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Documenting production process and the ranking factors causing yield gap in rice fields in Sari, Iran

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ABSTRACT- The documentation process is very important for identifying yield constraint factors and yield gap. For this purpose, all managing practices were recorded by monitoring paddy rice fields in Sari region, Iran from 2015 to 2016. Field identifications were undertaken in such a way that they included all the main production procedures with variations in management viewpoints. Results revealed that seed consumption varied from 40 to 95 kg ha^{-1} and the range of seedling age varied from 20 to 50 days. Planting density was 10 to 66 plants per m^2. Nitrogen application by 30% of the farmers ranged from 46 to 83 kg ha^{-1}, and 40% of the farmers applied 83 to 138 kg of nitrogen per hectare. In 73% of the fields, nitrogen was not used after the flowering stage. The range of yield varied from 3100 to 5430 kg ha^{-1}, and in 60% of the studied fields, the paddy yield varied from 4205 to 5200 kg ha^{-1}. In the comparative performance analysis (CPA) model, the actual yield and the yield potential were estimated to be 4495 and 6337 kg ha^{-1}, respectively, and the yield gap was 1841 kg ha^{-1}. Among the five variables entered in the model, the effects of potassium application and biological fight were remarkable so that the paddy yield increase by these variables was 709 and 806 kg ha^{-1}, respectively, that was equal to 39% and 44% of the total yield variation. Therefore, since the calculated potential yield was achieved through actual data in each paddy field, it seems this yield potential is attainable.

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of more than half of the world population, and has an obvious effect on feeding, income generation, and job creation for people around the world, especially in Iran (Pishgar-Komleh et al., 2011). The area of rice cultivation in the world has increased from 145 million hectares to 167.2 million hectares during recent years (FAO, 2019). Iran, with 571.6 thousand hectares of paddy fields and two million tons of white rice production, accounted for a 0.4% of rice production and cultivation area in the world, and most of these fields (about 40%) were located in Mazandaran province (Ministry of Jihad-e-Agriculture of Iran, 2016). The paddy field area in Sari city was about 23,000 hectares, accounting for 10% of the total paddy field area in Mazandaran province (Ministry of Jihad-e-Agriculture of Iran, 2016).

One of the major problems in crop production in Iran is a large disparity between the farmers' actual yield and attainable yield. In the recent years, owing to concerns over food security issues, yield gap analysis was vastly investigated into world-wide level (van Ittersum et al., 2013; Wang et al., 2015) as well as in Iran (Soltani et al., 2016). It is necessary to use appropriate statistical methods to estimate the yield gap and its causes, or to identify the possible limitations to achieving the potential yield (Soltani et al., 2016). In this regard, there are various methods to analyze the yield gap. One of these methods, which focuses on the ability to estimate potential yield and the reason for a yield gap, is comparative performance analysis (CPA). In fact, the analysis of a yield gap provides a quantitative estimation of the potential for increasing production capacity, which is an important component for designing food security strategies at the regional, national, and global levels (van Wart et al., 2013). Yield gap is defined as the difference between the potential yield and the actual farm yield under optimal management conditions (van Ittersum et al., 2013).

The majority of extent research has focused on the yield of the three main crops, wheat, rice, and maize that make up a large portion of human food supplies (Beza et al., 2017). Some important studies pertaining to the rice yield gap have globally used the CPA method to analyze the yield gap (Kayiranga, 2006). Other studies on rice yield have analyzed the yield gap in conventional and organic systems in the Mediterranean (Delmottea et al., 2011), determined the factors affecting the diversification of flooding rice in southern-central Benin (Tanaka et al., 2013), determined the constraint factors on rice yield in the floodplain systems in Senegal River Valley (Tanaka et al., 2015), analyzed the yield gap of rice systems in America (Epse et al., 2016 a,b), simulated the yield gap of rice in the world (Mueller et al., 2012), determined the flooding rice yield gap in China (Xu et al., 2016), analyzed the yield gap of rice in the Philippines by using a model (Silva et al., 2017), and analyzed crop planting systems to increase sustainability by reviewing the research conducted worldwide (Reidsma and Jeuffroy, 2017). Other studies conducted in Iran estimated the quantity of rice yield gap and input utilization (Gorjizad et al., 2019 a, b; Habibi et al., 2019 a, b; Halalkhpr et al., 2018; Rezvantalab et al., 2019) and estimated canola yield gap (Nezamzadeh et al., 2019) using CPA and boundary-line anslysis (BLA), or in other words, detected the restricting parameters of potential yield. Therefore, rice yield gap measures are necessary to understand the possibility of achieving higher yields and for proper planning as well. Thus, the aim of this research was to estimate the rice yield gap related to crop management by local rice cultivars at the Sari region of Mazandaran province located in northern Iran.

MATERIALS AND METHODS

Description of the Site and Climate

The present research was undertaken in 100 paddy fields located between the Alborz mountains range and the Caspian Sea in 2016. Sari city is located in Mazandaran province in northern Iran. The experimental region is geographically situated at 36°, 4’ N latitude and 53°, 5’ E longitude. The weather data were collected daily from the nearest synoptic meteorological station to the paddy fields (Table 1). *Srad_calc* and *PP_calc* programs can also be downloaded from “https://sites.google.com/site/CropModeling”.

Data Collection

All the managerial operations from nursery preparation to harvesting stages were recorded through field studies. To estimate the yield gap, 100 paddy fields in the Sari region were recorded through monitoring. All the farm cases pertained to local cultivars. The profile of the cultivars is shown in Table 2.

The method of each managerial operation in the paddy fields was determined during each of the phases of soil preparing, planting, cultivating, and harvesting. All the data about agricultural management, including soil preparation (plough frequency, disk frequency, etc.), transplanting time, fertilizer (amount and time of the applied fertilizer), pests, diseases and weed control, irrigation frequency, and harvesting issues (harvest time and yield) were collected. This information was gathered and complemented using questionnaires as well as face-to-face interviews with the farmers.

At the end of the growing season, the actual harvested yield is registered by farmers. For the purpose of this research, first, 100 farmers in the region were identified and chosen randomly. The farms were identified in such a manner as to cover all the main production methods in the specific region and the different management viewpoint as well. Then, information pertaining to farm management was collected. For collecting the information about paddy field management, all the agricultural functions were first separated. Next, from the start of each operation, data regarding temperature fluctuations, diversity in production methods, and different inputs quantities by the farmers in the region, and for providing broader information, typical information pertaining to agricultural operations, such as the data for starting operations and the entry quantities at each implementation stage (cultivation to harvest) in the paddy fields were collected and registered.

Estimation of the Yield gap by CPA Method

In order to determine the yield model (production model), the relationships between all the variables were measured, and the yield was evaluated by using the regression method (Soltani *et al.,* 2016). The final model was obtained through a controlled trial and error method to quantify the effect of yield constraints. The average paddy yield was calculated by placing the observed average variables (Xs) in the fields under study in the yield model. Thereafter, by placing the best observed values of the variables in the yield model, the maximum obtainable yield was calculated. The difference between these two values was considered as the yield gap. The difference between the multiplication of the average observed value for each variable by its coefficient and the multiplication of the best observed value for the same variable by the coefficient of the same variable revealed the value of the yield gap for that variable. The ratio of the yield gap for each variable to the total yield gap showed its share in creating the yield gap, and was represented in percentage. Different procedures of the software SAS version 9.1 were used for the analysis.

RESULTS AND DISCUSSION

Documentation of the Production Process

The field evaluation data showed that farmers in the region had a production history of one to 51 years. A significant proportion of the farmers (about 51%) showed a production history of 15 to 40 years. The selected paddy fields were varied and had a diverse area. The individual areas of the 100 fields were between 0.1 and eight hectares in which 64% of the paddy fields showed an area less than one hectare. According to the findings, the rate of seeding by farmers varied between 40 and 95 kg ha^{-1}. Also, the seed use of 69% of the farmers was 50 to 80 kg ha^{-1} (Table 3).

Table 1. Description of climatic parameters in the survey period (2015-2016) and in the long term period (2001-2016) in Sari region

Month	Average min. temp. (°C)		Average max. temp. (°C)		Evaporation (mm/month)		Rain (mm/month)		Mean relative humidity (%)		Mean sunshine hours		Solar radiation (MJ m^{-2} d^{-1})	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Apr.-May	9.5	10.8	19.5	18.6	71.8	63.2	98.7	99.3	76	77	157.7	123.6	14.7	13.5
May -Jun	15.8	16.4	25.2	24.8	115.9	85.9	27.0	41.4	77	78	168.8	140.9	17.0	15.9
Jun.-Jul.	19.2	19.9	28.6	27.8	154.4	121.8	23.7	24.6	76	80	252.2	232.8	22.2	21.1
Jul.-Aug.	22.2	22.3	31.4	30.7	169.4	130.2	59.4	39.6	75	79	238.0	203.0	21.3	19.7
Aug.-Sep.	22.6	22.5	33.5	33.1	193.9	142.3	6.7	11.4	73	76	269.5	232.5	21.9	20.2
Sep.-Nov.	21.2	21.6	32.0	31.0	156.6	113.9	99.3	88.5	71	65	240.5	193.0	18.6	16.5
Mean 15 years	18.3	18.5	25.2	25.2	147.6	147.6	89.0	89.0	73.5	73.5	208.8	208.8	19.5	19.5

Table 2. Description of name, origin and other characteristics of rice cultivars in the experiment

Cultivar	Plant stature	Maturity condition	Growing period (days from seedling in the nursery to harvesting)	Paddy yield (kg ha^{-1})	Quality condition	Tolerance to stress	Type	Origin
Tarom Hashemi	Tall	Early maturing	118 days	4100	High quality	Low sensitive	Local cultivar	Iran
Tarom Mahalli	Tall	Early maturing	123 days	3600	High quality	Sensitive	Local cultivar	Iran
Sang Traom	Tall	Early maturing	120 days	4100	High quality	Sensitive	Local cultivar	Iran
Tarom Deilamani	Tall	Early maturing	118 days	3850	High quality	Sensitive	Local cultivar	Iran
Tarom Talaii	Tall	Early maturing	120 days	4100	High quality	Sensitive	Local cultivar	Iran
Tarom Ashrafi	Tall	Early maturing	122 days	4200	High quality	Sensitive	Local cultivar	Iran
Gardeh	Tall	Early maturing	122 days	4500	High quality	Relative sensitive	Local cultivar	Iran
Tarom Alam Sabz	Tall	Early maturing	118 days	4000	High quality	Sensitive	Local cultivar	Iran

The data analysis of seeding date in the nursery showed that it started from March 11 and carried on till June 21 in the Sari region. Approximately, 70% of the farmers had completed seeding in the nursery in April; 34% of them doing it in the first half of April and 35% in the second half of April (Table 3). About 77% of the farmers had completed transplantation in May and 22 farmers did it in June. According to the findings, 30% of the farmers undertook transplantation in the first half of May and about 44% of the farmers started transplanting from mid-May (Table 3).

In terms of seedling frequency per plant, 100 fields varied (three to eight seedlings); three seedlings per hill were used in 11 paddy fields. In 28 fields, four seedlings per hill were used and in 23 fields, five seedlings per hill were used. Also, in 30 fields, farmers used six seedlings per hill (Table 3). The data analysis of the seedling age variable revealed that it ranged between 20 and 50 days. About 48% of the farmers used seedlings less than 30 days old. But, 42% of the studied fields were transplanted with old seedling from 30 to 40 days old. Based on the findings, seedling less than 30 days old were used in mechanized transplantation and seedling more than 30 days old was used in manual transplantation (Table 3). The planting density in 100 paddy fields was 10 to 66 plants per m^2. Planting density of 39% of fields was less than 20 plants per m^2; in 40% was reported to be 20 to 30 plants per m^2 (Table 3). In terms of top dressing nitrogen usage, in four fields, no top dressing was used; in 36 paddy fields, only one stage top dressing nitrogen was used; in 39 fields, top dressing was used in two stages (Table 3). Nitrogen top dressing was applied in two steps: most farmers carried out fertilizer top dressing at the start of tillering and panicle initiation, while some others did top dressing at full heading stage. The total amount of nitrogen used varied from 18 to 230 kg ha^{-1}. Moreover, 20% of the farmers reported nitrogen consumption of less than 46 kg ha^{-1}. Nitrogen usage by 30% of farmers was from 46 to 83 kg ha^{-1}. About 40% of the farmers consumed between 83 to 138 kg nitrogen per hectare (Table 3).

In terms of phosphorus usage, 100 studied fields varied from 0 to 130 kg ha^{-1}. In 20 fields, phosphorus usage was reported as 38 kg ha^{-1}; in 50% of the fields, phosphorus was used at 38 to 80 kg per hectare; in 20% phosphorus used was reported as 80 to 100 kg ha^{-1} (Table 3). Data analysis for potassium usage revealed that potassium usage varied from 0 to 150 kg ha^{-1}. Also, in 45% of the fields non potassium usage was reported; in 30% potassium usage was less than 45 kg ha^{-1}. In terms of nitrogen usage before transplanting, the 100 studied paddy fields varied from 0 to 230 kg ha^{-1}. In 60% of the fields, nitrogen consumed was less than 49 kg ha^{-1} before transplanting. In 30% of the fields, nitrogen usage before transplanting varied from 49 to 87 kg ha^{-1}. Data evaluation showed that nitrogen application in vegetative stage was from 0 to 92 kg ha^{-1}. Of the surveyed fields, 23 fields reported no consumption of nitrogen in the vegetative stage. In about 43% of the studied fields, nitrogen usage in the vegetative growing stage was less than 30 kg ha^{-1} (Table 3). The application of nitrogen after the flowering stage ranged from 0 to 58 kg ha^{-1}. In 73% of the fields, no nitrogen usage was reported at this stage. These results indicated that farmers in the region do not appreciate the importance of fertilizer splitting and the significant share of nitrogen consumed at the flowering stage, and need to promote scientific findings. The data evaluation showed that zinc consumption in the 100 paddy fields varied from 0 to 34 kg ha^{-1}. In 89% of the fields, zinc fertilizer application was not reported. In 11% of the remaining fields, the application of zinc fertilizer was reported as 3.4 to 34 kg ha^{-1}. Moreover, sulfur consumption varied from 0 to 45 kg ha^{-1} in the 100 studied fields. In 55% of the fields, sulfur application was not reported. In 20% of the fields, sulfur application was reported as 15 to 34 kg ha^{-1} and in 30% of the surveyed fields, sulfur consumption varied from 15 to 45 kg ha^{-1} (Table 3).

The frequency of insecticide usage in the 100 paddy fields varied from zero to three times. Insecticide was not used in five fields. In 36 fields, insecticide was used once, and in 50 fields, they were used twice to control pest (Table 3). Herbicide usage varied from zero to two times. There was no application of herbicide in six fields while they were used once in 26 fields and twice in 68 fields for weeds control. Moreover, in 83 fields, one-step weeding was done and it was undertaken twice for weed control in 17 fields. The frequency of fungicide application in the studied fields varied from zero to three stages. Out of these, there was no consumption of fungicide in 12 fields, one-step fungicide usage was reported in 59 fields, and fungicide was applied twice in 22 fields. In seven fields, the farmers applied fungicide in three stages (Table 3).

The data analysis shows that harvesting was carried out from 118 to 183 days after March 21 (beginning of spring). About 20% of the fields were harvested 132 days after March 21. In 50% of the fields, harvesting was undertaken 132 to 153 days after March 21 (Table 3). The range of paddy yields varied from 3100 to 5430 kg ha^{-1} in the 100 fields. In 10% of the fields, paddy yield was less than 3500 kg ha^{-1}. The paddy yields in 20% of the fields varied from 3500 to 4205 kg ha^{-1}. Also, in 60% of the studied fields, the paddy yields ranged from 4205 to 5200 kg ha^{-1} (Table 3).

Table 3. Mean, minimum, maximum, standard error (SE) and coefficient of variation (C. V.) for investigated variables in 100 paddy fields in Sari region

Variable	Unit	Mean	Minimum	Maximum	SE	C.V. (%)
Production history	Year	19.48	2	51	1.12	57.46
Paddy field area	Hectare	1.41	0.1	8	0.13	92.79
Seed rate	kg ha^{-1}	63	40	95	1.35	21.37
Seedling date in nursery	Days after 21 March	21	-19	72	1.46	67.88
Transplanting date	Days after 21 March	53	28	94	1.37	26.00
Seedling age	Day	31	20	50	0.63	20.00
Seedling per hill	Number	5.1	3	8	0.14	26.66
Planting density	Plant per m^2	25	10	66	1.04	41.37
Top dressing fertilizer	Number	1.8	0	4	0.09	49.31
Nitrogen	kg ha^{-1}	84.99	18	230	4.15	48.84
Phosphorous	kg ha^{-1}	62.13	0	130	3.17	51.03
Potassium	kg ha^{-1}	27.54	0	150	3.38	122.86
N before transplanting	kg ha^{-1}	52.05	0	230	3.18	61.10
N in vegetative stage	kg ha^{-1}	25.88	0	92	2.21	85.24
N after flowering	kg ha^{-1}	7.06	0	58	1.38	195.66
Zinc usage	kg ha^{-1}	1.68	0	34	0.56	332.81
Sulfur usage	kg ha^{-1}	8.18	0	45	1.14	139.35
Insecticide	Frequency	1.63	0	3	0.07	44.17
Herbicide	Frequency	1.62	0	2	0.06	37.00
Fungicide	Frequency	1.24	0	3	0.08	60.78
Weeding	Frequency	1.17	1	2	0.04	32.27
Harvesting date	Days after 21 March	147	118	183	1.37	9.30
Paddy yield	kg ha^{-1}	4485	3100	5430	60.48	13.49

Yield Gap Estimation by Comparative Performance Analysis (CPA Method)

Production Model

Results of the step-by-step regression to determine the most important management variables that affected the yield and production model are presented in Table 1. In this regression model, the paddy yield per unit area was considered as a dependent variable. The other variables such as Tarom Hashemi cultivar, potassium fertilizer, biological control by Trichogrammatidae bees, manual harvesting, and pest problem were considered as independent variables, and the result was presented in the final equation. Finally, using this production equation, the actual farm yield, the attainable yield, and the share of each variable on yield reduction were determined. Therefore, from about 150 studied variables, the model (final regression equation) was selected with five independent variables (Table 4). The final yield equation is as follows:

$$Y\ (\text{kg h}^{-1}) = 4399 + 246\ X_1 + 6\ X_2 + 823\ X_3 - 2X_4 - 182\ X_5$$

Where Y is the paddy yield in kilogram per hectare, X_1 is the Tarom Hashemi cultivar, X_2 is potassium application, X_3 is the biological control by Trichogrammatidae bees, X_4 is manual harvesting, and X_5 represents the pest problem, and these continue for the evaluation of each of the factors that influenced the paddy yield.

Paddy yield limiting factors and yield gap estimation

Table 2 presented the variables applied in the production equation with the mean, minimum and maximum values observed in the paddy fields. The characteristics of the variables applied in the model as the average, minimum, maximum, and best values that could be applied in the yield regression model are presented in Table 4. To derive the best condition for the variables including Tarom Hashemi cultivar, potassium consumption, and Trichogrammatidae bees with positive effect, their maximum values were selected. Hand harvesting and pest problem variables were negative variables and were selected in small amounts; therefore, the optimal value was equivalent to the minimum of these two variables. The increase in paddy yield caused by the difference between the best and the medium state of hand harvesting and pest problem variables was equal to 0 and 12% of the total paddy yield increase of 1 and 222 kg ha^{-1}, respectively. The paddy yield increase related to the effect of potassium consumption and biological control by Trichogrammatidae bees was 709 and 806 kg ha^{-1}, respectively, and equal to 39 and 44% of the total changes in yield (Table 4).

Among the five variables entered in the model, the effects of potassium consumption and biological fight were remarkable, which compensated for a significant part of the yield gap in the fields with the farmers managing potassium consumption and using integrative pest control method. The results listed in Table 4 show the total yield and the share of each factor limiting the production relative to it. In the production model, the average and the maximum yields were estimated to be 4495 and 6337 kg ha^{-1}, respectively, which is comparable to the average and maximum yields (4485 and 5430 kg ha^{-1}). The total yield gap estimated was equal to 1841 kg ha^{-1}. This means that there was a gap between the actual yields of the farmers and what they could have potentially harvested with 1841 kg ha^{-1}, which could be eliminated or reduced with better management (Table 4). The results in Fig. 1. illustrate the contribution of each variable to the yield gap along with the actual and the potential yields. Therefore, the actual yield and the potential yield were estimated to be 4495 and 6337 kg ha^{-1}, respectively, and the yield gap was 1841 kg ha^{-1}. This result suggests that this yield gap could be compensated (Fig. 1). The findings in Fig. 2 show the relationship between the actual yield (observed yield) and the predicted yield (simulated yield). These statistics show that the accuracy of the model (production equation) is appropriate, and it can be used to estimate the yield gap and to determine the contribution of each production-limiting variable.

Table 4. Quantifying the rice yield gap and the contribution of each variable entered in the production equation

Variable	Coefficients	Variable in model				Predicted yield		Yield gap (kg ha^{-1})	Yield gap share
		Min.	Mean	Max.	Best	Mean	Best		
Intercept	4399	-	-	-	-	4399	4399	-	-
Tarom Hashemi cultivar (X_1)	246	0	0.58	1	1	143	246	103	6
K consumption (X_2)	6	0	27.54	150	150	159	869	709	39
Biological protection (X_3)	823	0	0.02	1	1	16	823	806	44
Manual harvesting (X_4)	-2	0	0.35	1	0	-1	0	1	0
Pest problem (X_5)	-182	0	1.22	3	0	-222	0	222	12
Paddy yield (kg ha^{-1})	-	3100	4485	5430	-	4495	6337	1841	100

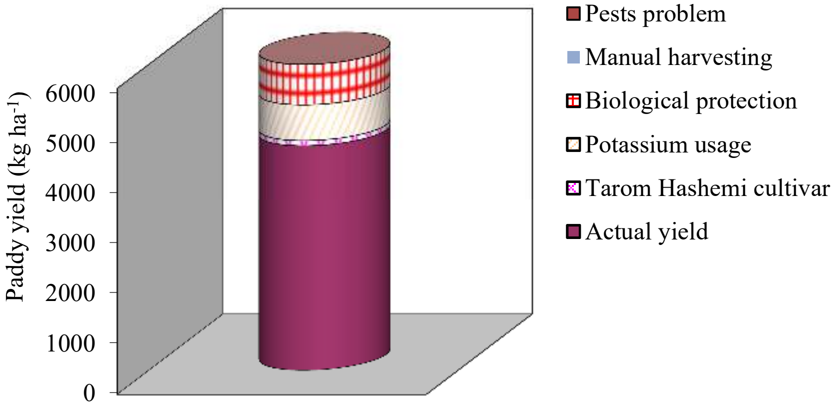

Fig.1. The amount of the main yield gap constraints in the 100 monitored paddy fields.

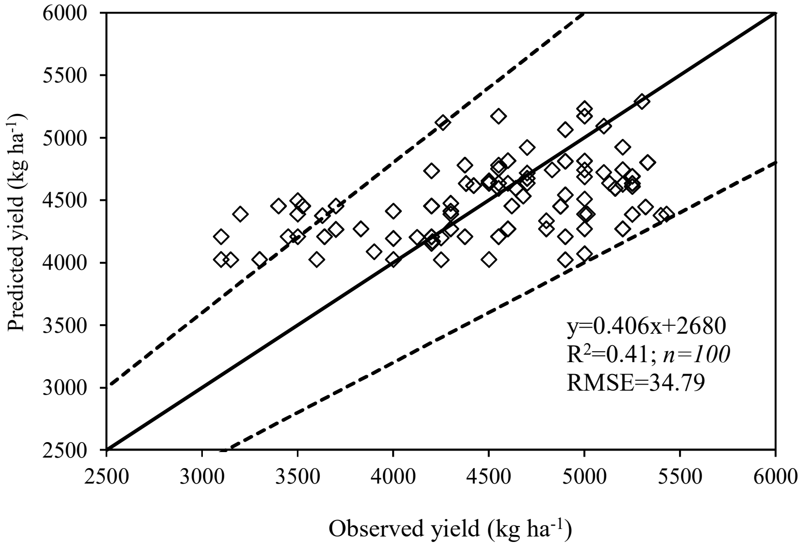

Fig. 2. The relationship between observed vs. predicted yields. Twenty percent of the differences between predicted and observed yields are shown by dashed lines.

The conventional cultivation faces many problems due to lack of understanding of the requirements of the rice crop (Dastan et al., 2015b). The excessive consumption of water, fertilizers and chemical pesticides not only leads to increased production costs, but also reduces yield and destroys resources and the environment in the long term (Dastan et al., 2016; Dastan et al., 2015a). Performing the related practices during the rice growing season will result in increase of the yield. Fertilization, irrigation and combating weeds and diseases are important in crop operations and are considered by most farmers during the growing season (Yadi et al., 2017). Crop management of important rice diseases includes: planting pests and disease-tolerant cultivars, deep plowing of plant remains after harvest, adherence to correct principles of rice farming such as planting distance, planting time (early planting to avoid blast disease), irrigation suitable optimum use of fertilizers, especially the use of nitrogen fertilizer splitting, eliminating weed host interfaces, observing crop rotation between local and high yielding cultivars, appropriate drainage of paddy field and crop health. Despite the fact that the use of chemical pesticides was not completely eliminated by farmers, it was significantly reduced as compared to the biological control (Dastan et al., 2018).

The goal of many researchers is to increase yield to a reasonable level for maintaining food prices to the extent that it is both affordable to the consumers and the product price can cover the costs for the farmers as well. It seems that a yield equivalent to 80% of the potential yield is economically desirable under most planting systems (Lobell et al., 2009). Huang et al. (2008) investigated the effect of management parameters, but the purpose of their probe was not to find the best management method. Rather, they investigated the effects of four treatment management methods on the relationship between precipitation and yield by using the boundary line analysis. Pradhan (2004) also investigated effective factors in maize yield gap, and perceived that soil with light texture, farm area, the number of cultivated seeds per hill, and non-carrying out of thinning operations were 27, 30, 30, and 13% effective, respectively, and they were the most important factors for yield reduction in corn. A global simulation study of the main crops corn, wheat, and rice found that the rice yield gap was internationally about 29%, but the calculated yield gap in this research was estimated to be 11.07-14.73% (Mueller et al., 2012). By considering the fact that the calculated potential yield was derived from actual data in each paddy field, the yield potential was related to the region, and could be achieved. In reality, multi-zone trace researches are restricted by cultivation and harvest data, and different climate and soil conditions (van Ittersum et al., 2013) whereas the potential yield obtained at a research station or calculated via simulation with a planting model does not have these constraints. Nalley et al. (2016) estimated that herbicide tolerant cultivars and hybrid ones had higher yields than local cultivars. Other researchers have reported that the use of improved cultivars of rice, soil fertility management, weed management, and irrigation had a big share in increasing the obtainable yield in China in past decades (Huang et al., 2011). Achieving a yield beyond 80% of the potential yield, although possible, may not be economically feasible for farmers in the region, given the cost of machinery, fertilizers, pesticides, as well as overlapping planting seasons. In addition, empirical observations showed that the most important gap problem for the high yield of crops in Iran was due to inefficient management practices in the fields by the farmers.

CONCLUSIONS

According to the findings, the high rate of yield gap and the contribution of each factor affecting yield gap showed that with proper management, a significant part of this potential yield gap could be compensated. It is rate to achieve the actual potential yield of crops, and in practice, only part of it is taken as real crop from the field. Although the purpose of this research was to estimate the rice yield gap in Mazandaran province, the reasons for this yield gap were studied further, and the most likely solution to increase yields and reduce the yield gap was found to be improved crop management by the farmers. Hence, among the five variables entered in the model, the effects of potassium application and biological fight were remarkable, which the paddy yield increase by these variables was 709 and 806 kg ha^{-1}, respectively, and equal to 39% and 44% of the total yield variation. In the production model, the average and the maximum yields were estimated to be 4495 and 6337 kg ha^{-1}, respectively, the total yield gap estimated was equal to 1841 kg ha^{-1}. Therefore, a significant part of the yield gap in the fields could be compensated with the farmers managing five variables entered in the model especially potassium application and using integrative pest control method.

CONFLICTS OF INTEREST

The authors have no financial conflicts of interest to declare.

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تحقیقات کشاورزی ایران (۱۳۹۸) ۳۸(۱) ۱۰۱-۱۰۹

مستندسازی فرآیند تولید و رتبه‌بندی عوامل ایجاد خلاء عملکرد برنج در ساری، ایران

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واژه‌های کلیدی:
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چکیده- مستندسازی فرآیند تولید برای تعیین عوامل محدود کننده تولید و ایجاد خلاء عملکرد دارای اهمیت زیادی است. به این منظور، همه عملیات زراعی برنج در اراضی شالیزاری منطقه ساری طی سال‌های ۱۳۹۴ و ۱۳۹۵ ثبت شد. انتخاب مزرعه‌ها به شیوه‌ای انجام شد که تنوع کافی از تمامی عملیات زراعی و مدیریتی در منطقه را نشان دهد. نتایج نشان داد دامنه مصرف بذر از ۴۰ الی ۹۵ کیلوگرم در هکتار متغیر بود. دامنه سن نشا بین ۲۰ الی ۵۰ روز بود. تراکم کاشت نیز ۱۰ الی ۶۶ بوته در متر مربع متغیر بود. مصرف نیتروژن توسط ۳۰ درصد از کشاورزان از ۴۶ الی ۸۳ کیلوگرم در هکتار و توسط ۴۰ درصد از کشاورزان ۸۳ الی ۱۳۸ کیلوگرم در هکتار بود. در ۷۳ درصد از مزرعه‌ها، مصرف نیتروژن بعد از مرحله گلدهی گزارش نشد. دامنه عملکرد شلتوک بین ۳۱۰۰ الی ۵۴۳۰ کیلوگرم در هکتار بود و در ۶۰ درصد از مزرعه‌های مورد مطالعه، عملکرد شلتوک بین ۴۲۰۵ الی ۵۲۰۰ کیلوگرم در هکتار متغیر بود. در روش تحلیل مقایسه کارکرد (CPA)، عملکرد واقعی و عملکرد پتانسیل برابر ۴۴۹۵ و ۶۳۳۷ کیلوگرم در هکتار برآورد شد و خلاء عملکرد برابر ۱۸۴۱ کیلوگرم در هکتار بود. از پنج متغیر وارد شده در معادله تولید، اثر کاربرد پتاسیم و کنترل زیستی آفات قابل ملاحظه بود که به‌ترتیب افزایش عملکرد برابر ۷۰۹ و ۸۰۶ کیلوگرم در هکتار معادل ۳۹ و ۴۴ درصد را نشان دادند. بنابراین، با توجه به اینکه پتانسیل عملکرد محاسبه شده از طریق داده‌های واقعی هر مزرعه حاصل شد، می‌توان گفت که این پتانسیل عملکرد قابل حصول است.