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ORIGINAL ARTICLE

Factors affecting wheat yield gap in Savojbolagh, Iran

Mohammad Yaghoobi[1], FayazAghayari[*1,]Khodadad Mostafavi[1]
Department of Agronomy, Karaj branch, Islamic Azad University, Karaj, Iran.
[*]Corresponding E-mail address: Aghayari_ir@yahoo.com

ABSTRACT
*Exploitation of both experts and farmers opinions in a region is an approach to determine factors gapping product yield in the area. In order to evaluate the yield of wheat, a field experiment through questionnaires was carried out in the agricultural fields of in Savojbolagh during the agronomic year 2014-15. The grain yield showed significant positive correlations with the amount of nitrogen usage in the second (0.45**) and third (0.74**) stages, and total nitrogen fertilizer (0.56**), respectively. Yield per hectare had significant negative relationships with the date of first irrigation (0.65**) and amounts of micronutrients fertilizer, respectively. The following Magus (−0.65**). Planting date showed significant negative relationships with the amount of manure (−0.27*) and dates of second irrigation (−0.87**) and harvesting (−0.91**), respectively. The pathanalysis showed that the third usage of nitrogen fertilizer had the highest (0.46) direct effect on the seed yield. Indirect effects of this trait through the traits of the first irrigation date and micronutrient fertilizers were 0.146 and 0.131, respectively. Direct effect of the first irrigation date (−0.34) and the indirect effect of this trait through the traits of the third nitrogen consumption and micronutrient fertilizers, respectively, were −0.195 and −0.108. The direct effect of micronutrient fertilizers on the grain yield was −0.24 and the indirect effect of this trait through the traits of third nitrogen consumption and the first irrigation date, respectively, were −0.255 and −0.157. Among various management factors, nitrogen consumption in the third round (56 percent) and on the first irrigation date (13 percent) had the greatest impacts on the wheat yield gap in the study area.*
Keywords: *Questionnaire, Path analysis, Yield gap, Wheat, Regression, Correlation.*

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INTRODUCTION

Increased crop yield is an important nowadays goal to cope with the increasing world population. The world population is growing at a rate of 1.6 to 1.7 percent and, in other words, 95 million people are yearly added to the consumers of agricultural products. This condition means that it is necessary to continuously increase food production to compensate the food shortage of human in many areas of the world [1].

A major problem in the production of agricultural crops in Iran is the marked difference between the real performance of farmers and harvestable yield. To fill the void of crop yields in agricultural systems, there are three stages: determination of the difference between regional potential yield and the actual yield (yield gap), optimization of the production system in order to reduce the gap, and improvement of agricultural systems. It seems important to determine environmental and agricultural factors limiting yield in a given area in order to reduce the gap between the potential and actual yields. There are no perfect approaches for this purpose because a lot of heterogeneities and interactions are associated with agricultural environment and management, which do not allow for a complete statistical analysis [2]. However, there are several methods for the detection of these factors, each if which have their own defects and advantages. In recent years, the voided crop yield has widely been analyzed at different levels in the world. The extent of these surveys can be categorized as global [3], continental [4], national [5, 6, 7] and regional [8]. The majority of these investigations have been focused on the cereals, in particular three major cereals namely wheat, corn and rice, which supply a considerable portion of man's food.

Some studies are based on surveying measurements, in which the problems of farmers are collected through questionnaires [9]. In other cases, the performance of farmers and the relevant crop management are specified and factors affecting the yield are realized by multivariate analysis and also statistical correlations between the yield and management Variables [10]. Simulation models are other among other methods for the determination of factors voiding the yield; these include both complex and simple models each with its defects and advantages [11, 12].

Agarwal *et al*. [13] used a simulation model and estimated potential wheat yield in India to be between and 2.5-7 t/h with a gap of 2-4 t/h. Bhatia *et al*. [5] evaluated potential wheat yield and the gap for rain-fed soy in 21 areas of India and reported an average potential yield in these areas of 3020 kg/ha with a mean gap of about 28 percent. Rajapaks [14] also showed that fertilizers with 33 percent, water shortage of 26 percent, late harvest of 18 percent, second-time hand weeding of 16 percent, and postponed transplantation of 6 percent accounted for the most important factors causing a gap in rice yield of 2365 kg/ha. Abledo *et al*. [15] reported a wheat yield gap of 40 to 70% in a Mediterranean area of Spain and showed that the amount of gap was a function of nitrogen and water access of farmers.

As noted, a number of parameters hinder farmers to attain various harvestable products. Apparently, through determination of the impact of each management factor on the extent of the observed yield gap followed by the farmers' awareness, the space between the actual and attainable yields can be reduced to a minimum. This research, therefore, aimed to survey corn yield in Savojbolagh, Iran.

MATERIALS AND METHODS

This field experiment was conducted through questionnaires in the agricultural fields (which had already been chosen by the authors) in Savojbolagh during the agronomic year 2014-15. The amount of moisture in the city is 24.54 percent. The city is geographically located in 50° 56' E and 35° 57' N.

Statistical procedures including correlation, stepwise regression to identify important traits affecting the yield, path analysis to determine the direct and indirect effects of important characters as dependent variables included in the regression model, all of which were analyzed by SAS 9.1 and Path. Then the corresponding graphs were drawn for analysis. In order to understand the correlation between variables, simple correlation can be employed, but it has flaws so that changes in one variable with another one are estimated by ignoring the effects of other variables present. To fix this flaw, path analysis was used. It should be noted that multistage sampling was applied in this study. The farmers were sampled from the city and then samples were taken from selected districts. Within each district, a list of villages was prepared, from which sampling was performed. A list of resident farms to be sampled was also obtained for each selected village.

RESULTS AND DISCUSSION

The grain yield showed significant positive correlations with the amount of nitrogen usage in the second (0.45**) and third (0.74**) stages, and total nitrogen fertilizer (0.56**), respectively. Meeting the need for nitrogen at different times in accordance with plant growth and its increased absorption can affect the rate of plant growth and yield. Nitrogen management, therefore, by regulating the timing and amount of nitrogen consumption can be evaluated as an important approach to reduce the yield gap. Such approaches include nitrogen relationship with photosynthesis, nitrogen distribution between the leaves, leaves extension and arrange and their subsequent effects on light absorption [16]. Increased nitrogen fertilizer usually leads to a reduction in the evaporation/perspiration ratio through increased leaf area index. Nitrogen may expand radicle length, rooting depth, and water consumption [17].

Grain yield per hectare was negatively correlated with the date of first irrigation (0.65**) and micronutrient fertilizers (0.65**), respectively, meaning that yield is decreased with increasing irrigation interval. Additionally, excessive micronutrient fertilizers had an adverse effect on the grain yield. Planting date showed significant negative relationships with the amount of manure (−0.27*) and dates of second irrigation (−0.87**) and harvesting (−0.91**) dates, respectively. Soil testing showed a significant positive correlation with plowing depth (0.21*) but a significant negative relationship seed culture (−0.22*).

The product of previous year displayed a significant positive correlation to both the foregoing yield (0.52**) and crop residues (0.33**). The increased yield of previous year may be attributed to an increase in the remnants of preceding year's crop resulting in elevated soil organic matter and the yield. The product of previous year was also negatively correlated to the in culture amounts of nitrogen (−0.27**), phosphate (−0.29**), potash (−0.41**) fertilizers as well as the amount of manure (−0.31**). The yield of foregoing year showed a significant negative correlation to the amount of manure (−0.30**) as well.

A significant positive correlation was found between the crop residue and the amounts of phosphate (0.44**) and potash (0.39**) fertilizers. The relationships between the plowing depth and the levels of nitrogen (−0.22*) in planting, the number of disks (−0.45**), seed cultivars (−0.27*), sowing (−0.24*), planted area (−0.33**), irrigation frequency (−0.22*), and harvesting height (−0.235*) were significantly negative. The plowing depth exhibited a significant positive correlation with the amount of nitrogen (0.23*) in the second period. The sowing depth was positively correlated to the amount of nitrogen at sowing (0.22**) and the harvest height (0.42**).

In addition, increased nitrogen consumption raised plant growth leading to improved harvest height. The plowing depth showed a significant negative correlation with the number of disks (−0.61**). The relationships between the planting amount of nitrogen and the nitrogen consumption in the second period (0.21*), total level of nitrogen (0.56**), phosphate (0.51**) and potash (0.60**) fertilizers, sowing (0.24*), irrigation frequency (0.35*), and harvesting height (0.31*) were significantly positive, indicating increased plant height and irrigation frequency with increasing nitrogen fertilizer.

Significant positive correlations were detected the amount of nitrogen consumption in the second period and that in the third period (0.56**), total nitrogen (0.84**), the amounts of phosphate (0.27*) and potash (0.23*) fertilizers, and harvest height (0.26*). Furthermore, the nitrogen depletion in the second period was negatively correlated with the number of disks (−0.27*), the date of first irrigation (−0.24*), and micronutrient fertilizers (−0.43**). The nitrogen consumed in the third period showed a significant positive correlation with the total amount of nitrogen (0.74**), the quantity of manure (0.22*), and planted area (0.29**); this variable, however, was negatively correlated to the date of first irrigation (−0.42**) and micronutrient fertilizers (−0.43**).

Total nitrogen content showed significant positive correlations with the levels of phosphate (0.37**) and potash (0.42**) fertilizers, irrigation frequency (0.23**), and harvest height (0.28*), whereas it was negatively related to the date of first irrigation (−0.34**) and micronutrient fertilizers (−0.50**). The phosphate fertilizer showed a significant positive correlation to the potash one (0.76**). The latter was positively correlated with irrigation frequency (0.27*). The manure level showed significant positive correlations with the second irrigation (0.24*) and harvesting (0.26*) dates. The amount of manure (−0.25*) showed a significant negative correlation with the micronutrient fertilizers. The number of disks was positively correlated to sowing (0.32**) and the planted area (0.41**) but it had a negative correlation with harvest height (−0.261*). Seed varieties displayed a significant positive correlation with the cultivated area (0.24*). These observations can be explained such that, based on the type of seed variety, the amount acquired differs per cultivated area. The amount of seed consumed showed a significant positive correlation with the irrigation frequency (0.26**) and the height at harvest (0.29**). The first irrigation date was also positively correlated to micronutrient fertilizers (0.45**) and the height at harvest (0.32**). The date of first irrigation showed significant negative correlations with the second irrigation date (−0.22*) and harvest date (−0.24*). The second irrigation date was positively related with harvest date (0.79**). Furrow length and micronutrient fertilizers (−0.22*) were negatively correlated. Irrigation frequency and the height at harvest (0.24*) were positively correlated, so that with increasing irrigation, both the vegetative growth and the height at harvest increase. Also, the frequency of irrigation showed a significant positive correlation with the type of combine (0.12*) (Table 1).

Variables	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y 8	Y9	Y10	Y11	Y12	Y13	Y14
Grain yield (Y1)	-	−0/05	−0/06	0/09	−0/10	−0/19	0/12	−/007	0/02	0/45**	0/74**	0/56**	0/06	0/12
Planting Date (Y2)		-	0/06	0/06	0/08	0/08	−0/03	0/08	0/05	0/16	0/006	0/11	0/07	0/08

The amount of potash fertilizer (Y 14)	The amount of phosphate fertilizer (Y 13)	The amount of total nitrogen (Y 12)	The amount of nitrogen in step III (Y 11)	The amount of nitrogen in the second phase (Y10)	The amount of nitrogen in step First (Y 9)	Planting depth (Y8)	Depth (Y7)	Culture remains of the previous year (there-no) (Y6)	Product performanc e last year (Y5)	Product type year ago (Y4)	Soil tests (carried- Failure to do) (Y3)
											–
										–	0/04
									–	0/52**	0/10
								–	0/20	0/33**	0/13
							–	0/18	0/07	0/09	0/21*
						–	-0/08	0/08	0/12	0/07	0/02
					–	0/22*	-0/22**	0/11	0/03	-0/27*	-0/03
				–	0/21*	0/17	0/23*	-0/03	0/03	-0/02	-0/002
			–	0/56**	0/05	-0/007	0/10	-0/16	-0/17	0/03	-0/11
		–	0/74**	0/84**	0/56**	0/18	0/06	-0/03	-0/04	-0/11	-0/06
	–	0/37**	0/03	0/27*	0/51**	0/06	0/12	0/44**	0/21	-0/29**	-0/04
–	**760/	**420/	0/08	0/23*	0/60**	0/002	0/06	0/39**	0/10	-0/41**	

Table 1. Correlation coefficient for the studied characteristics and Continue table 1

The amount of nitrogen in the second phase (Y10)	The amount of nitrogen in step First (Y 9)	Planting depth (Y8)	Depth (Y7)	Culture remains of the previous year (there-no) (Y6)	Product performance last year (Y5)	Product type year ago (Y4)	Soil tests (carried-Failure to do) (Y3)	Planting Date (Y2)	Grain yield (Y1)	Variables
0/08	0/11	-0/14	-0/03	0/01	-0/30**	-0/31**	-0/10	-0/27*	0/18	Y15
-0/27*	0/10	-0/61**	-0/4**	-0/207	-0/15	-0/12	-0/18	-0/16	-0/02	Y16
-0/10	0/10	0/08	-0/27*	-0/05	-0/16	-0/19	-0/17	0/003	0/03	Y17
0/16	-0/0007	0/08	-0/18	-0/19	-0/06	0/10	-0/01	0/02	0/12	Y18
0/004	0/24*	-0/03	-0/24*	-0/15	-0/10	-0/04	-0/22*	-0/02	-0/11	Y19
-0/24*	0/08	0/04	-0/10	0/10	0/06	-0/04	0/09	0/18	-0/65**	Y20
-0/07	-0/004	-0/03	-0/02	-0/12	-0/01	-0/0007	-0/12	-0/87**	0/16	Y21
0/03	-0/12	-0/03	-0/02	-0/13	-0/08	0/02	0/06	0/15	0/002	Y22
-0/06	0/14	-0/02	-0/33**	0-/14	-0/13	-0/01	-0/12	0/02	0/18	Y23
0/12	0/35**	0/17	-0/22*	0/15	0/01	-0/11	0/09	0/16	0/02	Y24
-0/43**	-0/10	-0/05	-0/01	0/08	0/13	-0/0009	0/06	0/04	-0/65**	Y25
-0/11	-0/008	-0/03	0/01	-0/05	-0/04	-0/10	-0/03	-0/91**	0/07	Y26
0/26*	0/31**	0/42**	-0/23*	-0/08	-0/004	-0/006	-0/05	0/18	-0/06	Y27
-0/11	0/20	0/01	-0/13	0/06	-0/06	-0/06	0/01	-0/03	-0/11	Y28

The second date watering (Y21)	Date of first irrigation (Y20)	Planting seeds (Hiromi-dried) (Y19)	The amount of seed (Y18)	Cultivars (Y17)	Number of Discs (Y16)	The amount of manure (Y15)	The amount of potash fertilizer (Y 14)	The amount of phosphate fertilizer (Y 13)	The amount of total nitrogen (Y 12)	The amount of nitrogen in step III (Y 11)
						–	0/11	0/03	0/19	0/22*
					–	0/16	0/000	-0/12	-0/08	0/000
				–	0/21	-0/02	0/12	-0/02	0/03	0/08
			–	0/14	0/08	0/001	-0/08	-0/11	0/13	0/10
		–	-0/03	0/05	0/32**	0/11	-0/03	-0/06	0/09	-0/03
	–	0/20	-0/01	-0/006	0/000	-0/06	-0/11	-0/054	-0/34**	-0/42**
–	-0/22*	0/001	0/04	0/01	0/14	0/24*	-0/09	-0/08	-0/01	0/04
-0/14	0/01	-0/10	0/002	0/16	-0/08	-0/11	0/08	0/13	-0/03	0/006
-0/007	-0/15	0/21	0/11	0/24*	0/41**	0/04	0/11	0/03	0/16	0/29**
-0/13	0/06	-0/02	0/26*	-0/07	-0/13	-0/08	0/27*	0/13	0/23*	0/04
-0/15	0/45**	0/03	-0/20	-0/07	0/000	-0/25*	-0/14	-0/013	-0/50**	-0/55**
0/79**	-0/24**	-0/10	-0/05	0/03	0/09	0/26*	-0/04	0/01	-0/05	0/002
-0/14	0/32**	-0/03	0/29**	0/13	-0/26*	0/04	0/12	0/19	0/28*	0/03
0/004	0/14	-0/07	-0/04	-0/04	0/000	0/08	0/07	-0/03	-0/04	-0/16

Combine Type (Y28)	Harvest height (Y27)	Harvest date (Y26)	Micronutrient fertilizers (Astfadh-non-use) (Y25)	Irrigation frequency (times) (Y24)	Cultivation (Y23)	Furrow length (Y22)
						–
					–	0/15
				–	0/05	−0/04
			–	−0/06	−0/21	−0/22*
		–	−0/06	−0/11	−0/09	−0/13
	–	−0/14	−0/06	0/24*	0/01	0/08
–	0/26	0/02	0/15	0/12*	−0/19	−0/10

Using stepwise regression can classify important traits affecting the yield. To determine the cumulative effects of traits on grain yield, stepwise multivariate linear regression were used. It may or may not be a significant variable beside the other ones. Accordingly, it is necessary to select important variables that have significant impacts on the yield. To remove less important variables in the model and making a decision to form the final version, there are many methods, one of which is stepwise procedure. The stepwise regression for grain yield against the other traits indicated that nitrogen consumption in the third phase alone (56 percent) explains the bulk changes in regression model. Next, date of the first irrigation describes about 13 percent of the rate of changes in the yield (R^2 = 0. 59). After that, the micronutrient fertilizers justify about 4 percent of the changes (Table 2). Our results correspond to those of Acquaah *et al.*, [18], Bacanamwo and Purcell [19].

Table 2. Stepwise regression for wheat yield as the dependent variable and other attributes as independent variables

Phase	Regression model	Coefficient of determination
1	$Y = 4.49 + 0.02562\ Y_{11}$	$R^2 = 0.56$
2	$Y = 5.93 + 0.0\ 198\ Y_{11} - 0.\ 1408\ Y_{20}$	$R^2 = 0.69$
3	$Y = 7.220 + 0.016Y_{11} - 0.118\ Y_{20} - 0.913\ Y_{25}$	$R^2 = 0.73$

(Y_{11}: nitrogen consumption in the third phase; Y_{20}: Date of first irrigation; Y_{25}: micronutrient fertilizers)

The path analysis is considered a very helpful method for the examination of genetic and phenotypic correlations and detection of both direct and indirect effects. Three traits were entered the model and explained a high percentage of the variations. Path analysis (causality) was applied to assess their direct and indirect effects on the grain yield. Path analysis is a method to study the principle of causality among a set of variables and is very useful for correlation analysis and also understanding the direct and indirect effects of traits. When referring to the concept of causality, some of the variables should be taken as the causes, and the others as the effects. Dewey and Lu [20] describing the path analysis noted that correlation between each of the parameters examined with a dependent variable in a multivariate system can be analyzed to its direct and indirect effects through the other independent variables. In such a system, the whole change in a dependent variable is divided into two justified and unjustified components with variables under consideration. What is expressed by the independent variables is the coefficient of determination in a standard multiple regression analysis. The relationship between different traits is important for increasing grain yield as a one-way choice for agronomic characteristics regardless of the effects of other traits will not provide trustable results. Hence, the correlation between traits as well as their direct and indirect effects on the yield should be taken into consideration, making the path analysis indispensable. The selected characteristics in regression analysis were the nitrogen rate in the third stage, first irrigation date, and micronutrient fertilizers. The third nitrogen fertilizer had the highest (0.46) direct effect on the grain yield. The indirect effects of this trait through the first irrigation date and micronutrient fertilizers were 0.146 and 0.131, respectively. The direct effect of the first irrigation date (−0.34) and its indirect effect through nitrogen consumptions in the third period and micronutrient fertilizers, respectively, were −0.195 and −0.108. The direct effect of the nutrient fertilizers on the grain yield equaled to −0.24 and its indirect effect through nitrogen consumption in the third period and the first irrigation date, respectively, were −0.255 and −0.157.

Table 3. Path analysis for wheat yield

All traits In the model	Indirect effect through			Direct effect of	Ensemble
	Y_{11}	Y_{20}	Y_{25}		
Y_{11}	-	0.146	0.131	0.46	0.74
Y_{20}	-0.195	-	-0.108	-0.34	-0.65
Y_{25}	-0.255	-0.157	-	-0.24	-0.65
The effects remained			**0.525**		

(Y_{11}: nitrogen in the third phase, Y_{20}: Date of first irrigation, Y_{25}: fertilizers, micronutrients)

According to the amounts recorded in the study area, the average wheat yield was 1.7 tons per hectare, which is the actual performance. To determine the potential yield, the regression model obtained in Step 3 was used. The maximum values (for parameters with negative coefficients) or minimum (for parameters with positive coefficients) three variables entered in the regression model obtained from the recorded data, and then were included in the regression model (Step 3) a potential yield of 9.389 ka/ha was obtained. Thus, the yield gap (difference between actual and potential yields) in the region was determined to be 289/2 tons per hectare. This means that the amount of actual wheat yield compared to the potential one has a deficiency of 24.37 (Figure 1).

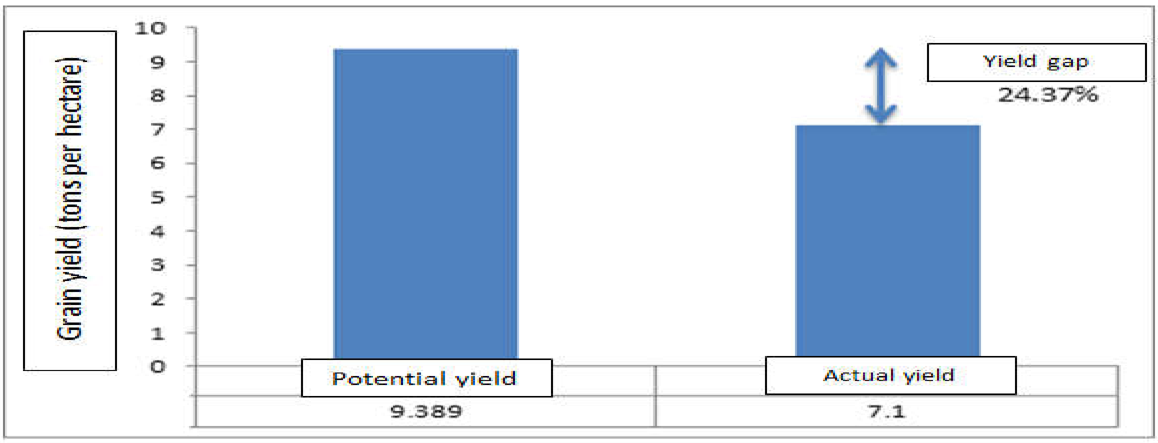

Fig. 1 - Wheat yield gap

CONCLUSION

The simple correlation between the grain yield and the traits studied in Savojbolagh, the nitrogen intake in the third stage showed a significant positive correlation (0.74**) among the rest of traits followed by the nitrogen consumption in the second phase with a significant positive correlation (0.45**). Grain yield per hectare had significant negative relationships with the first irrigation date (⁻0.65**) and amounts of micronutrient fertilizers (⁻0.65**), respectively. Among the different management factors in Savojbolagh, the amount of nitrogen in the third stage (56 percent), date of the first irrigation (13 percent) and micronutrients fertilizers (4 percent) had the greatest impacts on the wheat yield gap. The relationships by path analysis in Savojbolagh showed that the amount of nitrogen in the third stage (0.46) followed by the first irrigation date (−0.34) and micronutrients fertilizers (−0.24) displayed the highest direct effects.

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