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A detailed descriptive study of all the wheat production parameters in Punjab, Pakistan

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In this paper an effort has been made to conduct a detailed descriptive study of all the measurable parameters surveyed by Agriculture Department, each year that influence wheat production in the Punjab, Pakistan. A descriptive study of all individuals as well as interaction of various allied variables has been carried out to assess their influence on the production / variation of wheat. For this purpose a data of 25036 cases comprising almost 1.2 million values have been fed and used. Results have been compiled independently on districts, divisions and then on provincial levels to observe the impact of variables on all the levels. The detailed descriptive study of wheat is helpful in the model development for projection of yield and also for making various recommendations to farmers regarding different inputs / parameters of wheat resulting a conversion of a subjective approach about the variables into objective one and ultimately an enhancement in the crop production. Such detailed descriptive study of wheat is an unprecedented effort in the country.

Key words: Barani area, district, division, Kharif season, Mund, Rabi season.

INTRODUCTION

Area of Pakistan is 796,096 sq.km and the population is almost 170 million. The country has four provinces namely Sindh, Punjab, Khyber Pakhtoonkawa and Balochistan. The Punjab being the second largest (area of Punjab is 205,345 sq.k.m) and the most agricultural province of the country, contributes almost 75% to the wheat production of Pakistan. There are two zones of the Punjab: lower and upper. In Kharif season (May to September), rice crop is sown in the upper and cotton is sown in the lower Punjab. Wheat crop is sown in the Rabi season (October to April) throughout the province. There are two major categories of the area in the Punjab: Irrigated and Un-irrigated (Barani). In irrigated area, there is availability of canal as well as tube-well water, so farmers are comparatively less dependent on the rainfalls. But in case of Barani areas, crops are totally dependent on timely rainfalls as there is no availability of

any other source of water. The most of the upper Punjab area is hilly and Barani.

The Punjab is administratively and geographically divided into 113 tehsils, 35 districts and 8 zones (each zone is called a Division). Each division comprises 3 to 6 districts having meteorologically identical state. The name of District-Headquarter of a division is same as the division. A secondary data of wheat production for the year 2005-2006 to 2008-2009 have been taken from the Crop Reporting Service (CRS), an attached wing of Agriculture Department, Government of the Punjab, solely responsible for handling of all kinds of Agricultural Statistics in the Punjab. The total number of selected sample villages is 1086 and in each sample village, six randomly selected plots of 15 × 20 sq ft in three randomly selected fields of wheat have been harvested. Yield of each plot along with all the 16 variables, having 43

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Table 1. Reliability statistics.

Divisions	Cronbach's alph (stand)	No. of items	No. of sample points
Lahore	0.740	38	2988
Gujranwala	0.515	38	4120
Rawalpindi	0.735	37	2016
Faislabad	0.527	37	2832
Sargodha	0.540	38	3090
Multan	0.546	37	4794
Bahwalpur	0.786	37	2622
D.G.Khan	0.355	38	2574
PUNJAB	0.758	38	25036

categories impacting the yield of the crop, have been recorded. The variables recorded for each field are as follow, Agricultural Statistics of Punjab (2009):

(i) Source of seed: Urea used
(ii) No of Plough: DAP used
(iii) No of Levels: No of waters
(iv) Pesticides used on crop / seed: Total Rainfalls in the season
(v) Spray on crop: Weighted Rainfalls in the season
(vi) Variety of wheat   : Average Humidity of the season
(vii) Quantity of seed: Average Max/Min Temperature
(viii) Sowing time: Irrigated/Un-irrigated area

In Pakistan, yield of a crop is measured in '*maund*' (1 Maund = 37.3242 kg) per *'acre'* (1 Acre = 198x220 sq.ft). A total yield data of 25036 plots all over the Punjab amounting to almost 1.2 million values have been used in the study.

DESCRIPTIVE STUDY OF WHEAT IN THE PUNJAB

Each influencing variable on wheat production has some categorical segregation, which has been discussed in detailed in its relevant section. The different dimensions of descriptive study are as follows.

Reliability analysis

The reliability shows degree of relevance and consistency of measuring instruments (explanatory variables) across time and various items in the instruments with reference to the measure of response variable (Uma, 2009). It is measured in percentage. Table 1 shows reliability statistics of the data on Punjab as well as on all the divisional levels of the province. On Punjab level, the overall reliability of 25036 cases is 75.8% on account of 38 number of items, which is very good degree of reliability. The degree of reliability varies from division to division, which is the highest in case of Bahawalpur division that is, 78.6% and minimum against

D.G.Khan division that is, 35.5%, which is due to degree of variation in the regressor variables. Reliability decreases as variation decreases and vice versa. In D.G.Khan division, Rabi season temperature, humidity and rainfalls remain almost consistent in all the concerned districts, that is why it has minimum degree of reliability contrary to the Bahawalpur division having high variation in the regressor variables. The variables having less variation can be removed to increase the degree of reliability.

Normality analysis

For the most of statistical applications, normality in the data, is pre-requisite (Gujarati, 2003). As the size of the data is sufficiently large that is, it contains 25036 sample points; so graphical checking of normality has been done. Figures 1 and 2 show histograms and P-P plots of wheat production in Punjab and in each division of the province, respectively. All the histograms and P-P plots show that yield of wheat in Punjab, as well as, in each divisional level is almost normally distributed as depicted in the Figures 1 and 2, that is, there is no issue of abnormality of response variable in the data.

Histogram and P-P plot of Rawalpindi division show a little bit deviation from normality, as compared to the other divisions because the division comprises four districts, Rawalpindi, Attock, Jhelum and Chakwal, of which only one district Chakwal is irrigated and others three are totally un-irrigated. There is a massive difference between the production of irrigated and un-irrigated areas, that is why the yield of the division is not normal. But on the whole Punjab level both histogram and P-P plot show normality in the data, which accommodates the minor abnormality of Rawalpindi division.

Basic statistics of wheat in the Punjab

The Punjab as well as eight divisional basic statistics of wheat is given in Table 2. Multan division is on the top
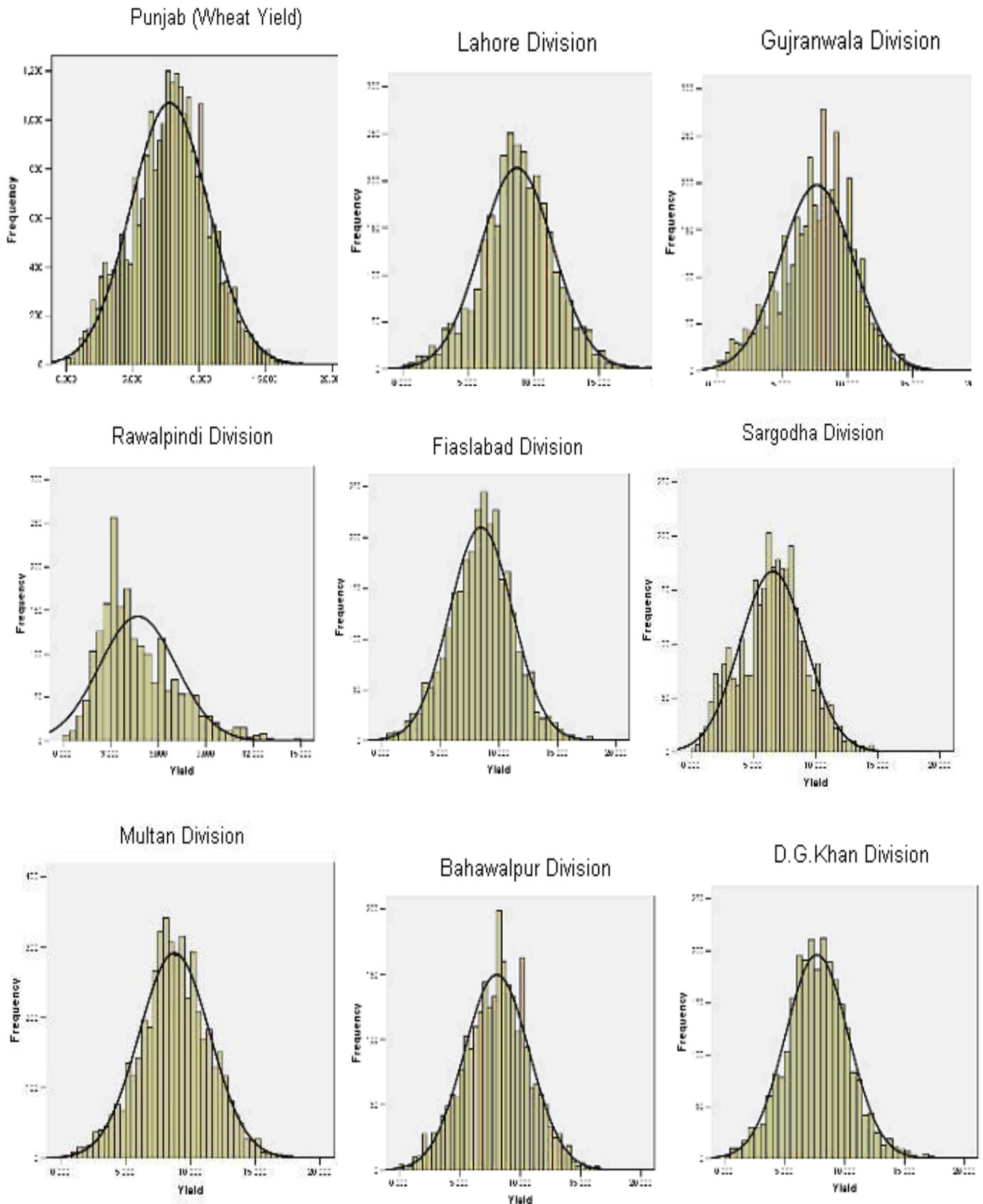
Figure 1. Histograms of wheat production.
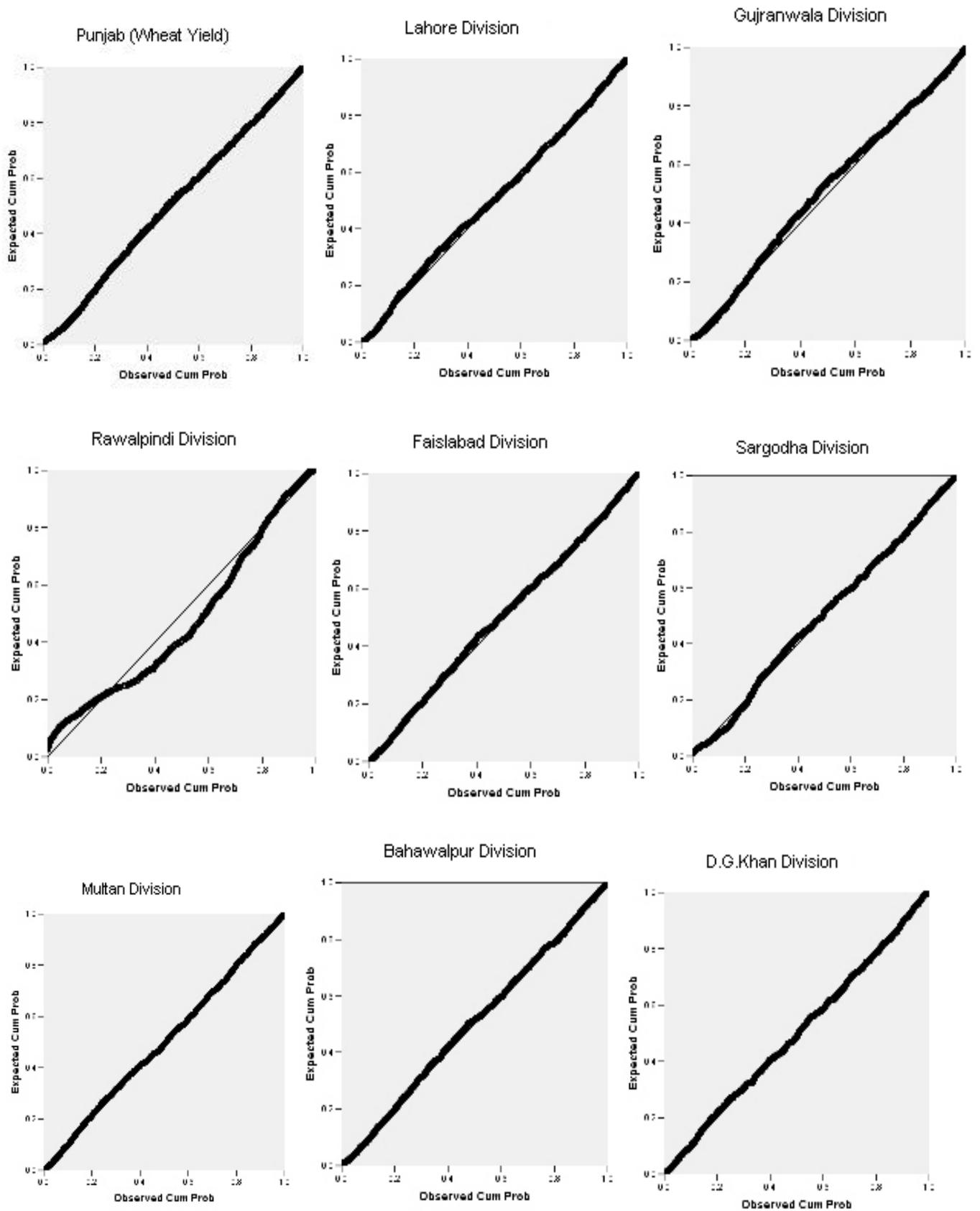
Figure 2. P-P plots of wheat production.

Table 2. Yield of wheat in Punjab.

Divisions	No. of sample points	Average yield (m/ac)	S.D (m)	C.V (%)	Min. yield (m)	Max. yield (m)	Skew
Lahore	2988	33.99	10.84	32	0.78	76.32	-0.092
Gujranwala	4120	29.86	10.78	36	0.08	63.60	-0.275
Rawalpindi	2016	18.42	9.36	51	0.18	57.49	0.940
Faislabad	2832	33.08	10.46	32	0.39	70.21	-0.037
Sargodha	3090	25.57	10.23	40	0.53	65.16	0.066
Multan	4794	34.15	10.62	31	0.39	71.58	-0.035
Bahawalpur	2622	31.44	10.43	33	0.68	63.69	-0.070
D.G.Khan	2574	29.98	10.19	34	0.89	75.35	0.163
PUNJAB	25036	30.27	11.35	37	0.08	76.32	-0.029

with 34.15 m/ac yield and Rawalpindi division is at the bottom with 18.42 m/ac as it is an un-irrigated area. Rawalpindi division has shown the most variant production where as Multan division is production wise maximum consistent, as it has minimum 31% variation in yield. Overall variation in wheat production in the Punjab is 37%. The highest production of the province comes from Lahore that is, 76.32 m/ac, where as the least production is from Gujranwala division that is, 3 kg/ac. Overall on the province level, skewness of production is -0.029, which depicts almost a normal trend (Montgomery, 2001). Except one division, Rawalpindi, all the divisions show normality in production of wheat. Values of skewness on provincial and divisional levels also support the normality issues discussed above.

Production of irrigated and un-irrigated areas

As it has been discussed that there are two major classifications of Punjab areas: irrigated and un-irrigated. Because both have significant difference of production of wheat so they have been independently described. Table 3 shows, 90% of the province area is irrigated because of availability of canal water (Pakistan has the largest network of canal system in the world), tube-well, well and other sources of water, where as only 10% of total area, mostly upper Punjab comprising Rawalpindi division and a little part of Gujranwala and Sargodha divisions, is un-irrigated. As it is shown in Table 3, average production of irrigated area is 93% more than the average production of un-irrigated area. Also production of irrigated area is more consistent to un-irrigated area, that is 33% as compared to 53% respectively. On divisional level, irrigated area of Sargodha division has 165% more average yield of wheat as compared to average yield of its un-irrigated area.

Source of seed and wheat production

In the Punjab, there are two types of source of seeds;

one of them is own home seed and second one is the certified seed. Along the private sector, one public sector organization, Punjab Seed Corporation (PSC) is responsible for the provision of certified seed of all the crops to the farmers of the province (Table 4). As shown in Table 4, 83% farmers use own home seed and 17% use certified seed. In most of the agricultural countries, proportion of usage of certified seed is not more than 30%. The average yield of wheat using certified seed is 11% more than the other category and also more consistent as compared to own home seed that is, 35% as compared to 38% variation in the yield, respectively. The maximum usage of certified seed is in Multan that is, 27% and maximum impact on yield is in Rawalpindi division that is, 24% more yield as compared to home seed. It indicates that impact of certified seed on yield in un-irrigated area is more than that of irrigated one.

Wheat variety comparison

Various varieties of wheat are sown in the Punjab like Inqlab-91 (with reference to the year when it was introduced), Pervaaz, Sehair, Miraj-08, Lasani-08, Faislabad-08 and Chakwal-50 etc. But, as shown in Table 5, 52% of farmers use Inqlab-91 and rest of 48% use other varieties. Overall on the Punjab level, average yield of wheat of other varieties is 12% more than Inqlab-91 and also yield wise other varieties are more consistent that is, 36% as compared to 39% variation. On divisional level comparison, in Rawalpindi division, average yield of other varieties is only 4% more than Inqlab-91, which is minimum in the Punjab. Hence it can be concluded that in Barani area Inqlab-91 variety and others have almost same production level of wheat. On upper Punjab level like Lahore and Gujranwala divisions, the average yield of other varieties is 14 and 24% more than Inqlab-91, respectively. But on lower Punjab level like DGKhan division, the impact of other varieties on average yield is merely 5% more than Inqlab-91.

Table 3. Irrigation mode.

Divisions	Irrigated					Unirrigated					Impact on yield (%)
	Sample points	%age share	Avg yield (m/ac)	S.D (m)	C.V (%)	Sample points	%age share	Avg yield (m/ac)	S.D (m)	C.V (%)	
Lahore	2988	100	33.99	10.84	32	-	-	-	-	-	-
Gujranwala	3756	91	31.10	10.02	32	364	9	17.00	9.86	58	+82
Rawalpindi	184	9	30.12	9.55	32	1832	91	17.25	8.50	49	+75
Faislabad	2832	100	33.08	10.46	32	-	-	-	-	-	-
Sargodha	2698	87	27.77	8.89	32	392	13	10.46	4.38	42	+165
Multan	4794	100	34.15	10.62	31	-	-	-	-	-	-
Bahawalpur	2622	100	31.44	10.43	33	-	-	-	-	-	-
D.G.Khan	2562	99	30.04	10.16	34	12	1	16.83	5.13	30	+78
PUNJAB	22436	90	31.90	10.46	33	2600	10	16.19	8.56	53	+93

Table 4. Source of seed.

Divisions	Own home					Certified					Impact on yield (%)
	Sample points	%age share	Avg yield (m/ac)	S.D (m)	C.V (%)	Sample points	%age share	Avg yield (m/ac)	S.D (m)	C.V (%)	
Lahore	2554	85	33.25	10.41	31	434	15	38.38	12.18	32	+15
Gujranwala	3904	95	29.59	10.73	36	216	5	34.74	10.39	30	+17
Faislabad	2440	86	32.57	10.29	32	392	14	36.25	10.98	30	+11
Rawalpindi	1634	81	17.61	9.17	52	382	19	21.90	9.39	43	+24
Sargodha	2765	89	25.16	10.27	41	325	11	29.09	9.19	32	+16
Multan	3522	73	33.50	10.51	31	1272	27	35.93	10.70	30	+7
Bahawalpur	2046	78	31.33	10.46	33	576	22	31.87	10.33	32	+2
D.G.Khan	1929	75	29.61	10.01	34	645	25	31.07	10.65	34	+5
PUNJAB	20794	83	29.70	11.23	38	4242	17	33.07	11.48	35	+11

Sowing time and wheat production

Sowing time plays a key role with reference to the yield of wheat. The sowing of wheat is started in Punjab with the start of Rabi season in October and is continued till the end of December. Total sowing time has been broken up in to five periods as shown in Table 6. Only 7% farmers in the Punjab sow the crop up to 31st of October and get an average yield of 22.0 m/ac, which is least in all the five periods with 57% variation in the yield, which is the highest one. The reason of the lowest average and the highest variation is due to 48% sowing of wheat in un-irrigated area of Punjab that is, Rawalpindi division. Analyzing divisional level results in the first period of sowing, it is evident that the sowing of wheat in irrigated area is just 1 to 4% in this specific period because during Kharif

Table 5. Wheat variety analysis.

| Divisions | Wheat variety comparision | | | | | | | | | | Impact on yield (%) |
| | Inqlab-91 | | | | | Others | | | | | |
	Sample points	%age share	Avg. yield (m/ac)	S.D (m)	C.V (%)	Sample points	%age share	Avg. yield (m/ac)	S.D (m)	C.V (%)	
Lahore	1864	62	32.29	10.17	31	1124	38	36.82	11.31	31	+14
Gujranwala	3314	80	28.54	10.55	37	806	20	35.30	9.94	28	+24
Rawalpindi	1314	65	18.17	9.25	51	702	35	18.89	9.56	51	+4
Faislabad	1228	43	32.11	9.88	31	1604	57	33.83	10.82	32	+5
Sargodha	1425	46	24.95	10.37	42	1665	54	26.11	10.08	39	+5
Multan	2102	44	32.04	10.14	32	2692	56	35.79	10.69	30	+12
Bahawalpur	785	30	29.36	11.19	38	1837	70	32.33	10.27	32	+10
D.G.Khan	955	37	29.05	10.02	34	1619	63	30.53	10.06	33	+5
PUNJAB	12987	52	28.62	11.03	39	12049	48	32.04	11.41	36	+12

season harvesting of rice paddy in upper Punjab and picking of cotton in lower Punjab irrigated areas are not completed up to 31st October. Otherwise average yield of wheat of irrigated areas in this period would have been significantly high.Maximum sowing of the crop on Punjab level takes place during the second half of November, that is, 38% of total sowing. But maximum yield is achieved against the sowing of the crop in the first half of November that is, 31.85 m/ac. But average yield against the sowing of wheat in second half of November is almost same that is, 31.37 m/ac with minimum variation of 34%. So for the sowing of wheat, month of November is the best one, which is quite in accordance with the instructions given to the farmers by the Agriculture Department, Punjab regarding the wheat-sowing period. It can also be observed that as the sowing time is delayed, average yield gradually goes down. It is indicated from the last sowing period of the divisional results that sowing in the rice growing areas (upper Punjab) is almost over but in the cotton growing areas (lower Punjab), 13 to 18% sowing takes place in this period as picking of

cotton remains continued till the end of December and January.

Usage of seed quantity

Production of wheat is also influenced by the quantity of seed used per acre. There are certain categories of quantity of seed per acre that is used by 95% farmers of the Punjab as shown in the Table 7. It is given that as the quantity of seed per acre increases, the average yield gradually increases and the maximum yield that is, 31.98 m/ac is obtained against 60 kg/ac quantities of seed on the Punjab level. As the quantity of seed increases from 60 kg/ac, the average yield gradually decreases.

Maximum 46% farmers of the province use 50 kg/ac seed quantity. It is also shown that 69% farmers of Rawalpindi division use seed quantity equal or less than 40 kg/ac, as it is an un-irrigated area. Also in the lower Punjab area like Multan, Bahawalpur and D.G. Khan divisions, only less than 3% farmers use 40 kg or below quantity of

seed as the sowing time of the crop is mostly delayed because of late picking of cotton. As the sowing time is delayed, the quantity of seed has to be increased to get better yield. In upper Punjab area, rice paddy is harvested comparatively early than cotton, so there is no usage of more than 60 kg/ac seed quantity of wheat in the rice growing zone.

Sowing time and seed quantity

In the Table 8, the impact of sowing time over the quantity of seed per acre has been observed. The results given in Table 8 show that as the sowing time is delayed, the quantity of seed per acre has to be increased to sustain the production level. Maximum 21% farmers in irrigated and 31% farmers in un-irrigated area use 50 kg seed and 40 kg seed against the sowing of the crop in the second half of November and at the end of October, respectively. Maximum average yield 35.1 m/ac with 30% variation is obtained in irrigated area against sowing in the first of

Table 6. Sowing time analysis.

Sowing periods	Items	Sowing time and wheat yield								PUNJAB
		Divisions								
		Lahore	G_wala	F_abad	R_pindi	Sargodha	Multan	B_pur	DGKhan	
Up to 31st October	Sample points	116	154	83	962	366	68	21	46	1816
	%age Share	4	4	3	48	12	1	1	2	7
	Avg yield (m/ac)	36.84	30.33	36.93	18.28	16.25	34.82	39.84	26.06	22.00
	S.D (m)	11.10	12.23	13.46	8.98	10.30	14.16	10.19	12.80	12.63
	C.V (%)	30	40	36	49	63	41	26	49	57
From Nov 1 to Nov 15	Sample points	815	1358	1082	780	1418	1228	564	718	7963
	%age Share	27	33	38	39	46	26	22	28	32
	Avg yield (m/ac)	37.43	31.70	34.88	19.54	26.83	38.02	35.64	30.98	31.85
	S.D (m)	10.32	10.82	10.50	9.90	9.62	10.98	9.83	9.94	11.71
	C.V (%)	28	34	30	51	36	29	28	32	37
From Nov 16 to Nov 30	Sample points	1575	2145	916	220	955	1880	975	756	9422
	%age Share	53	52	32	11	31	39	37	29	38
	Avg yield (m/ac)	32.80	29.66	33.42	15.42	27.26	34.81	32.74	30.27	31.37
	S.D (m)	10.82	10.32	10.40	8.44	9.29	10.11	9.71	10.90	10.78
	C.V (%)	33	35	31	55	34	29	30	36	34
From Dec 1 to Dec 15	Sample points	362	353	527	32	241	1010	688	596	3809
	%age Share	12	9	19	2	8	21	26	23	15
	Avg yield (m/ac)	30.73	26.63	30.86	14.18	25.85	32.17	29.05	30.28	29.93
	S.D (m)	9.97	9.95	9.10	6.89	9.42	9.29	10.25	9.81	9.93
	C.V (%)	32	37	29	49	36	29	35	32	33
From Dec 16 and later	Sample points	120	110	224	22	110	608	374	458	2026
	%age Share	4	3	8	1	4	13	14	18	8
	Avg yield (m/ac)	33.42	20.69	26.85	21.20	25.15	27.49	25.65	27.93	26.97
	S.D (m)	10.48	11.90	8.69	9.69	10.81	9.03	9.73	9.18	9.81
	C.V (%)	31	58	32	46	43	33	38	33	36

November and seed quantity 60 kg per acre whereas in un-irrigated area, the highest average yield 17.50 m/ac with 52% variation is against first half of November and 50 kg seed per acre. It is worthy to highlight that in the whole province, seed quantity and sowing time are almost equally

distributed that is, there is no congestion in a particular cell of Table 8. For early sowing that is, up to 31st October 40 kg seed quantity produces the maximum yield of 31.30 m/ac in irrigated area. For this particular period, increase in seed quantity causes the reduction in the yield. It is important to point out that for a particular seed quantity, especially in un-irrigated area, the yield is gradually increased as the sowing period is delayed.

Application of fertilizers

Table 9 shows an impact of combination of two types of fertilizers: Urea and DAP (Di Ammonia Phosphate) on the yield of wheat taking their different pairs of quantities. As the fertilizers have different impact on the crop of irrigated and un-irrigated areas, so they have been individually analyzed. As there is no application of urea fertilizer more than 100 kg per acre in un-irrigated area, therefore columns of un-irrigated area against 125, 150 and 200 kg urea have been omitted from Table 10 for simplification purpose. There are maximum 46% cases in un-irrigated area, where no fertilizer has been used and resultantly there is only an average yield of 12.90 m/ac with a high variation of 52% in the yield. The second highest share in un-irrigated area is 14% against a combination of 50 kg fertilizer of each type in an acre getting an average yield of 22.10 m/ac with a variation of 43% in yield. The maximum average yield in un-irrigated area is 29.2 m/ac with a variation of 37% against a combination of no DAP and 100 kg urea per acre, but combination of this fertilizers share is just 0.5% in the whole data of un-irrigated area, which is quite negligible.

In irrigated area, maximum 34% farmers use a combination of 50 kg fertilizer of each type giving an average yield of 30.2 m/ac with 31% variation. The second highest combination 28% of fertilizers in irrigated area is 50 kg DAP and 100 kg urea per acre yielding an average production of 34.1 m/ac with a variation of 29%. The maximum average yield 40.4 m/ac with a variation of 26% is produced against a combination 125 kg urea and 100 kg DAP in irrigated area with a minor share of 0.1%. The highest inconsistent yield in un-irrigated area is 14.3 m/ac with a variation of 55% against a combination of no DAP and 25 kg urea. In case of irrigated area, the most variant yield is 21.7 m/ac with a variation of 58% against usage of neither fertilizer.

Pesticides / Weedicides spray

A spray of pesticides / weedicides is extremely important for a good production of wheat. Table 10 shows an overall impact of pesticides on the crop. On the whole, 41% of farmers of the Punjab use pesticides spray on the crop and get 27% more yield as compared to the crop, which has not been sprayed. Also yield of sprayed crop is more consistent than the yield of unsprayed crop that is, 28% as compared to 42% variation in the yield. Individually on divisional level analysis, the maximum impact of pesticides spray is in Rawalpindi division that is, 62% more production as compared to unsprayed crop. Hence it can be concluded that pesticides positive impact considerably more incun-irrigated area as compared to irrigated one. But only 5% farmers in Rawalpindi division use pesticides spray on their wheat crop because of being barani area. The maximum usage of pesticides is in Lahore, Gujranwala and Multan divisions that is, 52, 48 and 49%, respectively Usage of pesticides is also an indicator of financial status of farmers of that particular area, as pesticides are comparatively much expensive items in the crop inputs.

Pesticides spray on a diseased crop

Table 11 is an elaborated form of Table 10. Pesticides are sprayed because of some diseases to the crop or for harmful weeds and may be for both of the reasons. Four categories have been designed to analyze the impact of pesticides spray on different status of the crop: No Diseases + No Spray, No Diseases + Spray, Diseases + No Spray and Diseases + Spray. Maximum average yield 34.67 m/ac with only 29% variation is against the category No Disease + Spray that is, spray for weeds on the diseases less crop and 36% farmers fall in this category. Minimum average yield 27.31 m/ac in maximum 56% number of cases with highest 42% variation is in the category of No Diseases + No Spray. Analyzing divisional level results, the maximum yield in all the categories is obtained in Multan division that is, 36.97 m/ac with a variation of 28% in the production is in the category of No Diseases + Spray. The minimum yield of wheat 26.90 m/ac with high 39% variation on Punjab level, is against the category Diseases + No Spray. All the results are logically true and also match with the ground realities.

Ploughing / leveling and wheat production

Table 12 shows various combination of ploughing and leveling in the province. A proper combination of suitable number of plough and level, subject to the availability of water, humidity level and nature of soil causes a good production of wheat. Minimum number of level in the Punjab is 1 and maximum 6 and minimum number of plough is 1 and maximum is 8. In this way, there are 48 combinations of level and plough. Each combination has been individually analyzed for irrigated and un-irrigated areas. In irrigated and un-irrigated areas, maximum 25 and 13% farmers use a combination of 2 levels and 4 ploughs getting an average yield of 31.0 and 14.4 m/ac with 33 and 42% variation in the yield, respectively.

Table 7. Use of seed quantity.

Seed quantity (kg)	Items	Quantity seed used per acre								PUNJAB
		Divisions								
		Lahore	G_wala	F_abad	R_pindi	Sargodha	Multan	B_pur	DGKhan	
Qty<= 40	Sample points	583	1333	-	1386	462	122	42	32	4230
	%age Share	20	32	-	69	15	3	2	1	17
	Avg yield (m/ac)	31.29	26.65	-	17.58	15.93	33.48	27.46	27.46	23.58
	S.D (m)	11.37	11.10	-	8.58	8.90	12.67	9.79	11.55	11.83
	C.V (%)	36	42	-	49	56	38	36	42	50
Qty = 45	Sample points	366	824	222	232	226	118	66	20	2074
	%age Share	12	20	8	12	7	2	3	1	8
	Avg yield (m/ac)	32.03	33.43	32.72	16.90	21.20	36.94	30.17	29.12	29.98
	S.D (m)	9.49	10.16	11.42	8.81	9.87	10.68	10.61	11.56	11.74
	C.V (%)	30	30	35	52	47	29	35	40	39
Qty = 50	Sample points	1957	1865	1650	356	1526	2263	1104	799	11520
	%age Share	65	45	58	18	49	47	42	31	46
	Avg yield (m/ac)	34.91	30.68	33.02	22.14	27.58	34.83	31.35	28.58	31.79
	S.D (m)	10.60	10.16	10.44	11.22	9.69	11.23	10.43	9.47	10.91
	C.V (%)	30	33	32	51	35	32	33	33	34
Qty = 60	Sample points	78	96	654	42	726	1735	1076	905	5312
	%age Share	3	2	23	2	23	36	41	35	21
	Avg yield (m/ac)	40.14	27.88	34.57	23.35	28.49	33.89	31.80	29.58	31.98
	S.D (m)	12.74	10.74	9.26	10.52	8.35	9.60	10.62	10.34	10.15
	C.V (%)	32	39	27	45	29	28	33	35	32
Qty = 70	Sample points	-	-	24	-	142	384	218	464	1238
	%age Share	-	-	1	-	5	8	8	18	5
	Avg yield (m/ac)	-	-	34.00	-	27.31	31.84	32.86	32.19	31.69
	S.D (m)	-	-	10.56	-	8.53	10.20	9.90	11.03	10.41
	C.V (%)	-	-	31	-	31	32	30	34	33
Qty>= 80	Sample points	-	-	-	-	-	146	98	328	584
	%age Share	-	-	-	-	-	3	4	13	2
	Avg yield (m/ac)	-	-	-	-	-	30.60	28.22	31.33	30.59
	S.D (m)	-	-	-	-	-	9.74	9.15	9.44	9.45
	C.V (%)	-	-	-	-	-	32	32	30	31

Table 8. The sowing time and seed quantity per acre.

Seed quantity (Kg)	Items	Sowing time and seed quantity used per acre									
		Sowing time									
		Up to Oct		Nov 1-15		Nov 16-30		Dec 1-15		Dec16 later	
		Irri	Un	Irri	Un	Irri	Un	Irri	Un	Irri	Un
=< 40	S.Pnts	98	806	864	722	1075	274	267	34	74	16
	%age	0.4	31	3.9	28	4.8	11	1.2	1	0.3	1
	Avg (m/ac)	31.3	16.4	31.1	16.4	28.9	15.1	25.8	11.7	26.8	13.9
	SD (m)	12.4	8.2	10.7	8.5	10.4	8.7	10.5	6.3	11.9	10.7
	C.V(%)	40	50	34	52	36	57	41	54	44	77
= 45	S.Pnts	69	130	604	96	800	32	149	-	62	-
	%age	0.3	5	2.7	4	3.6	1	0.7	-	0.3	-
	Avg (m/ac)	32.4	15.4	35.0	15.9	32.1	14.7	28.7	-	24.3	-
	SD (m)	11.6	8.3	9.7	7.9	10.1	7.6	10.3	-	10.7	-
	C.V(%)	36	54	28	50	31	52	36	-	44	-
= 50	S.Pnts	309	122	3886	64	4753	54	1518	-	574	14
	%age	1.4	5	17.3	2	21.2	2	6.8	-	2.6	1
	Avg (m/ac)	33.3	15.8	34.3	17.5	32.2	16.7	29.7	-	26.4	9.7
	SD (m)	12.5	8.5	10.5	9.1	10.4	10.1	9.8	-	9.7	8.2
	C.V(%)	38	53	31	52	32	61	33	-	37	85
= 60	S.Pnts	100	-	1039	-	1502	-	1131	-	618	-
	%age	0.4	-	4.6	-	6.7	-	5.0	-	2.8	-
	Avg (m/ac)	31.9	-	35.1	-	33.4	-	30.9	-	27.7	-
	SD (m)	12.9	-	10.5	-	9.8	-	9.4	-	9.4	-
	C.V(%)	40	-	30	-	29	-	30	-	34	-
= 70	S.Pnts	20	-	120	-	270	-	262	-	246	-
	%age	0.1	-	0.5	-	1.2	-	1.2	-	1.1	-
	Avg (m/ac)	32.9	-	35.1	-	33.1	-	32.8	-	28.3	-
	SD (m)	9.2	-	11.9	-	10.7	-	9.0	-	9.5	-
	C.V(%)	28	-	34	-	32	-	27	-	34	-
= > 80	S.Pnts	12	-	26	-	104	-	178	-	264	-
	%age	0.1	-	0.1	-	0.5	-	0.8	-	1.2	-
	Avg (m/ac)	37.4	-	34.8	-	33.4	-	32.2	-	27.7	-
	SD (m)	10.0	-	8.3	-	9.9	-	9.4	-	8.5	-
	C.V(%)	27	-	24	-	30	-	29	-	31	-

Table 9. Use of fertilizers.

		Usage of fertilizers and wheat yield in Punjab												
Fertilizer name		**U r e a**												
Qty (Kg)		**0**		**25**		**50**		**75**		**100**		**125**	**150**	**200**
		Irri	Un	Irri	Un	Irri	Un	Irri	Un	Irri	Un	Irri	Irri	Irri
	S.Pnts	230	1204	48	46	1397	212	134	-	688	12	18	102	16
	%age	1	46	0.2	2	6	8	0.6	-	3	0.5	0.1	0.5	0.1
0	Avg (m/ac)	21.7	12.9	19.8	14.3	24.3	17.4	27.7	-	29.4	29.2	28.5	30.9	28.7
	SD (m)	12.6	6.7	10.5	7.9	9.9	7.6	9.6	-	10.8	10.8	13.7	9.2	11.9
	C.V(%)	58	52	53	55	41	44	34	-	37	37	48	30	41
	S.Pnts	16	73	80	151	254	14	76	-	104	-	14	-	-
D	%age	0.1	3	0.4	6	1	0.5	0.3	-	0.5	-	0.1	-	-
25	Avg (m/ac)	11.9	15.5	24.9	19.5	26.5	21.7	27.4	-	30.7	-	31.1	-	-
A	SD (m)	5.7	6.2	11.7	10.1	10.2	9.5	8.8	-	10.9	-	12.3	-	-
	C.V(%)	48	40	47	52	39	44	32	-	36	-	39	-	-
	S.Pnts	121	187	74	92	7562	370	1248	-	6320	8	226	850	58
P	%age	1	7	0.3	4	34	14	6	-	28	0.3	1	4	0.3
50	Avg (m/ac)	23.8	17.4	30.9	21.1	30.2	22.1	33.6	-	34.1	14.4	36.5	36.2	37.2
	SD (m)	10.8	7.5	9.3	8.4	9.5	9.6	9.2	-	10.0	3.2	11.0	10.0	11.4
	C.V(%)	45	43	30	40	31	43	27	-	29	22	30	28	31
	S.Pnts	-	-	-	-	122	-	163	-	499	-	40	82	-
	%age	-	-	-	-	1	-	1	-	2	-	0.2	0.4	-
75	Avg (m/ac)	-	-	-	-	35.2	-	35.4	-	37.8	-	40.3	35.6	-
	SD (m)	-	-	-	-	8.8	-	7.7	-	8.9	-	11.3	10.9	-
	C.V(%)	-	-	-	-	25	-	22	-	23	-	28	31	-
	S.Pnts	16	-	-	-	282	-	84	-	698	-	28	173	38
	%age	0.1	-	-	-	1	-	0.4	-	3	-	0.1	1	0.2
100	Avg (m/ac)	34.6	-	-	-	35.0	-	40.2	-	37.2	-	40.4	38.2	36.1
	SD (m)	11.6	-	-	-	9.3	-	13.1	-	10.2	-	10.7	9.1	7.4
	C.V(%)	34	-	-	-	27	-	33	-	27	-	26	24	20

The maximum yield in case of irrigated area is 36.9 m/ac with a variation of 32% against a combination of 6 levels and 4 ploughs, where as in case of un-irrigated area, the maximum yield is 26.5 m/ac with 28% variation against 6 levels and 5 ploughs. It is a general trend, which can be

Table 10. Pesticides spray.

Divisions	Pesticides spray on wheat crop										Impact on yield (%) Inc
	Yes					No					
	Sample points	%age share	Avg yield (m/ac)	S.D (m)	C.V (%)	Sample points	%age share	Avg yield (m/ac)	S.D (m)	C.V (%)	
Lahore	1558	52	36.31	9.98	27	1430	48	31.51	11.17	35	15
Gujranwala	1970	48	33.56	9.20	27	2150	52	26.46	10.99	42	27
Faislabad	1272	45	36.45	9.41	26	1560	55	30.34	10.48	35	20
Rawalpindi	100	5	29.04	9.78	34	1916	95	17.87	9.01	50	62
Sargodha	970	31	30.06	8.54	28	2120	69	23.52	10.28	44	28
Multan	2354	49	36.47	10.43	29	2440	51	31.90	10.30	32	14
Bahawalpur	892	34	34.62	9.47	27	1730	66	29.81	10.53	35	16
D.G.Khan	1096	43	32.42	9.20	28	1478	57	28.18	10.51	37	15
P U N J A B	10212	41	34.61	9.85	28	14824	59	27.28	11.34	42	27

observed in Table 12 that as numbers of level and plough increase, the average yield also increases.

Number of water used to wheat crop

In irrigated area of the Punjab, number of water is very important for the yield of wheat. Becauseof availability of timely rainfalls, number of waters can be increased or decreased accordingly. The data has been segregated in to six categories on the basis of number of water from one to six and above as shown in Table 13. It is generally observed from Table 13 that as number of water is increased, average yield is also increased and after 4-number of waters, it comes down. Against 4-number of water, maximum yield 33.26 m/acwith a variation of 31% is obtained. Maximum 33% farmers of irrigated area of the Punjab use 4-number of waters. In Sargodha division 28% farmers use 4-number of water getting average yield of 28.57 m/ac with 31% variation and 24% farmers use 6 and more number of waters getting

27.77 m/ac yield with a variation of 27% in the yield. The maximum use of number of water that is, six or more is the highest in Punjab that is24% because the nature of soil in Sargodha division is sandy, especially in district Bhakhar. As the ground absorbs water rapidly so farmers have to increase the number of water to maintain the germination pace of the crop. It is also notable that as the number of water increased, the variation in the yield gradually decreased. It is important to highlight that in the upper Punjab, less number of water is used as compared to lower / central Punjab irrigated area like Bahawalpur, D.G.Khan and Sargodha divisions, 8 to 24% farmers use 6 or more water where as in upper Punjab, Lahore and Faislabad divisions only 2 to 4% farmers use 6 or more number of water. Particularly in Gujranwala division, no one uses 6 or more number of water.

Number of water and amount of rainfalls

With reference to Tables 15 and 16, Table 14 also

shows the application of weighted rainfalls methodology. According to the Punjab climate, 3 waters are essential to wheat crop throughout the Rabi season. In irrigated area farmers are comparatively less dependent upon rainfalls as they have other sources of watering. However number of water is totally dependent on the timely rainfalls. In case of timely rainfalls, cost of watering is saved and the crop receives rather better natural water. But in case of no, less or out time rainfalls, farmers have to increase the number of water to keep the crop germination momentum. It indicates an existence of association between number of water and amounts of rainfalls. Two methods have been used to find out the average number of water in all the districts of Punjab: mean and mode. Similarly, two methods of association between number of water and amounts of actual / weighted rainfalls have been used: Simple and Rank correlations. Table 14 shows that both simple and rank coefficients of correlation are higher between weighted rainfalls and number of water as

Table 11. Crop diseases and pesticides spray.

Disease and spray	Items	Divisions								PUNJAB
		Lahore	G_wala	F_abad	R_pindi	Sargodha	Multan	B_pur	DGKhan	
		Diseased crop and pestcides spray								
No disease + No spray	Sample points	1198	2006	1438	1862	2072	2228	1678	1434	13916
	%age Share	40	49	51	92	67	46	64	56	56
	Avg Yield (m/ac)	32.24	26.69	30.47	17.91	23.51	32.12	29.79	28.16	27.31
	S.D (m)	11.11	11.01	10.57	8.97	10.30	10.28	10.62	10.54	11.40
	C.V (%)	34	41	35	50	44	32	36	37	42
No disease + spray (for weeds)	Sample points	1234	1784	1110	98	946	1887	868	1050	8977
	%age Share	41	43	39	5	31	39	33	41	36
	Avg Yield (m/ac)	36.70	33.63	36.81	28.96	29.90	36.97	34.67	32.49	34.67
	S.D (m)	10.11	9.18	9.37	9.88	8.40	10.53	9.50	9.18	9.89
	C.V (%)	28	27	25	34	28	28	27	28	29
Disease + No spray	Sample points	232	144	122	54	48	212	52	44	908
	%age Share	8	3	4	3	2	4	2	2	4
	Avg Yield (m/ac)	27.49	23.30	28.80	16.56	24.04	29.61	30.56	28.84	26.90
	S.D (m)	10.65	10.28	9.27	10.32	9.24	10.27	7.21	9.55	10.56
	C.V (%)	39	44	32	62	38	35	24	33	39
Disease + spray	Sample points	324	186	162	-	24	467	24	46	1235
	%age Share	11	5	6	-	1	10	1	2	5
	Avg Yield (m/ac)	34.84	32.99	33.92	-	36.50	34.48	32.82	30.79	34.15
	S.D (m)	9.34	9.36	9.25	-	11.51	9.78	8.17	9.45	9.55
	C.V (%)	27	28	27	-	32	28	25	31	28

compared to between actual rainfalls and number of water. Also both coefficients of correlation are higher in case of mean number of water and amount of rainfalls as compared to mode number of water and amount of rainfalls. It depicts a strong association between the concerned variables and utility of weighted rainfall methodology (Qayyum and Pervaiz, 2010).

Rabi season rainfalls and wheat production

In climatic parameters, rainfalls have a great impact on the production of wheat. Table 15 shows divisional average yield of irrigated, as well as, un-irrigated areas along with their variations and monthly total rainfalls / weighted rainfalls (mm) of the Rabi season for all the years. Also

simple / rank coefficients of correlation between yield and amounts of actual / weighted rainfalls have been calculated. It is worthy to point out that rainfalls of various months of the season have different degree of impact on the yield as discussed earlier. In the analyses of rank correlations, this effect is evident that in un-irrigated area maximum positive impact on yield is

Table 12. Ploughing and leveling analyses.

No of levels	Items	Ploughing / Leveling and yield in Punjab															
		No of Plough															
		1		2		3		4		5		6		7		8	
		Irri	Un	Irri	Un	Irri	Un	Irri	Un	Irri	Un	Irri	Un	Irri	Un	Irri	Un
1	S.Pnts	86	28	1023	210	1704	166	1147	86	152	16	56	-	-	-	-	-
	%age	0.4	1	4.6	8	7.6	6	5.1	3	0.7	1	0.2	-	-	-	-	-
	Avg (m/ac)	31.8	11.8	28.2	11.4	29.7	13.8	31.7	16.5	31.0	17.2	37.7	-	-	-	-	-
	SD (m)	14.0	6.4	10.5	5.1	10.1	7.3	10.3	7.8	9.8	13.3	11.7	-	-	-	-	-
	C.V(%)	44	54	37	45	34	53	32	47	32	78	31	-	-	-	-	-
2	S.Pnts	65	-	510	80	2400	268	5555	348	1590	178	884	130	90	28	102	56
	%age	0.3	-	2.3	3	10.7	10	24.8	13	7.1	7	3.9	5	0.4	1	0.5	2
	Avg (m/ac)	32.0	-	29.5	11.8	30.3	12.3	31.0	14.4	33.5	16.9	33.5	16.9	34.4	18.7	33.8	16.6
	SD (m)	9.3	-	11.6	6.4	10.2	5.8	10.1	6.1	10.2	8.7	9.8	8.0	12.2	8.2	11.6	9.1
	C.V(%)	29	-	39	54	34	47	33	42	30	52	29	48	35	44	34	55
3	S.Pnts	24	-	27	-	271	32	1229	98	1241	124	1134	88	220	54	128	38
	%age	0.1	-	0.1	-	1.2	1	5.5	4	5.5	5	5.1	3	1.0	2	0.6	1
	Avg (m/ac)	30.4	-	33.6	-	31.6	19.2	32.6	16.8	33.3	18.2	34.9	20.2	35.9	18.7	34.5	20.6
	SD (m)	9.5	-	13.0	-	10.5	10.3	10.7	7.6	10.1	8.6	10.4	8.6	9.4	8.6	10.1	7.0
	C.V(%)	31	-	39	-	33	54	33	45	30	47	30	42	26	46	29	34
4	S.Pnts	-	-	-	-	54	32	398	38	416	74	642	84	100	30	292	38
	%age	-	-	-	-	0.2	1	1.8	1	1.9	3	2.9	3	0.4	1	1.3	1
	Avg (m/ac)	-	-	-	-	30.4	14.4	32.3	19.5	33.9	16.8	35.4	16.3	32.8	17.3	35.9	22.0
	SD (m)	-	-	-	-	11.4	8.2	9.8	8.4	10.4	9.9	10.0	6.5	11.3	8.2	10.2	12.2
	C.V(%)	-	-	-	-	38	57	30	43	31	59	28	40	34	48	29	55
5	S.Pnts	-	-	-	-	-	-	34	-	92	32	126	-	44	26	32	26
	%age	-	-	-	-	-	-	0.2	-	0.4	1	0.6	-	0.2	1	0.1	1
	Avg (m/ac)	-	-	-	-	-	-	25.0	-	32.6	23.0	35.7	-	35.1	20.8	31.6	22.8
	SD (m)	-	-	-	-	-	-	11.2	-	11.2	7.7	9.6	-	7.8	10.2	9.3	9.1
	C.V(%)	-	-	-	-	-	-	45	-	34	34	27	-	22	49	29	40
6	S.Pnts	-	-	-	-	-	-	20	-	32	18	84	18	14	-	38	-
	%age	-	-	-	-	-	-	0.1	-	1	0.1	3	0.1	1	-	0.2	-
	Avg (m/ac)	-	-	-	-	-	-	36.9	-	30.1	26.5	37.6	22.5	36.0	-	37.1	-
	SD (m)	-	-	-	-	-	-	11.7	-	8.6	7.4	11.7	9.0	15.7	-	14.2	-
	C.V(%)	-	-	-	-	-	-	32	-	29	28	31	40	44	-	38	-

Table 13. Number of waters and crop yield.

No of water	Items	Lahore	G_wala	F_abad	R_pindi	Sargodha	Multan	B_pur	DGKhan	PUNJAB
		over Divisions								
= 1	Sample points	148	832	36	30	64	-	22	38	1182
	%age Share	5	22	1	16	2	-	1	1	5
	Avg Yield (m/ac)	25.02	27.16	29.00	27.20	20.69	-	10.61	15.95	25.83
	S.D (m)	10.67	10.77	14.78	8.83	12.90	-	5.86	8.95	11.37
	C.V (%)	43	40	51	32	62	-	55	56	44
= 2	Sample points	406	1380	216	48	254	164	116	120	2704
	%age Share	14	37	8	26	9	3	4	5	12
	Avg Yield (m/ac)	30.20	31.22	29.40	27.93	25.41	32.75	22.39	21.89	29.61
	S.D (m)	11.56	9.44	11.51	9.18	8.81	11.55	11.14	11.51	10.61
	C.V (%)	38	30	39	33	35	35	50	53	36
= 3	Sample points	1054	1170	740	62	502	1152	514	458	5652
	%age Share	35	31	26	34	19	24	20	18	25
	Avg Yield (m/ac)	33.87	33.16	31.20	31.51	27.82	34.32	30.68	27.92	32.13
	S.D (m)	10.85	9.48	10.53	9.32	9.23	10.48	10.88	10.51	10.52
	C.V (%)	32	29	34	30	33	31	35	38	33
= 4	Sample points	1098	310	1192	36	742	2084	1100	748	7310
	%age Share	37	8	42	20	28	43	42	29	33
	Avg Yield (m/ac)	35.84	33.31	34.15	31.72	28.57	34.31	32.48	30.97	33.26
	S.D (m)	9.81	9.51	9.88	10.43	8.77	10.75	9.80	9.77	10.20
	C.V (%)	27	29	29	33	31	31	30	32	31
= 5	Sample points	224	50	538	-	490	1061	648	760	3779
	%age Share	7	1	19	-	18	22	25	30	17
	Avg Yield (m/ac)	38.08	32.43	34.75	-	28.83	34.42	33.31	31.65	33.19
	S.D (m)	9.30	8.77	10.14	-	8.97	10.31	9.74	9.60	9.03
	C.V (%)	24	27	29	-	31	30	29	30	27
≥ 6	Sample points	58	-	110	-	640	321	222	436	1801
	%age Share	2	-	4	-	24	7	8	17	8
	Avg Yield (m/ac)	34.91	-	34.69	-	27.77	32.95	29.43	31.41	30.48
	S.D (m)	10.27	-	10.06	-	7.59	9.96	9.30	8.64	9.08
	C.V (%)	29	-	29	-	27	30	32	28	30

Table 14. Number of waters and rainfalls.

Districts	Sample points	Avg. No. of water		Avg. total rainfall (mm)	Avg. weighted rainfall (mm)
		(Mode)	(Mean)		
Gujranwala	864	2	2.20	107.63	35.697
Gujrat	384	2	2.03	62.19	22.773
Sialkot	822	2	1.98	156.51	55.450
Narowal	456	2	2.05	177.50	57.623
Hafizabad	586	3	2.86	105.84	34.918
M.B.Din	642	3	2.73	187.30	56.341
Rawalpindi	8	1	1.25	301.40	104.580
Attock	58	4	3.17	226.75	62.180
Jehlam	96	3	2.56	270.18	80.970
Chakwal	24	3	2.83	191.21	50.970
Lahore	408	3	3.40	133.16	39.878
Sheikupura	540	2	2.54	108.01	37.249
Nankana Sb	432	4	3.41	70.89	22.285
Kasur	828	3	3.32	105.65	31.382
Okara	780	4	3.88	76.42	25.223
Faislabad	1008	4	3.79	84.45	28.432
Jhang	1062	4	3.79	56.47	16.463
T.T.Singh	762	4	3.90	104.47	34.060
Sargodha	936	4	3.38	121.13	34.848
Khushab	368	5	4.81	129.13	28.116
Mianwali	490	4	3.79	159.00	33.917
Bahkhar	898	6	5.50	95.02	23.610
Multan	762	4	4.08	78.65	21.908
Khanewal	882	4	3.92	72.90	20.790
Vehari	876	4	3.96	68.33	20.905
Lodhran	666	4	3.82	44.61	12.627
Sahiwal	906	4	4.46	69.16	27.311
Pakpattan	702	4	3.95	95.03	30.607
Bahawalpur	648	4	4.14	56.80	14.486
Bahawalngar	978	4	4.04	53.59	16.179
R.Y.Khan	996	4	4.19	72.30	21.116
D.G.Khan	520	4	3.62	100.42	25.649
Rajanpur	534	5	4.30	70.84	21.205
Layyah	660	5	4.92	74.24	15.915
Muzffergarh	846	4	4.43	102.94	28.967
PUNJAB	22428	4	3.71	94.64	28.535
Correlation coefficients	Simple	Mean no of Water		-0.594	-0.707
		Mode no of Water		-0.494	-0.631
	Rank	Mean no of Water		-0.568	-0.704
		Mode no of Water		-0.482	-0.649

of October rainfall that is, 56% rank correlation and the second highest positive impact is of January rainfall that is, 54%. Similarly, these two results in case of irrigated area are 21 and 41%, respectively that is, January rainfall has more positive impact on yield as compared to October rainfall in irrigated area. The impact of rainfalls on the yield of un-irrigated area is much higher than that of irrigated area, as un-irrigated area production is merely dependent on rainfalls rather on timely rainfalls. Therefore rank correlations between yield and actual rainfalls of irrigated and un-irrigated areas are 19 and 53.8% where as between yield and weighted rainfalls are

Table 15. The season rainfalls and divisional yield.

Years	Divisions	Average yield (m/ac)		C.V (%)		Average monthly total rainfalls (mm)							Avg. total rainfall (mm)	Avg. weighted rainfall (mm)
		Irri	Unir	Irri	Unir	Oct	Nov	Dec	Jan	Feb	Mar	Apr		
2005-2006	Lahore	32.08	-	30	-	0.1	0	0	6	2	26	0	34.45	6.938
	Gujranwala	30.92	15	30	71	0	0	22	6	30	0.4		58.79	19.259
	Faislabad	31.63	-	31	-	6	0	0	3	7	17	0	33.60	9.304
	Rawalpindi	31.98	15	30	42	31	3	0	51	17	40	9	151.90	64.104
	Sargodha	27.25	9	32	44	3	0	0	5	8	27	4	47.61	10.788
	Multan	30.74	-	31	-	2	0	0	4	1	12	3	22.24	5.637
	Bahwalpur	27.62	-	32	-	0	1	0	3	0	26	1	30.80	4.609
	D.G.Khan	28.73	-	36	-	0	0	0	1	4	25	1	31.69	4.306
2006-2007	Lahore	35.40	-	30	-	41	15	13	0	85	43	0	197.27	63.131
	Gujranwala	30.19	22	34	49	30	4	41	0	96	92	0	261.84	67.565
	Faislabad	34.15	-	29	-	23	10	30	0	34	26	0	123.00	38.954
	Rawalpindi	34.00	21	23	46	22	17	77	0	143	143	12	414.18	99.072
	Sargodha	29.04	13	30	35	5	15	32	0	134	66	6	261.89	65.036
	Multan	35.44	-	28	-	22	2	16	0	59	26	1	126.50	38.747
	Bahwalpur	35.38	-	26	-	0	0	21	0	86	19	0	126.44	33.118
	D.G.Khan	32.25	-	29	-	6	5	23	0	48	40	0	121.85	29.790
2007-2008	Lahore	32.28	-	33	-	0	3	11	24	7	4	32	49.00	25.574
	Gujranwala	30.12	16	33	51	0	1	2	48	9	0	49	108.84	43.370
	Faislabad	31.28	-	34	-	0	0	5	29	12	0.4	54	100.34	32.912
	Rawalpindi	29.61	14	34	53	0	13	0	61	27	12	100	213.40	70.038
	Sargodha	25.00	9	31	33	0	0.4	1	17	15	4	71	107.93	27.424
	Multan	31.44	-	33	-	0	0	7	11	11	0	29	58.61	17.444
	Bahwalpur	29.13	-	37	-	0	0	4	7	2	0	19	31.25	9.182
	D.G.Khan	27.62	-	35	-	0	0	2	9	12	3	16	41.60	12.871
2008-2009	Lahore	36.15	-	33	-	2	0	6	19	19	25	0.3	71.16	23.146
	Gujranwala	33.25	15	30	51	22	0	14	31	21	16	0	104.93	46.430
	Faislabad	35.17	-	31	-	0	0	27	14	7	12	0.6	59.69	20.251
	Rawalpindi	23.62	19	35	45	11	6	29	41	52	46	9	194.81	65.900
	Sargodha	29.95	11	32	43	4	0	15	4	14	33	3	72.94	16.901
	Multan	38.52	-	27	-	0	0	34	21	3	16	1	74.42	26.533
	Bahwalpur	34.76	-	30	-	0	0	34	23	3	15	1	76.35	28.028
	D.G.Khan	31.11	-	35	-	0	0	99	13	1	32	1	145.84	41.788
Correlation coefficients between yield and rainfalls		**Simple**			Irri	0.24	0.01	0.25	-0.09	0.11	0.05	-0.38	0.051	0.090

Table 15. Contd.

	Unir	0.64	0.30	0.67	0.11	0.52	0.65	-0.32	0.663	0.741
Rank	Irri	0.21	-0.06	0.41	-0.05	0.15	-0.02	-0.49	0.190	0.200
	Unir	0.56	0.29	0.54	0.07	0.46	0.47	-0.16	0.538	0.657

Table 16. The season humidity and divisional yield.

		Humidity level in rabi season and divisional wheat yield												
Years	Divisions	Average yield (m/ac)		C.V (%)		Monthly average humidity level (%)							Avgerage humidity season (%)	of
		Irri	Unir	Irri	Unir	Oct	Nov	Dec	Jan	Feb	Mar	Apr		
2005-2006	Lahore	32.08	-	30	-	56	50	60	60	55	52	29	51.714	
	Gujranwala	30.92	15	30	71	63	62	68	63	58	61	44	59.857	
	Faislabad	31.63	-	31	-	63	66	72	72	67	61	45	63.714	
	Rawalpindi	31.98	15	30	42	62	62	73	76	65	70	59	66.714	
	Sargodha	27.25	9	32	44	76	78	81	79	77	76	55	74.571	
	Multan	30.74	-	31	-	76	74	74	74	71	68	47	69.143	
	Bahwalpur	27.62	-	32	-	72	78	75	71	69	67	52	69.143	
	D.G.Khan	28.73	-	36	-	65	63	72	71	68	71	44	64.857	
2006-2007	Lahore	35.40	-	30	-	63	72	73	65	75	66	42	65.143	
	Gujranwala	30.19	22	34	49	62	62	66	62	62	58	46	59.714	
	Faislabad	34.15	-	29	-	65	71	74	72	70	63	46	65.857	
	Rawalpindi	34.00	21	23	46	59	66	67	71	75	72	56	66.571	
	Sargodha	29.04	13	30	35	71	82	87	84	80	74	58	76.571	
	Multan	35.44	-	28	-	75	76	80	76	79	74	49	72.714	
	Bahwalpur	35.38	-	26	-	70	76	75	71	68	63	53	68.000	
	D.G.Khan	32.25	-	29	-	63	62	66	66	69	67	56	64.143	
2007-2008	Lahore	32.28	-	33	-	62	69	72	66	63	53	45	61.429	
	Gujranwala	30.12	16	33	51	56	60	64	62	58	54	53	58.143	
	Faislabad	31.28	-	34	-	57	67	71	70	63	51	48	61.000	
	Rawalpindi	29.61	14	34	53	62	66	69	77	69	62	63	66.857	
	Sargodha	25.00	9	31	33	73	82	85	79	81	78	73	78.714	
	Multan	31.44	-	33	-	64	74	80	79	77	73	50	71.000	
	Bahwalpur	29.13	-	37	-	68	73	73	68	63	68	51	66.286	
	D.G.Khan	27.62	-	35	-	65	66	72	70	65	68	57	66.143	

Table 16. Contd.

2008-2009												
2008-2009	Lahore	36.15	-	33	-	66	70	75	80	68	59	47	66.429
	Gujranwala	33.25	15	30	51	65	62	67	69	66	53	46	61.143
	Faislabad	35.17	-	31	-	60	64	73	75	67	57	48	63.429
	Rawalpindi	23.62	19	35	45	57	59	69	75	71	60	57	64.000
	Sargodha	29.95	11	32	43	77	81	89	88	83	75	66	79.857
	Multan	38.52	-	27	-	70	71	82	83	73	66	53	71.143
	Bahwalpur	34.76	-	30	-	68	72	70	72	61	54	60	65.286
	D.G.Khan	31.11	-	35	-	65	60	75	80	75	69	62	69.429

Correlation coefficients between yield and humidity level													
	Simple				Irri	-0.05	-0.05	-0.07	-0.03	-0.10	-0.27	-0.36	-0.170
					Unir	-0.81	-0.76	-0.77	-0.63	-0.53	-0.59	-0.55	-0.730
	Rank				Irri	-0.10	-0.05	-0.03	-0.05	-0.10	-0.33	-0.34	-0.140
					Unir	-0.81	-0.75	-0.81	-0.79	-0.61	-0.76	-0.55	-0.800

20 and 65.7%, respectively.

Rabi season humidity levels and wheat production

Table 16 reveals humidity impact on the crop yield both inirrigated and un-irrigated areas separately. Like rainfalls analyses, both simple and rank coefficients of correlation have been calculated between humidity level and divisional production of wheat for all the years. A main commonality in all the coefficients of correlation is that neither value is positive that is, humidity level and production of wheat have negative association. In case of irrigated area, association between yield and humidity is minor except April average humidity, as it is the month when the crop is almost matured, ready to harvest and needs a complete hot and dry environment, so the rank correlation is –34% that is, increase in humidity causes low yield of wheat.In case of un-irrigated area, humidity comparatively has more negative impact on the yield. For instance, in the month of April, the association is –55%, which is more than irrigated area. The overall rank correlations between average humidity of the season and yield in irrigated and un-irrigated areas are –14 and –80%, respectively that is, both have inverse relationship.

Rabi season temperatures and wheat production

In general Pakistan climate mostly remains on extremes i.e. in winter season, the lowest temperature may be –20°C on the upper side of the country like Skardu and surroundings and +10°C on its lower side like interior Sindh etc. Similarly, in summer season, the lowest temperature may be 1°C on upper side and the highest about +52°C on lower and middle areas of the country like Sibi and Kashmor etc. As the variation between temperatures is very high, so average temperature cannot depict its real impact on the wheat yield, so average of maximum and minimum temperatures for each month of Rabi season has been observed for their individual analyses (Table 17). The results reveal that temperatures have opposite impact on the yield of un-irrigated and irrigated areas as both simple and rank coefficients of correlation are positive in irrigated case and negative in un-irrigated one. Also comparing monthly maximum / minimum temperatures of irrigated and un-irrigated areas, it is observed that coefficients of correlation are higher in case of irrigated area than that of un-irrigated one i.e. yield of wheat in irrigated area is more influenced by temperatures as compared to un-irrigated area.

The rank correlations between yield and maximum average temperature in irrigated and un-irrigated areas are 34 and –27% and with minimum average temperature are 31 and –17%, respectively. It indicates that yield is more affected by average maximum temperature as compared to average minimum temperature. There is 34% positive association between overall average

Table 17. The season temperatures and divisional yield.

		Temprature in Rabi season and divisional wheat yield														
		Average monthly temperature (°C)												Season temp (Avg)		Temp (Avg)
Years	Divisions	Oct		Nov		Dec		Jan		Feb		Mar		Apr				
		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	
2005-2006	Lahore	33	20	27	10	22	4	20	5	25	10	27	14	35	19	27	12	19
	Gujranwala	32	17	25	9	20	5	20	5	24	11	26	12	36	19	26	11	19
	Faislabad	36	21	27	13	21	6	18	4	26	10	28	14	36	19	27	12	20
	Rawalpindi	30	17	25	10	20	2	17	2	24	8	25	10	35	17	25	9	17
	Sargodha	34	18	26	12	20	5	16	4	23	11	24	14	37	20	26	12	19
	Multan	32	21	25	15	22	6	19	6	27	12	27	13	36	19	27	13	20
	Bahawalpur	33	21	27	16	25	5	21	5	28	13	30	16	40	23	29	14	22
	D.G.Khan	33	20	26	13	20	5	17	5	25	13	28	14	35	20	26	13	20
2006-2007	Lahore	32	22	27	14	21	8	20	3	22	9	26	13	37	20	26	13	20
	Gujranwala	31	19	24	13	18	6	17	3	21	8	26	13	37	20	25	12	18
	Faislabad	33	20	24	13	17	7	18	4	21	9	26	13	37	20	25	12	19
	Rawalpindi	32	17	26	13	19	6	16	2	18	7	22	10	34	17	24	10	17
	Sargodha	31	20	23	13	17	7	16	4	20	8	24	12	36	20	24	12	18
	Multan	32	21	26	16	20	8	21	6	21	10	26	13	38	21	26	14	20
	Bahawalpur	36	22	30	15	25	8	23	8	24	11	31	16	42	26	30	15	23
	D.G.Khan	32	23	26	18	21	11	19	7	23	11	28	15	40	22	27	15	21
2007-2008	Lahore	33	15	28	13	21	6	17	2	19	6	29	14	35	19	26	11	18
	Gujranwala	31	17	27	12	20	7	15	3	19	6	29	14	33	17	25	11	18
	Faislabad	32	16	27	11	20	5	16	3	21	6	31	15	33	19	26	11	18
	Rawalpindi	29	14	25	10	19	5	15	3	22	7	30	14	31	16	24	10	17
	Sargodha	31	17	25	12	19	6	15	2	17	5	31	15	33	18	24	11	17
	Multan	33	18	28	14	22	8	18	4	20	7	26	14	38	21	26	12	19
	Bahawalpur	36	20	32	15	23	7	20	5	24	7	30	15	42	24	30	13	21
	D.G.Khan	32	20	27	15	19	9	16	4	19	7	28	15	40	22	26	13	19
2008-2009	Lahore	35	20	29	13	23	8	20	6	23	10	29	14	33	18	27	13	20
	Gujranwala	31	19	26	11	20	7	16	5	21	9	27	13	34	19	25	12	18
	Faislabad	32	20	27	12	20	8	19	6	21	9	29	15	33	20	26	13	19
	Rawalpindi	31	16	25	10	19	7	16	4	19	7	25	11	31	16	24	10	17
	Sargodha	33	20	27	11	20	7	18	6	21	8	29	14	34	19	26	12	19
	Multan	33	21	28	14	21	9	20	8	24	11	29	16	35	20	27	14	21

Table 17. Contd.

	Bahawalpur	38	20	33	17	23	9	21	7	26	11	32	15	38	20	30	14	22
	D.G.Khan	34	22	28	14	19	8	17	6	22	11	27	16	32	19	26	14	20
R	Simple (Irri)	0.29	0.38	0.34	0.26	0.25	0.35	0.56	0.43	0.20	0.27	0.07	0.09	0.11	0.17	0.29	0.38	0.39
	(Unirri)	-0.30	-0.14	-0.12	0.11	-0.22	0.09	0.07	-0.24	-0.13	-0.13	-0.41	-0.59	-0.08	-0.29	-0.28	-0.30	-0.35
	Rank (Irri)	0.26	0.36	0.37	0.25	0.35	0.44	0.55	0.35	0.15	0.22	0.04	0.01	0.09	0.11	0.31	0.34	0.34
	(Unirri)	-0.21	-0.19	-0.05	0.13	-0.19	0.17	0.14	-0.20	-0.16	-0.12	-0.30	-0.59	-0.04	-0.26	-0.17	-0.27	-0.27

temperature of the season and yield in irrigated area where as 27% negative association in un-irrigated area.

Conclusions

As Pakistan is an agricultural country and has an agro-based economy, so government has to make dynamic and sound agricultural policies to attain self-sufficiency in food items especially in case of wheat, which is the most important crop of the country. Pakistan faced a very serious problem of wheat shortage in late 2007. Also Agriculture Department, government of the Punjab regularly prints instructions material for farmers to enhance the production of wheat and gives different directions about the wheat concerning variables discussed above. This study gives an unprecedented statistical / research base support to such sort of instructive material in terms of quantification of impact of these variables on the production of wheat in different dimensions.

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