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Effect of weather parameters on dry matter production of chickpea under different tillage and irrigation practices

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Abstract
A field experiment was conducted during the winter (*rabi*) season of 2019-20 and 2020-21 at Dhab research farm, Rajendra Prasad Central Agricultural University, Pusa, Bihar, India, to study the effect of weather parameters on dry matter production of chickpea under different tillage and irrigation practices. The treatment consisted of two tillage practices, including conventional and conservation tillage, and two irrigation methods, viz., flood and sprinkler irrigation. The treatments were allocated in a split-plot design with three replications. The results indicated that concerning tillage practices, conventional tillage produced significantly higher dry matter production at all stages over zero tillage. In the case of irrigation methods, sprinkler irrigation was the most effective, producing significantly higher dry matter production during both years. Correlation and regression studies weather parameters and dry matter production resulted that all weather parameters positively influenced dry matter production, except for the relative humidity. However, total evaporation was the most significant factor influencing dry matter production more than other weather parameters.

Keywords: Weather parameters, dry matter production, chickpea, tillage, irrigation practices

1. Introduction
As a pulse crop, chickpea is a major cultivated pulse during the rabi season in India's western and northern regions and is a great food source for protein. Chickpea increases the efficiency of the soil in terms of nitrogen that can be redeemed from fertilizer sources and increase soil fertility by providing the biological nitrogen source. Chickpea can fix the nitrogen up to 140 kg ha^{-1} in a growing period (Poonia and Pithia, 2013) [12]. The soil moisture in medium to low land helps ensure germinability, growth, and development for chickpea (Pande *et al.*, 2012) [14]. In the rainy (*kharif*) season, crops rely on rainwater for moisture sources, while in the winter (*rabi*) season, crops are completely dependent on residual soil moisture and snowfall (Dhar *et al*. 2008) [4]. The soil moisture content is directly influenced by irrigation and tillage practices. Tillage can affect the key properties of soil, like temperature, moisture, and density. So, the right practice of tillage techniques can provide the most appropriate plant growth and the yield. Conventional tillage can improve the growth and yield of chickpea by creating suitable seed beds, breaking down impermeable soil layers, cleansing soil surface from plant debris and discontinuing the life cycle of insects, weeds and diseases. However, these methods take a significant amount of energy and, over time, can damage the soil's physical properties and cause erosion (Quddus *et al.*, 2020) [13]. The practice of no-tillage increases the water permeability and the amount of moisture in soils because of the increase in soil organic matter and the activity of earthworms compared to conventional tillage systems. Furthermore, the use of no-tillage practices and freezes on the soil will decrease the expense of energy use (Salihi *et al.*, 2017) [16]. Chickpea is a victim of high temperatures and drought in this reproduction stage, which produces fewer pods and seeds and, ultimately, lower harvests (Fang *et al.*, 2010) [7]. In order to overcome the decrease in yield caused by drought, chickpea is cultivated with additional irrigation in the west of Asia and the northern part of India (Anonymous, 2003) [2], which enhances the productivity of the chickpea (Erman *et al.*, 2011) [6]. The application of one irrigation (Munirathnam and Sangita, 2009) [11], two irrigations (Abraham *et al.*, 2010) [1] or three irrigations (Mansur *et al.*, 2010) [10] has been found to boost yields of chickpea grain significantly. However, the actual number of required irrigations depends on many factors, including rainfall, soil texture, weather conditions, and crop duration.

Chickpea is directly influenced by temperature, relative humidity, rainfall, evaporation and solar radiation. It requires a fairly cold and dry climate. Severe cold and frost, particularly during the flowering or pod initiation stages, are harmful to the development of flowers to seeds. Temperature is a major factor in determining the development and growth of crops (Zinn *et al*., 2010) [20]. Relative humidity of 21-41% is optimum for the seed set. The plants grow well in areas have annual rainfall between 600 - 1000 mm (Sahu *et al*., 2021) [15].

2. Materials and Methods

The field experiment was carried out during the *rabi* season of 2019-2020 and 2020-2021 at *Dhab* Research farm, Dr RPCAU, Pusa, Bihar, India, located on the southern bank of river Bhurhi Gandhak at 25.98° North latitude and 84.69° East longitudes with an altitude of 52.92 m above the mean sea level. The soil of the experimental plot was sandy loam in texture with pH 7.63, EC 0.18 dSm^{-1}, medium in organic carbon (0.69%), medium in available nitrogen (268.3 kg/ha), low in phosphorus (20.4 kg/ha) and low in potassium (112.5 kg/ha). The combination treatments were used for two tillage practices, conventional tillage and conservation tillage, and two irrigation methods, flood and sprinkler irrigation. The treatments were evaluated in a split-plot design with three replications. "Sabour Chana-1" was taken as the test variety and sown in line manually with the help of a hand plough at 30 x 10 cm spacing in the respective tillage treatment plot. Irrigations were applied before flowering with respective irrigation methods of flood and sprinkler irrigation. All the recommended packages of practices of chickpea crops were adopted during the study period. The biometric observations at various growth phases, *viz*., Seedling vegetative, reproductive and maturity phase and the yield attributes were recorded at the time of harvest.

2.1 Meteorological Data collection

Meteorological data were recorded from Dr. Rajendra Prasad Central Agricultural University, Pusa's meteorological observatory for various phenophases viz., seedling, vegetative, reproductive and maturity phases. Actual weather parameters prevailed during the cropping period of both years given in table 1 and 2.

Table 1: Actual weather parameters prevailed during cropping period at different phenological phases of chickpea (05.11.2019 -26.03.2020).

Weather Parameters (2019-2020)							
	Mean Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Evaporation (mm)	Bright Sunshine Hours (hrs.)
Phenological stages of chickpea	Maximum	Minimum	Morning	Evening			
Seedling	27.65	15.08	92.94	67.83	0.00	58.80	182.00
Vegetative	18.67	8.78	91.69	76.56	23.80	29.30	36.90
Reproductive	23.02	10.20	91.43	65.86	28.40	63.00	283.30
Maturity	27.57	15.42	91.55	62.45	29.60	58.80	227.00

Table 2: Actual weather parameters prevailed during cropping period at different phenological phases of chickpea (18.11.2020 -08.04.2021)

Weather Parameters (2020-2021)							
	Mean Temperature (°C)		Relative Humidity (%)		Rainfall (mm)	Evaporation (mm)	Bright Sunshine Hours (hrs.)
Phenological stages of chickpea	Maximum	Minimum	Morning	Evening			
Seedling	23.93	12.08	93.00	68.39	0.00	36.90	135.90
Vegetative	20.38	9.29	94.53	71.64	0.00	43.40	149.40
Reproductive	26.30	12.76	90.83	64.31	0.00	95.00	309.70
Maturity	33.48	17.88	84.11	45.43	0.00	110.70	225.25

2.2. Correlation and regression analysis

The data collected on various crop growth phases were correlated with weather parameters at seedling, vegetative, reproductive and maturity phases to establish the relationship using a t-test. The significant relationship was further regressed using stepwise regression to arrive at a valid regression equation using SPSS software.

$$r = \frac{\sum xy}{(\sum x) - (\sum y)}$$

Where,
r = Correlation coefficient
x = Independent variable (attributes)
y = Dependent variable (yield)

The coefficient of determination (R^2) ranges from 0 to 1, where 0 indicates no agreement and 1 indicates a perfect agreement between predicted and observed data (Willmott, 1984) [18] Combination of different weather parameters will be worked out to find out the influence of weather parameters on Dry matter production under different growth stages.

2.3. Regression equation

After analysis, a simple equation has been developed, which may be a useful tool for yield prediction of chickpea crops in the region.

$$Y = a + (b_1)(x_1) + (b_2)(x_2) + (b_3)(x_3)$$

Where,
Y = Predicted yield
a = intercepted
b_1, b_2, b_3= Regression and X_1, X_2, X_3 = Dependent variables

3. Result and Discussion

3.1. Effect of tillage and irrigation practices on dry matter production (g/plant) of chickpea

Both tillage and irrigation practices significantly influenced the dry matter production of chickpea. Among the two-tillage practices, conventional tillage produced significantly higher dry matter production (Table. 3) in seedling (1.46), vegetative (5.60), reproductive (16.71) and maturity phase (22.22) of chickpea for both years as compared to zero tillage. It was due to conventional tillage creates good soil environments for chickpea by breaking hard soil pans and loosening soil which causes increasing root penetrability; due to proper root penetration, the plant can uptake nutrients and moisture sufficiently for appropriate growth and development (Kumar and Angadi, 2016). Concerning irrigation methods, sprinkler irrigation produced significantly higher dry matter production in vegetative (5.19), reproductive (16.29) and maturity phases (24.51). Nevertheless, no significant effect was found in the seedling phase of both years over than the flood irrigation (Table.3). This might be due to sprinkler irrigation can reduce crop transpiration by more than 50% during the irrigation process (Eid *et al*., 2014) [5], The sprinkler irrigation was increasing in photosynthesis rate and reduction in leaf respiration rate at night (Yang *et al*., 2000) [19]. Silber *et al*. (2003) [17] discovered that optimal water content in root zones might reduce variations in nutrient concentrations, increasing their availability for plants.

Table 3: Effect of tillage and irrigation practices on dry matter production in different phenological phases of chickpea (Pooled data for 2019-20 and 2020-21)

Dry matter production (g/plant)				
Treatments	**Seedling phase**	**Vegetative phase**	**Reproductive phase**	**Maturity phase**
A. Tillage practices				
Conventional tillage	1.46	5.60	16.71	22.22
Conservation tillage	0.93	3.80	14.20	21.79
S. Em±	0.020	0.150	0.150	0.140
CD (P = 0.05)	0.120	0.900	1.890	0.890
B. Irrigation methods				
Conventional irrigation	1.15	4.21	14.61	23.03
Sprinkler irrigation	1.24	5.19	16.29	24.51
S. Em±	0.030	0.120	0.140	0.250
CD (P = 0.05)	NS	0.460	0.540	0.970

3.2. Effect of weather parameters on dry matter production of chickpea

The correlation studies showed that the weather parameters of mean minimum and maximum temperature, total rainfall, total evaporation and total bright sunshine hours positively influenced the dry matter production of chickpea in all the phenological phases. In contrast, mean morning and evening relative humidity negatively affected dry matter production, but no significant relationship was recorded between dry matter production and weather parameters in the first-year crop season (2019-20). In the second-year crop season (2020-2021), rainfall did not influence the biomass yield, whereas all other weather parameters were influenced positively. However, the total evaporation alone had associated significantly positive on dry matter production of chickpea under different tillage and irrigation practices (Table.4 and 5). During the cropping period, the second-year total evaporation was received 285.3 mm. Chickpea is more sensitive to the higher moisture content, so higher evaporation may remove the extra moisture from the soil and create appropriate soil environments for crop growth.

Regarding the stepwise regression equation developed between dry matter production and weather parameters, in the first year (2019-20), the data revealed that among the weather parameters, mean maximum temperature, rainfall and bright sunshine hours only significantly contributed to the biomass of chickpea to the extent of 96.0, 97.0, 92.0 and 93.0 per cent in conventional tillage, zero tillage, flood irrigation and sprinkler irrigation respectively (Table.6). Whereas, second-year crop season (2020-21) only mean evening relative humidity, evaporation and bright sunshine hours contributed significantly on the dry matter of chickpea to the extent of 95.0 and 92.0, 95.0 and 96.0 per cent in conventional tillage, zero tillage, flood irrigation and sprinkler irrigation respectively (Table.7). It could be explained for ideal requirements of temperature, rainfall, evaporation and bright sunshine hours and received rainfall once in vegetative stage may influence significantly on dry matter production (Sahu *et al*., 2021) [15]. Chickpea responds well at 18 °C - to 20 °C during the vegetative and 20 °C to 25 °C of maximum temperature (ICRISAT, 2011) [3]. Solar radiation's interception directly influences chickpea's dry matter by increasing photosynthesis (Hughes *et al*., 2003) [8].

Table 4: Correlation co-efficient between direct weather parameters and dry matter production of chickpea in different tillage systems

Sl. No	**Weather parameters**	**Conventional Tillage**		**Conservation Tillage**	
Dry matter Production					
		2019-2020	**2020-2021**	**2019-2020**	**2020-2021**
1	Mean maximum temperature	0.223 NS	0.846 NS	0.324 NS	0.892 NS
2	Mean minimum temperature	0.150 NS	0.792 NS	0.265 NS	0.848 NS
3	Mean Relative humidity Morning	-0.765 NS	-0.870 NS	-0.693 NS	-0.918 NS
4	Mean Relative humidity evening	-0.690 NS	-0.845 NS	-0.744 NS	-0.900 NS
5	Total rainfall	0.813 NS	-	0.752 NS	-
6	Total evaporation	0.443 NS	0.992**	0.480 NS	0.982*
7	Total bright sunshine hours	0.622 NS	0.772*	0.631 NS	0.699*

Table 5: Correlation co-efficient between direct weather parameters and dry matter production of chickpea in different irrigation methods

Sl. No	Weather parameters	Conventional Irrigation Method		Sprinkler Irrigation	
Dry matter Production					
		2019-2020	2020-2021	2019-2020	2020-2021
1	Mean maximum temperature	0.314 NS	0.900 NS	0.275 NS	0.885 NS
2	Mean minimum temperature	0.258 NS	0.858 NS	0.218 NS	0.839 NS
3	Mean Relative humidity Morning	-0.700 NS	-0.927 NS	-0.728 NS	-0.913 NS
4	Mean Relative humidity evening	-0.736 NS	-0.911NS	-0.711 NS	-0.895 NS
5	Total rainfall	0.759 NS	-	0.784 NS	-
6	Total evaporation	0.469 NS	0.977*	0.445 NS	0.982*
7	Total bright sunshine hours	0.621 NS	0.679 NS	0.607 NS	0.702 NS

*Significant at 5% level, ** Significant at 1% level, NS: Non-Significant

Table 6: Stepwise regression equation for direct weather parameters and dry matter production of chickpea in different tillage practices and irrigation methods during 2019-2020

Sl. No.	Regression equation	Factors	R^2	Level of significance
1	Y=-31.7847+ 1.109908maxT +0.671476RF + 0.013737BSSH	CT	0.96	1%
2	Y= -42.188+ 1.526821maxT +0.703153RF + 0.004803BSSH	ZT	0.97	1%
3	Y= -42.5658+ 1.555201maxT +0.7214RF + 0.003724BSSH	CI	0.92	1%
4	Y= -41.7891+ 1.521132maxT +0.759622RF + 0.005073BSSH	SI	0.93	1%

CT: Conventional tillage
ZT: Conservation tillage
CI: Conventional irrigation
SI: Sprinkler irrigation
Y = Expected dry matter production (g/plant)
maxT: Maximum Temperature
RF: Total Rainfall
BSSH: Bright Sun Shine Hours

Table 7: Stepwise regression equation for direct weather parameters and dry matter production of chickpea in different tillage practices and irrigation methods during 2020-2021

Sl.No.	Regression equation	Factors	R^2	Level of significance
1	Y= -45.2733+ 0.553726RH2 +0.555048EVP-0.08518BSSH	CT	0.95	1%
2	Y= -32.4827+ 0.384268RH2 +0.510949 EVP -0.08611BSSH	ZT	0.92	1%
3	Y= -31.8765+ 0.380673RH2 +0.5345668EVP-0.09347BSSH	CI	0.95	1%
4	Y= -42.0278+ 0.513346RH2 +0.613166EVP-0.10622BSSH	SI	0.96	1%

CT: Conventional tillage
ZT: Conservation tillage
CI: Conventional irrigation
SI: Sprinkler irrigation
Y = Expected dry matter production (g/plant)
RH2: Evening Relative Humidity
EVP: Evaporation
BSSH: Bright Sun Shine Hours

4. Conclusion
The study proved that chickpea cultivated under conventional tillage and sprinkler irrigation produced higher dry matter in both years. The all-weather parameters directly affect chickpea's dry matter production under different tillage and irrigation practices. The plant had a positive effect when it received an optimum range of weather parameters; otherwise, it showed a negative effect.

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