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Research Article

Wheat Yield Gap Analysis: Productivity Enhancement Practices and Factor Level Categorizations

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Abstract: The demand for wheat is rising rapidly to sustain the growing population. In Pakistan, many farmers lack awareness of the optimal utilization of input factors. This study aims to determine the optimal use of these factors to enhance wheat productivity, address food security challenges and support effective policy decisions. The new concept for categorizations of agronomic factors is identified in current study as a high, medium and low loss factors to make accurate policy decisions for food sustainability. Statistical analysis is applied to 26430 crop cut experiments. The absolute and relative yield gap analysis is applied. Category-1 (major loss factors) refer to those factors, whose probability share (%) at optimum level lies in (1-25%) and these are urea (125-175) kg, DAP (100-125) kg, other fertilizers (25) kg and spray (2-3) for pest attack. The rest of the farmers are experiencing a decline in productivity. Category-II (Medium loss factors) refers those with a probability share of (26-50%) at optimum levels and these are 4 irrigations, harvesting between April 1st and 20th and certified seed (26.06%). Category-III (Minor loss factors) includes factors with a probability share of 51% or above at optimum levels such as November planting and soil type. A rise in the probability ratio of area share for categories I to III at their optimum levels results in enhancement in wheat productivity in diminishing order.

Keywords: Food Concerns, Wheat Yield Optimization, Yield Gap, Factors, Levels, Interactions.

1. INTRODUCTION

Agriculture is the biggest sector assuring food availability and straggling against food insecurity [1, 2]. It is projected that by 2050, the world's population will likely reach 9.1 billion and the main contributor to this increase will arise from developing countries. To feed the world, the production must be enhanced by about 70-100% [1, 3]. It is a human tragedy for us that each day our world witnesses 800 million individuals to go in hunger [4]. Despite the increase in world population, the growth rates of the yield for major cereals crops such as wheat, rice and maize are globally reduced [3, 5]. Wheat is the primary staple food crop in the world [6]. Pakistan is the 5th most populous country in the world with the highest population growth rate among South Asian countries. However, its wheat production is relatively low compared to other competing countries in the world [5, 7]. The agriculture sector of Pakistan is contributing about 18.9% share in the gross domestic product (GDP) and providing about 42.3% share of employment [8]. Wheat is the main food crop of Pakistan and is ranked first in acreage and production among all other food crops [9]. Pakistan stands 7th largest producer of wheat in the world [10]. Due to Pakistan's high population growth rate, it is emphasized that Pakistan will stand 4th populous state in the world instead of 5th by 2050 [1, 11]. In Pakistan, the population is growing rapidly, while the wheat crop yield is increasing at a slower pace and this is potentially creating a gap in meeting food requirements and raising the risk of food insecurity. Bajkani *et al.* [12] reported that applying traditional practices caused the Pakistan wheat crop's low productivity. Hussain [13] predicted that better inputs for food grain crop categories increasing return to scale for output. Tariq *et al.* [14] reported in Pakistan, the availability of wheat per capita will decrease from 198/kg in 2014 to 84/kg by 2050 due to the rising trend of population and adverse climatic variations. Abbas *et al.* [15] presented the factors liable for low wheat production and reported that

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poor management practices, weedicides, lodging, hailstorm etc., caused the low productivity of the wheat crop. Ali *et al.* [16] studied wheat production against different sowing times and concluded that the delay in sowing resulting a loss in productivity. Van-Ittersum and Cassman [17] presented the yield gap analysis to predict the need for food for the growing population and emphasized the yield gap analysis is one of the powerful measures to estimate production. Hatfield and Beres [18] depict that yield gap analysis is provide a framework and assessed the trend and yield difference of the wheat crop precisely. Van-Dijk *et al*. [19] presented the study on disentangling agronomic and economical yield gap and reported that the frame work of yield gap analysis is practically operational.

In Pakistan, wheat productivity is low compared to competitive countries, while the population growth rate is high, which may lead us to a food-insecure region. It is necessary to elaborate on the factors levels and their interactions that may statistically optimize the wheat productivity. Several studies were carried out in Pakistan on the individual contribution of inputs. At the same time, it is important to know that factors like fertilizers, pesticides, sowing period, harvesting periods, seed quantity, seed source, irrigations etc., applied at their various levels and have their individual and interaction effects on wheat productivity. The current study focuses on the individual and interaction study of these inputs at different levels responsible for enhancing wheat productivity. Moreover, in south Asian countries like Pakistan, maximum farmers are low educated or illiterate and they are applying different agronomical constrains in field experiments. They are not aware about the optimum level of factors which can maximize the productivity. This research gives the direction to those low or illiterate formers for using the optimum level of factors. At the same time this study introduces the new concept for categorizing agronomic constraints into high, medium and low-risk (loss) factors, which leads to the layout of the true policy's decision to attain food sustainability. It is based on statistical analysis to elaborate on the optimum level of wheat productivity with the application of various inputs and their interaction levels. The absolute and relative yield gap analysis is also emphasized to elaborate on the yield loss for different input levels. The significance of the results is assessed through statistical analysis.

2. MATERIALS AND METHODS

2.1. Data Source, Validity and Sampling Techniques

According to the area, Punjab is 2nd largest province of Pakistan. Punjab is responsible for 76% share of the total wheat area [20]. For the present study, secondary data of 26430 crop cut experiments (CCE) is collected from the Crop Reporting Service (CRS), Agriculture Department Punjab from 2017 to 2020. The CRS is the only statistical organization working independently since 1978 and is responsible for forecasting the area, yield, and production of all major and minor crops [20, 21]. The estimates of CRS are further published by the Bureau of Statistics (BOS), Punjab, Pakistan Bureau of Statistics (PBS) and many other government agencies for the researchers and policymakers. Table 1 shows the sampling design for area frame sampling. In stage-I, probability proportional to size (PPS) is used to select the sample village and in stage-II, Simple Random Sampling (SRS) is used to select the village (segments) [20-22].

2.2. Factors Levels and Statistical Analysis

The average yield mound (mds)/acre of crop cut experiments in Punjab is taken as a dependent factor

Table 1. The 2nd stage area frame sampling design.

Area Frame Sampling Design		
Stage-I	Sampling Technique	(Probability Proportional to Size sampling (PPS)
	Union Council (UC)	Population
	Villages	Sampling Unit
Stage-II	Sampling Technique	(Simple Random Sampling (SRS)
	Village	Population
	Land Segment	Sampling Unit

and the effects of following variables and their levels are studies as agronomic constrains (Table 2). Descriptive statistical analysis is presented with tabulation and graphical presentation of individual factors with their levels and interaction effect of factors with their levels. The significance of the groups (levels) means differences is testing using analysis of variance (ANOVA). Normality of the data is a fundamental assumption in applied data analysis. For the current large dataset, the most effective approach to evaluate and interpret normality is through graphical methods using histograms with a normal curve and Q-Q plots [23, 24]. Statistical tools are used as mean yield, relative frequency (R.F), absolute yield gap (loss) and relative yield gap (loss) etc. The following yield gap analysis is applied.

I. The absolute yield gap analysis is applied to check the yield loss in absolute term.

$$Abs\bar{Y}_{igap} = \bar{Y}_{i(op)} - \bar{Y}_{i(ay)} \quad (1)$$

II. The relative yield gap analysis is employed to determine the percentage loss in productivity.

$$Rel\bar{Y}_{igap} = [\frac{\bar{Y}_{i(op)} - \bar{Y}_{i(ay)}}{\bar{Y}_{i(op)}}] * 100 \quad (2)$$

Where "i" = individual levels of "ith" factor, "op" = optimum (maximum) average yield of "ith" factor at a specific level, "ay" = average yield of "ith" factors levels.

2.3. Concept of Categorization of Agronomical Constrains

Wheat yield varies by changing the level of inputs factor. At some level of inputs factors, the wheat yield found optimum, while on the rest of inputs levels, the yield reduced on some or more extends. However, the probability share (%) of the farmers using different level of inputs also various from one level to another level. Categorization of variable is applied in term of probability share (%), yield gap analysis and productivity.

I. Major loss factors mean factors, whose probability share (%) at optimum level of inputs lies in 1-25%, while the rest of the farmers are applying non-optimum level and getting loss in productivity.
II. The medium loss factors mean factors, whose probability share (%) at optimum level of inputs lies in 25.1-50%, while the rest of the farmers are applying the non-optimum level and getting loss in the productivity.
III. Minor loss factors mean factors, whose probability share (%) at optimum level of inputs lies in 50.1% and above, while the rest of the farmers are applying the non-optimum level and getting loss in the productivity.

2.4. Analysis of Variance (ANOVA) for the Significance of Mean Difference

ANOVA is applied to compare the significance mean differences in the groups of variables. F-Statistic is applied to investigate whether or not the groups are statistically differing or not. The following statistical hypothesis is examined:

H_0: There is no significant difference between the means of factors (variables) groups.
H_1: There is significant difference between the means of factors (variables) groups.

Table 2. Factor levels of agronomic inputs.

Input factors	Factor levels
Planting period	October 15-31, November 1-15, November 16-30, December 1-15, December 16-31, January 1-15
Harvesting period	April 1-10, April 11-20, April 21-30, May 1-15
Fertilizers (DAP, Urea, Other fertilizers	0 kg/acre, 25 kg/acre, 50 kg/acre, 75 kg/acre, 100 kg/acre, 125 kg/acre, 150 kg/acre, 175> kg/acre
Irrigation/ No. of water	(0-9) irrigations
Seed type	Certified or un-certified
Soil type	Chikny soil and other type (sandy etc.)
Pest attack	Pest attack yes or no
Pest spray	Pest spray (0-3)

2.5. Limitations of the Study

The article addresses a critical issue of global significance. The innovative approach of categorizing agronomic factors into high, medium, and low risk groups provides actionable insights for policy formulation. The focus on optimizing input levels and identifying key yield gap contributors is highly relevant, particularly for South Asian countries like Pakistan. However, certain key limitations are associated with this study. This research did not emphasis on the individual yield of the specific farmers located in different region of Punjab. It only focuses on over all Punjab average yields in mds/acre obtained from crop cut experiments and it may not fully capture the dynamic variability of field conditions across different regions in Punjab. The findings may not be directly applicable to farmers with diverse socio-economic backgrounds or varying levels of access to resources. This research focuses on certain levels and categorizations of factors. However, there is a need for more intricate levels and categorizations of agronomic factors in field experiments. The research does not account for potential climate change impacts on wheat productivity and the applicability of the identified optimal levels under changing environmental conditions. The study emphasizes statistical analysis while excluding advanced techniques such as supervised and unsupervised machine learning methods.

3. RESULTS

3.1. Normality Analysis

It is evident from Figures 1 and 2, that the normality through histogram and Q-Q plot of wheat crop productivity exhibits a strong pattern of normality.

3.2. Wheat Productivity in Response of Planting and Harvesting Periods

In Punjab, wheat crop sowing starts in late October and ended up by mid- January. From Table 3, the disparity in average wheat productivity was observed for various levels of planting periods. The maximum average yield in Punjab is 36.76 mds/acre for the best planting period, which is the first fortnight of November, while for the second fortnight, it is 36.46 mds/acre with an absolute yield loss of 0.30 mds/acre and relative loss of 0.82%. The lowest productivity is observed for October sow, with an absolute yield gap loss of 12.31 mds/acre and relative yield loss of 33.48%. Fortnights of December exhibit average yield gains of 34.30 mds/acre and 32.75 mds/acre with an absolute yield gap of 2.46 mds/acre and 4.01 mds/acre having percentages of 6.70% and 10.91%. For January and onward, the absolute yield gap found 10.03 mds/acre. The maximum wheat area is sown in the second fortnight of November at about 53.20%, while the optimum level of output gained for the first fortnight of November, having sown area share of about 33.83%. The wheat gains good productivity for the sow of November.

The wheat harvesting period prevails in Punjab from April to May. Table 3 shows the variation in output in response of harvesting periods. The optimum level of average productivity of 39.94 mds/acre is attained for harvest of April (1-10). The

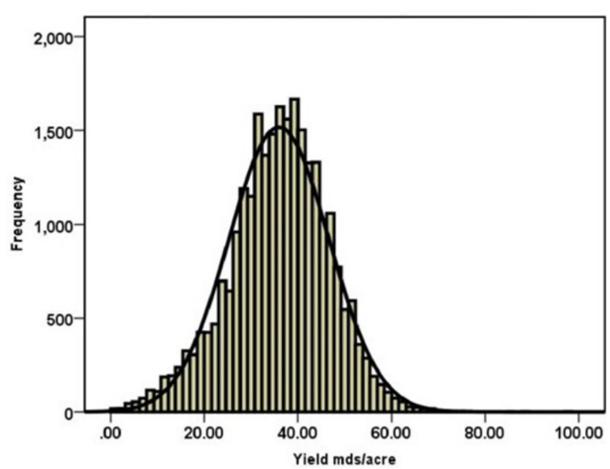

Fig.1. Histogram for the wheat yield.

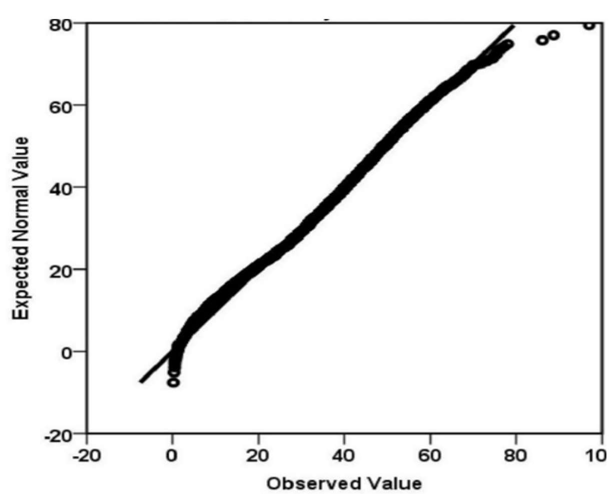

Fig.2. Q-Q plot for the wheat yield.

loss in average yield is noted for April (11-20) is 2.45 mds/acre and 6.13% and for April (21-30) is 5.15 mds/acre and 12.89%. The harvest period of May (1-15) depicts an average yield loss of 10.44 mds/acre and 26.13%, and for the last fortnight of May, it is 18.74 mds/acre and 46.92%. Delay in harvesting resulting higher the yield loss while planting other than in November, resulting in a loss in productivity.

3.3. Interactions Study for the Planting and Harvesting Periods

From Table 3, it is clear that the wheat crop was planted from the end of October and ended up to start January, and its harvesting started from the start of April and ended in May. The optimum wheat output must depend upon the period required to mature the crop from sown to harvest. The interaction effects of planting and harvesting periods are proposed and need to be elaborated statistically to determine the optimum output level. Table 4 shows the disparities in wheat productivity in response to the interaction effect of different sowing and harvesting periods. It is predicted that the optimum productivity gained for harvest periods of April and planting periods of November. It indicates that the wheat crop should be sown at the beginning of November and harvested between April 1st and 20th. Sowing the wheat crop in October, December and January leads to an average productivity loss.

3.4. Wheat Productivity in Response of Different Fertilizers Levels

Optimum level of different fertilizers is a yielding characteristic for wheat productivity, but excess fertilizer may lose productivity. The most prominent fertilizer in Pakistan is Diammonium phosphate (DAP) consists of nitrogen 18% and phosphate 46%,

Table 3. Wheat average productivity disparity with varies in levels of planting and harvesting period.

Planting period	R.F. (%)	Yield mds/acre	Abs. gap	Rel gap (%)	Harvesting period	R.F. (%)	Yield mds/acre	Abs. gap	Rel gap (%)
Up to Oct 31	3.14	24.45	12.31	33.48	April 1-10	6.67	39.94	0.00	0.00
Nov 1-15	33.83	36.76	0.00	0.00	April 11-20	37.80	37.49	2.45	6.13
Nov 16-30	53.20	36.46	0.30	0.82	April 21-30	51.38	34.79	5.15	12.89
Dec 1-15	7.56	34.30	2.46	6.70	May 1-15	3.96	29.50	10.44	26.13
Dec 16-31	2.06	32.75	4.01	10.91	May 16>	0.17	21.2	18.74	46.92
Jan 1-onward	0.22	26.73	10.03	27.29	--	--	--	--	--

Table 4. Interaction study of planting and harvesting period for wheat crop productivity.

Planting periods	Harvesting period	Yield mds/acre	Abs. gap	Rel gap (%)	R.F. (%)	Planting periods	Harvest period	Yield mds/ acre	Abs gap	Rel gap (%)	R.F. (%)
Up to Oct 31 3.14(%)	April 1-10	37.84	0.00	0.00	0.17	Dec 1-15 7.56 (%)	April 1-10	38.07	0.00	0.00	0.50
	April 11-20	25.91	11.93	31.52	0.75		April 11-20	35.94	2.13	5.59	2.78
	April 21-30	23.52	14.32	37.84	1.86		April 21-30	33.42	4.65	12.22	3.86
	May 1-15	20.78	17.06	45.09	0.34		May 1-15	27.69	10.38	27.26	0.38
	May 16>	9.80	28.04	74.10	0.03		May 16>	10.50	27.57	72.43	0.02
Nov 1-15 33.83 (%)	April 1-10	40.97	0.00	0.00	3.09	Dec 16-31 2.06 (%)	April 1-10	37.12	0.00	0.00	0.12
	April 11-20	37.88	3.09	7.54	13.33		April 11-20	35.88	1.24	3.34	0.64
	April 21-30	35.56	5.41	13.20	16.25		April 21-30	31.83	5.29	14.24	1.12
	May 1-15	30.38	10.59	25.84	1.09		May 1-15	23.78	13.34	35.94	0.17
	May 16>	14.54	26.43	64.51	0.06	Jan 1-onward 0.22 (%)	April 11-20	25.48	4.05	13.72	0.02
Nov 16-30 53.20 (%)	April 1-10	39.39	0.00	0.00	2.78		April 21-30	29.53	0.00	0.00	0.14
	April 11-20	37.93	1.46	3.70	20.28		May 1-15	19.11	10.42	35.30	0.05
	April 21-30	35.45	3.94	10.00	28.14		May 16>	25.68	3.85	13.05	0.00
	May 1-15	31.66	7.73	19.61	1.93		--	--	--	--	--
	May 16-onward	34.51	4.88	12.40	0.07		--	--	--	--	--

and urea contains phosphate 46%. In Punjab, some farmers supplement their use of DAP and urea with other fertilizers such as Ammonium Nitrate, Single Superphosphate (SSP) and Nitrofast. Table 5 depict the different levels of DAP, urea and other fertilizers used to gain optimum output. Fertilizers DAP and urea is available in 50/kg bags. For the urea, the maximum output is gained at between (125-175) kg/acre. In contrast, the farmer's majority uses the 100 kg/acre urea with a probability ratio of about 47.9% and losses the production of about 3.45 mds/acre and 8.29% compared to 175 kg/acre. The no use of urea resulted in 51.58% yield loss, while for half bag of urea it is 38.49%, compared to the optimum output level. The DAP gained maximum output at 100 kg/acre (2 bags), but only 4.40% of farmers use this DAP level. 81.4% of farmers use 50 kg/acre (one bag) and get a loss of productivity of about 6.03 mds/acre. The 41.43% yield losses to those farmers who are not using the DAP. In the case of other fertilizers, 92.3% of farmers did not use other fertilizers and lost the average productivity about 14.86%, while the others applied the other fertilizers with or without DAP and urea. The optimum level of the other fertilizers is 25 kg/acre with DAP and urea application and for upper levels of other fertilizers, the productivity losses are 8.75%, 4.84%, 6.49%, and 11.57%. It is clarified that the optimum level of DAP is up to (100-125) kg/acre, and below that level, the productivity gradually losses, while for urea, the good level is (125-175) kg/acre and below that levels productivity gradually losses.

3.5. Interactions Study for Different Fertilizers Levels

Fertilizers DAP and urea is commonly used in Pakistan. The interaction study for different levels of DAP and urea is critiqued in Table 6. It interacts that for the level at no use of DAP, the urea predicted almost optimum level at 125 kg/acre with 46.41 mds/acre followed by 42.43 mds/acre at 175 kg/acre urea. For 25 kg/acre use of DAP, the wheat crop predicted a maximum output at 125 kg/acre urea of about 40.69 mds/acre. The yield is good for 50 kg/acre DAP at (125-175) kg/acre urea, followed by lower urea levels. At 75 kg/acre application of DAP, the productivity maximized at 46.37 mds/acre for > 175 kg/acre urea, followed by 125 kg/acre at 44.85 mds/acre and 42.63 mds/acre for 150 kg/acre. With the 100 kg/acre used of DAP, the yield is almost attaining maximum at (125-175) kg/acre urea level. The highest optimum yield level is 51.12 mds/acre attained for > 125 kg/acre DAP with 100 kg/acre urea, and at this level of DAP, the yield is followed by a lower level of urea, while decreasing for a higher level of urea.

3.6. Wheat Productivity in Response of Irrigation, Certified Seed and Soil Type

Irrigation is a productive part of wheat productivity. Table 7 indicates four irrigations is optimum level, where the wheat crop yields maximum productivity of 39.17 mds/acre. About 27.82% of farmers are applying the optimum level of irrigation in Punjab, while the rest are not applying the optimum level and get a yield loss of about 52.0% for no irrigation, 22.08% for one irrigation, 8.42% for two irrigations, 3.19% for three irrigations, 3.42% for five irrigations, 13.68% for 6 irrigations and this gap is increasing up to 23.31% for 9> irrigations. The seed is an important part of better productivity. The analysis in Table 7 predicted that only 26.06%

Table 5. Different fertilizers, their levels and wheat productivity.

Fertilizers levels in kg	Urea				DAP				Other fertilizers			
	R.F. (%)	Yield mds/acre	Abs. gap	Rel gap (%)	R.F. (%)	Yield mds/acre	Abs. gap	Rel gap (%)	R.F. (%)	Yield mds/acre	Abs. gap	Rel gap (%)
0	3.29	20.15	21.47	51.58	4.91	24.59	17.43	41.43	92.3	35.69	6.23	14.86
25	1.14	25.60	16.02	38.49	2.12	26.57	15.5	36.84	0.64	41.92	0.00	0.00
50	30.2	32.86	8.76	21.04	81.4	36.04	6.03	14.33	5.62	38.25	3.67	8.75
75	10.1	37.47	4.15	9.97	7.07	41.37	0.70	1.66	0.13	39.89	2.03	4.84
100	47.9	38.17	3.45	8.29	4.40	42.07	0.00	0.00	1.08	39.20	2.72	6.49
125	2.06	41.50	0.12	0.29	0.04	41.83	0.24	0.57	0.20	37.07	4.85	11.57
150	4.87	40.01	1.61	3.87	--	--	--	--	--	--	--	--
>175	0.37	41.62	0.00	0.00	--	--	--	--	--	--	--	--

Table 6. Interaction study for optimum productivity at different levels of DAP and urea.

DAP	Urea	Freq	Yield mds/acre	DAP	Urea	Freq	Yield mds/acre	DAP	Urea	Freq	Yield mds/acre
0	0	396	16.17	25	0	69	16.18	50	0	375	23.72
	25	28	21.36		25	114	24.32		25	147	25.68
	50	542	25.65		50	212	25.67		50	6684	33.14
	75	69	34.20		75	68	33.76		75	2167	37.10
	100	227	32.44		100	84	32.82		100	10797	37.80
	125	7	46.41		125	9	40.69		125	365	40.0
	150	27	33.43		150	4	32.43		150	923	38.88
	>175	1	42.43		>175	--	--		>175	72	40.0
75	0	14	34.30	100	0	14	38.99	>125	0	2	47.07
	25	11	45.55		25	2	43.89		25		--
	50	273	38.54		50	278	40.12		50	1	47.17
	75	304	40.77		75	67	41.55		75		--
	100	985	41.76		100	567	41.93		100	3	51.12
	125	116	44.85		125	44	45.31		125	3	25.78
	150	162	42.63		150	172	44.80		150		--
	>175	5	46.37		>175	19	46.08		>175	1	46.25

Table 7. Irrigations, certified seed, soil type and wheat productivity.

Factors	Levels	R.F. (%)	Yield mds/acre	Abs. gap	Rel gap (%)
Irrigations level	0	5.74	18.80	20.37	52.00
	1	8.15	30.52	8.65	22.08
	2	15.15	35.87	3.30	8.42
	3	26.82	37.92	1.25	3.19
	4	27.82	39.17	0.00	0.00
	5	10.14	37.83	1.34	3.42
	6	4.25	33.81	5.36	13.68
	7	1.30	30.63	8.54	21.80
	8	0.39	29.58	9.59	24.48
	9>	0.23	30.04	9.13	23.31
Certified seed	Yes	26.06	37.27	0	0
	No	73.94	35.45	1.82	4.90
Soil type	Chikny	66.30	36.88	0	0
	Others	33.70	34.05	2.83	7.67

of farmers are using certified seed in Punjab and getting maximum output compared with 73.94% of farmers who are debarred from certified seed and getting yield loss of 1.82 mds/acre. The soil type (chikny) produced productivity of 36.84 mds/acre with a relative share in the area is 66.30%, and other types of soil (sandy etc.) reported yield loss of 7.67%, having a share of 33.70%.

3.7. Interactions Study of Pest Attack and Spray Operations

Pest attack is a common phenomenon for the agriculture sector in Pakistan and the world, which have become the case of losing productivity. The interactions study for the pest attack with its eradication through a spray operation shown in

Table 8. It interacts that 75.2% of farmers are those who lost a loss of 3.82% and reported no attack of pest and did not opt for any spray operation but the optimum productivity is gained for those who opted for one spray for the wheat crop with no pest attack reported. The farmers who did two spray operations for no pest attack also lost about 3.55% in productivity. The attack of pests on wheat crops emphasized that productivity loss is 21.56% (8.35 mds/acre) for no spray, and this gap is reduced to 2.24% and 1.78% for one and two spray operations. The analysis depicts that for the optimum productivity levels, the area share is nominal and needs to be enhanced to get the wheat output maximization.

3.8. Categorization of Factors Levels and Significance of Mean Difference

This study layout the good design for the most optimum plan for categorizing the agronomic constraints in view of wheat yield enhancement practices for true policies decision to attain food sustainability. Table 9 shows the categorization of factors levels and their significance of mean difference. Category-1 (Major loss factors), refer to those factors whose probability share (%) at optimum level of inputs lies in (1-25%) and these are urea for (125-175) kg/acre, DAP for (100-125) kg/acre, other fertilizers for 25 kg/acre, spray (2-3) for pest attack, one spray for no pest attack. The rest of the farmers are losing their productivity. Category-I are responsible for major loss as larger share of the formers are not using the best level and losing the productivity. Category-II (Medium loss factors), refer to those factors whose probability share (%) at optimum level of inputs lies in (26-50%) and these are reported four irrigations, harvesting for April (1-20) and certified seed (26.06%). The rest of the farmers are losing their productivity. Category-II is responsible for medium loss as medium share of the formers are not using the best level

Table 8. Interaction study for pest attack and spray operation.

Factors levels		Pest attack							
		Yes				No			
		R.F. (%)	Yield mds/acre	Abs. gap	Rel gap (%)	R.F. (%)	Yield mds/acre	Abs. gap	Rel gap (%)
No. of pest spray	0	4.32	30.37	8.35	21.56	75.2	35.72	1.42	3.82
	1	16.77	37.85	0.87	2.24	2.42	37.14	0	0
	2	1.16	38.03	0.69	1.78	0.10	35.82	1.32	3.55
	3	0.04	38.72	0.00	0.00				

Table 9. Categorization of factor levels and significance of means differences.

Factors levels	Probability share of farmers using the optimum/best level of inputs	Rest of the farmers who using non-optimum level of inputs	Category	Testing the significance of mean difference using ANOVA (F- Statistic)
Planting period November	83.03%	16.97	III	247.8**
Harvesting period April 1-20	44.47%	55.53	II	281.1**
Urea 125-75 kg	7.3%	92.7	I	634.4**
DAP (100-125) kg	4.44%	95.56	I	606.2**
Other fertilizers 25 kg	(0.64%)	99.36	I	33.5**
Irrigation/ 4 water	27.82%	72.18	II	795.8**
Certified seed	26.06%	73.94	II	149.3**
Soil type Chikny	66.30%	33.7	III	420.1**
Spray 2-3 with pest attack	1.2%	98.8	I	--
Spray 1 with No. pest attack	2.42%	97.58	I	--

** show the results are highly significant.

and losing the productivity. Category-III (Minor loss factors), whose probability share at optimum level of inputs lies in 51% and above is reported as planted in November and soil type. The rest of the farmers are losing their productivity. Category-III is responsible for minor loss as slight share of the formers are not using the best level and losing the productivity. Any rise in the probability ratio of area share for categories I to III at their optimum levels results in enhancement in wheat productivity, but in diminishing order. The value of F-statistic depicts that there is significance difference between the means of the groups for all the factors groups.

4. DISCUSSIONS

Food demand is rising worldwide, while its production is not enough to meet this demand. In Pakistan and neighboring countries, the majority of farmers are illiterate and they are applying different agronomic constrains in field experiments. They are unaware about the best level of factors. This research is supporting by the findings of Van-Ittersum and Cassman [17] that the yield gap analysis is one of the powerful measures to estimate production. Hatfield and Beres [18], Van-Dijk *et al*. [19] and Van-Oort *et al.* [25] also supporting this research methodologies by indicating that the yield gap analysis provides a practical and operational framework to assess the trend and average yield difference of crop. Similar studies were conducted by Islam [5], Islam [20], Qayyum [22] and also by Qayyum and Pervaiz [23], but these studies did not layout the categorization of agronomic constrain in scientific way. However, this research introduces new categorizations of agronomic factors to identify the optimal conditions for enhancing wheat productivity. A similar approach was employed by Hameed *et al*. [26] for the cotton crop, whereas our study focuses on wheat crop. The concept for categorizations of agronomic factors identified in the current study is practically applicable for sustainable precision agriculture and policy decisions.

5. CONCLUSIONS

The demand for wheat as a primary food crop is increasing at an accelerated rate to meet the needs of the expanding population. In south Asian countries like Pakistan, majority of farmers are illiterate and they are applying different non-optimal agronomic constrains in field. The research introduced the new concept of categorizations of agronomic factors into high, medium and low risk (loss) factors, liable to identify the reason of low wheat yield and to make the policies for the enhancement practices of wheat productivity in Pakistan. The 26430 crop cut experiments are statistical analyzed to determine the optimum levels of individual levels and their interactions effects. Category-1 (Major loss factors) refer to those factors, whose share at better level of output falls in (1-25%) and these are urea (7.3%) for (125-175) kg/acre, DAP (4.44%) for (100-125) kg/acre, other fertilizers (0.64%) for 25 kg/acre, Spray (2-3) for pest attack (1.2%), one spray for no pest attack (2.42%). Category-I are major risk factors as larger share of the formers are not using the best level and losing the productivity. Category-II (Medium loss factors) refer to those factors, whose share at a better level of output lies between (25.1-50%) and these are four irrigations (27.82%), harvesting period (44.47%) for April (1-20) and certified seed (26.06%). Category-II is responsible for medium loss. Category-III (Minor loss factors) refer to those factors, whose share at a better output level is above 50.1% and these are planting period November 87.03% and soil type 66.30% for chikny type. Category-III is responsible for minor loss as maximum farmers is already using the best level of inputs. There is a foremost need to enhance the relative share of factors for category-1, which can rapidly enhance the productivity, while the increased relative share of category-II will also enhance the productivity, but it will be below from category-1. A rise in the relative share of factors for category III increases the productivity, but less from categories I and II. There is a foremost need to apply the factors, levels and their interaction at their optimum output level to meet the yield gap and ensure the food security and its availability concerns in the region. This study may layout the design to formulate direction ordinated policies decision in view of wheat productivity enhancement practices to attain food sustainability through precision agriculture.

6. CONFLICT OF INTEREST

The author declares no conflict of interest.

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