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Research Paper

Western disturbances: Occurrence and impact on wheat productivity in Punjab

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ABSTRACT

Western disturbances (WD) bring moderate to heavy rain in the northern parts of the country as well as heavy snow to the mountain areas of the Indian subcontinent. It is the source of most of the winter and post-monsoon rainfall in northwest India. Spatio-temporal analysis of western disturbances was carried out by using weather data recorded at Ballowal Saunkhri (sub-mountainous region), Ludhiana (central plain region) and Bathinda (south west region). The WD events per month were lowest in November and highest in March month averaged over all the agroclimatic regions. The highest numbers of WD events were found during February month in the Sub-mountainous region and during March in central plain region and south-western region. Winter rainfall quantity and number of rainfall events were higher in the sub-mountainous region followed by the central plain region and lowest in the south-western region. Higher number of WD during wheat growing season along with less and well distributed rainfall resulting in lower maximum temperature conditions were conducive for higher productivity in Punjab. The significantly positive correlation was observed between the number of western disturbances and wheat productivity during April month at central plain region and southwest region, whereas, the seasonal total number of WDs showed significant positive relationship at submontane region and southwest region.

***Keywords*:** Wheat yield, Western disturbances, Frequency analysis of WD, Correlation, Punjab.

Globally, India ranks third in wheat production, after the European Union and China. India's main wheat production comes from the northwest of the Indo-Gangetic Plain (IGP) (Kumar and Aggarwal, 2014; Singh *et al.,* 2012). Punjab state of India, occupies 1.5 per cent geographical area of the country and contributed 46 per cent wheat to the central pool of India during 2022-23 (Anonymous 2024). Wheat is a *rabi* season crop, sown during October–December and harvested in April-May in Punjab. Wheat requires cool climate for expressing potential productivity. Higher temperatures during the later growth stages reduces the duration of grain formation and hinder proper grain filling. Unusual changes in weather parameters, especially increase in temperature from normal at any growth stage of crop, adversely affect the growth and ultimately the potential productivity of wheat (Anonymous, 2023).

Western disturbances (WD) are quite common during wheat growing season and it alters the microclimate of wheat crop. During the winter season, western disturbances moving from west to east across the north western part of India greatly influence the weather parameters like precipitation, sunshine hours, solar radiation, temperature, humidity and soil moisture. Thunderstorms associated with the WD may occasionally occur during the winter season in Northern India. Increased rainfall during different critical stages (crown root initiation, flowering and physiological maturity) of wheat leads to higher productivity than dry years, while higher night time temperature associated with cloudiness during western disturbances may threatens the productivity (Kalra *et al.*, 2008). Thus, WDs have profound influence on the winter crops as it provides moisture and alters the thermal regimes affecting the growth and productivity of the crops. During *rabi* season the western disturbances are the major phenomenon causing the aberrant change in prevailing weather in north India and affect the production of different crops (Yadav *et al*., 2012; Dadial *et al.*, 2024).

Punjab being irrigated state rainfall may not have that much effect as seen in rainfed or dryland area but decreased day time temperatures and increased night time temperatures associated with the western disturbances have a great impact particularly during

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grain formation and development of wheat. Therefore, it becomes important to study the impact of altered environment (favourable in terms of moisture supply and reduced daytime temperature and unfavourable in terms of increased night time temperatures) due to cloudiness associated with WD on the performance of wheat crop. Therefore, the present study was planned to understand the frequency of occurrence, monthly distribution and rainfall associated with western disturbances and ultimately the impact of WD on performance of wheat.

MATERIALS AND METHODS

The daily rainfall data for October to April months of three stations viz. Ballowal Saunkhri (1984-2022), Ludhiana (1971-2022) and Bathinda (1977-2022) representing respectively sub-mountainous, central plain and south-west agroclimatic zones of Punjab was obtained from agrometeorological observatories situated at Regional Research Stations of Punjab Agricultural University, Ludhiana. The number of continuous days having rainfall was counted as one WD event. Rain on a single day was considered as one WD event. The data of October to April was analysed on a seasonal and monthly basis for all the zones of Punjab. The duration of WD was categorised as one, two, three, four, five and more than five day's duration. The average rainfall per western disturbance was worked out for each month by using the following formula:

Rainfall/WD = Total rainfall in a month / Total number of WD in that month

In order to understand the impact of WD on productivity of wheat the district average wheat productivity data (2001-02 to 2021-22) was collected from the Statistical Abstracts. District wise average productivity of wheat (for 22 years of data) was calculated and then the years with productivity higher and lower than the average value were identified and corresponding monthly total number of western disturbances, total rainfall, average maximum and average minimum temperatures were worked out and correlated with the yield.

RESULTS AND DISCUSSION

Frequency and duration of western disturbances (WD)

Total number of WD during the study period from October to April (*rabi* season) at three stations Ballowal Saunkhri, Ludhiana and Bathinda were 559, 651 and 449 in a time span of 39, 53 and 46 years, with the average number of WDs of 14.3, 12.2 and 9.8, respectively (Table 1). Their total number during different months of *rabi* season varied between 32-110, 43-136 and 30-93, in Ballowal Saunkhri, Ludhiana and Bathinda, respectively. The study revealed that the WD in all three agro-climatic zones can persist from 1-5 days. Dadial *et al.*, (2024) also reported WD of 1-5 days in Solan Himachal Pradesh. Among the durations of WD, the frequency of occurrence of WD of one-day duration was maximum at all the locations. The maximum number of WD per month occurred during March at Ludhiana and Bathinda while during the month of February at Ballowal Saunkhri. Averaged over locations the maximum number of WD occurred during March.

In the sub-mountainous zone (Ballowal Saunkhri), the rainfall per WD was observed highest during October (19.5 mm) and lowest during April month (8.1 mm). The number of WD per month was found to be maximum during February and March (2.8). In the central Punjab (Ludhiana), the highest number of WD were received during March (136) followed by February (130). The rainfall per WD were observed highest during January (14.6 mm) and lowest during the November month (8.2 mm). The highest and lowest number of western disturbances per month was observed during March (2.5) and November (0.8), respectively. In the south western zone, the highest number of WD were received during March (93) followed by February (91). The rainfall per WD were observed highest during October (13.2 mm) and lowest during the November month (7.3 mm). The highest and lowest number of western disturbances per month was observed during March (2.0) and November (0.6), respectively (Table 1).

WD and wheat productivity at Ballowal Saunkhri

At Ballowal Saunkhri, the average wheat productivity during last 22 (2001-02 to 2021-2022) years was 4464 kg ha^{-1}. The monthly average number of western disturbances during the high productivity years was higher than that during low productivity years, except during October (Table 2). The October month has less significance as very few farmers sow the wheat crop during the October month in Punjab, so mainly the wheat growing period received higher number of WD during the high productivity years. The average monthly rainfall during high productivity years was less during the months of October (-30.3 mm), January (-2.8 mm), February (-7.1 mm) and March (-7.2 mm) as compared to low productivity years. The average monthly maximum temperature during the high productivity years was less as compared to low productivity years, except during October (Table 2). The maximum temperature was lower by 1.1 and 1.0 °C during the February and March months of high productivity years as compared to low productivity years. These months coincide with grain development stage so lower temperature helped in getting higher productivity (Sandhu *et al*., 2016; Singh *et al*., 2008). The deviation in minimum temperature due to WDs was not significant and varied between -0.3 to 0.7 °C only. The negative impact slightly higher (0.7 °C) temperature during January might have been modified due to lower temperature during the February. This means that a greater number of WD along with less and well distributed rainfall resulting in lower maximum temperature were conducive for higher productivity of wheat at Ballowal Saunkhri. In the Sub-mountainous region (Ballowal Saunkhri), a significant positive correlation (r= 0.43) between wheat productivity and the total number of WDs during wheat growing season has been observed (Table 2).

WD and wheat productivity at Ludhiana

At Ludhiana, the average wheat productivity during last 22 years was 4849 kg ha^{-1}. The monthly average number of western disturbances during the high productivity years was slightly lower than that during the low productivity years, except during April. Similar trend of monthly rainfall has been observed at Ludhiana, where the average monthly rainfall during high productivity years was less during the months of October (-11.6 mm), January (-4.8 mm), February (-6.2 mm) and March (-5.4 mm) as compared to low productivity years. The average monthly maximum temperature

Table 1: Frequency analysis of western disturbances (WD) of different durations in different agroclimatic regions of Punjab

Month	Frequency (days)						Total (WD)	Rainfall / WD (mm)	No of WD/ month
	One	Two	Three	Four	Five	>five			
Ballowal Saunkhri (1984-2022)									
October	36	8	5	0	0	0	49	19.5	1.2
November	18	8	5	1	0	0	32	7.9	0.8
December	34	15	5	1	1	0	56	16.7	1.4
January	48	39	9	2	1	1	100	15.2	2.6
February	39	43	20	5	3	0	110	15.9	2.8
March	48	37	16	5	4	0	110	10.6	2.8
April	58	27	14	2	0	1	102	8.1	2.6
Total	281	177	74	16	9	2	559		
Ludhiana (1970-2022)									
October	41	7	3	0	0	0	51	11.2	0.9
November	27	14	1	0	1	0	43	8.2	0.8
December	43	19	4	1	0	0	67	11.8	1.2
January	55	42	8	1	2	1	109	14.6	2.0
February	66	44	15	3	0	2	130	13.7	2.4
March	83	31	17	2	3	0	136	8.9	2.5
April	81	21	8	5	0	0	115	8.5	2.1
Total	396	178	56	11	6	3	651		
Bathinda (1977 – 2022)									
October	26	12	3	0	0	0	41	13.2	0.9
November	22	7	1	0	0	0	30	7.3	0.6
December	27	13	2	0	0	0	42	8.6	0.9
January	48	20	6	1	1	0	76	9.7	1.6
February	53	30	7	1	0	0	91	12.5	1.9
March	58	25	10	0	0	0	93	9.3	2.0
April	56	13	5	0	1	1	76	8.5	1.6
Total	290	120	34	2	2	1	449		

Table 2: Occurrence of western disturbances and rainfall during above and below average productivity (4464 kg ha^{-1}) years at Ballowal Saunkhri

Parameter	Oct	Nov	Dec	Jan	Feb	Mar	Apr
High productivity years (>4464 kg ha^{-1})							
No of WD	1.0	1.2	1.5	2.5	3.1	3.0	3.0
Rainfall (mm)	8.2	7.4	19.6	41.0	40.9	28.0	26.3
Max. temp. (°C)	26.8	21.2	18.5	22.9	28.2	34.9	26.8
Min. temp. (°C)	16.6	10.9	6.7	5.9	8.6	13.3	18.4
Low productivity years (<4464 kg ha^{-1})							
No of WD	1.5	0.4	1.3	2.1	2.6	2.4	2.4
Rainfall (mm)	38.5	1.7	17.8	43.8	48.0	35.2	21.7
Max. temp. (°C)	31.8	27.3	22.0	18.6	24.0	29.2	35.3
Min. temp. (°C)	16.9	10.6	6.4	5.2	8.7	13.3	18.3
Correlation between yield and WD							
Seasonal	Oct	Nov	Dec	Jan	Feb	Mar	Apr
0.43*	0.14	0.12	0.08	-0.17	0.16	0. 20	0.23

*Significant correlation at 0.05%

during the high productivity years was less as compared to low productivity years, except during October and January having slightly higher temperatures of 0.4 and 0.3 °C, respectively (Table 3). The maximum temperature was lower by 0.4, 1.0 and 1.5 °C during the February, March and April months of high productivity years as compared to low productivity years, respectively (Saikia *et al.*, 2011). These months coincide with grain formation and development stages so lower temperature helped in getting higher productivity. The deviation in minimum temperature due to WDs was not significant and varied between -0.8 to 0.3 °C only. The slightly

Table 3: Occurrence of western disturbances and rainfall during above and below average productivity (4849 kg ha^{-1}) years at Ludhiana

Parameter	Oct	Nov	Dec	Jan	Feb	Mar	Apr
High productivity years (>4849 kg ha^{-1})							
No of WD	0.5	0.7	1.1	2.0	2.3	2.0	2.8
Rainfall (mm)	4.2	6.1	12.8	30.7	31.5	20.1	24.7
Max. temp. (°C)	32.1	26.5	20.2	17.4	21.6	27.6	34.7
Min. temp. (°C)	17.9	11.4	7.0	6.1	8.7	13.1	18.6
Low productivity years (<4849 kg ha^{-1})							
No of WD	1.3	0.7	1.1	2.2	2.5	2.5	1.6
Rainfall (mm)	15.8	2.4	8.3	35.5	37.7	25.5	16.2
Max. temp. (°C)	31.5	26.5	20.4	17.1	22.0	28.6	36.2
Min. temp. (°C)	17.6	11.1	7.1	6.4	9.1	13.9	19.1
Correlation between yield and WD							
Seasonal	Oct	Nov	Dec	Jan	Feb	Mar	Apr
-0.21	-0.32	-0.04	-0.20	0.002	0.03	0.02	0.44*

*Significant correlation at 0.05%

Table 4: Occurrence of western disturbances and rainfall during above and below average productivity (4631 kg ha^{-1}) years at Bathinda

Parameter	Oct	Nov	Dec	Jan	Feb	Mar	Apr
High productivity years (>4631 kg ha^{-1})							
No of WD	0.5	1.0	0.5	2.1	2.3	2.4	1.9
Rainfall (mm)	2.9	6.0	2.1	11.1	12.8	26.2	11.3
Max. temp. (°C)	33.0	27.0	20.8	17.4	22.4	28.3	35.9
Min. temp. (°C)	17.3	10.8	6.0	5.9	8.2	12.9	18.6
Low productivity years (<4631 kg ha^{-1})							
No of WD	1.0	0.3	0.7	1.3	1.8	1.3	1.4
Rainfall (mm)	14.9	1.9	9.8	14.3	26.0	10.8	9.5
Max. temp. (°C)	33.1	28.2	21.8	17.8	22.4	29.4	37.1
Min. temp. (°C)	17.5	10.6	6.2	4.9	7.9	12.8	18.1
Correlation between yield and WD							
Seasonal	Oct	Nov	Dec	Jan	Feb	Mar	Apr
0.53*	-0.38	0.22	-0.02	0.49*	0.26	0.28	0.42*

*Significant correlation at 0.05%

higher temperature (0.3 °C) during both October & November does not affect much but lower temperature during January (0.3 °C) and February (0.4*°C*) definitely played a significantly positive role in improving the crop productivity. This means that lesser number of WD (during January to March) along with less and well distributed rainfall coupled with lower maximum and minimum temperature (during February and March) and higher number of WDs along with higher rainfall during April having significantly lower maximum (-1.5 °C) and minimum temperature (-0.5 °C) resulting in higher productivity at Ludhiana. Generally, wheat crop matures in April month but in case of active WDs the maturity may get delayed up to May month. Thus, delayed harvesting caused by lower temperature during April might also had contributed to higher productivity of wheat. A significant positive correlation (r= 0.44) between wheat productivity and the number of WDs in April month was observed at Ludhiana (Table 3).

WD and wheat productivity at Bathinda

At Bathinda, the average wheat productivity during last 22 years was 4631 kg ha^{-1}. The monthly average number of western disturbances during the high productivity years was higher than that during low productivity years, except during October and December. The October month has less significance as very few farmers sow the wheat crop during the October month in Punjab, so mainly the wheat growing period received higher number of WD during the high productivity years. The average monthly rainfall during high productivity years was less during the months of October (-12.0 mm), December (-7.8 mm), January (-3.2 mm) and February (-13.2 mm) as compared to low productivity years. The average monthly maximum temperature during the high productivity years was less as compared to low productivity years, except during February (Table 4). The maximum temperature was lower by 1.1 and 1.2*°C* during the March and April of high productivity years as compared to low productivity years. These months coincide with grain development stage so lower temperature helped in getting higher productivity. The deviation in minimum temperature due to WDs varied between -0.2 to 1.0 *°C*. This means that more number *of WD* during January to April along with less and well distributed rainfall resulting in lower maximum temperature were conducive for higher productivity at Bathinda. A significant positive corelation was observed between wheat productivity and the number of WDs during January (r=0.49) and April (r=0.42) months and also with total number of WDs during the whole wheat growing season (r=0.53) (Table 4).

The analysis highlights that, averaged upon the regions, the higher number of WDs, coupled with well distributed rainfall, lower maximum and minimum temperatures are conducive for higher wheat productivity. The impact of WDs is more significant during the reproductive and grain development stages of wheat which falls during January to April months in this part of India. Dadial *et al.* (2024) also reported that the number of western disturbances during January to March had favourable effects on wheat, barley and peach crops in Himachal Pradesh while the same during April and May had adverse effects on these crops.

CONCLUSIONS

Analysis of occurrence of western disturbances was carried out by using weather data recorded at BallowalSaunkhri (sub-mountainous region), Ludhiana (central plain region) and Bathinda (south west region). The analysis highlighted that the total number of WD events per month were lowest in November and highest in March month. The duration of WDs were found to be 1-5 days. The amount of rainfall per western disturbance and total numbers of one-day rain events were lowest during November. The analysis highlights that the higher number of WDs, coupled with well distributed rainfall, lower maximum and minimum temperatures are conducive for higher wheat productivity. The impact of WDs was more significant during the reproductive and grain development stages of wheat which falls during January to April months in this part of India.

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