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Growth and Yield Responses of Soybean under Rainfed Condition in Selected Districts of Madhya Pradesh, India

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ABSTRACT

This study is aimed at assessing the impact of rainfall distribution pattern on the growth and yield of soybean crop in selected districts of Madhya Pradesh. The crop growth is found to be more sensitive to rainfall pattern at critical stages. Prolonged dry spells at critical life stages of the soybean crop are found to adversely affect crop development and growth and hence the yields at selected sites. Rainfall and yield data of selected districts of Madhya Pradesh were collected and analysed for the period of 11 years (2004-2014). Stage wise yield reduction of soybean due to less amount of rainfall at critical stages was determined. Crop water requirement of soybean was determined through CROPWAT 8.0 software for selected districts. Our findings show that, repeatedly low rainfall at vegetative stage resulting yield reduction in almost all selected districts of MP. Deficient rainfall during the growing season at critical stages could be a crucial factor for the soybean productivity.

Introduction

Agriculture continues to draw a major share (90%) of available water resources and the demand is likely to increase further (Amarasinghe *et al.,* 2008). MP has a unique distinction of having more than 87% soybean (*Glycine max*) (Dwivedi *et al.,* 2006) area of the country and is rightly designated as Soya State. Soybean is one of the major kharif crop in the rainfed agro ecosystem of central and peninsular India. The state Madhya Pradesh contributes 60% of the total area under soybean production in the country. The crop is predominantly grown on vertisols and associated soils with an average crop season rainfall of about 900 mm. Though this varies greatly across locations and years. Over the globe several studies quantitatively examined the warming impacts on soybean grain yields and reported significantly decreased in grain yields with rise in temperature during growing season. But there have been few studies in

India aimed at understanding the nature and magnitude of gains/losses in yields of soybean crop under different climatic scenarios. Soybean cultivation in India has steadily increased. It was a minor crop during the early 1970s but at present, it occupies third place in the oilseed production in India. The area under soybean in India has rapidly increased from 0.03 million ha in 1970 to 2.6 million ha in 1990 and to 5.7 million ha in 2000. Increased soybean production is mainly driven by increased area sown to the crop. In 2000, the soybean production was 5.4 million t. The progress in soybean production is most impressive, however, these growth figures belie the fact that the productivity continues to remain low and major steps are required to enhance production by increasing productivity rather than increasing area under the crop.

In India, soybean crop is primarily cultivated in the states of Madhya Pradesh, Rajasthan, Maharashtra, and Uttar Pradesh. Currently Madhya Pradesh accounts for nearly 87% of the area under the crop in the country and contributes about 83% of the total national production. Therefore, the present study was undertaken with following objectives:

Detection in changes of soybean yield with variation in rainfall distribution pattern.

Determination of yield reduction with respect to critical growth stages of soybean.

Estimation of crop water requirement through CROPWAT 8.0 software.

Materials and Methods

Study area

The study was carried out in selected districts i.e. Bhopal, Raisen, Hoshangabad, Chhindwara, Indore and Khandwa of Madhya Pradesh. Figure 1 shows the location of study area with respective latitude and longitude.

Soils of Madhya Pradesh

Soils of Madhya Pradesh vary as per the structure, colour, texture and composition in the different regions. Madhya Pradesh is that part of the peninsular plateau of India where residual soils are found in an extensive area. The rock formation determines the soil structure and composition in this state. Madhya Pradesh comprises of a variety of soils ranging from rich clayey to gravelly. The major groups of soils found in the state can be divided into five major categories namely:- Alluvial Soil, Black Soil or Regur Soil (medium and deep black, shallow and medium black, mixed red and black coloured), Clayey Soil, Mixed Soil Red and Yellow Soil. Soils of Madhya Pradesh Medium and deep black coloured soil is extensively found it is distributed are nearly 47.6 percent of the land of Madhya Pradesh. Such soils mainly consist of Iron and lime rocks. The presence of Iron gives it the Black colour and the presence of lime increases its moisture retention capacity therefore needs less irrigation. Cotton and soya bean are most suitable crops to be grown in such soil. The quantity of Calcium, Magnesium, Aluminum, Iron, Potassium and Magnesium Carbonate is more in black soil but it lacks in Nitrogen, Phosphorous and Carbonic elements. Figure 2 shows soil map of Madhya Pradesh. Selected districts lies in deep medium and shallow black soil.

Climate

Maximum and minimum annual average temperature in Hoshangabad district during period 2004-14 is 32.9 and 19.6ºC respectively and receives average annual of about 1153.5 mm. Maximum and minimum annual average temperature in Bhopal district during period 2004-14 is 32.1 and 19.7ºC respectively and receives average annual of about 724.7 mm. Maximum and minimum annual average temperature in Chhindwara district during period 2004-14 is 30.5 and 18.2ºC respectively and receives average annual of about 1133 mm. Maximum and minimum annual average temperature in Indore district during period 2004-14 is 31.9 and 17.9ºC respectively and receives average annual of about 607 mm. Maximum and minimum annual average temperature in Khandwa district during period 2004-14 is 26.6 and 19.7ºC respectively and receives average annual of about 932 mm. Maximum and minimum annual average temperature in Raisen district during period 2004-14 is 25.5 and 19.2ºC respectively and receives average annual of about 1159mm. For analysing monthly rainfall data during crop growth stages i.e. from June to September are used during years 2004-2014.

Estimation of crop evapotranspiration

To improve water use efficiency in irrigated agriculture fields, water loss due to crop evapotranspiration is an important factor which should be estimated. Estimation of evapotranspiration can be done by various methods ranging from the complex energy balance equations such as FAO P-M method to simpler equations that require limited meteorological data. CROPWAT is one such model which was developed by the Land and Water Development Division of FAO for efficient planning and management of irrigation. For the present study, CROPWAT version 8.0 is used. CROPWAT model use the FAO (1992) Penman-Montieth method for calculating the reference crop evapotranspiration. The input data used in Crop Wat model is cover crop, climate, and soil. The climate data includes: (1) maximum and minimum temperature; (2) wind speed; (3) sunshine hours; (4) relativity humidity; and (5) rainfall.

Methodology

The methodology adopted for the above study involves the use of meteorological data viz. rainfall, max and min temp, humidity, sunshine hours and wind velocity in conjunction with yield data for the period of 11 years. Figure 3 depicted below shows the overall methodology.

Monthly rainfall values from June to September of selected districts of Madhya Pradesh has been collected for the period of 11 years (2004-2014). Yield data of 11 years for selected districts has been collected for selected districts. Yield reduction is calculated through following formula:

$$\text{Yield reduction (\%)} = \frac{Y-\bar{Y}}{\bar{Y}} * 100$$

Where Y: Yield

$\bar{Y}$: Average yield

Negative value shows yield reduction in that area.

Estimation of growth stage-wise yield reduction

Critical growth stages of soybean are vegetative, flowering and pod initiation. Figure 4 shows the different stages of growth of soybean (Source FAO). If there is yield reduction in some year, variation in rainfall pattern during growth period particularly at critical growth stages has been observed.

Results and Discussion

Crop water requirement

The estimated crop water requirement using CROPWAT 8.0 model of soybean for growth period (100-110 days) is shown in Table 1.

Relationship between district-wise rainfall

and yield

According to Figure 5 Indore is high yielding district with average yield of 1174 Kg/ha followed by Chhindwara with 1162 Kg/ha. Bhopal is low yielding with average yield of 539 Kg/ha followed by Khandwa with average yield of 586 Kg/ha.

The effect of rainfall is positive on crop yield. Almost in all districts decrease amount of rainfall at critical growth stages decreases the crop yield. Whereas increase in yield was observed in districts which received good amount of rainfall at critical stages. As, Figure 6 shows rainfall distribution pattern and crop yield for selected districts.

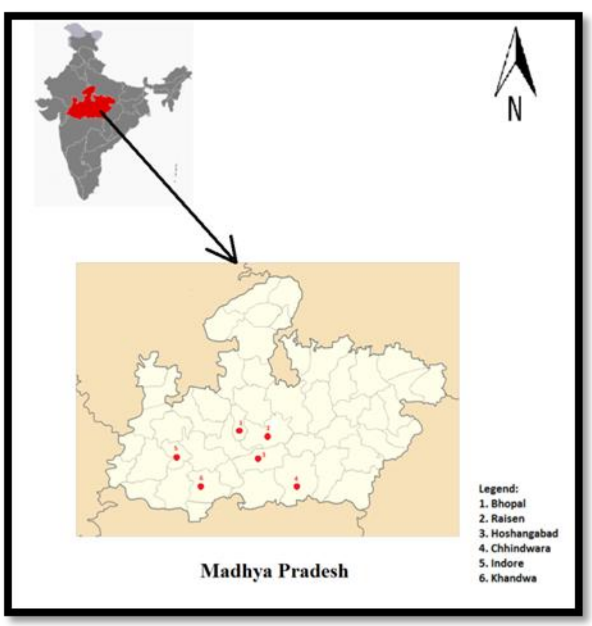
Year wise representation of yield and yield reduction

Particularly decrease in rainfall at vegetative, flowering and pod initiation the grain yield of soybean reduced by 54.06% in Bhopal as compared to Indore. Merely increase or decrease in rainfall except critical stages did not had much effect on yield. Figure 7 representing district wise yield and yield reduction.

Table.1 Crop water requirement for selected districts

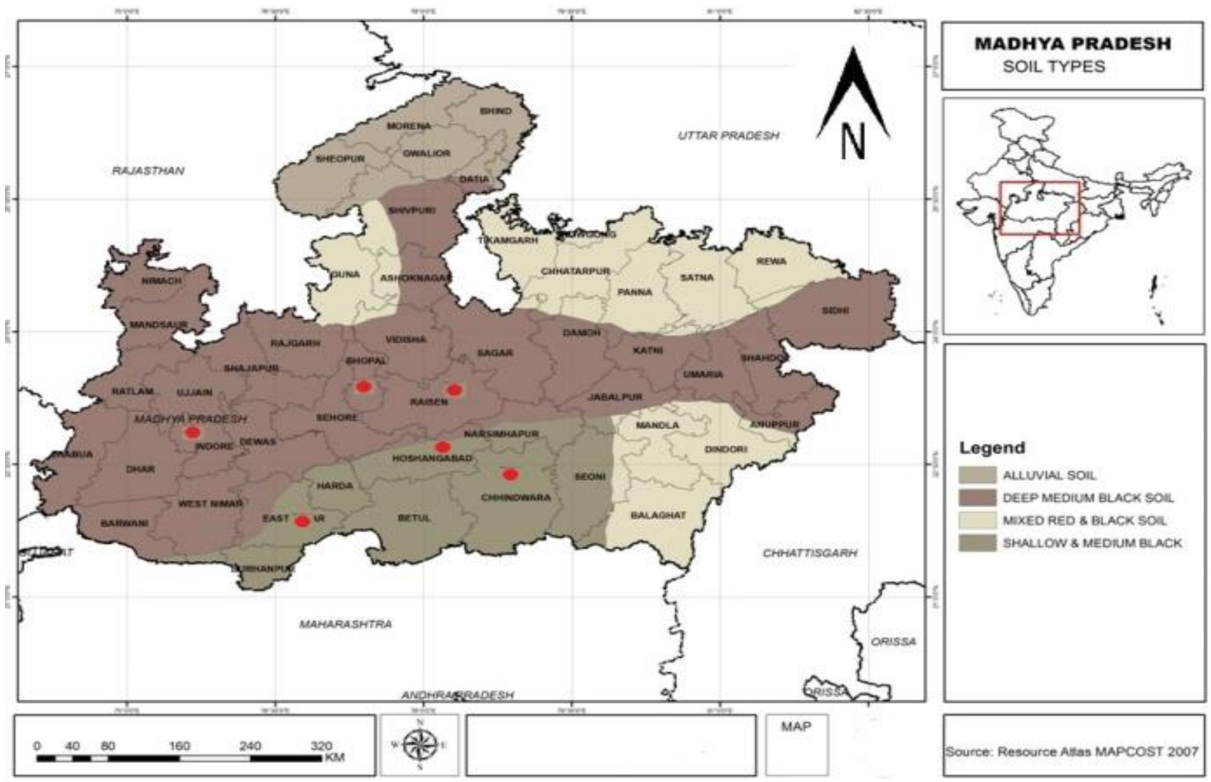
District	Crop Water Req (mm)
Raisen	450.5
Hoshangabad	431.3
Indore	368.1
Chhindwara	361.7
Bhopal	391.2
Khandwa	452.8

Fig.1 Location map of study area



1. **Bhopal:** 23.2599° N, 77.4126° E
2. **Raisen:**23.3301° N, 77.7843° E
3. **Hoshangabad:**22.7441° N, 77.7370° E
4. **Chhindwara:**22.0574° N, 78.9382° E
5. **Indore:**22.7196° N, 75.8577° E
6. **Khandwa:**21.8257° N, 76.3526° E

Fig.2 Soil map of Madhya Pradesh



● : Selected districts

Fig.3 Flow chart of methodology

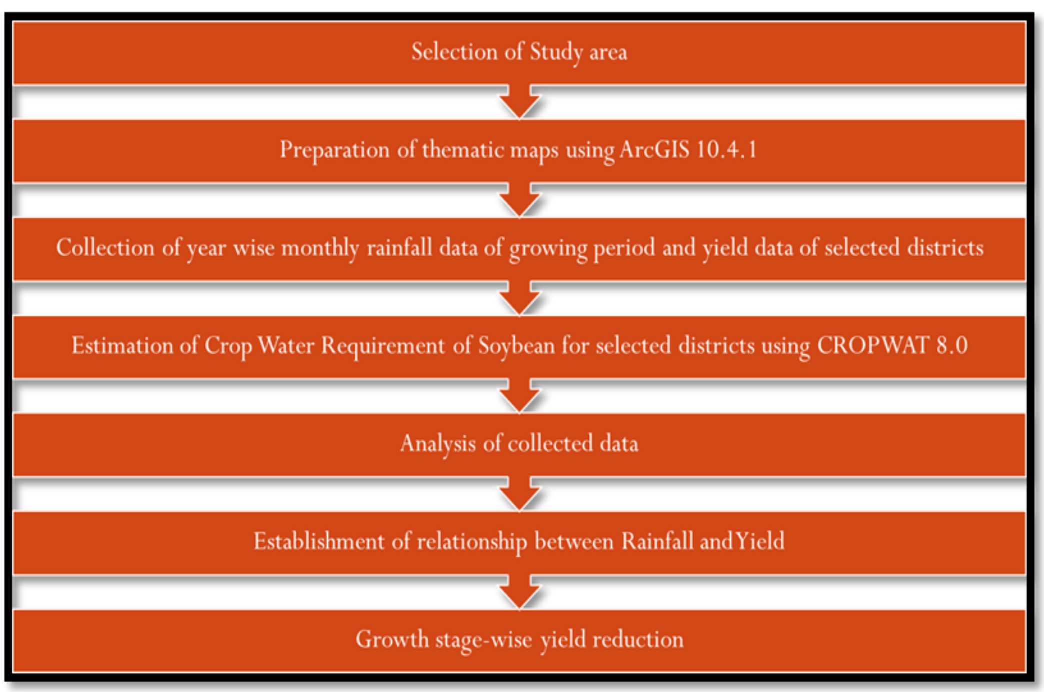


Fig.4 Stages of growth of soybean

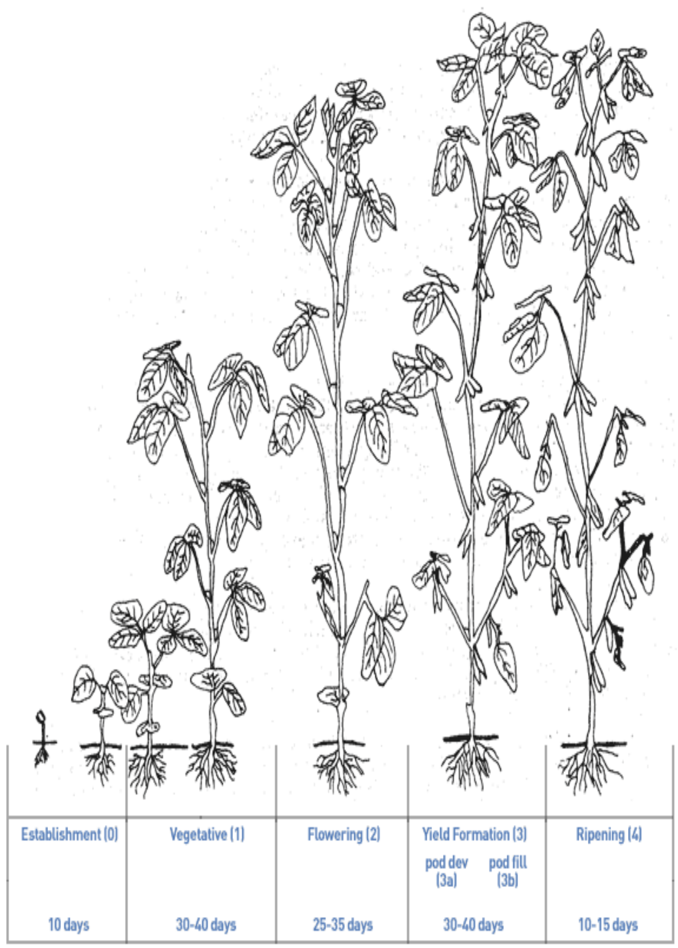


Fig.5 District wise average yield

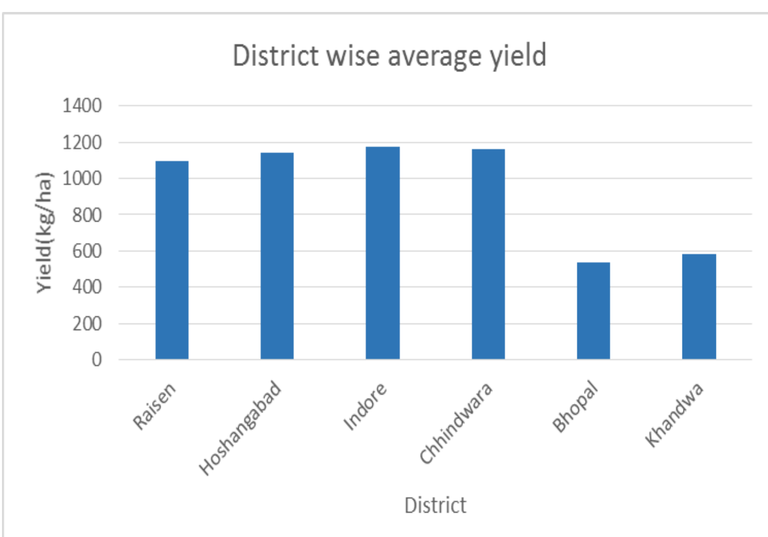
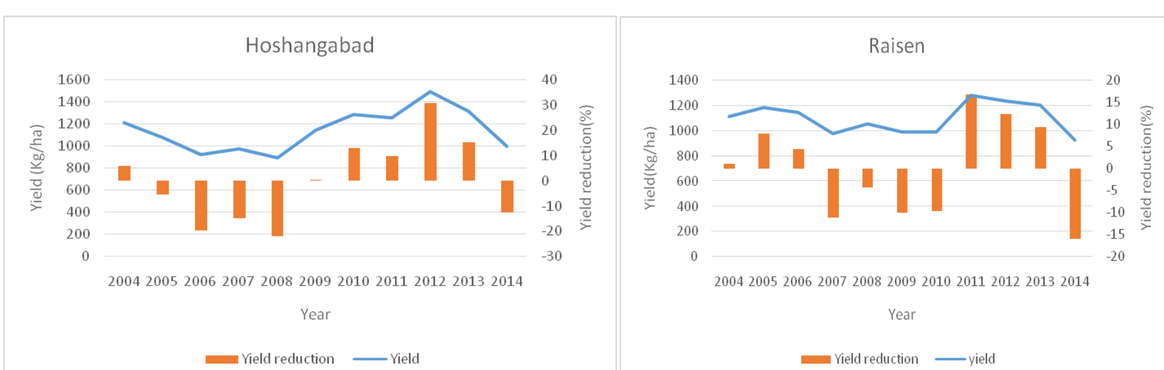
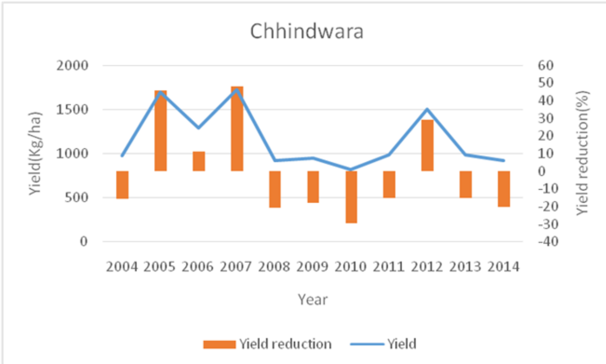
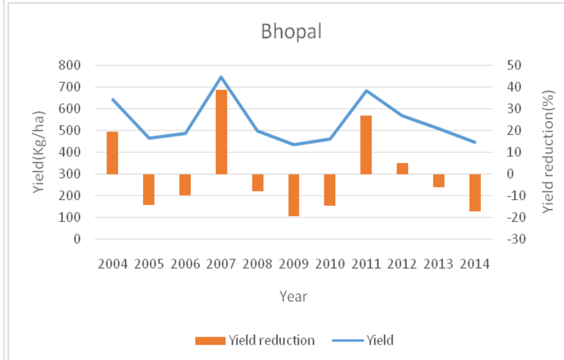


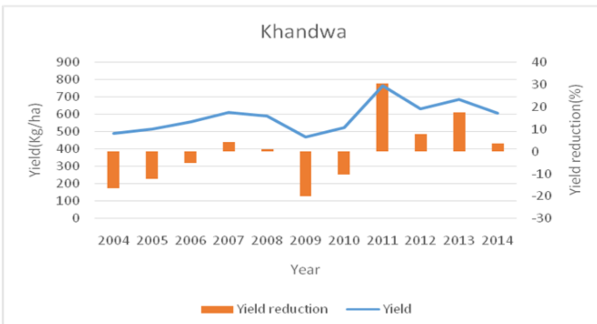
Fig.6 Relationship between yearly rainfall distribution pattern and yield

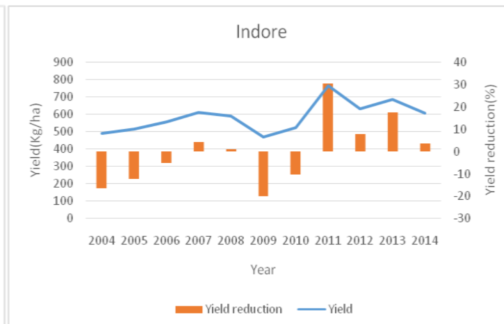
Fig.7 District wise representation of yield and yield reduction











This study revealed that rainfall at critical stages had positive effect on the soybean yield. Our findings suggest higher yield for soybean crop as a result of rainfall received at critical stages. Indore is high yielding of Soybean followed by Chhindwara district during period of 2004-2014.While Bhopal and Khandwa are found to be low yielding districts of Soybean during the mention period. Maximum yield reduction due to low rainfall at flowering and pod initiation stage was 29.17% in Chhindwara district. Repeatedly low rainfall at vegetative stage resulting yield reduction in almost all selected districts of MP except Chhindwara district. Apart from low amount of rainfall, reduction in yield might be due to some unknown reasons such as pest and insect infestation, weeds infestation etc.

Future Scope

Water harvesting structures such as check dam, percolation dam etc. should be developed to conserve runoff for supplemental irrigation at critical stages during growing period of Soybean.

Stress tolerant variety of Soybean should be adopted to avoid yield reduction due to scarce rainfall at critical stages.

Future simulated rainfall data should be used for yield prediction.

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