BIOGLOBIA Vol. 2 (2): 2015 **ISSN: 2349-5626**

An agroclimatic approach for identifying sowing window and production potential of rainfed *kharif* maize in different districts of Bihar

A. SATTAR AND S. A. KHAN*

Rajendra Agricultural University, Pusa, Samastipur, Bihar-848 125
* Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal-741 252

ABSTRACT

Thermal and moisture regimes are the important agroclimatic factors governing time of sowing of a crop. In rainfed agro-ecosystem, identification of sowing window is an essential prerequisite for farmers to plan sowing of their crops at appropriate times for achieving higher yield. In this paper, sowing windows for rainfed *kharif* maize, which is an important crop in Bihar, contributing significantly to its economy, have been identified based on probabilistic assured weekly total rainfall for 36 districts spread over 4 agroclimatic zones of Bihar state. The concept of moisture availability index (MAI), the ratio of weekly total assured rainfall to potential evapotranspiration (PET), postulated by Hargreaves (1974) and adopted by Sarker and Biswas (1986), has been employed as an index of water availability for evaluation of potential productivity. Results revealed that at 30 to 50 per cent probability levels, sowing windows of all the 13 districts under Zone I prevail during 21 to 27 SMWs, during 18 to 24 SMWs in 7 districts under Zone II, 22 to 26 SMWs in 5 districts under Zone IIIA and 23 to 27 SMWs in 11 districts under Zone IIIB. The earliest commencement of sowing week (18 SMW) occurs in Zone II followed by Zone I (21 SMW), Zone IIIA (22 SMW) and Zone IIIB (23 SMW). In terms of the longer length of growing period and higher values of MAI at all probability levels, the Zone II (North east alluvial plains) is adjudged as the most potential zone for cultivation of rainfed *kharif* maize followed by Zone I (North west alluvial plains), and Zone IIIA and Zone IIIB both under South Bihar alluvial plains zone in Bihar. Thus the determination of sowing windows and quantification of MAI values during growing season are useful agronomic criteria for cultivation of rainfed *kharif* maize in Bihar State.

Keywords: *Sowing window, Kharif maize, Moisture availability index, Potential production, Bihar.*

INTRODUCTION

Maize is a very important crop in Bihar occupying about 0.9 million ha of land. Apart from r*abi* and summer maize, *kharif* maize is extensively grown across all agroclimatic zones of the state as a rainfed crop. Low productivity of *kharif* maize (20.8 q ha^{-1}) in Bihar is attributed among others to moisture stress during crop growing season. Several agrometeorological constraints such as dry spell/drought, scanty and erratic monsoon rainfall and occurrences of abnormally high temperatures during crop growing season affect crop production adversely in the state.

Thus, successful raising of rainfed *kharif* crops depends on the availability of rainfall during land preparation and sowing for better germination and emergence. Farmers need to take the advantage of the first sowing rain received during the recommended period of sowing (Raman, 1974). One of the modern strategies for rainfed crop production resorts to historical rainfall data analysis to ascertain sowing dates. Sowing at inappropriate time may lead to crop failure. The sowing window is a range of time of sowing of crops and such windows are narrower for rainfed crops than those grown with irrigation. In areas with limited or no irrigation facilities, identification of sowing windows is necessary for guiding the farmers to sow their crops at appropriate times. To avoid such an uncertainty, sowing needs to be done based on probabilistic approach. The India Meteorological Department, Pune developed classical criteria for sowing rain for different states in India. A rainfall of 25

mm in a spell of 7 days with at least 5 days receiving as much as 1 mm was presumed suitable to commence sowing operations in Maharashtra state (Raman, 1974). Similar approaches were also used by Chowdhury and Ganesan (1984) and Chowdhury and Shyamala (1986) to determine sowing time for Karnataka and Rajasthan, respectively. To identify the start of growing period for Madhya Pradesh, the week when MAI was greater than or equal to 0.30 was taken as the beginning of growth period (Das, 1987). While working at ICRISAT, Hyderabad, Virmani (1975) considered 20 mm rainfall received in 2 or 3 days in sequence as sowing rain. Gupta *et al.* (1975) suggested that the rainfall at 80 % probability could safely be taken as assured rainfall, while 50 % rainfall probability limit was considered as medium limit for taking risk in agricultural crop planning. Shankar *et al.* (1992) identified commencement of rainy season and sowing time from the week receiving 30 mm rainfall per week and cessation of rainy season from the week with no subsequent rainfall of that amount for at least 3 consecutive weeks towards the end of rainy season. Rajegowda (1994) termed the weekly total rainfall being equal to or greater than PET as wet week and suggested that for successful crop production, the amount of rainfall in any meteorological week during crop growing period should meet the atmospheric demand without any moisture deficiency. Banik and Sharma (2009) suggested possibility of rice cultivation from 23 SMW in eastern plateau region of Jharkhand using the concept of moisture availability index. Khan (2011) identified sowing window for jute in different jute growing districts of West Bengal by considering 30 mm rainfall per week at 30 to 50 % probability levels. Saha *et al.* (2012) while assessing crop potential using rainfall probability analysis for Birbhum district of West Bengal observed that sowing could be possible in 23 and 25 SMWs in 50 and 75 per cent levels respectively based on moisture availability index. The information on sowing rain, sowing window and its agrometeorological appraisal of production potential of *kharif* maize at district level in Bihar has not yet been reported. Hence, an attempt has been made in this paper to identify the sowing window and production potential in different districts as an aid for evolving strategic plan for the policy makers and tactical plan for the farmers to further enhance rainfed maize production in Bihar.

DATA AND METHODOLOGY

The study was conducted for 36 districts under different agroclimatic zones of Bihar. The state is located between 24°17´ and 27°31´ N latitudes and between 83°19´and 88°17´ E longitudes covering an area of 9.38 million hectares. It is broadly divided into three agro-climatic zones viz. Zone I (North west alluvial plains), Zone II (North east alluvial plains) and Zone III (South Bihar alluvial plains). Zone III is further subdivided into Zone IIIA and Zone IIIB on the basis of rainfall variability and topography. The map showing various agroclimatic zones of the state is presented in Figure 1.

Fig.1: Map showing various agroclimatic zones of Bihar

For determining sowing windows and moisture availability index in 36 districts in Bihar, assured weekly total rainfall estimated at 30, 40, 50, 60 and 70 % probability levels, published by India Meteorological Department, Pune (Anon., 1995), have been used. The concept of moisture availability index (MAI), postulated by Hargreaves (1974) and adopted by Sarker and Biswas (1986) for agroclimatic classification for assessment of crop potential in dry farming tract, has been used in the present study as index of water availability. The MAI which is the ratio of weekly total assured rainfall determined at 30, 50 and 70 % probability levels to potential evapotranspiration (PET) has been computed for all the 36 districts for assessing production potential of *kharif* maize crop. Considering the sub humid sub tropical climate of Bihar, in the present study, as suggested by Shankar *et al.* 1992, 30 mm rainfall per week at 30, 50 and 70 % probability levels, has been considered for working out sowing rain. The initial week in the ranges of sowing period, hereinafter referred to as sowing window, was determined at 30 % probability i.e. in 3 years out of 10 years and 50 % probability *i.e.* 5 years out of 10 years and likewise for other probability levels. The normal growing season of *kharif* maize as per usual practice adopted by the farmers of Bihar is from 23 (4-10 June) to 39 SMW (24-30 September). Monthly normal PET data of Purnia, Patna, East Champaran, Darbhanga, Bhagalpur, Jamui, Rohtas and Gaya were collected from India Meteorological Department, Pune (Rao *et al.*,1971), whereas PET values of remaining districts were calculated using PET Calculator software (V 3.0) developed by Central Research Institute for Dryland Agriculture, ICAR, Hyderabad. Monthly PET data were converted into weekly total values by interpolation method (Rao and Vyas, 1983). Hargreaves (1975) considered 0.34 to 0.67 MAI as moderately deficient, 0.68 to 1.00 MAI as somewhat deficient, 1.00 to 1.33 as adequate moisture and MAI > 1.33 as excessive moisture condition. Further, as suggested by Hargreaves (1974) and Sarker and Biswas (1986), the growing seasons with MAI≥0.34, ≥0.70 and ≥1.00 providing different degrees of moisture availability have been estimated for productivity evaluation of *kharif maize* grown under rainfed condition in different districts of Bihar.

RESULTS AND DISCUSSION

Sowing window

Of all the climatic factors, rainfall is the most dominant abiotic factor determining germination, emergence and successful growth and yield of crop raised under rainfed condition. Usually time of sowing of a crop is determined through agronomic evaluation trials, but carrying out such trials in all the crop growing regions is not practically and economically feasible. In contrast, agrometeorological appraisal of sowing window under rainfed, based on sowing rain worked out through probabilistic rainfall analysis is regarded as an useful and rational approach. The sowing windows for rainfed *kharif* maize in different districts of Bihar have been identified and presented in Table 1. The initial week in the ranges of sowing periods was determined at 30 % probability *i.e.* in 3 years out of 10 years and 50 % probability i.e. in 5 years out of 10 years and likewise for 70 % probability. In Zone I, at 30 per cent probability level, the earliest sowing week (SW) occurs at Madhubani district, whereas the latest sowing week occurs at Begusarai and Siwan districts. In about half of the districts of the zone, *i.e.* West and East Champaran, Darbhanga, Muzaffarpur, Sitamarhi and Shivhar districts, sowing window starts at 22 SMW, while in four districts, such as in Samastipur, Vaisali, Gopalganj and Saran, sowing window starts at 23 SMW. In case of 50 per cent probability level, the earliest sowing week occurs at West Champaran, as against the latest sowing week occurring in Begusarai at 27 SMW. In about half of the districts, i.e. East Champaran, Samastipur, Darbhanga, Madhubani, Sitamarhi and Shivhar, the sowing week starts at 24 SMW, whereas in Mazaffarpur, Vaisali, Gopalganj, Siwan and Saran, sowing

week starts at 25 SMW. With delay in onset of sowing rain which has been fixed at 30 mm per week and in increasing probability levels from 60 to 70 per cent, sowing week occurs at later weeks in the range of 27 to 29 weeks in 11 districts. So in order to utilize the advantage of the earliest sowing rain, the farmers need to be alerted through agromet advisories to undertake sowing operation of maize crop in the sowing windows identified at 30 to 50 per cent probability levels. The sowing windows identified are 21 to 24 SMW in Madhubani, 22 to 25 SMW in West and East Champaran, Darbhanga, Muzaffarpur, Sitamarhi and Shivhar, 23 to 26 SMW in Samastipur, Vaisali, Gopalganj and Saran, and at 24 to 26 SMW in Begusarai and Siwan districts (Table 1). Thus it is observed that at 30 to 50 per cent probability levels, sowing windows of all the 13 districts under Zone I prevail during 21 to 27 SMW. In Zone II, at 30 to 50 per cent probability levels, sowing window prevails during 18 to 21 SMW for Krishnaganj district, 19 to 24 SMW for Araria, 21 to 24 SMW for Supaul, 22 to 24 SMW for Purnia, Saharsa and Katihar, and 23 to 24 SMW for Madhepura district (Table 1). Thus it appears that at 30 to 50 per cent probability levels, sowing windows of all the 7 districts under Zone II occurs during 18 to 24 SMWs.

In Zone IIIA, at 30 to 50 per cent probability levels, sowing window exists during 22 to 24 SMW in Bhagalpur district, 23 to 24 at Banka, Jamui, Shekhpura and 24 to 26 SMW in Munger district (Table 1). Thus it is apparent from the results that at 30 to 50 per cent probability levels, sowing windows in all the 5 districts under Zone IIIA exists during 22 to 26 SMWs. In Zone IIIB, at 30 to 50 per cent probability levels, sowing window occurs during 23 to 26 SMW in Patna and Nawada districts, 24 to 26 SMW in Nalanda, Gaya, Aurangabad, Jahanabad, Arwal, Buxar and Bhojpur districts, and 25 to 27 SMW in Kaimur and Rohtas districts (Table 1). Thus it is seen from the findings that at 30 to 50 per cent probability levels, sowing windows in all the 11 districts under Zone IIIB prevail during 23 to 27 SMWs.

Evaluation of potential productivity

The average MAI values have been determined, based on the sowing windows (Table 1), and presented in Table 2 which revealed that in Zone I, at 70 per cent probability (7 out of 10 years), Sitamarhi and Madhubani districts recorded MAI of 0.67. All other districts in this agroclimatic zone are having MAI ranging from 0.68 to 1.00, indicating possibility of variable moisture deficient condition during maize growing period. No district of this Zone recorded MAI within 1.00-1.33 range in this probability. At 50 per cent probability, Begusarai, Vaishali, Gopalganj and Saran fall under MAI range of 1.00 to 1.33, while the remaining districts recorded MAI>1.33. At 30 and 40 % probability levels, all the districts in Zone I recorded MAI>1.33. In Zone II, at 70 % probability, MAI values of the remaining districts indicate somewhat deficient moisture condition. All other districts in this Zone at all probabilities are showing favourable moisture condition for *kharif* maize production. However, at 30 and 50 % probabilities, all districts are showing excessive moisture condition, with average MAI values over different districts ranging between 2.22 and 3.00 and between 1.28 and 1.84, respectively. It implies the fact that for successful *kharif* maize production, cultivation should be done in upland areas and where there is provision of good drainage facilities during *kharif* season.

In Zone IIIA, all districts exhibited somewhat deficient moisture condition at 70 per cent probability level, with average MAI values extending from 0.69 to 0.85. However, all the districts in this Zone are exhibiting very high MAI at 30 and 50 % probability levels, indicating the need for good drainage provision in the crop fields. In Zone IIIB, the moisture situation is comparatively poor at 70 % probability level compared to other agroclimatic zones of the state. Nalanda district recorded the lowest average MAI of 0.61 at 70 %

probability level, whereas Aurangabad recorded the highest average MAI of 0.85. At 50 per cent probability level, Patna, Nalanda, Jahanabad, Arwal, Buxar and Bhojpur districts registered average MAI values ranging between 1.20 and 1.50, indicating better moisture condition than that in 70 per cent probability level. Although the greater moisture regime environment for maize production in this agroclimatic zone is observed in few districts at 50 % probability, copious moisture is available at 30 % probability level in all the districts under study.

Table 1
Sowing window of *kharif* maize in different districts of Bihar

Zone	District	Sowing period (weeks) at different probability levels					Sowing window at 30-50 % Prob.
		70 %	60 %	50 %	40 %	30 %	
Zone I (North west alluvial plains)							
	W. Champaran	25-27	24-25	23-25	22	22	22-25
	E. Champaran	26-29	26-26	24-25	23-24	22-23	22-25
	Samastipur	27-28	27	24-26	24	23	23-26
	Begusarai	27	27	27	25	24	24-27
	Darbhanga	27-29	26-27	24-25	24-25	22-24	22-25
	Madhubani	27-28	24-27	24	22-24	21-24	21-24
	Muzaffarpur	28	26-27	25-26	24-25	22-24	22-26
	Vaishali	28-32	27-28	25-26	24-25	23-24	23-26
	Sitamarhi	27-29	25-26	24-25	23-24	22	22-25
	Shivhar	27	27	24	24	22	22-24
	Gopalganj	28-31	26-27	25-26	24-25	23-24	23-26
	Siwan	28-29	26-27	25-26	25	24	24-26
	Saran	28-31	27-28	25-27	25	23-24	23-27
Zone II (North east alluvial plains)							
	Purnia	26	24	24	22	22	22-24
	Kishanganj	24	24	21	19	18	18-21
	Araria	26	24	22-24	22	19-21	19-24
	Saharsa	28	26	24	22	22	22-24
	Katihar	27	26	24	24	22	22-24
	Madhepura	27	26	24	23	23	23-24
	Supaul	26-27	24	24	22	21-22	21-24
Zone III (South Bihar alluvial plains)							
A	Bhagalpur	27-32	25-27	24	23-24	22	22-24
	Banka	27	25-27	24	23-24	23	23-24
	Munger	28-31	27	25-26	24	23-24	24-26
	Jamui	27	26-27	25	24	23	23-24
	Shekhpura	28	27	25	25	23	23-25
B	Patna	27-30	27-28	25-27	25-26	23-25	23-26
	Nalanda	27-31	27-31	25-27	25-26	24-25	24-26
	Gaya	27-28	27	26	25-26	24-25	24-26
	Aurangabad	27-29	26-27	26	24-26	24-25	24-26
	Nawada	28-32	27-28	26	25	23-25	23-25
	Jahanabad	32	28	26	25	24	24-26
	Arwal	30	28	26	25	24	24-26
	Kaimur	29	27	26	25-25	25-26	25-26
	Buxar	31	27-28	27	25	24	24-27
	Rohtas	28-31	26-27	25-27	25	25	25-27
	Bhojpur	28-31	27-28	25-26	25	24-25	24-26

Table 2
Moisture availability index (MAI) for *kharif* maize at different probability levels in various districts of Bihar

Zone	District	MAI at the probability of		
		70 %	50 %	30 %
Zone I (North west alluvial plains)				
	W. Champaran	1.00	1.84	3.00
	E. Champaran	0.81	1.52	2.69
	Samastipur	0.82	1.63	2.95
	Begusarai	0.70	1.28	2.30
	Darbhanga	0.71	1.41	2.33
	Madhubani	0.67	1.46	2.57
	Muzaffarpur	0.68	1.36	2.39
	Vaishali	0.75	1.29	2.36
	Sitamarhi	0.64	1.44	2.68
	Shivhar	0.73	1.64	2.90
	Gopalganj	0.72	1.33	2.33
	Siwan	0.70	1.57	2.39
	Saran	0.68	1.29	2.22
Zone II (North east alluvial plains)				
	Kishanganj	1.64	2.71	4.21
	Purnea	0.99	1.79	3.01
	Araria	1.17	1.95	3.30
	Saharsa	0.89	1.63	2.10
	Katihar	0.76	1.49	2.63
	Madhepura	0.90	1.61	2.83
	Supaul	0.91	1.61	2.62
	Khagaria	0.75	1.38	2.41
Zone IIIA (South Bihar alluvial plains)				
	Bhagalpur	0.81	1.39	2.60
	Banka	0.85	1.44	2.29
	Munger	0.80	1.41	2.46
	Jamui	0.84	1.45	2.44
	Shekhpura	0.69	1.24	2.34
Zone IIIB (South Bihar alluvial plains)				
	Patna	0.68	1.24	2.05
	Nalanda	0.61	1.20	2.16
	Gaya	0.78	1.34	2.37
	Aurangabad	0.85	1.50	2.56
	Nawada	0.76	1.35	2.35
	Jahanabad	0.70	1.25	2.16
	Arwal	0.70	1.24	2.19
	Kaimur	0.80	1.44	2.53
	Buxar	0.69	1.23	2.25
	Rohtas	0.81	1.42	2.46
	Bhojpur	0.72	1.32	2.37

At 70 % probability, moisture availability indices during maize growing period in various districts under different agroclimatic zones have been presented in Figs 2-4, which revealed that there exists immense potential for growing rainfed *kharif* maize in most of the districts. However, lower values of MAI were recorded in Zone IIIB at all probability levels

compared to the remaining agroclimatic zones of the state (Table 3 and Fig.5). As evidenced by higher values of MAI at all probability levels, the rainfed maize crop experiences least water stress in Zone II during *kharif* season and thus Zone II has greater potential for cultivation of rainfed *kharif* maize crop followed by Zone I and Zone IIIA. The growing seasons expressed in weeks with MAI ≥0.34, ≥0.70 and ≥1.00 providing different degrees of moisture availability have been estimated for productivity evaluation of *kharif* maize grown under rainfed condition in different districts of Bihar and presented in Table 4. At 50 % probability level, the average duration of growing periods in terms of MAI ≥0.34, 0.70 and 1.00 are 15.8, 14.0 and 12.8 weeks in Zone I, 17.6, 16.0 and 14.8 weeks in Zone II, 15.4, 14.0 and 14.0 weeks in Zone IIIA and 14.2, 12.7 and 11.5 weeks in Zone IIIB, respectively. So length of growing period is longest in Zone II (North East Alluvial Plains) followed by Zone I (North West Alluvial Plains), and Zone IIIA and Zone IIIB both under South Bihar Alluvial Plains zone in Bihar. The longer growing period provides better prospects for rainfed crops giving rise to more productivity and well being of the farmers. To identify the start of growing period for Madhya Pradesh, the week when MAI≥0.30 was taken as the beginning of growth period (Das, 1987). The approach similar to that of Das (1987) was earlier employed by Sarker and Biswas (1986) for assessment of crop potential and its application to dry farming tract.

Table 3
Moisture availability index (MAI) for *kharif* maize at different probability levels in various agroclimatic zones of Bihar

Agroclimatic zone	MAI values during growing period of *kharif* maize at different Probability levels		
	70 %	50 %	30 %
Zone I	0.73	1.45	2.52
Zone II	1.06	1.87	3.10
Zone IIIA	0.81	1.42	2.51
Zone IIIB	0.66	1.18	2.07

Table 4
Maize growing season expressed in weeks with moisture availability index (MAI)≥0.34, ≥0.70 and ≥ 1.00 in different districts of Bihar

Zone / District	30 % probability			50 % probability			70 % probability		
	No. of weeks with MAI			No. of weeks with MAI			No. of weeks with MAI		
	≥0.34	≥0.70	≥1.00	≥0.34	≥0.70	≥1.00	≥0.34	≥0.70	≥1.00
Zone I (North west alluvial plains)									
West Champaran	17	17	17	17	15	14	15	13	7
East Champaran	17	17	16	16	14	13	13	12	5
Samastipur	17	16	15	16	14	13	14	10	0
Begusarai	16	16	15	15	14	13	13	7	0
Darbhanga	17	16	15	16	14	13	13	7	0
Madhubani	18	17	16	17	14	14	14	11	3
Muzaffarpur	17	16	16	16	14	13	13	11	0
Vaishali	16	16	14	15	13	11	13	5	1
Sitamarhi	16	16	16	16	16	14	13	8	2
Shivhar	16	16	16	16	16	13	13	7	2
Gopalganj	16	16	16	16	14	12	12	10	3
Siwan	15	15	15	15	13	13	13	6	2
Saran	16	16	16	15	12	12	11	4	0
Mean	16.4	16.1	15.5	15.8	14.0	12.8	12.9	8.2	1.5

Zone II (North east alluvial plains)									
Kishanganj	21	21	21	21	19	19	19	16	17
Purnea	17	17	17	17	15	15	15	12	9
Araria	20	20	20	20	18	16	16	13	10
Saharsa	17	16	16	16	14	13	14	8	2
Katihar	17	17	17	17	16	15	15	12	6
Madhepura	16	16	16	16	16	14	15	13	5
Supaul	18	18	18	18	16	13	13	10	4
Khagaria	16	16	15	16	14	13	13	8	0
Mean	17.8	17.6	17.5	17.6	16.0	14.8	15.0	11.5	6.6
Zone IIIA (South Bihar alluvial plains)									
Bhagalpur	17	17	16	16	14	14	14	10	3
Banka	16	16	15	16	14	14	14	10	4
Munger	15	15	15	15	14	14	14	10	0
Jamui	16	15	15	15	14	14	14	9	4
Sheikhpura	16	16	15	15	14	14	14	14	3
Mean	16.0	15.8	15.2	15.4	14.0	14.0	14.0	10.6	2.8
Zone IIIB (South Bihar alluvial plains)									
Patna	16	15	14	15	13	12	13	9	1
Nalanda	15	14	14	14	13	12	12	2	1
Gaya	15	15	14	15	13	10	12	6	3
Aurangabad	15	15	14	14	12	11	11	6	4
Nawada	16	14	13	14	13	10	12	2	0
Jahanabad	15	14	14	14	13	12	12	2	1
Arwal	15	14	14	14	13	11	11	4	0
Kaimur	14	14	14	14	13	12	12	7	4
Buxar	15	14	14	14	13	12	12	9	3
Rohtas	14	14	14	14	12	12	12	6	4
Bhojpur	15	15	14	14	12	12	12	7	0
Mean	15.0	14.4	13.9	14.2	12.7	11.5	11.9	5.5	1.9

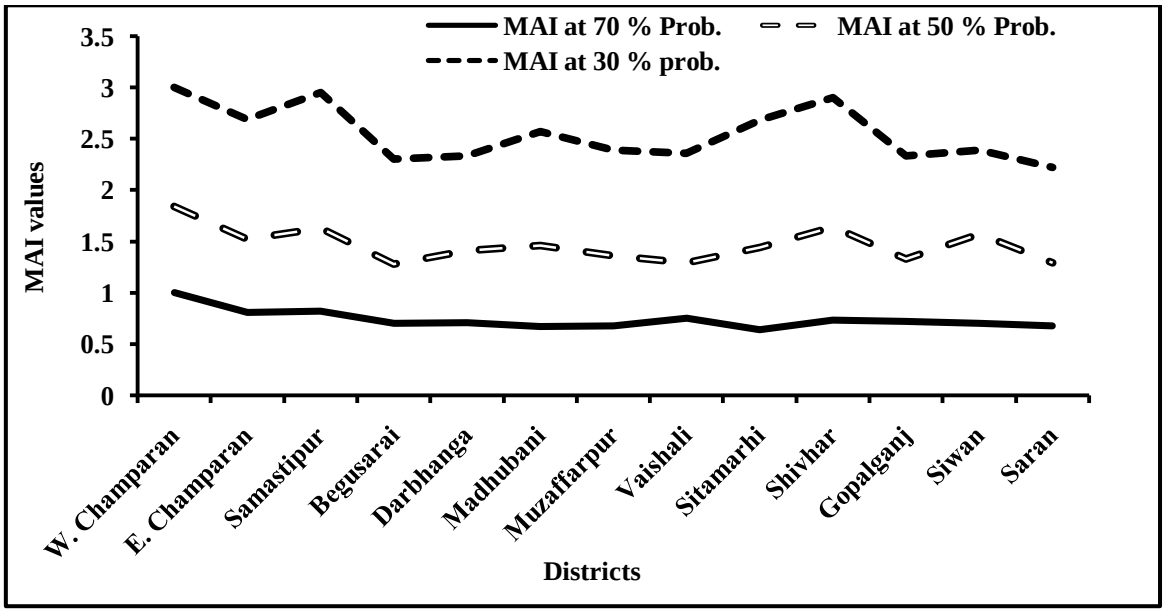

Fig. 2: Moisture availability indices during growing period of *kharif* maize in zone 1 of Bihar

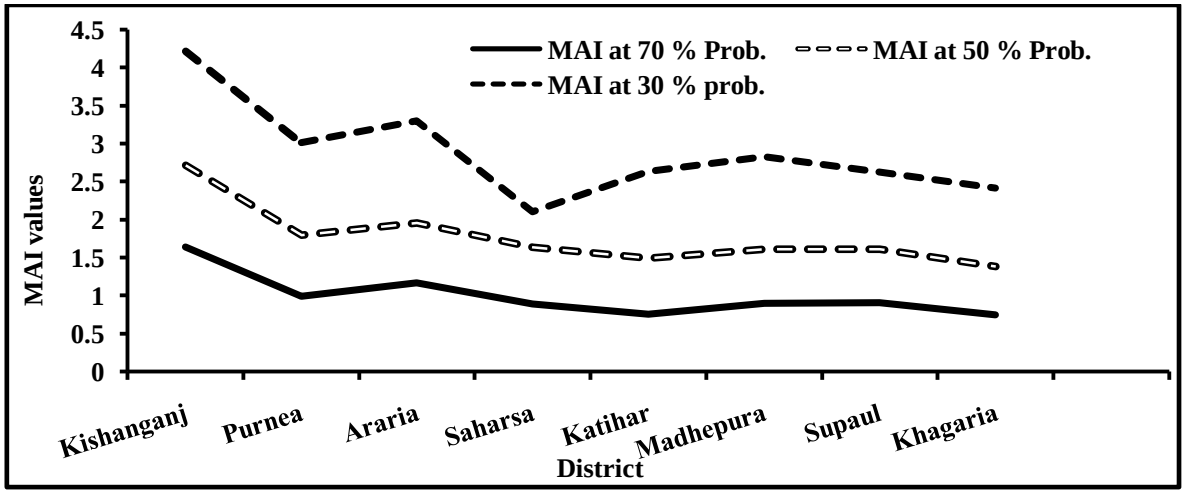

Fig. 3: Moisture availability indices during growing period of *kharif* maize in zone II of Bihar

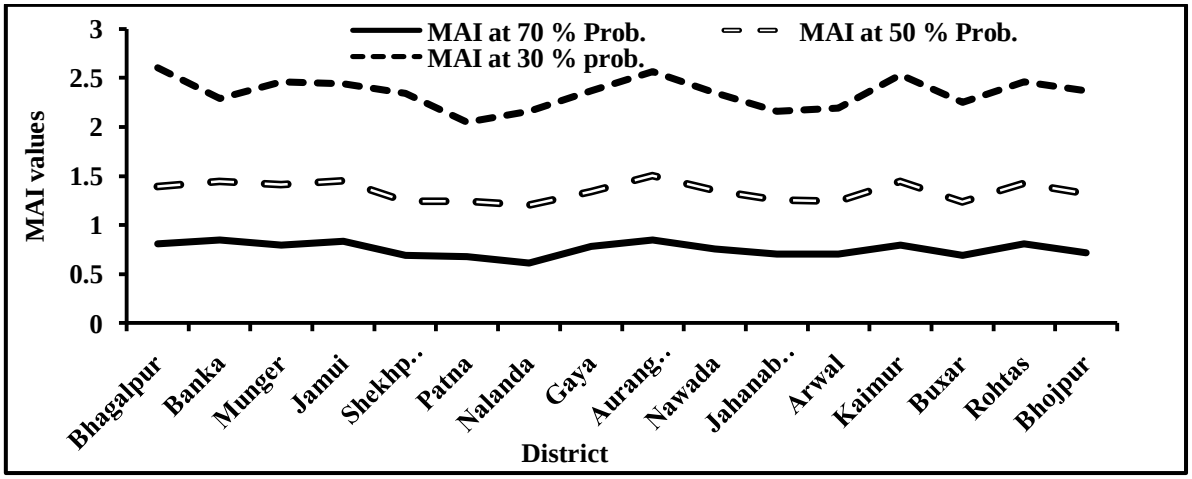

Fig. 4: Moisture availability indices during growing period of *kharif* maize in zone 1II (A & B) of Bihar

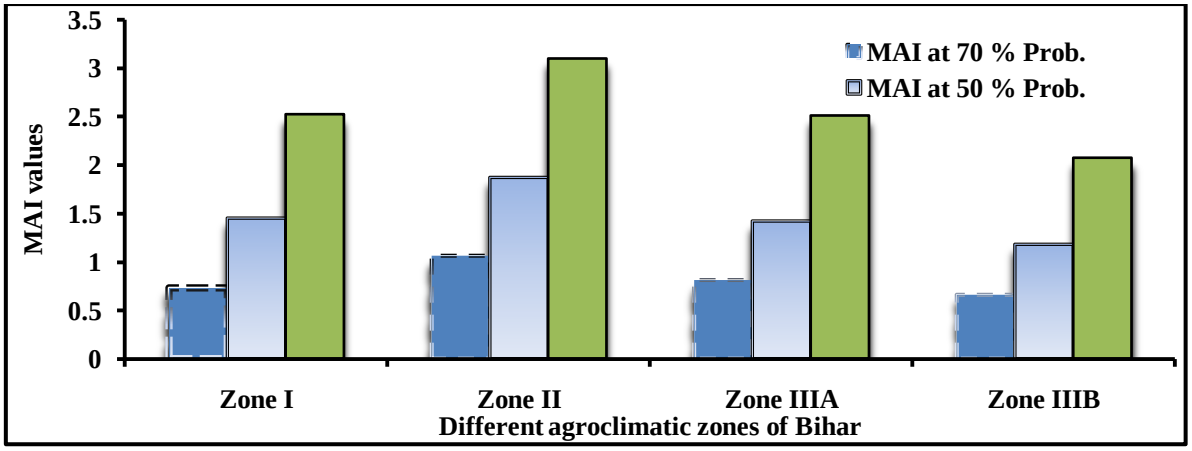

Fig. 5: Moisture availability indices during growing period of *kharif* maize at different probability levels in various zones of Bihar

In terms of the longer length of growing period and higher values of MAI at all probability levels, the Zone II is adjudged as the most potential zone for cultivation of rainfed kharif maize followed by Zone I, and Zone IIIA and Zone IIIB.

CONCLUSION

Time of sowing of a crop is governed by several factors, of which rainfall and temperature are the dominant ones. *Kharif* maize has huge potential in all the districts of Bihar excepting few districts in Zone IIIB (South Bihar alluvial plains). Under scanty and erratic rainfall condition during *kharif* season, this crop has ample diversification potential and can replace rainfed *kharif* rice in the state particularly in up and medium land situations amid concerns about poor prospect of *kharif* rice under changing climatic scenario. When the sowing windows estimated at 30 to 50 per cent probability levels for all the 36 districts across 4 agroclimatic zones, the earliest onset of sowing week occurs in Zone II followed by Zone I, Zone IIIA and Zone IIIB. In terms of the length of growing period, the Zone II (North east alluvial plains) seems to be the most potential zone for cultivation of rainfed *kharif* maize followed by Zone I (North west alluvial plains), and Zone IIIA and Zone IIIB under (South Bihar alluvial plains). In Zone II, *kharif* maize should be grown preferably in upland condition and in areas where there is provision for good drainage facility during *kharif* season. The assessment of sowing windows and length of growing period based on MAI at different probability levels are useful agronomic guidelines for field application for further augmentation of grain yield of rainfed *kharif* maize in the State of Bihar.

REFERENCES

1. Anon., 1995. Weekly rainfall probability for selected locations of India, Volume-II. Division of Agricultural Meteorology, India Meteorological Department, Pune, pp. 293.
2. Banik, P. and Sharma, R.C. 2009. Rainfall pattern and moisture availability index in relation to rice (*Oryza sativa* L.) crop planning in eastern plateau region of India, *J. of Agrometeorology*, 11 (1):54-58.
3. Chowdhury, A. and Ganesan, H. R. 1984. Sowing rain for agronomic planning of *kharif* crops over Karnataka state", Met. Mono. Agrimet No. 9, Ind. Met Dept.
4. Chowdhury, A. and Shyamala, B. 1986. Analysis of sowing rains in Rajasthan. Met. Mono. Agrimet No. 10, Ind. Met Dept.
5. Das, H. P. 1987. Some aspects of climatological resources and its application to agriculture in Madhya Pradesh, Ph.D. Thesis submitted to Poona University.
6. Hargreaves, G. H, 1974. Precipitation dependability and potential for agricultural production in Northeast brazil, EMBRAPA and Utah State University, Publication No. 74-D-159. Water requirement manual for irrigated crops and rainfed agriculture. Bulletin. 75-D-158, Utah State University. Utah, USA. 40 pp.
7. Hargreaves, G. H., 1975. Water requirement manual for irrigated crops and rainfed agriculture. Bulletin. 75-D-158,Utah State University, Utah, USA.40 pp.
8. Gupta, R.K, Rambau and Tewawani K.G. 1975. Weekly rainfall of India for crop planning programme. *Soil cons. Digest*, **3**:31-39.
9. Khan, S.A. 2011. A rational agroclimatic approach for scheduling sowing of rainfed jute, Paper presented at the International Symposium on "System Intensification towards Food & Environmental Security" held during 24-27 February 2011 at FTC, BCKV, Kalyani.
10. Rajegowda, M. B. 1994. Estimation of evapotranspiration. *Mausam* **45(** 3): 278.
11. Raman, C. R. V. 1974. Analysis of commencement of monsoon rains over Maharashtra State for agricultural planning. Pre-published Scientific Report, No. 216, Ind. Met. Dept.
12. Rao, K. N., George, C.J. and Ramasastri, A. 1971. Potential evapotranspiration (PE) over India. India Meteorological Department. Sci. Rep. No. 136, pp.11
13. Rao, G. G. S. N. and Vyas, B. M. 1983. Risk analysis for *kharif* crop production under rainfed conditions in Nagaur district. *Mausam* **34** (1):111-116.
14. Saha, A., Khan, S.A. and Das, L., 2012, "An agrometeorological study for crop planning under rainfed condition", *J. of Agrometeorology*,**14 :** 346-350
15. Sarker R.P. and Biswas, B.C.1986. Agroclimatic classification for assessment of crop potential and its application to dry farming tract, *Mausam.* **37**:27-38.
16. Shankar, U., Agrawal, K.K. and Gupta, V. K. 1992. Rainfall pattern and cropping strategy for Jabalpur region. *Indian J. Agric. Sci.*, **62 (**1): 58-59.
17. Virmani, S. M. 1975. *The agricultural climate of Hyderabad region in relation to agricultural planning,* ICRISAT, Patancheru, Andhra Pradesh, 54 pp.