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Modelling of the Factors Creating the Yield Gap of Wheat in the Shushtar Area

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Abstract: One of the main problems in crop production in our country is the huge gap between farmers' actual yields and potential yields. Inappropriate management, in many situations, yields a significant difference that can be accounted for. Studies have shown that the first step in reducing the performance gap is to identify the performance constraints in a particular area. Understanding performance constraints can help us reduce performance gaps. Reducing the yield gaps not only helps to increase yield and production but also improves the use of land and labor, reduces production costs, and increases performance stability. This study was conducted in 2017 in the Shushtar area to estimate the potential and yield gap performance of wheat (Triticum aestivum L.) plant, as well as the factors limiting the yield and the contribution of each of these factors to the creating yield gap, based on the information and the yield gap collected through a questionnaire and collecting data from the fields of Shushtar area using the method of analysis Functional Comparison (CPA) was reviewed. The real mean of the yield from fields in the Shushtar area was about 3880.38 kg ha-1 and the potential yield of farms was about 9092.78 kg ha^{-1} the difference between them was 5212.43 kg ha-1. In addition, the results showed that the factors causing the yield gap were important in order of importance including nitrogen percentage of soil (27.09%), soil acidity (25.57%), drainage and flooding (17.93%), soil salinity (11.73%), weed density (9.38%) and nitrogen stem content before flowering (8.30%) On the yield gap the effect on the fields was affected.

Keywords: Boundary Line Analysis, Potential Yield, Simulation, Yield Gap

1. Introduction

Wheat (*Triticum aestivum* L.) has a special place in the country as one of the main food items and the most important crop. In Iran, like in many countries of the world, bread is the most important daily food of the people, in such a way that the share of bread consumption in providing the total daily calorie intake of each Iranian person is about 40% [19]. The population of Iran will reach 92.2 million people in 2050 according to the forecasts of the Food & Agriculture Organization of the United Nations. Also, according to the World Food Organization, providing enough food for the growing world population by 2050 requires a 70% increase in the production of agricultural products [7] The yield gap was first introduced by De Datta in 1981 and defined as the gap between field performance and yield potential. This definition has recently been referred to as the absolute or relative difference between each level of performance [4]. Average yield or average yield (Ya) is defined as the actual yield obtained in a farmer's field. To represent temporal and spatial variability within a defined geographical area, Ya is defined as the average yield achieved by farmers (in space and time) in the area under widely used management practices (planting date, cultivar maturity, planting density). crop plant, nutrient management and crop plant protection) are defined. The number of years used to estimate the average performance should be in agreement between the variability of the performances and the necessity of avoiding the disturbing effects of the time trend of the performance due to climate change and technology [26].

Yield potential (Yp) or yield potential is defined as the yield of a variety of crop plants when growing in conditions with no water and nutrient limitations and effective control of living stresses [11]. The yield potential of a cultivar of a crop is determined by the climate, especially the location, but theoretically, assuming that the required water and nutrients can be added through management, it is not dependent on soil characteristics, which of course, in cases where In that, overcoming the main soil limitations such as salinity, soil acidity, or physical barriers to root expansion would be difficult, practical, or cost-effective. Hence, in areas without major soil constraints, yield potential is the most appropriate measure for irrigated systems and systems in humid climates with sufficient water availability to avoid water stress [27]. (Yield Gap) and (Yield water) are both calculated for cultivar, planting density, and recommended planting dates (which determine the period of growth to maturity). Planting dates and cultivar maturity are determined within dominant cropping systems because the framework of the cropping system determines the length of the growing season possible, especially in tropical and subtropical environments where two or even three crops are grown per year on the same plot of land, is very important [10]. The yield capacity of agricultural products can be evaluated by estimating the yield potential and limited water conditions as an indicator for water and rain conditions [26]. The yield potential for different places and growing seasons of each crop is determined by the three major and important factors of sunlight, temperature and available water [17]. The factors mentioned throughout the year are constantly changing depending on the weather conditions, so the yield potential can be different not only to the place, but also to many major conditions such as: the date of planting, the degree of various treatments and the application of proper farm management. [17]. The evaluations of the yield vacuum are mostly focused on important grain plants from the cereal family, the most important of which are rice (Oryza sativa), wheat and corn (Zea mays). Yield gap analysis for crops such as cotton (Gossypium herbaceum) and wild mustard (Sinapis arvensis L.) by Aggarwal et al. [1] was investigated and it was concluded that the yield vacuum in the respective corn field can be significant. In the researches [5, 6, 8, 9], these researchers reported a performance gap between 45-100% between the studied farms. The researches [17] also confirms the information [8, 9] although some of his samples showed a difference of about 100 to 200 percent and in some cases more than this value.

One of the basic problems of crop production in our country is the big difference between the actual performance of farmers and the achievable performance. Therefore, identifying areas with the greatest potential to increase food supply is important for four reasons. First, performance gap analysis provides a basis for identifying managerial and soil limiting factors of current practices in farms or performance limiting factors related to crop management and soil limiting factors of current practices in fields or performance limiting factors related to crop plants and It also provides improved methods to close this gap. Second, it enables effective prioritization of research, development and government actions. Third, the effect of climate change and other future scenarios affecting the use of land and natural resources will be evaluated. And fourth, the results of such analyzes are key inputs for economic models that assess food security and land use at various spatial scales [26]. The reduction of yield in farmers' fields compared to the potential yield per unit area and the identification of the factors causing this yield gap necessitated the implementation of such research in the Shushtar region, so the present research is aimed at determining the yield gap of wheat and determining the limiting factors of yield and the contribution of each. Among them, it was done in the creation of yield vacuum using the CPA method in the wheat fields of the Shushtar region.

2. Materials and Methods

This research was conducted in the agricultural year of 2016-2017 in Shushtar city (between 48 degrees 35 minutes to 49 degrees 12 minutes east longitude and 31 degrees 36 minutes to 32 degrees 26 minutes north) with an area of 2436 square kilometers in the north of Khuzestan province. became. This survey research was conducted in 55 plots of land cultivated with water wheat (Chamran 2) in Shushtran City. Farms were randomly selected to cover the entire city. In this research, the management and soil factors investigated include: age of the farmer, history of crop production, fallow and crop rotation, drainage and preparation of fields, date of plowing, number of plows, number of discs, leveling operations of fields, plowing operations, amount of seed consumed (kg per hectare), the cultivated area of the fields, the cultivated variety, the density of weeds per square meter, the date of planting, the number of irrigations, the amount of urea fertilizer consumption (kg per hectare), the amount of triple superphosphate fertilizer consumption (kg per hectare), the frequency of urea fertilization in the fields, Chemical management of pests, poison used to control pests, time of pesticide use against pests, growth stage of crop plants for chemical control against weeds, soil texture, pH, salinity, percentage of soil organic carbon, soil potassium, leaf potassium, soil phosphorus, phosphorus Leaf, leaf nitrogen percentage, soil nitrogen percentage and harvest date were investigated in order to evaluate the productivity of farms. Sampling of the studied fields was done in such a way that the soil was taken randomly from several points of the agricultural land from a depth of 30 cm and all the samples taken were combined and finally a certain amount (one kilogram) of the soil sample was taken for Measurement of chemical and physical properties of soil was transferred to Khuzestan University of Agricultural Sciences and Natural Resources for measurement. A sampling of wheat and weeds in two stages before spike and before processing was done randomly in 8 points of each field using 1 x 1 meter squares. In each stage, the number of wheat plants and weeds was counted by species. To determine the performance model, the relationship between all measured variables and performance was examined by the stepwise regression method [22]. It was obtained by placing the average observation of variables (x) in 55 farms of the city in the average farm performance model. Then by placing the optimal limits of the variables in the performance model, the potential performance of the area was calculated. The difference between the average field yield and the vacuum potential yield indicated the field yield. The difference between the product of the average observed for the variable in its coefficient and the product of the optimal amount for the same variable indicates the amount of performance gap created for that variable. The ratio of the performance gap for each variable to the total performance gap shows the contribution of that variable in the performance gap of farms and is shown as a percentage. SAS 9.3 software was used for data analysis and graphing [24].

3. Results and Discussion

Among the studied variables, the following regression relationship with six independent variables was selected: relationship (1).

Grain yield (kg. ha-1)=14758-7.85X1 +1.68 X2 + 0.24 X3 - 7.5 X4-25.96 X5 +2.98 X6

Grain yield (kg. ha-1), performance (kg/ha), X1 soil pH; X2 percent of soil nitrogen; X3 drainage and flooding; X4 soil salinity (de siemens /cm); X5 is weed density (plants per square meter) and X6 is leaf nitrogen percentage.

The relationship between the predicted and observed performances of farms was significant. The correlation coefficient of the relationship was 0.72, the root mean square (RMSE) was 674.6, and the coefficient of variation of the model (the ratio of the root mean square error to the mean) was 17.34% (Figure 1). These statistics show that the accuracy of the model is acceptable and can be used to determine the performance gap and the contribution of each of the influencing factors in the performance gap. The performance gap caused by each factor and the contribution of each limiting factor to the performance gap is presented in Table 1. The results of the yield model predicted about 9092.78 kg of seeds per hectare, and the observed average yield of the fields was about 3880.35 kg/hectare, which showed the difference between the two 43.5212 kg/hectare of yield gap in the studied fields.

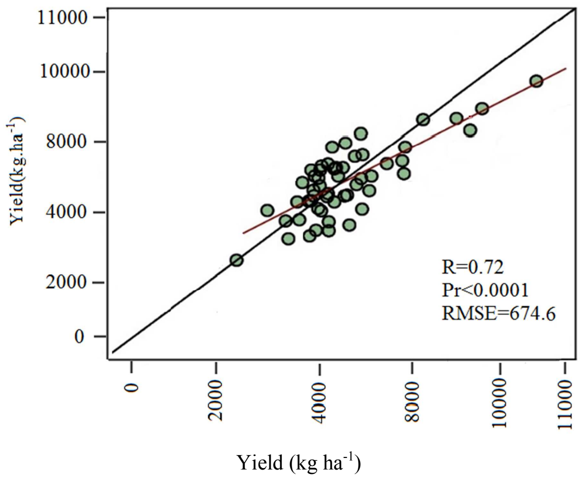

Figure 1. *Scatter plot of observed and predicted grain yield of wheat.*

Table 1. *Quantifying of irrigated wheat yield gap in Shushtar area, Iran.*

Variable	Coefficient	Variable rate				Yield calculated with mode		Yield gap	
		Mean	Min.	Max.	Opt.	Mean	Opt.	Yield (kg. ha^{-1})	Yield gap (%)
Intercept	14758	1	-	-	1	14758	14758	0	-
Soil nitrogen	1261.1	1.68	1.2	2.73	2.8	2118.648	3531.08	1412.43	27.09
Soil pH	1801.2-	7.85	7.24	7.5	7.11	14139.42-	12806.53 -	1332.89	25.57
Drainage	1229.86	0.24	0	1	1	295.16	1229.86	934.7	17.93
Soil salinity	100.25-	7.5	1.2	23.4	1.4	751.87-	140.35-	611.52	11.73
Weed density	-18.75	25.96	0	76	0	486.75-	0	486.75	9.38
Nitrogen content before flowering	700.20	2.98	2.1	4.15	3.6	2086.59	2520.72	434.13	8.30
Granyield	-	3880.35	1850	11250	-	3880.35	9092.78	5212.43	100

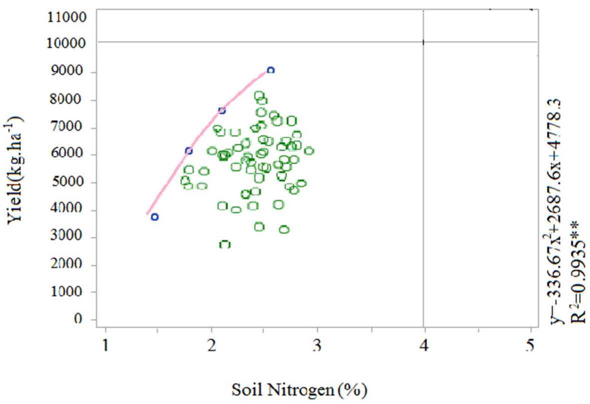

Figure 2. *Linear factor analysis of soil nitrogen.*

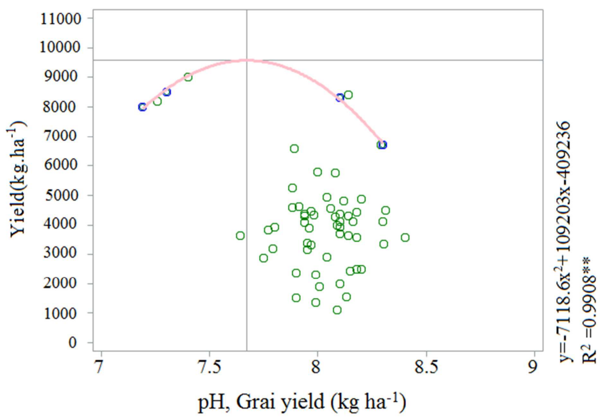

Figure 3. *Linear factor analysis of soil ph.*

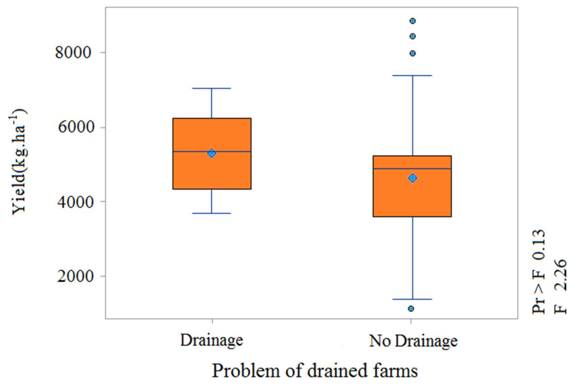

Figure 4. *Linear factor analysis of problem of drained farms.*

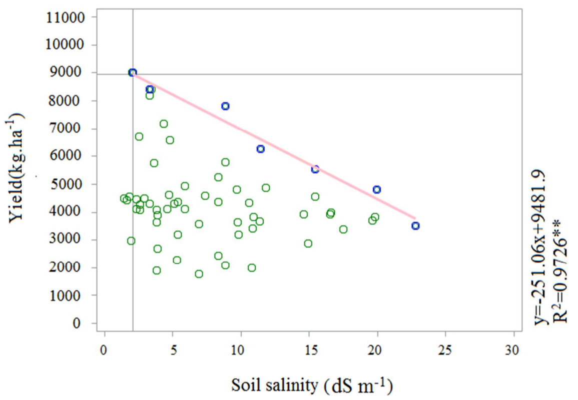

Figure 5. *Linear factor analysis of soil salinity.*

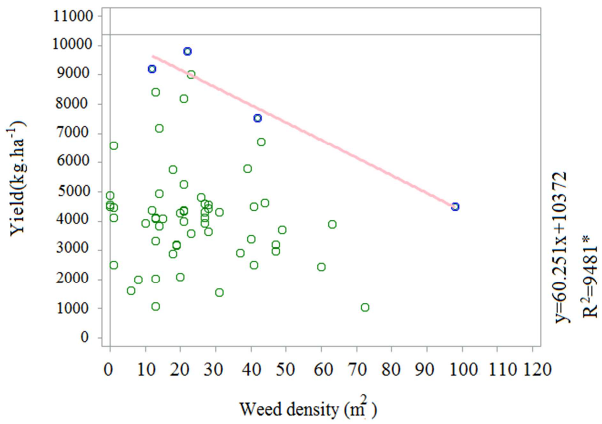

Figure 6. *Linear factor analysis of Weed density.*

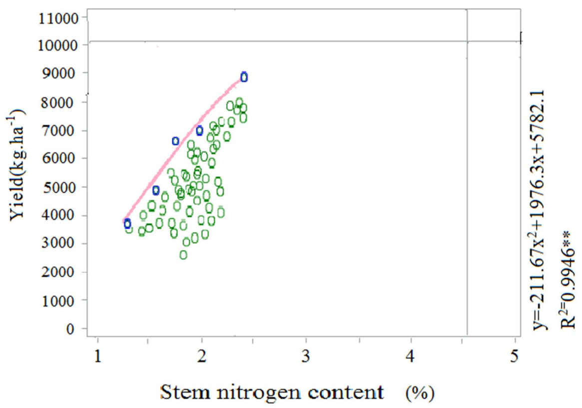

Figure 7. *Linear factor analtsis of Stem nitrogen content.*

The border line analysis of wheat grain yield by the percentage of nitrogen in the soil of the fields followed a quadratic relationship (Figure 2). In terms of the highest yields obtained in the fields, a significant level was shown with an explanation coefficient of about 99.35%, and also the value of 3.99% of soil nitrogen predicted a yield of about 10142 kg of seeds in wheat fields. In an experiment, various factors such as biophysics, soil characteristics, climate, water availability, pests and diseases, technical, managerial, social and economic issues were investigated in a project of performance gap analysis in rice production in Ghana. The reported yield is equal to 3.87 tons per hectare and the optimum yield is between 4 and 11 tons per hectare with an average of 7.5 tons per hectare and the performance gap is reported to be about 47% [20] It seems that depending on the type of plant, agricultural management, the level of the desired element in the soil and the characteristics of the soil, the response of the plant to the amount of fertilizer used is different [14]. The border line analysis of the performance of 55 farms in the studied Shushtar city according to soil pH is presented in Figure 3. According to the maximum yields obtained from the farms, the boundary line diagram of the farms was fitted, so that in the soil pH of 7.67, a yield of about 9571.60 kg per hectare was predicted, while from the studied farms, the maximum yield was in the acidity of 7.53 and showed a yield of 11250 kg/ha. However, the coefficient of explanation for the maximum points in the borderline analysis showed 99.08% and was statistically significant. An excessive increase in soil pH causes the stabilization of zinc on the surface of soil particles, such as clay minerals and metal oxides. Surface stabilization of zinc reduces the solubility and usability of zinc for plants [2, 4] investigated various factors such as rice cultivars, cropping pattern, soil characteristics (pH and soil texture), land preparation, planting, weeds and diseases on rice yield in northern Thailand, and the yield gap was equal to 6.2 tons in hectare (90% difference in yield) between the average rice yield and optimal yield. Farmers reported that the contribution of soil texture and pH (36.5% of the studied lands with pH equal to 6.5 to 6.5) in the vacuum reported was about 8%. The wheat yield of the farms according to the drainage operation of the fields is presented in the form of average comparison (box Weibull diagram) in Figure 4. Accordingly, there was no significant difference between non-drained and drained fields. In Shushtar city, the fields that had applied drainage showed an average yield of 5280 kg/ha and the non-drained fields showed an average yield of 4569 kg/ha of wheat grains. The reason for the meaningless operation of field drainage can be pointed out to the farmers' lack of awareness of the importance of field drainage, as well as the lack of tools needed for field drainage to deal with stagnant conditions in fields. Waterlogged conditions cause the emergence of diseases and pests and saturation of the soil and the root environment, and it causes a decrease in yield in the fields under study. The main stress factor for plants in mandabi soils is lack of oxygen [3] The reduction of available oxygen in stagnant conditions reduces the development of roots and the aerial part of the plant [3]. Trought, M. C. T., & Drew, M. C. [25] stated that waterlogging conditions directly through stopping root growth and respiration as a result of reducing the absorption and movement of nutrients and also indirectly through creating toxicity in the root zone and limiting nutrients, plant growth and development limits The intensity of Mandabi effects on the growth and production of photosynthetic products depends on the plant species, and even the cultivars in the same species, the stage of plant development, soil characteristics (such as pH and amount of organic matter) and especially soil temperature [13].

Salinity is also one of the influential factors in the performance of farms, which causes salinity stress and then water stress in farms. The boundary line analysis of grain yield (kg/hectare) of wheat in the fields was obtained by the maximum yield points in different salinities of the fields in the form of a simple linear relationship (Figure 5). This relationship was able to predict the soil salinity point of 1.2 (millisiemens/cm) to achieve a yield of about 8954.67 kg/ha of wheat grains. Also, the above relationship showed the decrease in farm yield due to the increase in soil salinity in the fields. The increase in salinity and the accumulation of salts in the root area of the plant causes a decrease in yield. The results of most studies show that salinity increases the concentration of zinc in various plants [15] The effects of salinity stress on wheat yield and yield components have been studied by many researchers. Most of the results obtained from these studies indicate a decrease in grain yield due to salinity [14] It has been reported that with increasing soil salinity, grain and straw yields decrease linearly [21] This reduction in yield is applied by shortening the growth period and reducing the leaf area necessary for photosynthesis (reduction in the number of leaves due to premature fall caused by ion toxicity and reduction in leaf area index) [18].

As can be seen in figure 6, the relationship between the boundary line of the field wheat yield and the density of weeds per square meter is presented in a simple linear form. The presence of weeds in the fields reduces the yield of wheat in the field due to the competition for water resources and nutrients. Based on this, the fitting of the borderline of the maximum points showed a downward trend with the increase of weeds per square meter, and also in fields that were free of weeds, a yield equal to 10372 kg/ha was predicted, which showed a lower yield in field conditions. Reger's relationship.

4. Conclusion

The increase in wheat production due to the decrease in resources and the increase in population should be to the extent that it solves the challenges in food security. Examining the amount of yield vacuum as a solution for sustainable product production has been the focus of agricultural researchers in recent years. Based on sampling from 55 farms in the 2016-2017crop year, the average yield of wheat in Shushtar region was 3880.35 kg per hectare; The yield of the region was also predicted to be around 9092.78 kg/ha, which indicated a performance gap of around 5212.43 kg/ha. Using the boundary line analysis of the optimal limit, the influencing factors to achieve the yield were identified, and among these traits such as: soil nitrogen, soil acidity, drainage and waterlogging, soil salinity, weed density, and the percentage of nitrogen in the stem before flowering, respectively. 27, 25.57, 17.93, 11.73, 9.38, and 8.30 percent were effective on the yield vacuum created in the fields.

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