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RELATIONSHIP BETWEEN WHEAT CROP PRODUCTIVITY AND MACRO SOIL NUTRIENT LEVELS: A CROSS-SECTIONAL STUDY OF PUNJAB

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Abstract

In the present study, single factor analysis of variance **(**one-way ANOVA) was employed to study the relationship between wheat crop productivity and soil macro nutrient levels across areas with varying levels of wheat crop productivity in Punjab. The overall average values of both nitrogen (47.11 kg/ha) and potassium (64.62 kg/ha) were observed to be much below the critical limit of 280 kg/ha and 108kg/ha, respectively prescribed by the Indian Ministry of Agriculture. This is reflective of the existence of deficiency of these two macro soil nutrients in the state of Punjab. Further, as per the results of Scheffe post hoc multiple comparison test, the mean values of two macro soil nutrients (nitrogen and potassium) in the low wheat productivity area was observed to be significantly less than that of the high wheat yield area, which reflected that as we move from low to high wheat yield areas, the average values of these soil nutrients display an increasing trend. Thus, there appeared to be a negative relation between levels of macro soil nutrients and wheat productivity levels across selected areas of Punjab.

Subject under which the research article should be included : **Economics**

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1. Introduction

Agriculture productivity is dependent on the availability of several essential nutrients present in the soil in adequate quantities. The role of essential soil nutrients in determining crop productivity has been recognized by the researchers from diverse fields of study. The Ministry of Agriculture, Government India (2011) has identified sixteen soil nutrients which are regarded essential for crop growth and productivity and depending upon the quantity required by the plants, these soil nutrients can be classified into macronutrients and micronutrients (FAO and IFA, 2000). While macro soil nutrients are required in large quantities, micro soil nutrients are so named because they are needed in relatively small (micro) quantities for crop growth and productivity. It is the lower levels of the essential soil nutrients which limits the productivity of the crop; therefore identification of the limiting soil nutrient, removing its deficiency by appropriate fertilization is the key to achieve higher food production and larger crop yields (Krebs, 2008).

Wheat crop, an important component of human diet, is a rich source of protein and it contains vital nutrients required to perform day to day body functions, thus making it a fundamental food crop imperative for human sustenance. Owing to its abundant nutritional benefits, wheat crop in much demand over other cereals and therefore, is believed to be the most widely cultivated cereal throughout the world (Wheat Initiative, 2013). Wheat crop has remained the mainstay of the green revolution since 1970-71, and has become the leading food crop of India in terms of its productivity. Wheat happens to be the staple food crop of people of north-west India. This is why the north-west states of the country have been dominating the cultivation of wheat. As per the 'Handbook of Statistics on the Indian Economy' released by RBI in 2013, the state of Punjab has emerged as the second highest producer of wheat after Uttar Pradesh, and recorded the highest rank in terms of wheat productivity. However, the results of various empirical studies have corroborated that the levels of macro soil nutrients such as Nitrogen, Potassium, Organic Carbon have been declining in the soils of Punjab (Verma, Patel, Toor & Sharma, 2005; Benbi, Nayyar & Brar, 2006). The low levels of soil nutrients are somewhat linked with lower crop productivity levels as pointed by the research evidence. Thus, on account of Punjab being a dominant wheat producing state in India and the importance of macro soil nutrients in influencing crop productivity in general, an attempt has been made in the present study; firstly, to assess the levels of three important macro soil nutrients, namely; Nitrogen (N), Phosporus (P) and Potassium (K) across areas with varying levels of wheat crop productivity in Punjab and secondly, to study the relationship between macro soil nutrient levels and wheat crop productivity in the state of Punjab. The districts of Punjab have been grouped into three distinct wheat crop productivity groups (wheat growing areas) and subsequently the distribution of the three macro soil nutrients (N,P,K) have been studied across these selected wheat growing areas. The procedure of selecting the districts and categorizing them into three distinct wheat productivity areas has been described in detail in the methodology section.

2. The Main Objectives of the Study

1. To assess the levels of macro soil nutrients across selected wheat crop productivity areas of the state of Punjab.
2. To study the relationship between macro soil nutrient levels and wheat crop productivity by comparing the mean values of the macro nutrients across selected wheat productivity areas of Punjab.

3. The Main Hypotheses

The present study is based on the following hypotheses:

Null Hypothesis (H_0): There exists no significant difference in the mean values of a macro soil nutrient across the three wheat productivity areas of Punjab.

Alternate Hypothesis (H_1): There exists a significant difference in the mean values of a macro soil nutrient across the three wheat productivity areas of Punjab.

As a general rule, when the ANOVA (F-test) comes out be significant either at 1% ($p<0.01$) or at 5% ($p<0.05$) levels of significance, we reject the null hypothesis and accept the alternate hypothesis that there exists a significant difference in the mean values of a particular macro soil nutrient across different wheat productivity groups (wheat growing areas).

4. Data Source and Methodology

The present study falls in the domain of multi-stage sampling design in which the population is divided into a series of stages of sampling units (cross-sectional units). Following the multi-stage sampling design, the first stage consisted of dividing the state of Punjab into selected high, medium and low wheat yield districts. The criterion behind the identification of districts was based on data on yield of wheat per hectare of land. On the basis of the information obtained from Statistical Abstract of Punjab and Department of Agriculture, Government of Punjab for the year 2010-11, two highest, two medium (closest to Punjab state level wheat yield figures) and two lowest wheat productivity districts were identified. Accordingly, districts identified were Sangrur and Moga as the high wheat productivity districts; Nawanshahr and Jalandhar as medium wheat productivity districts; Gurdaspur and Rupnagar as low wheat productivity districts. The second stage of sampling consisted of selecting two blocks from each chosen districts on the basis of wheat crop productivity data. Therefore, two highest wheat productivity blocks from each high wheat yield district, two medium wheat productivity blocks from each medium yield district and two lowest wheat productivity blocks from each low wheat yield district were selected. In the third and the final stage of sampling, a total of 120 soil samples were randomly collected from these blocks located across six districts of Punjab, during September, 2012 to November, 2012. These soil samples were then sent to Panjab University research laboratory for the purpose of assessment and estimation of levels of the macro soil nutrients (N,P,K), which has already been discussed in the introductory section of the present study. The identified blocks and their respective districts were then clubbed together as low, medium and high wheat crop productivity areas so as to compare the average values of macro soil nutrient levels across these three distinct groups (areas) in order to assess whether or not there exists any relationship between macro soil nutrient levels and wheat crop productivity in the state of Punjab using a specific statistical technique known as ANOVA.

Analysis of Variance (ANOVA) is a statistical technique to compare the mean values of dependent variable across several independent groups (Field, 2005). It helps to test whether the mean values of several groups are equal or not and therefore, in the present study the ANOVA F-test was used to assess whether or not there exists a significant difference in the mean values of each of the macro soil nutrients across the three groups, i.e., high, medium and the low wheat productivity areas. The dependent and independent variables used in the present study has been described below:

Dependent variable - The dependent variable is the mean value of each of macro soil nutrients that was compared across three groups through the ANOVA F-test.

Independent variable - The independent variable is the wheat crop productivity, which being categorical in nature was categorized into three wheat productivity groups (areas).

Since, the present study deals with only one independent variable or factor (wheat crop productivity), therefore single factor (one-way) ANOVA was used to compare the mean values of each of the macro soil nutrients across wheat productivity areas of Punjab. Although, the ANOVA procedure is quite robust to the violation of normality assumption (Morgan, Leech, Gloeckner & Barrett, 2004), nevertheless the normality assumption in the present research work was tested through the application of Shapiro -Wilk test, the results of which have been discussed in the analysis section.

5. Results and Analysis

5.1. Test of Normal Distribution of Macro Soil Nutrient Levels across Selected Wheat Growing Areas of Punjab

Using the statistical software SPSS, the Shapiro-Wilk test was performed to assess the normal distribution of the dependent variable across each category (group) of the independent variable. As a thumb rule, when the p-value of Shapiro-Wilk test comes out to be statistically significant either at 1% ($p<0.01$) or 5% ($p<0.05$) levels of significance, null hypothesis of the test is rejected and the alternate hypothesis is accepted that the dependent variable is not normally distributed. The results of the Shapiro-Wilk test across the three wheat productivity areas are presented in table 1.

Table 1: Shapiro-Wilk test of normality across selected wheat growing areas of Punjab

Macro Soil Nutrients	Low Wheat Productivity Area		Medium Wheat Productivity Area		High Wheat Productivity Area	
	Shapiro-Wilk test statistic	p-value	Shapiro-Wilk test statistic	p-value	Shapiro-Wilk test statistic	p-value
Nitrogen (N)	0.970	0.361	0.968	0.301	0.981	0.718
Phosphorus (P)	0.970	0.355	0.972	0.419	0.947	0.061
Potassium (K)	0.949	0.068	0.958	0.142	0.974	0.462

Source: Authors' calculations based on soil test data.

Table 1 displays the Shapiro-Wilk test statistic for each of the macro soil nutrients across the three wheat yield areas. The p-value of Shapiro-Wilk test statistic was not found to be significant ($p>0.05$), for each of the nutrients, thereby indicating that each soil nutrient is normally distributed for each of the three wheat productivity groups (areas).

5.2. Distribution of Macro Soil Nutrients Levels across Selected Wheat Growing Areas of Punjab

Table 2 shows the distribution of available macro nutrients in the soils of different wheat productivity areas of Punjab. The available nitrogen content in the soils of all the three wheat yield groups was found to be low and it ranged from the minimum value of 15.25 kg/ha in the low wheat productivity area to the maximum value of 89.22 kg/ha in the high wheat yield area, with an overall mean value of 52.95 kg/ha, which was much below the critical limit of 280 kg/ha for nitrogen prescribed by the Indian Ministry of Agriculture. On the contrary, the soils of all the three wheat yield areas showed high levels of the phosphorus content and it ranged from 16.83 to 41.31 kg/ha with an overall mean value of 28.68 kg/ha, which was found to be much above the prescribed high fertility rating level (> 24.6 kg/ha) for phosphorus.

Table 2: Distribution of Macro soil nutrients levels across selected wheat growing areas of Punjab

Wheat Productivity Areas	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
	Range	Range	Range
Low Wheat Productivity Area	15.25–77.39 (47.11 ± 16.06)	16.83–37.89 (27.53 ± 5.54)	23.52–124.41 (64.62 ± 28.03)
Medium Wheat Productivity Area	26.28–76.12 (50.27 ± 12.79)	17.49–38.36 (28.61 ± 4.96)	21.50–172.40 (94.35 ± 39.88)
High Wheat Productivity Area	37.68 -89.22 (61.47 ± 12.17)	21.05–41.31 (29.91 ± 4.99)	32.25–204.28 (111.60 ± 40.77)
Total	15.25–89.22 (52.95 ± 15.00)	16.83–41.31 (28.68 ± 5.22)	21.50–204.28 (90.19 ± 41.27)

Note: i) Figures in the parentheses indicate mean value ± standard deviation.
ii) kg/ha indicate kilograms per hectare.
Source: Authors' calculations based on soil test data.

The overall available potassium content varied from 21.5 to 204.28 kg/ha with a mean value of 90.19 kg/ha, which was observed to be lower than the prescribed critical limit of 108 kg/ha, thereby indicating that overall low potassium content was observed across the selected wheat growing areas of Punjab. Interestingly, the mean values of all the macro soil nutrients in the low wheat productivity areas were observed to be comparatively less than that of high wheat productivity areas. Thus, one- way ANOVA F- tests were then conducted to validate whether or not there exist a significant difference in the mean values of each of macro soil nutrients across the three wheat productivity areas of Punjab state.

5.3. Results of the Single Factor Analysis of Variance (One Way-ANOVA) with respect to the Selected Wheat Growing Areas of Punjab

The comparison of the mean values of each of the macro soil nutrients across the wheat yield areas was undertaken by using the ANOVA F-test**.** Table 3 shows the results of one-way ANOVA tests (F-tests) for each of the macronutrients.

Table 3: Results of ANOVA F-test

Macro Soil Nutrients	One Way-ANOVA Results	
	F statistic	p-value
Nitrogen	11.987	0.000**
Phosphorus	2.121	0.124
Potassium	16.778	0.000**

Note: **denotes that ANOVA F-test is significant at 1% level.
Source: Authors' calculations based on soil test data.

It is clearly evident from table 3 that statistically significant F-test values ($p<0.01$) were observed in case of nitrogen and potassium which indicated that there is a significant difference in the mean values of these nutrients across the three wheat productivity areas. Since, ANOVA F-test was not found to be statistically significant with regard to phosphorus, therefore the null hypothesis was accepted that there exists no significant difference in the mean values of phosphorus content across the three wheat productivity areas of Punjab.

Once, the F-test comes out to be significant, the next step was to conduct follow up or post hoc multiple comparison tests. Generally, the post hoc tests are conducted only if the ANOVA F-test comes out to be significant and since the ANOVA F- test was not found to be significant with regard to phosphorus, therefore the post hoc test was not conducted with respect to the said macro soil nutrient. The decision regarding which type of post hoc test is to be used depends on the outcome of the test of homogeneity of variances. Thus, before conducting the post hoc tests, the assumption of homogeneity of variances was tested using the Levene's test of homogeneity of variances.

5.4. Results of Levene's Test of Homogeneity of Variances

The assumption of equal variances was tested through Levene's test of homogeneity of variances using the statistical software SPSS. When the value of Levene's test comes out to be statistically significant, the null hypothesis of the test is rejected in favour of alternate hypothesis, thereby indicating that the assumption of homogeneity of variance is not fulfilled.

Table 4: Results of the Levene's test of homogeneity of variances

Macro Soil Nutrients	Test of homogeneity of variances	
	Levene Statistic	p-value
Nitrogen	1.465	0.235
Potassium	2.688	0.072

Source: Authors' calculations based on soil test data.

As depicted in the table 4, Levene's test of homogeneity of variances was not found to be significant in case of nitrogen and potassium, thereby indicating that the assumption of equal variance was fulfilled with regard to these nutrients, thus as a general practice Scheffe post hoc test was used for multiple comparisons with respect to these soil nutrients.

5.5. Post Hoc Analysis of Macro Soil Nutrient Levels across Selected Wheat Growing Areas of Punjab

Once the ANOVA F-test comes out be significant, post hoc multiple comparison test was then conducted to identify those pair of wheat productivity groups (areas) which are significantly different from each other with regard to the mean value of the particular macro soil nutrient. As presented earlier in table 3, the ANOVA F-test was found to be significant with regard to nitrogen, and potassium. Hence, the post hoc tests were conducted only with regard to these two macro soil nutrients.

Table 5: Post Hoc Analysis of Nitrogen across selected wheat growing areas of Punjab

Dependent variable = Nitrogen (kg/ha) Scheffe post hoc test

(I) Yield Category	(J) Yield Category	Mean Difference [I-J (kg/ha)]	Std. Error	p-value
Low Wheat Productivity Area	Medium Wheat Productivity Area	-3.16	3.08	0.593
	High Wheat Productivity Area	-14.36	3.08	0.000**
Medium Wheat Productivity Area	Low Wheat Productivity Area	3.16	3.08	0.593
	High Wheat Productivity Area	-11.20	3.08	0.002**
High Wheat Productivity Area	Low Wheat Productivity Area	14.36	3.08	0.000**
	Medium Wheat Productivity Area	11.20	3.08	0.002**

Note: i) ** denotes that the mean difference is statistically significant at 1% level.
ii) The mean difference (Mean Diff.) is expressed in terms of kg/ha.
Source: Authors' calculations based on soil test data.

Table 5 depicts the difference in the mean values of nitrogen levels across different wheat yield categories. Post hoc Scheffe test revealed that statistically significant difference in the mean values of nitrogen exists between the low and high wheat productivity areas of Punjab, with mean values of nitrogen in the low wheat yield area being significantly lower than that of the high wheat yield area by 14.36 kg/ha. Further, a significant difference in the nitrogen values exist between medium and high wheat productivity areas (-11.20 kg/ha). However, no statistical significant difference in the mean values of nitrogen was found between low and medium wheat yield areas of Punjab.

Table 6: Post Hoc Analysis of Potassium across selected wheat growing areas of Punjab

Dependent variable = Potassium (kg/ha) Scheffe post hoc test

(I) Yield Category	(J) Yield Category	Mean Difference [I-J (kg/ha)]	Std. Error	p-value
Low Wheat Productivity Area	Medium Wheat Productivity Area	-29.73	8.20	0.002**
	High Wheat Productivity Area	-46.98	8.20	0.000**
Medium Wheat Productivity Area	Low Wheat Productivity Area	29.73	8.20	0.002**
	High Wheat Productivity Area	-17.24	8.20	0.114
High Wheat Productivity Area	Low Wheat Productivity Area	46.98	8.20	0.000**
	Medium Wheat Productivity Area	17.24	8.20	0.114

Note: i) ** denotes that the mean difference is statistically significant at 1% level.
ii) The mean difference (Mean Diff.) is expressed in terms of kg/ha.
Source: Authors' calculations based on soil test data.

As presented in table 6, the mean value of potassium in the low wheat productivity area was found to be significantly lower than both the medium and high wheat yield categories by 29.73 kg/ha and 46.98 kg/ha, respectively at 1% level of significance. The mean difference of potassium content between high and medium yield areas came out to be 17.24 kg/ha, however it was not found to be statistically significant.

6. Conclusion

In the present study, the assessment and comparison of the mean values of macro soil nutrients across the selected wheat growing areas of Punjab was undertaken by using the statistical technique of one-way ANOVA so as to study the relationship between wheat crop productivity and soil macro nutrient levels across areas with varying levels of wheat crop productivity. Since the ANOVA F- test was not found to be significant with regard to phosphorus content, therefore the post hoc analysis was not carried out with respect to this macro soil nutrient. Two important findings emerged from the present study; firstly, the overall distribution of macro soil nutrients clearly pointed out that the mean values of both nitrogen (47.11 kg/ha) and potassium (64.62 kg/ha) in the low wheat productivity areas were found to be much below their prescribed critical limits of 280 kg/ha and 108 kg/ha, thereby pointing out towards the existence of deficiency of these two macro soil nutrients in the state of Punjab. The presence of lower levels of macro soil nutrients (below the critical limits prescribed by Indian ministry of Agriculture) in the low wheat yield area, reflected that macro nutrient soil deficiency was more prevalent in the low wheat productivity area as compared to the high productivity one. This observation pointed out that the deficiency of macro soil nutrients is apparently linked with lower levels of wheat crop productivity in the state of Punjab. The second observation that emanated from the results was that the mean values of two macro soil nutrients (nitrogen and potassium) in the low wheat productivity area was observed to be significantly less than that of the high wheat yield area, which reflected that as we move from low to high wheat yield areas, the mean values of these soil nutrients display an increasing trend. Thus, there appears to be a negative relation between levels of macro soil nutrients and wheat productivity levels of selected areas of Punjab. Consequently, targeted soil management techniques aimed at improving the soil nutrient levels are required to be undertaken so as to augment wheat productivity levels in the state.

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