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Prospects of growing *yellow sarson* under rainfed condition in the new alluvial agroclimatic zone of West Bengal

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ABSTRACT

Using 100 years of weekly rainfall data for Baharampur, profile moisture at sowing were simulated for coarse, medium and fine textured soils for six different sowing weeks starting from 38th (Sep 17 – 23) standard meteorological week (SMW) at two weeks interval and associated climatic risk was quantified using climatological water balance approach for yellow *sarson,* an important *rainfed rabi* crop of West Bengal. Same database was also used to run a FAO crop specific water balance model at weekly time steps to assess model outputs for *Binoy* variety. Yield prospects were estimated from water requirement satisfaction index (WRSI). At least 100 mm moisture is present to start sowing upto 42nd and 46th SMW in medium and fine textured soil respectively, at 75 percent probability level, for good initial growth of the plant. At least mediocre crop yield, in every alternate year, is possible when sown upto 40th SMW in medium and upto 44th SMW in fine textured soil. Prospect of getting good yield exist in more than 20 percent of the year if sown within 7th October in fine textured soil.

***Key words*:** Profile moisture, water balance model, climatic risk, water requirement satisfaction index (WRSI).

Rapeseed mustard is the second important oilseed crop in our country. In West Bengal, it ranks first in terms of production among all oilseeds and is grown in about 4.12 lakh hectares with the production of around 3.07 lakh tonnes and the average yield of the crop is around 745 kg ha^{-1}. The yield of mustard in West Bengal is low due to various factors, viz, untimely sowing, inadequate stand establishment, absence of high yielding varieties, lack of agroclimatic zone specific crop production technology, moisture stress and uncertain and abnormal weather condition. In eastern India the rainfall receipts are usually high and some amount of rainfall is received during post-monsoon season, that is, from October to March. A fairly good amount of moisture remains stored in the soil after the harvest of *kharif* rice, which, in some years, delays the sowing of *rabi* crops beyond the recommended time. Besides, the water table fluctuates between one or two metres below the ground level in the medium land in several parts of this tract. All these facilitate growing more than two crops in this predominantly rice growing areas even without having the facility of irrigation (Chatterjee, 1985).

Since the yield potential of the *rabi* crop depend on profile moisture status as well as small amount of winter rain that is received in the state, it is therefore, necessary to assess the dynamics of profile moisture availability throughout the crop growing season at different soil and climatic conditions of our state under early, optimum as well as delayed sowing situations. The quantum of profile soil moisture will indicate whether it will be able to take care of the water need of a crop during different growth stages based on atmospheric water demand during that period. Since ground water can hardly contribute towards the water need of the crop during *rabi* season in West Bengal in most of the soils, the status of profile moisture at a particular time is primarily based on the interrelationship among rainfall, atmospheric water demand as indicated by potential evapotranspiration, soil water holding capacity and evapotranspiration potential of the specific crop at a particular growth stage. As a matter of fact, these aspects are very well integrated in different climatological water balance models that estimate crop moisture use and level of water surplus/deficit at different growth stages of crop as a function of these parameters.

The crop water balance model developed by Food and Agricultural Organizations is a suitable option for simulating soil water and crop water use in weekly time step. This model estimates, at a given stage of the growing cycle of the crop, an index known as Water Requirement Satisfaction Index (percent) expressing the degree of satisfaction of the crop water requirements. This index is strongly correlated with the yield and gives a very good idea, at least qualitatively, of the crop yield to be expected. The spatially explicit water requirement satisfaction index (WRSI) is an indicator of crop performance based on the availability of water to the crop during a growing season. FAO studies have shown that WRSI can be related to crop production using a linear yield-reduction function specific to a crop (FAO, 1977; FAO, 1979; FAO, 1986).

Since under *rainfed* condition, crops cannot be grown every year with same degree of success, assessment of region specific climatic risk of crop water availability is very much necessary. In order to quantify the climatic risk, historical weather data can be employed to estimate the statistical probability (indicator of risk) of a given weather parameter for use in the decision support system. In this study, estimated soil water balance parameters with respect to new alluvial agroclimatic zone of the state were subjected to probability analysis to provides direct quantitative estimates of crop water stress as a function of crop, weather and soil condition in this zone.

MATERIALS AND METHODS

Weather and soil data

Daily rainfall data for Murshidabad district IMD station Baharampur representing New alluvial agroclimatic zone of West Bengal for 100 years period from 1901-2000 were collected from National Data Centre, Indian Meteorological Department, Pune. These daily rainfall data were then summarized on standard meteorological week (SMW) basis suitable for this analysis. Weekly average potential evapotranspiration data for this study were collected from Annual Reports of All India Coordinated Research Project (AICRP) on Agro meteorology, Bidhan Chandra Krishi Viswavidyalaya. In order to run climatological water balance programme, information on available water holding capacity (AWHC) of soil was required for this study. Since available water holding capacity information is not available directly, it was derived using soil texture information and standard values of respective soil textural class as described in Doorenbos and Pruitt (1977). In this study, three soil textural classes, viz, coarse, medium and fine textured soil were considered for simulation of water balance for rape and mustard. AWHC values for these soils were considered to be 60, 140 and 200 mm/m depth of soil respectively for coarse, medium and fine textured soil.

Crop coefficient

The Kc value, which represent the ratio of actual evapotranspiration of a crop under water non-limiting and disease free condition to the potential evapotranspiration, for different growth stages of rape was collected from. (Choudhary *et al,* 1999) as presented by Bhowmick (2001). From this, weekly values of Kc corresponding to vegetative, reproductive and maturity stages were interpolated using the method described in Doorenbos and Pruitt (1977). The interpolation and the corresponding weekly values of Kc are presented in Table 1. In this study, total growing period of rape/yellow sarson (*Brassica campestris* var. Yellow sarson) was considered to be 13 weeks (Vegetaive-5; reproductive-4; maturity-4) and "Binoy" was considered to be the representative cultivar. The duration of each stage was considered following local information from experiments as well as farmer's field.

Sowing dates

For simulating water availability indicators for yellow sarson, six different sowing periods on weekly interval (based on Standard Meteorological Week) were considered at 2 weeks interval, viz, 38 SMW (Sep 17-23), 40 SMW (Oct 1-7), 42 SMW(Oct 15-21), 44 SMW(Oct 29 – Nov 4), 46 SMW(Nov 12-18) and 48 SMW(Nov 26- Dec 2). These dates of sowing were considered keeping in mind the earliest and latest possible sowing of these crops under West Bengal condition.

Simulation of profile soil moisture

Amount of soil moisture present at the end of each SMW corresponding to coarse, medium and fine texture soil for each database year were simulated using Thornthwaite and Mather (1955) climatological water balance analysis where this was estimated as a function of available water holding acapacity and accumulated potential water loss (rainfall minus potential evapotranspiration).

Simulation of crop water use and estimation of WRSI

Using FAO water balance (FAO, 1979), weekly values of crop water use as a function of crop water requirement and soil water reserve were estimated. Water Requirement satisfaction Index indicates in percentage the extent to which the water requirement of an annual crop has been satisfied cumulatively at any stage of its growing cycle. The index is calculated as follows: It is assumed that at the beginning of the growing cycle sowing takes place when the water availability in the soil is ample. The value of index is thus assumed to be 100 and will remain at 100 for the successive weeks until either a surplus of more than 100 mm or a deficit appears. If a surplus of more than 100 mm occurs during a week the index is reduced by 2.1 units to 97.9 during this week (@ 0.3 unit /day) and remains at that level until a further stress period occurs. If after a certain week, the water reserves fall to zero and a deficit appears, then the quotient between the water deficit of that week and the total water requirement of the crop for the entire season (as calculated previously) expressed as percentage will be deducted from previous weeks WRSI to determine current weeks value. In this way, the calculation is pursued to the end of the growing season, taking into account the fact that the index number starts in the first week at 100 and thereafter can only remain at 100 or go down. The index at the end of the growing season will reflect the cumulative stress endured by the crop through

Table 1: Weekly crop coefficient (Kc) values of yellow sarson (cv. Binoy).

Crop growing Week	Crop Coefficient	Crop growing Week	Crop Coefficient
1	0.49	8	1.23
2	0.49	9	1.23
3	0.49	10	1.23
4	0.58	11	1.23
5	0.77	12	0.91
6	0.95	13	0.54
7	1.14		

Table 2: Classification of the crop status based on water requirement satisfaction index (source: Smith, 1992).

Percentage of yield in relation to average of 3 best yields	Crop performance index	Water requirement satisfaction index (WRSI)
> l00 %	Very good	100
90-100 %	Good	95-99
50-90 %	Average	80-94
20-50 %	Mediocre	60-79
10-20 %	Poor	50-59
<10 %	Crop failure	< 50

Table 3: Profile stored soil moisture (mm) at the beginning of sowing yellow sarson crop at different times of Rabi season.

Standard Week	Coarse Textured Soil (AWHC			
	Mean	SD	CV%	P
38	55.4	8.2	14.7	
40	52.1	10.2	19.6	
42	44.1	13.9	31.5	
44	29.6	14.6	49.4	
46	18.7	12.5	67.0	
48	10.5	7.5	72.0	
	Medium Textured Soil (AV			
38	134.5	9.5	7.0	
40	130.9	11.9	9.1	
42	120.8	17.7	14.6	
44	100.2	21.6	21.5	
46	80.1	22.2	27.7	
48	61.4	17.5	28.1	
	Fine Textured Soil (AWI			
38	193.9	11.6	6.0	
40	190.4	12.5	6.6	
42	179.8	19.0	10.6	
44	157.4	24.1	15.3	
46	133.8	25.9	19.4	
48	111.0	21.7	19.5	

excess and deficits of water during the growing stage, which is usually closely linked with the final yield of the crop.

Climatic risk analysis

Simulated water balance components like, water use and water requirement satisfaction index were subjected to statistical analysis for estimating value of the components at different probability level. These probabilities were estimated considering normal distribution of water balance components. Subtracting probability values from 100 was considered as climatic risk levels for different components.

Classification of crop performances based on WRSI

A seasonal WRSI value less than 50 is regarded as a crop failure condition and other intermediate values of WRSI were considered for classifying crop status as per description given by Smith (1992) and presented in Table 2. On the basis of this condition individual database year was assigned with different status viz, very good, good, average, crop failure etc and their frequency over the entire time series were analyzed.

RESULTS AND DISCUSSION

Profile stored moisture (mm)

Data presented in Table 3 clearly shows that under the same rainfall regime higher the available water holding capacity of soil higher will be the profile stored moisture at the start of cropping season. Since the prospect of yellow sarson crop under *rainfed* condition mainly depends on quantity of profile moisture at sowing, the change of profile moisture with advancement of sowing period is of major concern to crop planner. Data presented in this table indicate that there is massive reduction in profile stored moisture as sowing is delayed from 38th SMW to 48th SMW. This reduction is to the tune of around 5 times in coarse textured soil, 54percent in medium textured soil and 43percent in fine textured soil. Also the coefficient of variability (CV) changes with change in the time of sowing but in opposite direction as compared to the quantity of moisture, i.e., as the sowing time is delayed the coefficient of variability of profile stored moisture over the years greatly increases which indicates that the mean value of profile moisture is less dependent for the purpose of crop planning particularly under late sown condition. It is evident from the table that 75 percent of AWHC can be expected as initial profile moisture for sowing of *rainfed* yellow sarson crop up to 44th SMW both in medium and in fine textured soil. This level of initial profile moisture can be considered adequate for sowing *rainfed* yellow sarson crop in West Bengal. The result of climatic risk analysis reveals that if a farmer wants to operate at a lower climatic risk level, which is assured profile moisture in three out of four years (P=75 percent) he has to sow the crop two week in advance of above-mentioned period in medium and fine textured soil. It is also to be pointed out here that crops sown up to 42nd SMW are likely to get substantial rainwater contributed by the end of rainy season. However, crops grown beyond this period can expect only small amount of winter rain as a source of water in addition to profile moisture at sowing.

Water requirement

It has been noted that total water requirement gradually decreases with delay in sowing which is mostly contributed by the variation in water requirement during vegetative stages since air temperature, one of the major input in estimating PET is highly variable during this stage due to such shift in sowing. Due to such shift in sowing from 38th SMW to 48th SMW, total water requirement reduces by 10 percent and that in vegetative stage reduces by 22 percent (Table 4).

Water use

Due to better retention of moisture in fine textured soil total water use was always higher with increase in available water holding capacity of the soil which was mainly contributed by higher water use during reproductive and maturity stages (Table 5). With delay in sowing from 38th SMW to 48th SMW total water use gradually decreases and rate is faster in case of coarse textured soil. However, due to some late winter rainfall during February and March, crop sown during 46th to 48th SMW secure little more water use at maturity stages particularly in coarse and medium textured soil as compared to the same in early sown crop. Due to presence of profile moisture in sufficient amount water use in vegetative stage did not vary much in medium and fine textured soil. However, in coarse textured soil profile moisture is relatively less and accordingly water use for successive sowing is highly variable in this growth stage, though, in such soil the rate of reduction of water use in vegetative stage of rape and mustard crop is much faster as compared to that in medium and fine textured soil as the sowing is delayed from 38th SMW to 48th SMW.

The coefficient of variability of water use studied at different growth stages of the crop showed that maturity stage have maximum CV of water use followed by reproductive and vegetative stage. In medium textured soil the coefficient of variability during maturity stage is more than 100 percent and for sowing for the entire range of sowing weeks, which in fine textured soil, happens for sowing at 44th SMW and beyond. Very high CV at the maturity stage is indicative of extremely erratic winter rainfall in this agroclimatic zone over the years as these growth stages hardly receive any contribution from profile stored soil moisture.

Water requirement satisfaction index (WRSI)

Mean WRSI of *rainfed* yellow sarson crop in new alluvial agroclimatic zone varied from 80 to 100 percent at the end of vegetative stage, 44 to 99 percent at the end of reproductive stage and 15 to 91 percent at the end of maturity stage across different textural classes and dates of sowing (Table 6).

The rate of decrease of WRSI with delay in the dates of sowing is most pronounced in maturity stage which is followed by reproductive and vegetative stage. This is mainly due to the fact that any stress experienced by the crop at any growth stage is reflected in final WRSI. Even at maturity stage if the crop receives some rainfall late in the winter its water use may increase for the time being but it may not be reflected in WRSI since its value can move only in reducing direction. It is clearly evident that in coarse textured soil less than half of water requirement is satisfied up to the harvest of crop irrespective of dates of sowing except the earliest sowing week of 38th SMW which clearly indicates unsuitability of growing this crop under rain fed condition in such soil.

Since crop production under *rainfed* condition is not assured every year, climatic risk associated with water availability to crop was studied which showed that the chance of getting at least mediocre crop yield (60 to 79 percent)

Table 4: Water requirement (mm) of yellow sarson for different sowing dates

Sowing weeks	Growth stages			Total
	Vegetative	Reproductive	Maturity	
38	108.4	122.4	97.4	328.2
40	93.5	115.0	96.7	305.1
42	82.4	111.3	96.6	290.3
44	76.2	110.9	95.9	282.9
46	73.5	110.6	94.6	278.7
48	72.7	109.7	94.2	276.6
Mean	84.4	113.3	95.9	293.6

Table 5: Phasic water use (mm) of yellow sarson (cv. Binoy) indifferent soils

Soil	Sowing week	Crop growth stage								
		Vegetative			Reproductive			Maturity		
		Mean	SD	CV%	Mean	SD	CV%	Mean	SD	CV%
Coarse	38	106.9	5.5	5.1	53.0	33.8	63.8	7.0	14.6	209.0
	40	87.7	11.8	13.5	28.2	24.6	87.2	5.0	11.3	224.8
	42	65.9	18.3	27.8	14.3	18.8	131.0	5.8	12.2	210.5
	44	44.4	21.2	47.8	7.3	13.4	183.8	9.4	14.6	155.7
	46	26.9	17.4	64.7	7.8	14.9	191.8	11.7	14.6	124.9
	48	17.5	15.5	88.6	10.6	16.8	158.3	14.4	14.6	101.7
Medium	38	108.4	0.0	0.0	111.9	16.8	15.0	26.4	27.6	104.6
	40	93.5	0.0	0.0	94.4	23.1	24.5	12.4	17.0	136.6
	42	82.4	5.9	7.2	73.7	28.5	38.7	7.4	13.3	178.7
	44	75.5	3.0	4.0	47.3	30.1	63.7	9.7	15.0	155.3
	46	70.0	7.2	10.3	26.0	25.0	96.1	12.3	16.7	135.6
	48	69.6	12.1	17.4	17.9	21.0	117.5	15.1	16.7	110.4
Fine	38	108.4	0.0	0.0	122.1	1.7	1.4	69.1	28.0	40.5
	40	93.5	0.0	0.0	113.5	6.0	5.3	51.8	29.1	56.2
	42	82.4	5.9	7.2	106.8	11.1	10.4	33.2	27.0	81.2
	44	76.2	3.9	5.1	93.1	20.9	22.5	20.2	20.6	101.9
	46	73.5	0.0	0.0	73.7	27.0	36.6	14.2	17.9	126.0
	48	72.7	0.3	0.3	54.9	27.7	50.5	15.7	18.5	117.6

WRSI level is once in four years (25percent probability) when the crop was sown up to 42nd SMW in medium textured soil. However, in fine textured soil, WRSI at this risk level available for crop sown up to 46th to 48th SMW. At lower climatic risk level i.e., the chance of success of three out of four years (75 percent probability) this kind of yield prospect is possible for crops sown up to 38th SMW in medium textured soil and almost up to 42nd SMW in fine textured soil. The result indicates that the lower yield prospect under *rain fed* condition is attributed mostly to the moisture stress during maturity stage of the crop irrespective of date of sowing. In one out of four years (High risk, 25percent probability) mediocre yield of mustard (WRSI 60 to 79 percent)can be expected for crop sown up to 42nd SMW in medium textured soil and upto 48th SMW in fine textured soil respectively. Integrating FAO crop water balance and GIS approach, Patel (2004) estimated and classified water deficit for wheat crop to assess water limited yield potential in the Surana watershed of Dun valley of India.

Yield prospect of yellow sarson crop under rain fed condition

It was revealed from data presented in the Table 7 that the chance of crop failure is always more than 50 percent in coarse textured soil irrespective of date of sowing. However, crop failure up to that extent is possible if the yellow sarson crop is sown only beyond 42nd SMW under medium textured soil. In fine textured soil, the frequency of crop failure condition is below 50 percent even when sowing was delayed upto 48th SMW. In coarse textured soil, the possibility of at

Table 6: WRSI of yellow sarson (cv. Binoy) at three different stages

Week	Mean			Prob = 25%			Prob=75%		
	Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Medium	Fine
Vegetative Stage									
38	99.1	99.5	99.5	100	100	100	97.9	90.9	98.9
40	97.8	99.7	99.7	100	100	100	95.2	99.2	99.2
42	94.3	99.9	99.9	98.5	100	100	90	99.6	99.6
44	88.7	100	100	93.8	100	100	83.7	99.8	99.8
46	83.3	100	100	87.5	100	100	79.1	100	100
48	80	99.9	99.9	83.8	73.7	100	76.2	99.9	99.9
Reproductive Stage									
38	77.9	96.3	99.4	85.1	99.7	100	70.7	92.9	98.7
40	69.4	93	99.3	76.2	98	100	62.6	88	97.9
42	60.9	87	98.4	67.7	93.5	100	54.1	80.4	95.8
44	52.1	77.3	93.7	58.5	84.6	98.7	45.7	69.9	88.7
46	46.4	68.4	86.7	51.9	75.3	93.3	40.8	61.4	80.2
48	44.2	62.7	80.1	49.8	69.5	86.8	38.5	55.8	73.4
Maturity Stage									
38	50.3	74.6	90.8	58	82.2	96.5	42.7	67.1	85
40	39.4	65.4	84.6	46.6	72.7	91.4	32.1	58.1	77.7
42	29.5	56.2	76.5	36.8	63.8	84.2	22.3	48.6	68.8
44	21.5	46.8	66.9	28.8	55.1	75.5	14.3	38.4	58.4
46	16.6	38.3	57.9	23.4	47.4	66.5	9.8	30.3	49.3
48	15.3	34.1	57.8	22.4	43	60.6	8.2	25.2	42.9

Table 7: Frequency of yellow sarson (cv. Binoy) yield prospect under rain fed condition

Soil	Sowing week	Failure	Poor	Mediocre	Average	Good	Very good
Coarse	38	51	28	21	0	0	0
	40	81	17	1	0	0	0
	42	98	1	0	0	0	0
	44	98	1	0	0	0	0
	46	98	0	1	0	0	0
	48	98	1	0	0	0	0
Medium	38	1	5	62	28	2	2
	40	6	23	63	7	1	0
	42	30	28	40	1	0	0
	44	57	26	15	1	0	0
	46	81	15	1	2	0	0
	48	93	4	1	1	0	0
Fine	38	0	0	14	41	21	21
	40	0	2	32	43	15	7
	42	1	6	51	39	2	1
	44	9	26	46	16	1	1
	46	32	25	38	2	1	1
	48	49	26	21	1	1	1

least mediocre (20 to 50 percent of best yield) yield is practically negligible for sowing beyond 38th SMW.

Considering an acceptable limit of at least mediocre rape yield in 40 percent of the years it can be advocated that sowing of this crop should not be done beyond 42nd SMW in medium textured soil. In fine textured soil, mediocre yield prospect, at least in the 40 percent of the years, can be expected for yellow sarson crop sown up to 46th SMW. It has also revealed from this study that, only in fine textured soil, the prospect of good yield (95 to 100 percent) of this crop exists in 42 percent and 22 percent of the years if sown within 38th and 40th SMW respectively.

The study reveals that vegetative stage of the crop hardly faces any moisture stress whereas; moisture stress at the maturity stage is obvious. Water stress during reproductive stage depends on soil texture and sowing time. Coarse textured soil is unsuitable for growing *rainfed* yellow sarson crop during *rabi* season. At least 100 mm profile stored moisture is present to start sowing operation in this zone upto 42nd (Oct 15-21) and 46th SMW (Nov 12-18) in medium and fine textured soil respectively, at 75 percent probability level, for good initial growth of the plant. Chance of getting at least mediocre (60-79 percent WRSI) crop yield in every alternate year under *rainfed* condition is possible when yellow sarson is sown upto 40th SMW (Oct 1-7) in medium and upto 44th (Oct 29-Nov 4) SMW in fine textured soil. The prospect of getting good yield (95-100 percent WRSI) of this crop exist even under *rainfed* condition in this zone in more than 20 percent of the year if sown within 7th October in fine textured soil.

CONCLUSION

Sufficient initial profile moisture for sowing of yellow sarson is available up to 42nd SMW in medium and upto 44th SMW in fine textured soil. Under *rainfed* condition, fine textured soil will have better prospect for yellow sarson for better level of satisfaction of water requirement at reproductive and maturity stages. In medium textured soil, *rainfed* yellow sarson can be sown up to 40th to 42nd SMW in medium and up to 44th SMW in fine textured soil. Water balance parameters like WRSI, water deficits etc. are most favorable for yellow sarson in red and lateritic zone and least favourable in coastal saline zone in similar textural classes of soil. Other zones are in between these two and are similar in status under same textured classes of soil. Coarse textured soil is unsuitable for growing *rainfed* yellow sarson crop. Under *rainfed* condition, with delay in sowing from 38th SMW to 48th SMW water requirement satisfaction index at the harvest of the crop gradually decreases irrespective of soils and agroclimatic zones. Vegetative stages of yellow sarson hardly require any irrigation except in coarse textured soil. Maturity stages require irrigation irrespective of sowing conditions, soil texture and agroclimatic zones. In reproductive stage, irrigation requirement depends on above conditions. At lower climatic risk level, favourable moisture regime for the crop can be expected upto two weeks prior to the week with favourable condition based on mean values of water balance parameters.

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