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Statistical Analysis of Determinants of Wheat Crop: A Case Study of Bahawalpur

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Abstract

The primary objective of this article is to examine and evaluate the variables and determinants that influence the yield per acre of the staple wheat crop in the Bahawalpur area. During the years 2011 to 2022, secondary crop data is gathered from the crop reporting service (CRS), the Agriculture Department, and the Government of the Punjab. A descriptive analysis is presented and discussed to show the effect of determinants on the yield of wheat crops. Five main independent variables (regressors) are examined using multiple linear regression models to examine how the determinants affect the output of the yield of the staple wheat crop. The findings revealed that determinants like seed sown time, seed ratio, wheat varieties, irrigations, and the previous crop had a statistically significant impact on the yield of the staple wheat crop in the study area. All the discussed determinants of wheat play less or more significant role in the increase of the wheat production.

Keywords

Wheat crop, Descriptive analysis, Multiple regression model.

1. Introduction

Agriculture is the backbone and most important sector of the economy of Pakistan. For Pakistan's rural prosperity and food supply, the agriculture industry must grow sustainably. It contributes significantly to both employment and profits from foreign exchange. Also, it serves as a source of industrial raw materials; therefore, expansion in the industry is intricately linked to the health of the entire economy. It makes 22.7% of the GDP, employs around 37.4% of the labour force, manages the rural landscape, and acts as an environmental buffer to safeguard and improve the climate and ecological system. Together with creating an exportable surplus, the development of agriculture production systems will boost various food sources, lower consumer costs, and raise farm revenue. The significant increase in commodity prices after COVID-19 has increased the importance of this sector even more, particularly for nations that are reliant on food imports (Pakistan Economic Survey 2021-2022).

In terms of area grown, tradable value, and importance to family diets, wheat is a major worldwide commodity (Enghiad *et al*., 2017). The Pakistani nation's food security is guaranteed by the fundamental crop of wheat. Over 22 million acres are used for the

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cultivation of wheat, which contributes 1.8% of GDP and 7.8% of the value contributed to agriculture (Pakistan economic survey 2021-2022). As wheat is a crucial crop, any output deficit might result in difficult circumstances, political unrest, a major loss of foreign reserves, an increase in the price of wheat flour, and a money shortage in vulnerable areas. The amount of wheat produced decreased from 27.464 million tons to 26.394 million tons (3.9%) in the year 2021-2022. Wheat output decreased as a result of a decrease in the amount of land planted a lack of irrigation water during the sowing process, and the climate temperature. Besides these factors, there are several other factors that have a significant impact on wheat crop production.

Shah (2020) investigated the factors affecting the production of agricultural crops in Bahawalpur district. The primary goal of this study was to examine and evaluate the variables and factors that influenced the yield per acre of the staple crops in the Bahawalpur area. The results showed that a greater yield of all crops was caused by elements like the number of ploughs and rotavators, planking, irrigation, seed type, seed treatment, DAP and urea fertilizer, farmyard manure, the newest varieties, certified seed, weed spray, diseases, and pests' spray, among others.

Zhang *et al*. (2018) claimed that even though human population is increasing, the amount of land and fresh water available for cultivation is not one of our biggest problems. Climate change-related increases in drought and other abiotic pressures are aggravating this issue. To assure yield stability under stress and to reduce the environmental effects of agricultural production, stress-resistant crops are required. Enghiad *et al*. (2017) presented a detailed review of the fundamentals of the wheat market as well as trend analysis utilizing a specially created data set relevant to key wheat-producing regions to find out how these elements differently affect wheat markets. Wheat prices are influenced by a variety of variables, such as the environment, yields, oil prices, lagging prices, and imports. These market factors are hypothesized to affect world pricing and, eventually, food security, in addition to gradually and steadily rising worldwide wheat demand.

Safa *et al*. (2015) presented a case study in the Canterbury province of New Zealand to predict the wheat production using artificial neural networks (ANN) and investigate indirect factors affecting it. The final ANN model created was able to forecast wheat production utilizing both direct and indirect technical elements under various circumstances and farming techniques. Six variables were chosen as relevant inputs into the model after more than 140 distinct variables were examined.

Iqbal *et al*. (2014) investigated the elements influencing wheat production in the research region of Peshawar, Pakistan. The goal of this research was to assess the cost and return of producing wheat and to contrast wheat output in relation to certified seed, flood-affected areas, and educational attainments. The findings indicate that output price, cost, and total wheat production all play a significant role in determining a farmer's net return.

Cofas *et al*. (2014) investigated how climate variables affected agricultural crops. They discovered a strong link between crop productivity and all climate conditions. They also deduced from their statistical research that the output of crops is strongly influenced by fertilizers, irrigation, high-quality seed, and pesticides, among other factors. Smith (2013) claimed in his book that the best agricultural plants for erosion and steep locations are trees. He realized that one major drawback of annuals as agricultural plants is that they leave the soil vulnerable to erosion for a significant portion of the year. The annual crops perform worse on higher terrain. Trees, on the other hand, are everlasting intuitions. According to him, crop-yielding trees provide the finest means of bringing agriculture to the hills, steep slopes, rocky terrain, and areas with insufficient rainfall.

Dangwal *et al*. (2010) investigated the impact of weeds on wheat productivity in Tehsil Nowshehra, district Rajouri. He discovered that weeds are a big competitor of wheat crops and significantly contribute to the study area's reduced wheat crop output of up to 25%. Hassan *et al*. (2010) conducted a study on the factors influencing wheat crop production in the Punjab province's mixed cropping zone. The study's main goal was to determine the impact of several parameters, including seed rate, sowing period, fertilizers, irrigation, and education, on the production of wheat in Punjab's mixed cropping zone. Education, seed rate, usage of rotavators, price of weedicides, and use of nitrogenous fertilizer all had a highly significant impact.

Qayyum et al. (2010) investigated the effect of weighted rainfalls on wheat yield in Pakistan's Punjab province. By using a statistical model to estimate crop production, weighted rainfall was successful. Ashfaq et al. (2009) examined the effect of ground water on the yield of wheat crops. It was clear from the data that using subpar groundwater without taking the necessary measures might lower wheat output.In order to determine the impact of various irrigation schedules on the development and output of wheat, Jamal et al. (2007) conducted research in the NWFP agriculture university field during the Rabi season, 1997-1998. For statistical analysis, a randomized full block design was employed. Wheat should be irrigated after a five-week gap for maximum yield, according to the findings.

The elements that impact the production of agricultural products in Punjab, Pakistan, were found by Badar et al. (2007) in their study. The findings indicated that cropped area, agricultural labour, seed distribution, expenditure on research, and support for wheat prices all contributed to higher agricultural production.

2. Study area and important crops of the study area

The 12th-largest city, Bahawalpur, is situated in the Punjab province of Pakistan. It is located between 27 and 29-50 North latitude and 70 and 72-50 East longitude. On the north, this district is bordered by the Lodhran district; on the east, the Bahawalnagar district; on the south, India; and on the west, the Rahim yar khan and MuzafarGarh districts. The Bahawalpur district has a total land area of 24830 km^2 and an agricultural area of 920000 acres. Wheat, cotton, rice, and sugarcane are the primary agricultural crops of this district. In 2021-2022, a cotton crop was grown on 538000 acres, rice on 58000 acres, sugarcane 60000 acres, and wheat on 731000 acres (Revenue Department, Bahawalpur 2021-2022, CRS.BWP 2021-2022). The district experiences harsh summer and winter weather, with average temperatures of 40^{o}C and 22^{o}C, respectively.

3. Collection of data

The secondary statistics for the wheat crop were obtained from the Bahawalpur crop reporting service between 2011 and 2022. The data on cultivation and the determinants that influence wheat crop cultivation are collected from 39 villages spread across 5 tehsils in the district of Bahawalpur. Three fields of each crop from each sample village were chosen at random from the corresponding crop frame. Two plots, each measuring 15 x 20 square feet, were gathered from each field. The yield of each plot as well as data on all the determinants and factors influencing the yield of all crops have been recorded.

4. Analysis of determinants of wheat yield

The statistical package for social sciences (SPSS) 28 program is used to examine the data. The determinants affecting the cultivation per acre of the wheat crop were identified using descriptive analysis, multiple regression analysis, f-tests, and t-tests.

4.1 Descriptive analysis

In order to examine wheat crop production, a descriptive analysis of the determinants of wheat crop such as sowing time, seed ratio, wheat varieties, irrigation, and the last crop using tabulation, mean yield, standard deviation (S.D), coefficient of variation (C.V), and farmer percentage share is presented.

4.1.1 Influence of sowing time on wheat yield

In various growing regions, wheat is sown at distinct intervals. Diversity, climate, ambient temperature, drainage capabilities, and land reclamation all have a role. In the research region (Agriculture Extension BWP), wheat seeds are sown from November 10 to November 25 in order to maximize the productive potential of prospective wheat variants under irrigation.

Table1: Sowing time and wheat yield.

Sowing time	Sample points	% Farmers	Average yield/acre (mds)	S.D.	C.V%
Nov 1-15	262	25.61	41.64	9.47	22.74
Nov 16-30	493	48.19	38.78	8.88	22.90
Dec 1-15	206	20.14	34.29	9.65	28.14
Dec 16 & later	62	6.06	33.67	9.68	28.75

According to Table 1, 25.61% of farmers plant wheat in the first fortnight of November, 48.19% in the second fortnight of November, 20.14% in the first fortnight of December, and 6.06% in the sixteenth and subsequent fortnights of December. In comparison to farmers who sow wheat in December or later, those who sow wheat in the month of November receive at least 13% to 15% greater output. Also, the November planting crop produces wheat with greater consistency. The month of November is the ideal time to seed wheat in the research region for a healthy crop, indicating that sowing time is a significant element that impacts wheat output.

4.1.2 Influence of seed ratio on wheat yield

The number of seed required to plant an acre varies depending on the variety. Also, it depends on the degree of germination, seed size, degree of tillering, timing, and technique of sowing. It is claimed that 50-60 kg of seed per acre should be sown using the broadcast sowing technique (Agriculture Extension BWP, Agriculture Research BWP).

Table 2: Seed ratio and wheat yield.

Seed quantity (kg/acre)	Sample points	% Farmers	Average yield/acre (mds)	S.D.	C.V%
50	272	26.59	37.76	11.07	29.32
60	560	54.74	38.69	9.44	24.39
70-80	191	18.67	37.91	7.72	20.36

According to Table 2, 26.59% of farmers use 50 kg of seed per acre, 54.74% use 60 kg, and 18.67% use 70-80 kg. In the research region, farmers who utilize 60 kg of seed per acre produce a maximum of 38.69mds/acre. Due to an overabundance of plants, farmers who use more than 60 kg per acre produce less than those who utilize 60 kg per acre. The findings show that seed rate has an impact on wheat yield as well.

4.1.3 Influence of wheat varieties on wheat yield

In the research region, various wheat types are being sown. Over time, new types with strong production potential are eliminating outdated ones. The three most recent varieties, Arooj (2022), Galaxy (2013), and Akbar (2019) are producing the most in the study area.

Table 3: Wheat varieties and wheat yield.

Varieties of wheat	Sample points	% Farmers	Average yield/acre (mds)	S.D.	C.V%
Aari-2011	57	5.57	34.74	11.23	32.33
Galaxy-2013	170	16.62	35.37	5.52	12.56
Ujala-2016	13	1.27	38.19	7.15	18.72
Anaj-2017	67	6.55	37.36	6.06	14.52
Akbar-2019	312	30.50	38.08	5.99	13.92
Dilkash-2020	57	5.57	38.17	7.93	20.24
Mh-2021	56	5.47	39.51	8.73	22.09
Subhani-2021	69	6.74	38.44	9.46	24.60
Arooj-2022	161	15.74	42.97	5.98	13.91
Others	61	5.96	38.48	11.41	29.56

The Arooj-2022, Galaxy-2013, and, above all, Akbar-2019 were cultivated by the most farmers in the research region due to their newness and high production potential. According to Table 3, farmers who plant the Arooj-2022 variety have the maximum yield, 42.91 mds/acre. Moreover, the Galaxy-2013 variety's output is more constant than that of any other kind, as seen by the coefficient of variation value 13.91%. As a result, the variety of the wheat crop is a significant component that significantly affects yield.

4.1.4 Influence of previous crop on wheat yield

The previous crop is the crop that was sown immediately before the standing crop. Cotton is the primary crop of the Kharif season. Hence, in the study region, wheat is often sown in place of cotton. The production of the following crop is also influenced by the previous crop.

Table 4: Previous crop and wheat yield.

Previous crop	Sample points	% Farmers	Average yield/acre (mds)	S.D.	C.V%
Cotton	802	78.40	38.54	9.30	24.14
Rice	67	6.55	38.91	10.68	27.46
Sugarcane	14	1.36	31.78	8.73	27.48
Fodder	42	4.11	40.71	8.49	20.86
Fallow land	81	7.92	36.31	12.02	33.13
Other	17	1.66	33.70	6.43	19.44

Table 4 demonstrates that 78.40% of the farmers' plant wheat instead of cotton and achieve an average yield of 38.54 mds/acre, 6.55% of farmers' plant rice instead of sugarcane and achieve an average yield of 38.91 mds/acre, 1.36% of farmers plant instead of fodder and achieve an average yield of 40.71% mds/acre, 7.92% of farmers plant instead of fallow land and achieve an average yield of 36.31 mds/acre, and 1.66% of farmers' plant wheat in place of other crops. In comparison to other crops, the output of the wheat crop sown in place of fodder is more reliable. Evidently, the wheat crop that is sown in place of fodder produces the highest yield. It may be inferred that the previous crop affects the one that is sown just after it.

Table 5: Irrigations and wheat yield.

Irrigations	Sample points	% Farmers	Average yield/acre (mds)	S.D.	C.V%
2	24	2.35	27.67	13.96	50.45
3	126	12.32	32.73	9.59	29.30
4	456	44.57	38.37	9.34	24.34
5	376	36.75	41.00	8.54	20.82
6	41	4.01	36.04	6.94	19.26

4.1.5 Influence of irrigation on wheat yield

The number of watering (irrigations) varies depending on the type of soil, rainfall, and volume of water used during each irrigation. For the wheat crop to develop normally at all phases, soil moisture is necessary.

In order to guarantee healthy sprouting, normal tops, and a robust plant root system, the first watering should be applied 20-25 days after sowing. For healthy tillering growth, a second watering should be applied 40-45 days following seeding. At the late jointing stage, a third irrigation should be applied within 70-75 days. For higher grain quality and quantity, the fourth irrigation is crucial and should be applied between 90 and 95 days. At 110-115 days after seeding, the last irrigation should be provided at the dough stage (Agriculture Research BWP 2015). Wheat yield can be poor because of an abundance of water (Khan et al. 2007).

According to Table 5, the research area's wheat crops are irrigated by 2.35% of farmers using two irrigations, 12.32% of farmers using three irrigations, 44.57% of farmers using four irrigations, 36.75% of farmers using five irrigations, and 4.01% of farmers using six irrigations. According to the findings, farmers who use five irrigations are able to produce a maximum of 41.00 mds/acre of wheat, but those who use six irrigations produce less wheat in the research region. As a result, the quantity of water is a crucial component in determining the wheat yield, and the production of wheat can be increased by making the appropriate number of irrigations at the appropriate time.

4.2 Regression analysis

Multiple linear regressions are the most appropriate modelling strategy since the response variables, or the amount of wheat yield, are continuous. For the analysis of wheat yield, the subsequent multiple regression model is given as:

$$Z_i = \beta_o + \beta_1 ST + \beta_2 SR + \beta_3 WV + \beta_4 PC + \beta_5 I + u_i.$$

where,
Z_i = wheat yield in Mds/acre.
β_o= intercept of the regression line.
$\beta_1, \beta_{2, \ldots,} \beta_5$= coefficients of the explanatory variables.
ST= sowing time.
SR= seed ratio.
WV= wheat varieties.
PC = previous crop.
I = irrigations.

Numerous statistical testing approaches are employed to examine the overall significance of the models, the significance of the regression coefficients, and the validity of the inferences drawn (Dobson, A. J., and Barnett, A. G. 2018). For this purpose, we use and calculate the mean square error (MSE), F-test (to evaluate the overall significance of the model), coefficient of determination (R^2) (to check the amount of variation explained by the model), adjusted R^2 (to evaluate the unexplained variations by the model), Durbin-Watson (to evaluate the autocorrelation), standard error (S.E), T-test (to evaluate the individual parameters), and the variance of the inflation factor (VIF) (to check the Multicollinearity). Figure 1 is furnished to check the assumptions of the regression line. The regression normalized residual histogram and normal P-P plot from the Figure 1 demonstrated that the connection between the response and the explanatory factors is substantially linear and the error term is nearly normally distributed with a mean of zero and constant variance.

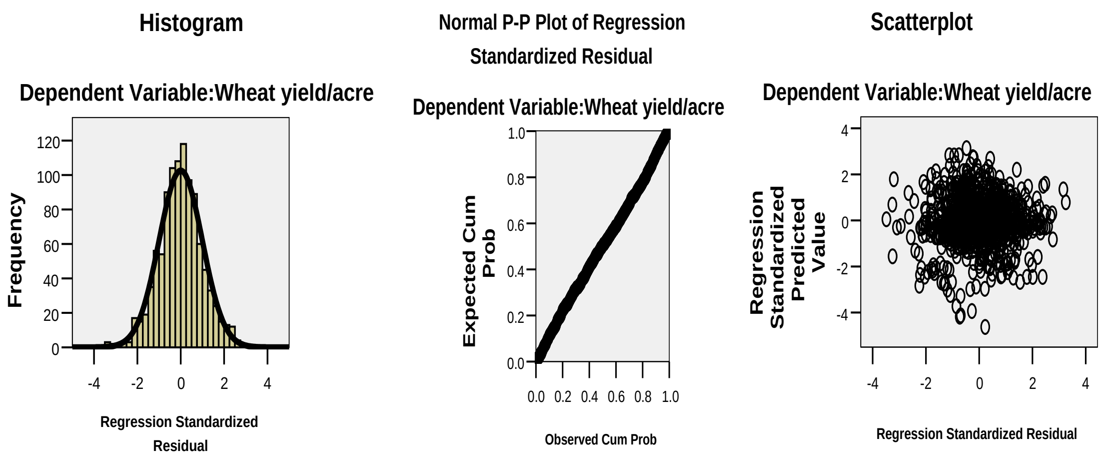

Figure 1: Plots of histogram, normal P-P plot of regression standardized residual and scatter plot.

Table 6: Model summary of the wheat crop.

Model	Sum of squares	d.f.	MSE	F	Sig.	R	R^2	Adj R^2	Durbin-Watson
Regression	31233.6	12	2912.3	48.3	.000	.588	.354	.443	1.890
Residual	65216.2	1012	62.9	____	____	____	____	____	____
Total	96539.8	1024	____	____	____	____	____	____	____

According to Table 6, the fitted model for wheat crop, the explanatory factors account for 35.4% of the variance in the wheat output, with an R^2 value of 0.354 indicating that there is a better link between the independent variable and the explanatory variables. The model has statistical significance with a MSE of 62.9. There is no autocorrelation in the model, according to Table 6, where the Durbin-Watson test result is 1.890. This is because a value of about 2 implies a lack of autocorrelation in the data.

Table 7: Results of regression model of the wheat crop.

Model	Coefficient (β)	S.E.	t-value	Sig.	Tolerance	VIF
Constant	12.91	2.76	3.989	.000	----	----
Sowing time	1.842	.308	5.143	.000	.989	1.212
Seed ratio	0.088	0.041	1.799	.051	.991	1.111
Wheat varieties	3.368	0.895	4.189	.000	.923	1.095
Previous crop	.127	.015	8.123	.000	.924	1.182
Irrigations	0.021	.009	2.481	.005	.984	1.113

Table 7 shows that the regressors (sowing time, seed ratio, wheat varieties, previous crop, and irrigations) have a significant effect and that the results are statistically significant based on their, S.E, t-value, significant, and VIF values. It is evident from Table 7 that the increase in one unit of each regressor significantly results in an increase of 1.842, 0.088, 3.368, 0.127 and 0.021 in the production of wheat for sowing time, seed ratio, wheat varieties, previous crop and irrigations, respectively.

5. Conclusion

The current study employed both descriptive and multiple regression analysis to assess the impact of various determinants on major crop wheat yield per acre. The study discovered that seed sowing time, seed ratio, wheat varieties, irrigations, and previous crop had a significant impact on wheat crop yield in the study area. For the wheat crop, it was determined that every determinant was statistically significant in both the descriptive and multiple regression analysis. All the discussed determinants of wheat play less or more significant role in the increase of the wheat production.

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