (factor A) were native and modified named "Hashemi", "Ali Kazemi", "Hassani", and "Hybrid Spring 1", the main varieties in the region. Cultivation methods (factor B) were transplanting, direct seeded in wet bed as distribution, linear and hill. In all methods and based on the varieties features, seedling density was 150 to 200/m^2.

Measurements

In addition to exerting the different managements related to irrigation, weeds, nutrition, pests and diseases, some traits such as growth and development process, seed germination, the number of effective and non-effective tillers, plant height, panicle length, spikelet number/panicle, sterility percentage, 1000 grain weight, assessment of lodging and yield were evaluated. Grain yield, sterility percentage and total tillers were calculated using following equations:

Grain yield = Spikelet number/panicle × grain weight × number of effective tillers × sterility percentage.

Sterility percentage = Total seed number/number of sterile seeds × 100.

Total tillers = The number of effective tillers + non-effective tillers.

Mean 1000 grain weight was recorded by counting of 5 samples (each sample containing 1000 grain). Mean effective tiller was recorded by counting the number of tillers per each plot to become changed into complete panicle. Plant height was calculated to take the measurement of crown to the top of the panicle.

These traits were measured and evaluated daily and periodically, referring to the farm, based on Standard Evaluation System (SES) of rice (Akhgari, 2004). Evaluation of some traits in each experimental plot was performed as randomly selection of 10 panicles or hills or surface unit (based on the kind of trait).

Table 1. Analysis of variance (ANOVA) for the effect of DSR and TPR methods on different traits of rice cultivars.

Source of variations	df	Mean of squares								
		grain yield (g/m^2)	1000 grain weight (g)	Sterility (%)	Sterile grain /panicle	Grain /panicle	Plant height (cm)	Panicle length (cm)	Total tiller /m^2	Grain tiller/m^2
Factor A (cultivars)	3	76.697^{ns}	171.619**	932.619**	932.722**	21495.87**	6665.54**	55.557**	54116.63*	*6771.51
Factor B (planting method)	3	1.814**	71.141^{ns}	59.729*	59.729*	1472.53*	332.63**	5.015*	52895.42**	20288.48^{ns}
A × B	9	5.832*	38.312^{ns}	52.768*	53.768*	572.89*	46.15*	2.736^{ns}	9895.45^{ns}	6691.68^{ns}

**Significant at α = 1%; *significant at α = 5%; ns = not significant.

Table 2. Mean comparison for the effect of cultivar type on different traits of rice varieties.

Factor A (cultivars)	Grain yield (g/m^2)	1000 grain weight (g)	Sterility (%)	Sterile grain /panicle	Grain /panicle	Plant height (cm)	Panicle length (cm)	Total tiller per (m^2)	Grain tiller per (m^2)
Hassani V1	403.915A	27.897A	12.652AB	11.279B	87.658B	143.00A	24.92C	248.192B	349.120AB
Kazemi V2	437.5A	28.714A	7.488C	5.996C	86.222B	147.722A	29.71A	402.806B	270.508C
Hashemi V3	434.64A	24.681B	0.303BC	7.562C	82.183B	146.122A	27.66B	389.878B	311.502BC
Hybrid (spring 1) V4	461.517A	3.431C	16.052A	25.346BC	168.908A	98.650B	25.67C	525.525A	379.665A

In each column, means with the similar letters are not significantly different at 5% level of probability using LDS test.

Statistical analysis

The means of 10 samples were used for analysis of components. The SPSS and MSTAT-C software were used for analysis of variance (ANOVA). Means were compared using LSD.

RESULTS

Analysis of data showed that the effect of variety (factor A) on 1000 grain weight, sterility percentage, grain number/panicle, fertile tiller number, plant height, panicle length, and total panicle number were significant at level of 0.01 and 0.05% (Table 1). The effect of variety on grain yield was not significant (Table 1). The effect of cultivation method (factor B) was significant on the aforementioned traits except for 1000 grain weight, and fertile tiller number. Effect of these factors showed that the 1000 grain weight, panicle length, total tiller number, and fertile tiller number were not influenced by interaction between variety and cultivation method. Interaction effect of cultivar and cultivation method was significant (0.05%) on grain yield, sterility percentage, and seed number/panicle and plant height (Table 1). Mean comparison of the effect of variety on the traits showed that the most and least yield were obtained in "Hybrid Spring 1" and "Hassani" cultivars, respectively. However, this difference was not significant (Table 2). The highest grain number/panicle, total tillers number and fertile tillers number was obtained from "Hybrid Spring 1. Least amount of grain number/panicle, total tillers number and fertile tillers number were observed in "Hashemi", Hassani" and "Ali Kazemi", respectively. "Ali Kazemi" and "Hassani" had the longest and shortest panicle length, respectively. Plant height was observed in two levels (Table 2). Totally, investigation of the effect of cultivar on measured components revealed that "Hybrid Spring 1" was the best cultivar in most components. Mean comparison of cultivation methods on the measured traits showed that the TPR was the most effective method due to its effect on some yield components such as grain number/panicle, plant height and panicle length, while this method was not proper on some other components such as sterility percentage, total tillers number and fertile tillers number. DSR method as distribution had the best effect on total tillers number and fertile tillers number, while its effect on other components was not suitable (Table 3). DSR method as linear had higher effect on the 1000 grain weight, sterility percentage, and panicle length than DSR method as hill and distribution. It is noteworthy that the most yield

Table 3. Mean comparison for the effect of planting methods on different traits of rice varieties.

Factor B (planting method)	grain yield (g/m^2)	1000 grain weight (g)	Sterility (%)	No sterile grain/ panicle	No grain/ panicle	Plant height (cm)	Panicle length (cm)	Total tiller/m^2	effective tiller/m^2
D_1 TPR	496.167A	25.911A	7.917B	9.250B	121.742A	140.867A	27.672A	338.957B	272.892B
D_2 DSR	412.291BC	25.808A	11.877A	12.812AB	96.717B	128.117B	26.117B	499.273A	372.248A
D_3 DSR	461.994AB	26.626A	12.622A	14.422A	101.822B	132.822B	27.122A	428.523B	336.765AB
D_4 DSR	67.123C	26.267A	12.067A	13.588A	101.792B	122.700B	27.06AB	435.912AB	328.9AB

D_1=TPR= Trans planting rice; D_2=broadcast; D_3=linear; D4=hill; DSR=direct seeding rice. In each column, means with the similar letters are not significantly different at 5% level of probability using LDS test.

Table 4. Mean comparison for the interaction effect of planting methods and cultivar type on different traits of rice varieties.

A×B	Grain yield (g/m2)	1000 grain weight (g)	Sterility (%)	No sterile grain/ panicle	No grain/ panicle	Plant height (cm)	Panicle length (cm)	Total tiller/m^2	Effective tiller/m^2
$V_1 \times D_1$	481.553D	27.169	42.85CD	13.483/C	92.967E	147.333D	25.09	338.433	312.693
$V_1 \times D_2$	378.2920H	26.907	26.71F	6.750FG	77.5H	137.667G	24.267	368.94	337.367
$V_1 \times D_3$	417.103G	29.93	45.32C	13.533C	89.2E	142.00F	24.833	396.587	379.427
$V_1 \times D_4$	338.610J	27.587	36.95DE	11.350D	90.967E	145.0E	25.507	432.813	367.033
$V_2 \times D_1$	505.287B	26.93	14.49G	4.400H	89.733E	154.133B	29.7	354.64	264.073
$V_2 \times D_2$	373.6130I	27.678	31.77EF	7.983EF	77.667H	138.8G	28.867	479.527	302.207
$V_2 \times D_3$	491.613C	29.478	27.12F	7.200FG	83.8FG	149.933C	30.767	373.707	227.847
$V_2 \times D_4$	379.497HI	30.753	16.48G	4.400H	81.122GH	148.067CD	29.533	400.4	287.907
$V_3 \times D_1$	482.000D	24.463	17.22G	5.317GH	92.6E	157.4A	28.4	306.02	241.193
$V_3 \times D_2$	378.0970I	25.14	29.46F	7.133FG	66.667I	136.667G	25.667	519.427	348.92
$V_3 \times D_3$	449.673E	24.453	39.54E	9.600DE	81.133GH	142.667F	25	386.1	343.2
$V_3 \times D_4$	428.7900F	24.667	28.41F	8.200EF	88.333EF	147.80CD	28.6	347.967	312.693
$V_4 \times D_1$	515.828A	25.087	20.45G	14.200C	211.667A	104.60H	27.5	352.733	373.607
$V_4 \times D_2$	519.060A	23.5	54.59B	29.383A	164..33B	99.333I	25.667	629.2	500.5
$V_4 \times D_3$	489.586CD	22.673	54.62B	27.400B	153.2C	96.733J	24.933	557.7	396.587
$V_4 \times D_4$	321.597K	22.463	62.96A	3.400A	146.733D	93.933K	24.6	562.467	347.967

In each column, means with the similar letters are not significantly different at 5% level of probability using LDS test.

after the final cultivation methods belong to the DSR method as linear. Statistically, the rate of grain yield was the same in TPR method and DSR method as linear. Grain yield in direct cultivation method as linear was 20% higher than that of DSR method as hill. The lowest yield and highest sterility percentage were obtained in DSR method as hill (Table 4). According to the mean comparison of interaction effect of the factors on the components, the highest grain yield was achieved in combination of "Hybrid Spring 1" × DSR method as broadcasting and "Hybrid Spring 1" × TPR method (Table 4). The lowest grain yield was obtained in combination of "Hybrid Spring 1" × DSR method as hill. The combination of "Hybrid

Table 5. Effect of planting method on growth duration of rice cultivation.

Methods / Cultivars	TPR D1 (day)	DSR D2 (day)	DSR D3 (day)	DSR D4 (day)	TPR-DSR (day)	Reduction in growth duration (%)
Hassani (V1)	137	91	91	91	46	33.5
Ali Kazemi (V2)	134	98	98	98	36	26.8
Hashemi (V3)	134	98	98	98	36	26.8
Hybrid Spring 1(V4)	144	108	108	108	36	7.5

D1=TPR= Trans planting rice, DSR=Direct seeding rice (D2=broadcast, D3=linear, D4=hill).

Spring 1" × DSR method as hill, containing the lowest yield, showed the highest sterility percentage, while the lowest sterility percentage was seen in treatments "Ali Kazemi" × TPR method, and "Hybrid Spring 1" × TPR method. The highest grain number/panicle and the lowest grain number/panicle were obtained in combination of "Hybrid Spring 1" × TPR method, and "Ali Kazemi" × DSR method as distribution, respectively (Table 4). The highest and the lowest plant height were measured in combination of "Hashemi" × TPR method, and "Hybrid Spring 1" × DSR method as hill, respectively. The highest and the lowest total tillers number and fertile tillers number were obtained from "Hybrid Spring 1" × DSR method as broadcasting, and "Hashemi" × TPR method, respectively (Table 5). Based on Table 5, rice growth duration in DSR methods is 29% less than that of TPR method. Also, there is 25 to 30% reduction by elimination of transplantation operations. Totally, yield components (the number of effective tillers, spikelet number/panicle, sterility percentage and 1000 grain weight) determine the best variety. Sterility percentage is in contrast to the seed function.

DISCUSSION

DSR is both cost- and labor-saving, although grain yield in DSR is comparatively less than that of TPR (Farooq et al., 2006a, b, 2007, 2009c; Naklang et al., 1996). Bhuiyan et al. (1995) showed that the rice growth duration decreased for 7 to 10 days by direct cultivation. Also, land occupation decreased, thus it saves water and labor for 25 to 30%. Field experiments in the Indo-Gangetic Plain showed that irrigation water savings of 12 to 60% for DSR on beds, with similar or lower yields for transplanted ,compared with puddle-flooded transplanted rice (Gupta et al., 2003), and usually slightly lower yields with DSR in flat fields (Balasubramanian et al., 2003; Gupta et al., 2003). Pandey et al. (2002) proposed that the technical ability in increasing production, releasing of early cultivars and methods of weed chemical control are needed to the extension of DSR method. It is not necessary to create early varieties, because there is no significant difference between the length of plant growth duration and saving rate in each occupation time in the studied area. According to the results obtained from the tables of plant growth duration and yield analysis, there is significant difference between DSR and TPR methods in wet bed. This result is the same as the result presented by Pandey et al. (2002), where water available and wage of workers are the main factors to determine the cultivation method. DSR reduces the labor requirement for establishment by transferring field activities to periods when labor costs are comparatively lower (Pandey and Velasco, 1999). Substantial water savings are possible from DSR (Dawe, 2005). The main reason for choosing DSR method in wet bed in this study is that water availability and wage of workers are two major factors in the studied region. Main cultivation method in this region is TDR in the wet bed.

In spite of these reasons, a DSR method that is consistent with the major regional concern must be selected, and this same result have been introduced by Pandey et al. (2002). By comparing the number of total tillers and fertile tillers in different cultivars and cultivation methods revealed that the number of total tillers was no significant in different varieties. Hill and linear cultivation methods are a little better than transplanting method. It shows that in early process of cultivation, plant establishment in these methods is faster. The number of fertile tillers is more effective in DSR method than that of TPR method. This represents more effective plant arrangement and intensity that cause the increase of land area in DSR method (Bisvaz and Yamauchi, 1997). In this study, at the end of growth period, the shoot percentage was high in the whole plots used as broadcasting method in DSR. This finding is in agreement with Yomouchi et al. (1995). According to these researchers, DSR causes the increasing of lodging at maturation time because the main roots were in the soil surface. In other words, increasing the plant lodging content could be a negative factor in DSR if there has not been a precise investigation about density and arrangement of cultivation. Pandey and Velasco (2002) confirmed results obtained by our studies. Evaluation of panicle sterility percentage of grain/panicle showed that this trait in all DSR methods was higher than that of TPR method. This can result from high plant density and unsuitable cultivation arrangement of plant in DSR method that cause compacting canopy and decreasing the air flow around the plant, especially in irregular broadcasting method at the end of growth period. Panicle transpiration resistance increased rice spikelet fertility during flowering when water stressed (Garrity et al., 1986). Reduced starch levels have been observed in anthers of plants exposed to water stress (Lalonde et al., 1997); which may reduce pollen viability (Garrity et al., 1986; Lalonde et al., 1997); and hence panicle fertility. The number of sterile spikelet increased, as well as abortive, opaque and chalky kernels in DSR compared with TPR (Farooq et al., 2006a, b, 2007, 2009c). Investigation of grain number/panicle revealed that there is significant difference between all forms of DSR and TPR methods. It indicates the effects of environmental competition such as seed density and cultivation arrangement. More studies are needed to improve the seed potential in different methods of DSR which have much effect on grain yield. Some reports claim similar or even higher yields of DSR with good management. Finally, investigation of grain yield in different cultivation methods and cultivars showed that there is significant difference between different cultivars used in this research, which has the same growth duration. Also, Pantuwan et al. (2002) showed the yield potential of early genotypes is often low because of their shorter growth duration. Though there is significant difference between different cultivation methods and the most yields are related to TPR, DSR as linear, broadcasting and hill, respectively; Gupta et al. (2003) reported 10% higher yields in DSR than flooded TPR. In a two-year field experiment in the Indo-Gangetic Plain evaluating various establishment systems, rice yields under conventional puddle or non-puddle (no-tillage) flat bed systems were the same (Bhushan et al., 2007). Closing the function of DSR as linear to the function of transplanting cultivation is a positive effect. Contrary to our results, Nourbakhshian (2000) showed that the grain yield is very low in DSR method. Similar to our results, Kukal and Aggrawal (2002) showed that with respect to yield, both DSR (wet, dry or water seeding) and TPR had similar results. Regarding the results obtained from varieties and mean comparison tables in which transplanting method as broadcast had the best conditions; we propose to consider the varieties in subplots, carefully.

Conclusion

There is no significant difference between varieties, but regarding the mean comparison, the best interaction and seedling establishment belong to "Hybrid Spring 1". Researches have to concentrate on the better genotype and management factors to obtain a new method containing reduction of water consumption, reduced production costs, reduction of duration time and higher seed function.

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