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Effect of weather parameters on productivity of soybean crop

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Abstract
The stepwise regression equation method was used to assess the effect of weather parameters on productivity of soybean crop in Udham Singh Nagar district of Uttarakhand, India. The analysis was done for ten years (2007 to 2016) considering different growth stages. SPSS showed both positive and negative effect of weather variables in different months of the year. The yield and weather elements were considered as dependent and independent variables, respectively. Three regression equation models were developed to see the correctness of the model. Model 1, Model 2 and Model 3 showed R values as 0.71, 0.95 and 0.98, respectively. Model 3 showed highest accuracy. The observed and predicted yield was then compared to make model more accurate for work. The comparison of weather factors with observed soybean yield showed that increasing yield was obtained in bright sunshine hour and maximum temperature whereas minimum temperature of week decreased crop yield in all ten years. The result of SPSS version 16 showed that bright sunshine hours (BSS) of 1st week of July was the most important factor to influence crop productivity followed by average minimum temperature of 4th week of October and average maximum temperature of 1st week of November, respectively.

Keywords: Soybean, productivity, SPSS, regression equation models, weather variables, Bright Sunshine Hours (BSS).

Introduction
Soybean is an important economic crop with average 40% protein. It is an important oilseed crop of the world and used for several purpose such as feed, soyfood products and oil [1]. In 2019, India's soybean production and productivity was 9 MMT and 800 kg/ha, respectively, while documented sowing area under soybean in kharif season of 2019 was 107.615 lakh ha. [2]. The changing climatic patterns have prompted the scientists to keep a check on depleting growth variables of soybean crop so as to sustain and augment its production and yield. Weather plays a vital role in regulation of crop yield [3]. The Indian agriculture is highly dependent on weather conditions. By modifying the microclimate of a crop, better growth and development of crop can be achieved which will lead to an increase in its yield [4]. Weather parameters like maximum and minimum temperature, precipitation, relative humidity, bright sunshine hours etc. are widely used as effective indicators in the formulation of standard empirical statistical models considering multiple linear regression methods [5]. The 'Statistical Package for the Social Sciences' (SPSS) is a software used for analyzing and presenting data sets [6]. The SPSS can be used for calculation of Linear Regression and multiple regression equations. The Linear Regression analysis can identify relationship between independent and dependent variables [7].

Materials and Methods
The study to determine effects of individual weather parameters on productivity of soybean crop using SPSS (Statistical Package for Social Sciences) software was conducted for Udham Singh Nagar district of Uttarakhand. The metereological data alongwith crop yield were used to simulate weather parameter's effect on crop yield by using SPSS model following Zhu *et al.* 2010 [8]. The weather parameters were taken as independent factors whereas yield was taken as dependent factor. The soybean yield data (in tons per ha) [9] for 10 years (2007 to 2016) and

corresponding weather data (Source: Dapartment of Agrometeorology, GBPUA&T, Pantnagar) were taken from authentic government sources.

The mean weekly data of various weather variables such as rainfall, bright sunshine hours, relative humidity, wind speed, evapotranspiration, maximum and minimum temperature were used in this study. The average weekly weather data was calculated for 10 years (2007 to 2016) and a multiple regression model (meteorological model) was developed using SPSS similar to Singh *et al*. (2014) [10]. The predicted and observed yields of 10 years (2007 to 2016) were then further compared to check performance of 'meteorological models'. The model performance was evaluated by calculating percent RMSE following Jain (2016) [11] and Amir *et al*. (1991) [12]. The efficiency of developed 'meteorological model' was examined by predicting soybean yield using equations generated by SPSS. The RMSE was calculated between predicted and observed yield following Palosuo *et al.* (2011) [13].

Result and Discussion

Table 1: Meteorological yield models of soybean crop based on the weekly weather parameter

Model No.	Regression Equation	R^2
1	$Y= 0.62+0.14*X_1$	0.71
2	$Y=2.156+0.098*X_1-0.087*X_2$	0.95
3	$Y=-1.14+0.099*X_1-0.078*X_2+0.107*X_3$	0.98

where, Y = Yield (q ha^{-1}), X_1 = Average Bright Sunshine Hours (BSS) of 1st week of July, X_2= Average minimum temperature of 4th week of October, X_3= Average maximum temperature of 1st week of November.

Table 1 showed that by adding more weather variables in a regression equation, the accuracy of yield prediction can also be increased. The accuracy of yield prediction using regression equation is directly proportional on the number of weather variables present in equation. The first meteorological model considered mean bright sunshine hour (BSS) of 1st week of July as most important factor that can influence crop yield similar to Pandey *et al*. (2015) [14]. The second and third weather variables affecting crop productivity were average minimum temperature of 4th week of October and mean maximum temperature of 1st week of November, respectively. SPSS results emphasised that soybean yield was dependent primarily on these three weather variables. The co-efficient of determination (R^2) was used to show relationship between yield and weather elements. This analysis showed the positive and negative influence of weather elements on soybean yield as was depicted by Landau *et al*. (2000) [3].

Table 2: Simulated yield of various model by SPSS

Year	Y_O	Y_P Model 1	Y_P Model 2	Y_P Model 3
2007	1.60	1.63	1.55	1.57
2008	1.45	1.65	1.57	1.49
2009	1.93	1.72	1.93	1.92
2010	1.18	1.33	1.14	1.21
2011	1.29	1.22	1.21	1.21
2012	1.56	1.38	1.55	1.57
2013	1.13	1.30	1.11	1.11
2014	0.92	1.06	1.01	0.93
2015	1.06	0.98	1.11	1.08
2016	1.36	1.19	1.29	1.38
RMSE		0.15	0.06	0.03
%RMSE		11.35	4.79	2.62

where, Y_O: Observed Yield; Y_P: Predicted Yield

Table 2 depicts both observed [8] and predicted yield (calculated using SPSS) of soybean for ten years (2007 to 2016). The three different predicted yields were calculated by SPSS for getting accurate results of yield, in turn, for which three models (M_1, M_2 and M_3) were developed. In the first model (M_1), only bright sunshine hours of 1st week of July was taken to predict soybean yield. The second weather factor affecting soybean yield viz., minimum temperature of 4th week of October was then further considered alongwith bright sunshine hours of 1st week of July in M_2 to develop more accurate simulation results. The second model (M_2) predicted soybean yield by using equation $Y=2.156+0.098*X_1-0.087*X_2$. It was found that second equation gave slightly better result than M_1 but underestimated the yield. The SPSS showed best result with third model (M_3) which included maximum temperature of 1st week of November in its equation alongwith other two factors to predict soybean yield. By using this process, it was found that adding more weather variables can predict better results in SPSS. The percent RMSE values between observed and predicted yield of M_1, M_2 and M_3 were 11.35, 4.79 and 2.62, respectively. The model 3 was more accurate than other models.

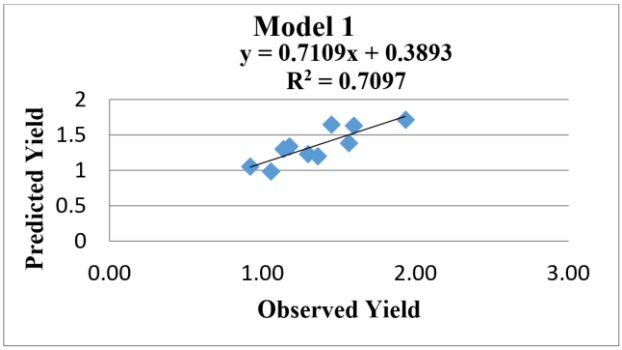

Fig 1: Scatter plot showing correlation between predicted and observed yield (Model 1)

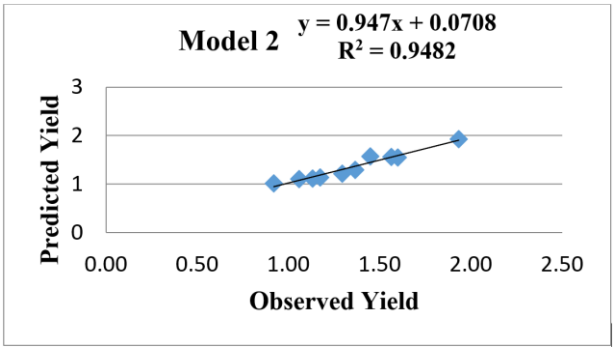

Fig 2: Scatter plot showing correlation between predicted and observed yield (Model 2)

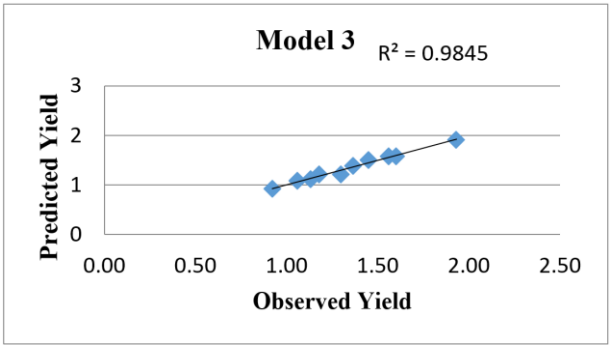

Fig 3: Scatter plot showing correlation between predicted and observed yield (Model 3)

Fig. 1 showed the correlation between predicted and simulated yield using bright sunshine hour data. The R^2 value depicted that predicted yield was related to observed yield. Model 1 contained only one variable to predict soybean yield. The graph of model 1 showed predicted yield based on only one weather variable which affected soybean yield more than any other variable. The result showed that predicted yield was close to observed yield for all ten years. Model 2 included bright sunshine hours and minimum temperature to predict all ten years yield. It was found that model 2 gave better results than model 1 (Fig 2). Fig. 3 showed best result among all three models. The strong correlation was found between predicted and observed yield. It was found that as we considered more weather parameters in developing models to predict soybean yield the result got more finer and accurate. The similar results were reported by Ranjan *et al*. (2012) [15] for wheat at Pantnagar in which they found positive relation between observed and predicted yield.

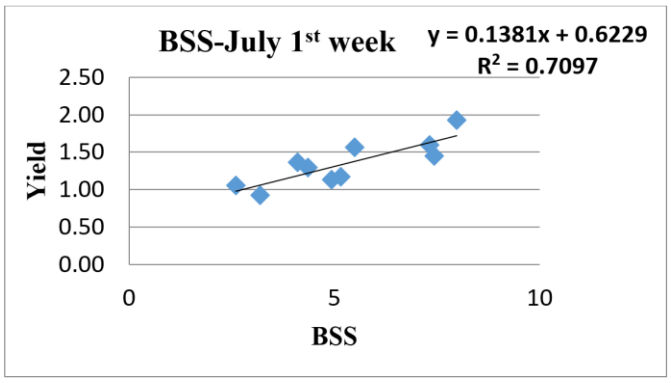

Fig 4: Scatter plot depicting correlation between BSS of July 1st week and soybean yield

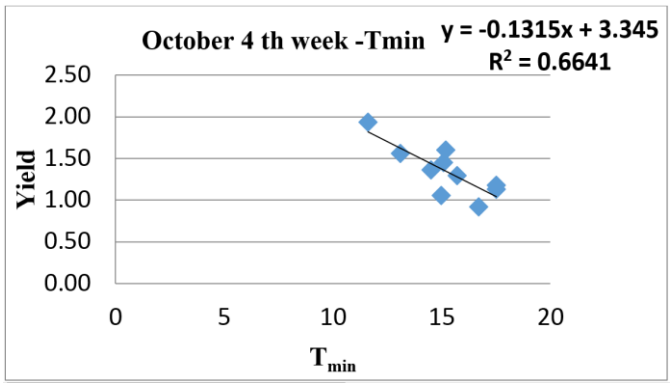

Fig 5: Scatter plot depicting correlation between minimum temperature of October 4th week and soybean yield

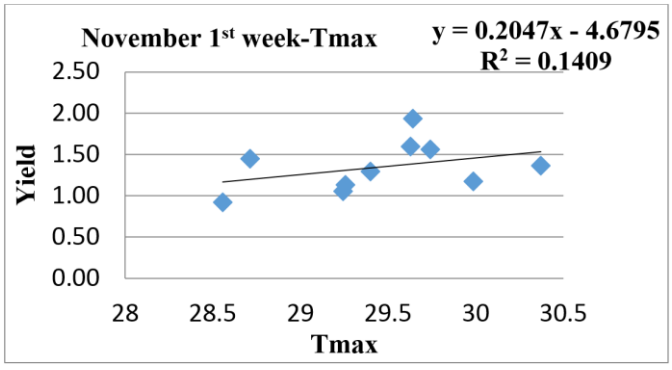

Fig 6: Scatter plot depicting correlation between maximum temperature of November 1st week and soybean yield

Fig. 4 showed that bright sunshine hours had positive effect on soybean yield. It may be due to increase in photosynthesis rate of crop as was found Long *et al*. (2006) [16]. The first week of July at study area, viz., Pantnagar observed soybean in its vegetative stage which mostly requires good amount of sunshine hours for its early development and growth stages. The bright sunshine at initial stage of crop development is beneficial for increasing dry matter of crop. The increase in bright sunshine hour also increase the photosynthesis rate in soybean crop which increased dry matter in shoots. Bright sunshine hour shows intense effects on yield and productivity of some crops like rice etc. as compared to wind velocity and rainfall [13]. Fig. 5 depicted that minimum temperature had negative effect on soybean yield. At Pantnagar, in fourth week of October, soybean started its maturity phase. Soybean is a heat loving crop and require higher temperature during its maturity phase so increasing the minimum temperature during maturity stage will have negative effect on its seed yield [17]. Fig. 6 showed that maximum temperature of November first week had positive effect on crop yield. It may be due to the fact that in November first week soybean was in its ripening stage at Pantnagar and as the temperature increases it would create suitable conditions for ripening and moisture management in crop as was found by Kumar *et al*. (2008) [18].

Conclusion

The bright sunshine hour (during 1st week of July) was found as the most important parameter that affected soybean yield followed by minimum temperature (during 4th week of October) and maximum temperature (during 1st week of November). The percent RMSE between simulated and observed yield for model 1, model 2 and model 3 was 11.35, 4.79 and 2.62, respectively. The model 3 was found to be the best method for predicting weather's effect on soybean yield. From this research, it can be concluded that SPSS may be used to predict effect of weather parameters on soybean yield.

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