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Introduction

Oilseed crop occupies an important position in the agricultural and industrial economy of the country and accounts for about 14 per cent of the total crop area (Shekhawat *et al*., 2012). Mustard is one of the five major oil seeds from which edible oil is produced. The place of origin of rapeseed is eastern Afghanistan and adjoining part of India and Pakistan. India is one of the largest rapeseed-mustard growing countries in the world, occupying the first position in cultivated area and second position in production after China (Hedge, 2005). Rapeseed-mustard is the second most important edible oilseed crop after groundnut and accounts for nearly 30% of the total oilseeds produced in the country. Compared to other edible oils, the rapeseed-mustard oil has the lowest amount of harmful saturated fatty acids. It also contains adequate amounts of the two essential fatty acids, linoleic and linolenic, which are not present in many of the other edible oils. Mustard oil is used for cooking in almost all the states of the eastern region, including West Bengal and its cake is the common cattle feed which has got high nutritional value.

The rapeseed-mustard group broadly includes Indian mustard, yellow sarson, brown sarson, Rai, and Toria crops. Mustard is cultivated mostly under temperate climates. It is also grown in certain tropical and subtropical regions as a winter season crop. Indian mustard is reported to tolerate annual precipitation of 500 to 4200?mm, annual temperature of 6 to 27°C, and pH of 4.3 to 8.3 (Shekhawat *et al*., 2012). Rapeseed-mustard follows C_3 pathway for carbon assimilation. It has efficient photosynthetic response at 1520°C temperature. At this temperature the plant achieves maximum CO_2 exchange rate which declines thereafter. Mustard requires well-drained sandy loam soil. Rapeseed-mustard has a low water requirement (240-400 mm) which fits well in the rainfed cropping systems. In India, nearly 20% area under these crops is rainfed. In this technical bulletin an attempt has been made to summarise optimum agro-meteorological requirement of rapeseed-mustard along with its normal package of practices followed in Gangetic W.B.

Importance of rapeseed-mustard in Indian agriculture

In India rapeseed-mustard is generally cultivated in Rabi season. Sowing of seeds starts in the middle of October and continues up to the end of December. It is mainly grown in North-Western parts of India. Rajasthan and Uttar Pradesh are the major mustard seed producing states of the country. The cultivation of mustard in Rajasthan is highly monsoon dependent. The other significant producers are Madhya Pradesh, Haryana, Gujarat, West Bengal and Assam. Among the seven edible oilseeds cultivated in India, rapeseed-mustard contributes 28.6% in the total oilseeds production and ranks second after groundnut sharing 27.8% in the India's oilseed economy (Shekhawat *et al.*, 2012). The area, production and productivity of mustard in West Bengal is shown graphically in Annexure-I.

Characteristic features of important types of rapeseed-mustard

Several *Brassica* species are cultivated in India as rapeseed-mustard. Three species viz. *B. campestris*, *B. juncea* and *B. napus* are grown for their economic perspective. Based on seed colour and shape, rapeseed- mustard grown in the country can be grouped as:

Yellow and brown sarson *(Brassica napus var. glauca and var. dichotoma):* It is widely grown in north and central India. There are two main types under *B. campestris*, namely, yellow and brown sarson. They are named according to their seed colour. The crop is sown in October and harvested in March/April. The crop duration is about 90-120 days. The seeds are bold and large size; Round in shape and have a smooth surface.

Toria *(Brassica napus var. toria):* It is grown as an autumn crop. This variety is susceptible to clod and is sown early in middle or late September and takes about 75-100 days to mature. The variety is obviously low yielding but it responds to irrigation and adequate fertilization. The seeds are spherical or ovoid in shape and have slightly wrinkled surface. Colour of the seed is reddish or dark brown. Seeds are smaller than sarson.

Indian mustard *(Brassica juncea)*: It is grown in very limited areas and known as rai. The plants are tall, erect and much branched. It is very widely grown in India. The crop is sown in October/November and harvested in March/April with duration of 110-160 days period. This type gives better yield than *Brassica napus*. It has very low oil content, but the main purpose of its cultivation is to use it as condiment. The seeds are spherical or ovoid in shape and have slightly wrinkled surface. Colour of the seed is dark brown or black. Seeds are smaller in size.

Both rapeseed and mustard are self pollinated crop, up to a certain extent cross pollination also occur.

Overall climatic requirement of rapeseed-mustard

Rapeseed and mustard is grown during winter season and it favours the temperature in the range of 10 to 25^{0}C and low humidity. During germination and seed maturation stage slightly higher temperature (27^{0}C) is required though cold condition is favourable for crop growth. An optimum average temperature of 26^{0}C is required for the proper germination and establishment of seedlings (Lallu and Dixit, 2008). Excessive cold and frost are harmful for the crop. Cold temperature, bright sun shine and enough soil moisture increases oil content of seed, but excessive cold (< 0^{0}C) is harmful to the crop. *Toria* is light sensitive crop and very much sensitive to cold temperature. It should be sown in 1st week of October. High rainfall, humidity and cloudy condition during flowering stage onwards is very much detrimental for its growth as these weather situation increases the flower drop and invites aphid infestation. Pre-flowering rainfall boosts up the grain yield significantly. The areas having 625 to 1000 mm annual rains are best suited for this crop.

Sarson and *Toria* are preferred low rainfall areas, whereas *Rai* is grown in medium and high rainfall areas. Rapeseed and mustard are highly photo-sensitive crops. The optimum time of sowing is influenced by the atmospheric temperature. During crop maturation stage dry clear weather and open sky is essential.

Overall soil requirement of rapeseed-mustard

Rai and mustard can be grown in sandy to heavy clay soils but mustard thrives best in medium or heavy loam soils. Well drained medium to deep soils are most ideal for this group of crop. For brown and black mustard, light soils are preferable. Yellow mustard can be cultivated in heavy soils. For Mustard cultivation alluvial loam is the best soil. Tarai soils of U.P., Sandy loam of Punjab and Haryana, and heavy loam of Bihar and West Bengal are best suitable for yellow mustard cultivation. Black cotton soil is not recommended for mustard cultivation because in heavy black soil slight rain reduces germination percentage and rain during flowering weakens the plants. So, heavy soils subjected to water logging should be avoided, as the crop cannot tolerate such conditions. As mustard crop is very sensitive to water logging, soil should be well drained. In very light soils, the crop may face serious moisture stress. In its whole life span enough soil moisture is required. This can be grown in calcareous, sandy and shallow soil if enough moisture is available. Mustard can be grown in acidic soils but slightly alkaline and neutral soils are considered better. Soils having 7-8 pH are considered as the best.

Agrometeorological requirements of mustard crop

To work out the optimum requirement of meteorological parameter of mustard crop, field experiments were conducted consecutively for ten years with different dates of sowing in lower Gangetic West

Bengal. In the study, forty sets of environmental or meteorological conditions along with various crop data were taken into consideration. At first we divided the whole sets of data based on crop productivity. When the productivity is more than the state average productivity, then that set is considered as "good yield condition". Similarly below the state average productivity is considered as "poor yield". Thereafter, the data on meteorological parameters (crop phenological stage wise) were arranged for good years as well as for poor years. Then the weather parameters of all the good years were averaged to get the optimum meteorological condition.

To identify the favourable or ideal date of sowing (DOS), the average weather data was computed on daily basis from last 10 years weather data. Then six different date of sowing (1st October to 16th December, which covers the sowing window in the zone or state) was assumed. From 40 sets of experimental data, the average days required to achieve different phenological stages under different dates of sowing was calculated. Later, the weather data requirement for every phenological stage under those six dates of sowing from daily average weather data was computed. The meteorological conditions prevailed under six dates of sowing is compared with the optimum weather condition generated from forty sets of experimental data. The date of sowing which provides the weather conditions closed to the optimum condition will be regarded as the optimum date of sowing in Southern West Bengal. The main crop growth stages (phenological stages) which were considered in the technical bulletin are as follows:

Germination : 2-3 DAS

Branching : 30-35 DAS

Flowering : 45-50 DAS

Siliqua formation : 50-55 DAS

Maturity : 85- 90 DAS

Table 1. Optimum range of weather parameters for different crop growth stages based on 10 years experimental data of AICRPAM Mohanpur. **

Phenological Stages	Max. T (^{0}C)	Min. T (^{0}C)	RH I	RH II	BSS (hr)	Rainfall (mm)	Evapora-tion(mm)
DOS - DOE	31.4 (30.2- 32.4)	20.0 (19.1- 21.1)	96 (93- 98)	60 (51-68)	8.8 (5.1-13.0)	0.4 (0.0- 2.2)	1.8 (1.3- 2.3)
DOE - 5th Leaf	30.2 (27.5- 32.3)	18.6 (16.0- 22.0)	97 (92- 99)	59 (44- 76)	7.4 (2.7- 9.0)	3.5 (0.0- 18.3)	1.7 (0.8- 2.7)
5th Leaf - 1st Flower Bud	29.4 (27.2 - 31.2)	16.1 (13.0 - 20.0)	97 (91 - 100)	52 (40 - 72)	8.3 (4.0 - 8.8)	1.1 (0.0 - 10.8)	1.5 (0.9 - 2.2)
1st Flower Bud- 1st Flower	28.4 (26.8 - 29.9)	13.9 (11.5 - 17.5)	97 (93 - 99)	49 (39 - 61)	8.5 (5.3 - 8.7)	0.1 (0.0 - 0.3)	1.5 (0.9 - 2.1)
1st Flower - 50% Flowering	28.0 (26.7 - 29.1)	12.8 (11.2 - 14.6)	98 (94 - 99)	47 (41 - 56)	8.6 (6.4 - 8.5)	0.0	1.3 (1.0 - 1.8)
50% Flowering - End of Flowering	27.0 (24.4 - 29.5)	11.6 (8.3 - 15.4)	98 (92 - 100)	48 (36 - 91)	8.2 (3.8 - 8.8)	0.0 (0.0 - 0.1)	1.3 (0.8 - 1.9)
1st Siliqua - 100% Siliqua	27.4 (25.5 - 29.2)	12.2 (9.8 - 14.7)	98 (94 - 100)	48 (40 - 60)	8.2 (5.0 - 8.5)	0.0 (0.0 - 0.1)	1.3 (0.8 - 1.8)
100% Siliqua - Harvesting	26.7 (21.9 - 31.1)	11.5 (7.2 - 17.2)	98 (87 - 100)	49 (32 - 78)	8.0 (1.5 - 9.0)	0.2 (0.0 - 6.1)	1.5 (0.5 - 2.6)

** Data within the brackets represents range of the data

Table 2. Variation of different weather parameters during different crop growth stages for the years corresponding to poor yield. **

Phenological Stages	Max. T (^{0}C)	Min. T (^{0}C)	RH I	RH II	BSS (hr)	Rainfall (mm)	Evapora-tion (mm)
DOS - DOE	29.2 (28.3 - 30.6)	15.7 (14.8 - 18.0)	97 (94- 99)	53 (45 - 65)	8.6 (6.0 - 9.0)	0.8 (0.0- 5.3)	1.7 (1.2 - 2.2)
DOE - 5th Leaf	28.5 (25.8 - 30.6)	14.9 (12.0- 18.2)	97 (91- 99)	52 (41- 72)	8.2 (3.5 - 9.2)	1.1 (0.0 - 12.6)	1.6 (0.8 - 2.3)
5th Leaf - 1st Flower Bud	27.4 (25.0 - 29.4)	13.3 (10.6 - 16.3)	98 (94 - 99)	54 (42 - 87)	8.2 (5.2 - 8.9)	0.2 (0.0 - 3.2)	1.5 (0.9 - 2.0)
1st Flower Bud- 1st Flower	26.5 (24.5 - 28.2)	12.1 (10.0 - 14.4)	98 (95 - 99)	51 (43 - 64)	7.9 (4.7 - 8.7)	0.2 (0.0 - 0.9)	1.4 (0.9 - 1.9)
1st Flower - 50% Flowering	26.0 (24.5 - 27.3)	11.6 (10.3 - 12.9)	98 (97 - 99)	52 (44 - 62)	7.9 (5.3 - 8.4)	0.1 (0.0 - 0.7)	1.4 (1.0 - 1.7)
50% Flowering - End of Flowering	26.0 (22.3 - 29.3)	12.2 (8.6 - 16.5)	98 (92-100)	55 (40 - 96)	7.5 (3.0 - 9.0)	0.3 (0.0 - 3.3)	1.4 (0.6 - 2.3)
1st Siliqua - 100% Siliqua	26.6 (24.7 - 28.5)	12.0 (10.2 - 14.3)	98 (95 - 99)	53 (43 - 85)	8.1 (5.8 - 8.6)	0.1 (0.0 - 1.3)	1.5 (1.0 - 2.0)
100% Siliqua - Harvesting	27.1 (20.8 - 31.7)	13.6 (7.5 - 19.8)	98 (83-100)	55 (31 - 82)	7.5 (1.1 - 9.4)	1.5 (0.0 - 12.0)	1.9 (0.5 - 3.9)

** Data within the brackets represents range of the data

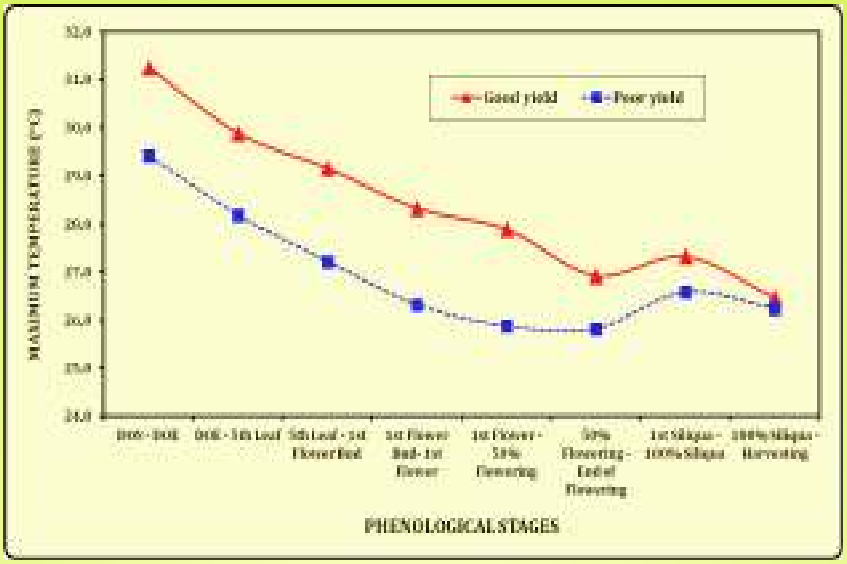

Fig. 1: Variation of maximum temperature during different crop growth stages

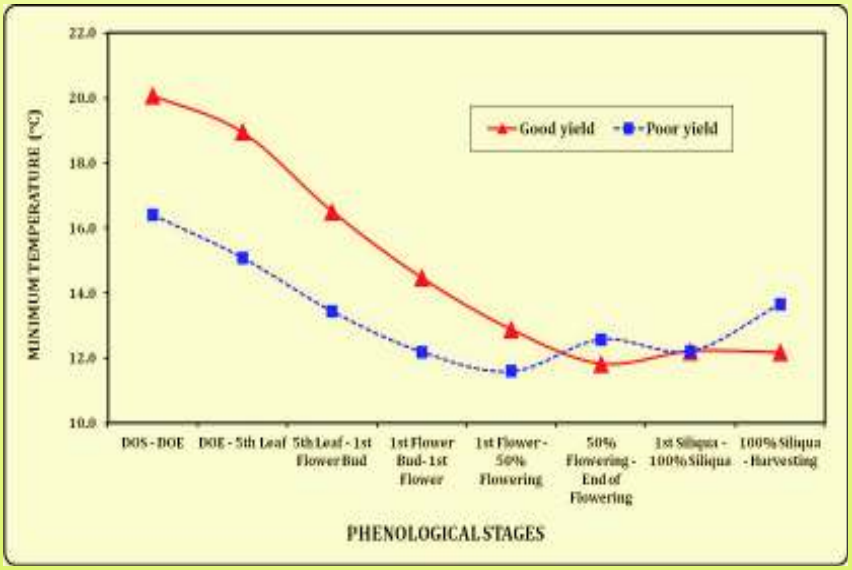

Fig. 2: Variation of minimum temperature during different phenological stages

Weather parameters governing growth and yield of rapeseed-mustard

Variation of different weather parameters namely, maximum temperature, minimum temperature, relative humidity, bright sunshine hours, rainfall and evaporation, responsible for good and poor yield have been presented in Table 1 and 2. The most effective parameters are discussed below.

Temperature: Temperature has immense influence on the biomass and yield of mustard. High temperature may enhance plant development but 2-3^{0}C increase in temperature above optimum during terminal or reproductive stages may cause flower abortion leading to tremendous yield reduction.

Maximum Temperature: From our experimentation over the last decade it has been observed that during germination mustard crop required higher temperature regime (Fig.1). To get optimum yield, the maximum temperature should be in the range of 30-32^{0}C and 27-28^{0}C during early vegetative stage and reproductive or flowering stages respectively. But throughout our experimental years it has been observed that when the maximum temperature remained below the optimum range (27-32^{0}C), tremendous yield reduction was noticed. Maximum temperature 2-3^{0}C higher or lower than the range may cause flower abortion or may halt the procedure of pod formation respectively.

Minimum Temperature: Minimum temperature also plays a vital role in the growth of mustard. During developmental or vegetative stages 17-20^{0}C temperature is optimum (Fig.2). In contrast, during reproductive stages, comparatively low temperature (12-15^{0}C) is required. Beyond and below the range may affect the pod or siliqua formation in same way as discussed above.

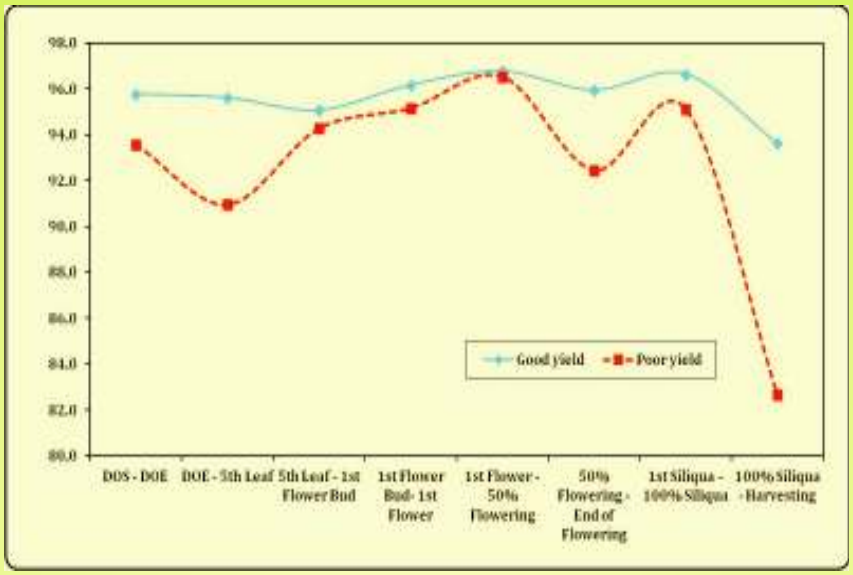

Fig. 3: Variation of morning RH during different phenological stages

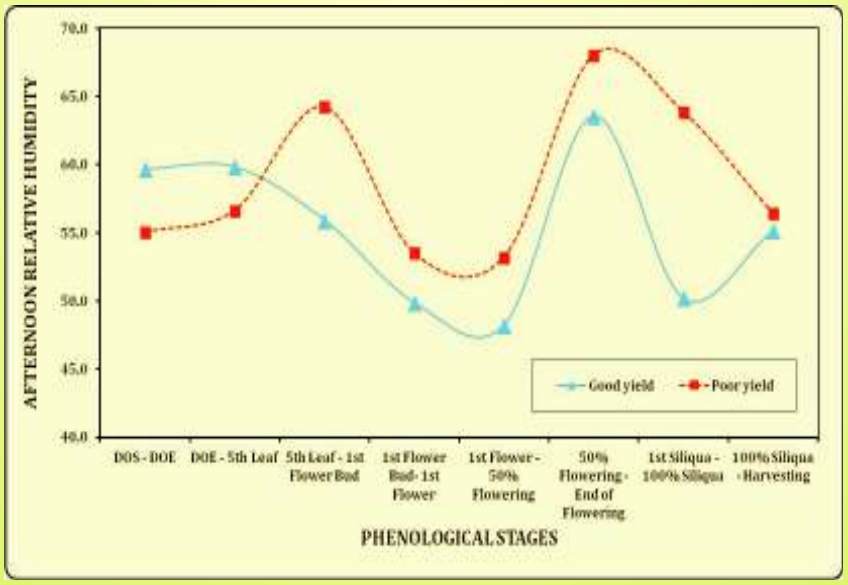

Fig. 4: Variation of afternoon RH during different crop growth stages

Relative Humidity: From the graph of morning relative humidity (Fig.3) it has been observed that a steady RH (94% 96%) pattern is helpful for obtaining optimum yield. It was observed that fluctuation of RH (83% 94 %) was closely associated with low/poor yields.

Lower RH during afternoon time is favourable for obtaining optimum yield. From germination to the emergence of flower, RH decreased gradually from 60% to 50% but during 100 % flowering RH value remained at little higher (65%) level (Fig.4). During siliqua formation and harvesting the low RH value (50%) is desirable. But increase in afternoon RH (4% - 6%) may harm the crop by increasing the disease-pest infestation.

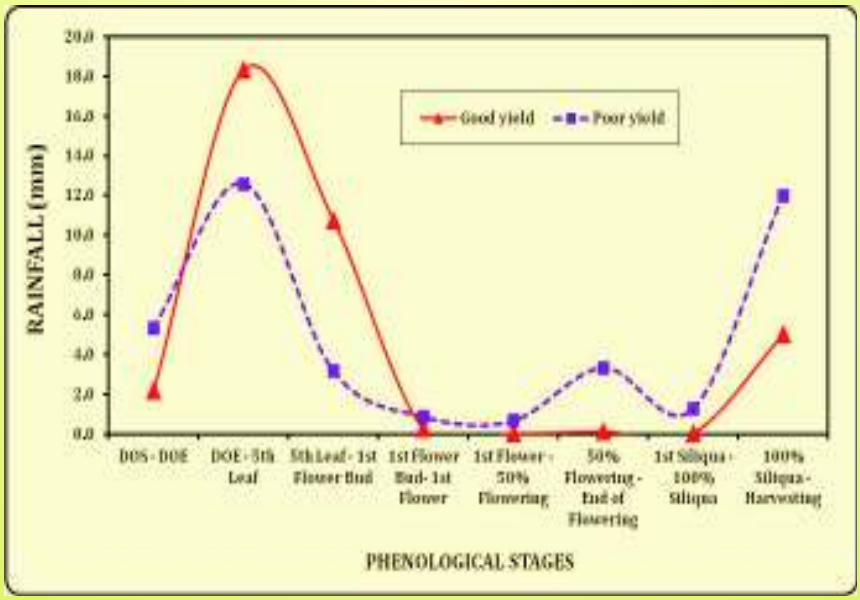

Fig. 5: Variation of rainfall during different crop growth stages of mustard over all the experiments

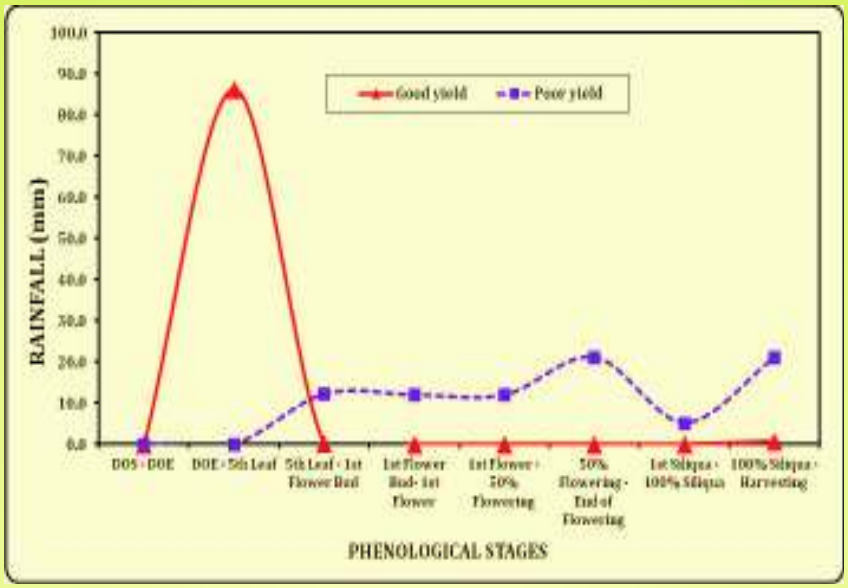

Fig. 6: Variation of rainfall during different phenological stages of mustard over a specific experiment

Rainfall: From our experiments over the years it has been observed that rainfall during the early vegetative stages i.e., before flowering is helpful in the accumulation of good biomass followed by good yield. But rainfall (Fig.5) during the flowering or reproductive stage adversely affects the siliqua or pod formation. Heavy rainfall increases the process of flower drop which is the major cause for yield reduction.

During a specific experimental condition (Fig.6), it has been observed that heavy rainfall during the early crop growth stage is beneficial for crop as the yield of that year is 1411 Kg ha^{-1} whereas medium rainfall during the flowering stage drastically reduced the yield to 610 Kg ha^{-1} by the process of flower drop.

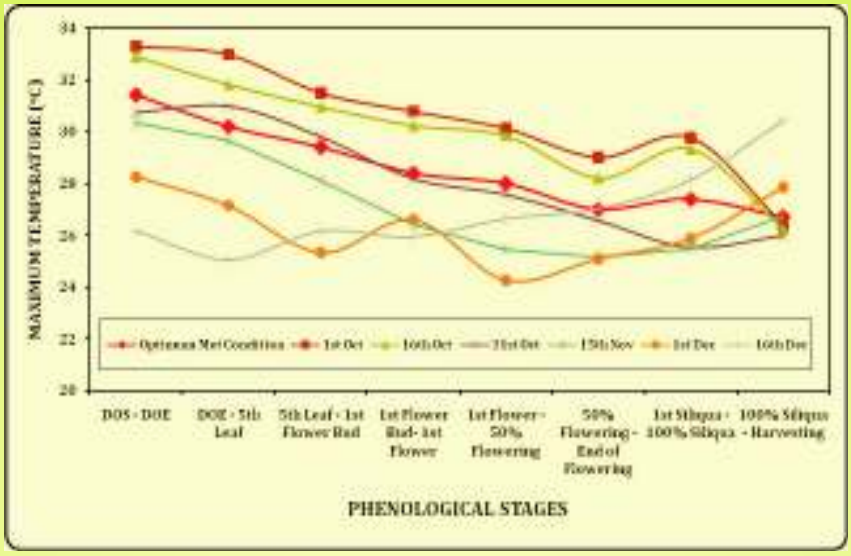

Fig. 7: Variation of maximum temperature over different phonological stages to identify the optimum date of sowing

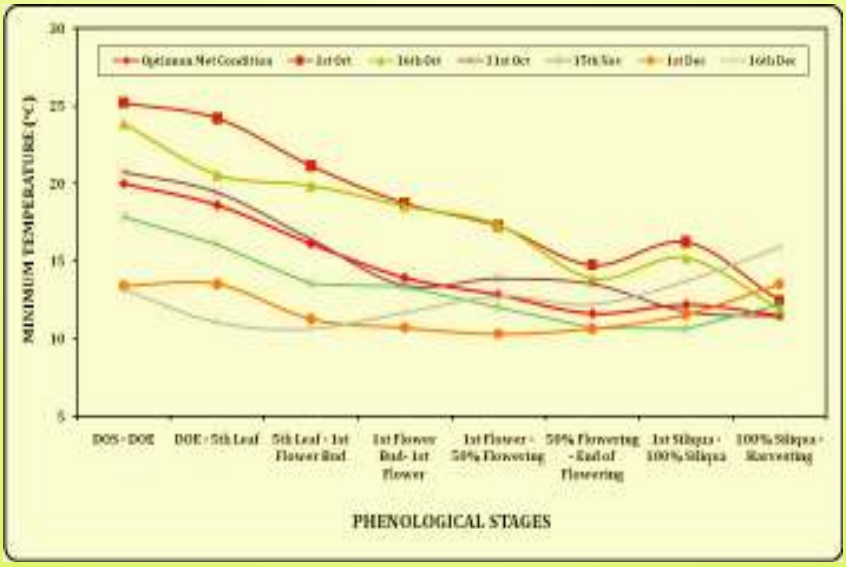

Fig. 8: Variation of minimum temperature over different phonological stages to identify the optimum date of sowing

Optimum date of sowing: Weather is one of the major controlling factors for crop growth and yield. To get optimum yield, crop must be sown and grown in a suitable weather condition. To identify the favourable or ideal date of sowing (DOS), we compared the average weather data of good yield years over the last decade with the average weather data of six different dates of sowing (DOS: 1st October, 16th October, 31st October, 15th November, 1st December and 16th December).

From both the graphs of maximum (Fig. 7) and minimum (Fig. 8) temperature, it has been observed that when the crop is sown in 31st October, the stage wise prevailing weather conditions (purple line) followed almost similar trend like that of optimum condition (red lines) needed for mustard crop. Thus, end of October is the ideal time for sowing to meet the crops optimum meteorological needs. The sowing window can be extended up to 15th November as the weather conditions during different stages corresponds to this sowing time is also more or less suitable for crop growth. But the other four dates (1st October, 16th October, 1st December and 16th December) of sowing showed that the crops sown under those dates faced a fluctuating weather conditions which may hamper their growth and as a result the yield may be reduced immensely. If the crops are sown during the first half of October then the crops will face 2- 3 ^{o}C higher temperature which may cause flower abortion. On the other hand, pod formation may be halted due to 3-5 ^{o}C temperature decrease if the crop is sown during the end of November or early of December.

Normal management practices for growing rapeseed and mustard

The important steps involved in the sowing of rapeseed-mustard are discussed below.

Growing season in West Bengal:

Rapeseed / Mustard seed is usually a *Rabi* crop i.e. the sowing of the Rapeseed / Mustard seed is done in the winter (October and

November) under assured irrigation facilities. Rapeseed and mustard are sown when the average temperature ranges from 20-22°C. Delay in sowing results in high aphid attack.

Warm and wet seasons are not suitable for its cultivation. High temperatures, during early stages of plant growth cause improper development and profuse branching. Warm weather favours the spread of some common pests. Cool dry weather favours the aphids development. High humidity, cloudy weather and rainfall results in poor seed setting and high plant mortality. Heavy rains at flowering cause less pollination and results in poor yield. Frost during January causes damage to the floral parts and causes partial to total failure of crop. Mustard crop is a risky crop owing to natural vagaries which encourage most of insects and diseases.

Some Important varieties

Toria:

Agroni (B-54): This variety takes 70-75 days to get maturity. It is suitable under rainfed condition. The seed contains 38 percent oil. Its average yield is 8-10 q/ha.

***Panchali* (TWC-3):**

DK-1: This is a quick flowering and early maturing variety that vacates fields earlier for sowing wheat. Its comparative yield is lower but is preferred for sowing in the State on account of its earliness.

Bhawani: Plants are dwarf, profusely branched, long siliquae, seeds shining brown in colour and test weight (3-3.5 g/1000 seeds). It matures in 70-80 days and due to short duration, it escapes from aphid attack. The seed contains 43 percent oil. Its average yield is 7-8 q/ha.

White / yellow sarson:

Binoy (B-9): It is recommended for growing under rainfed condition in West Bengal, Assam etc. This variety takes 90-95 days to mature. Seed contain 46 percent oil.

Type-42: This variety takes 125-130 days to get maturity. Seeds are yellow in colour and oil content is 46 percent. Its average yield is 12-15 q/ha.

Rai:

Varuna (T-59): It is a medium tall variety maturing in about 125-140 days. It is prolific pod bearer and fairly resist ant to aphids. Both pods and grains of this variety are bold. The grains carry 42-44% oil. It is suitable for cultivation both under monoculture and mixture with wheat.

Vagirathi (RW-351): It is suitable under rainfed and irrigated condition in West Bengal, Assam, Bihar. It is matur in 100 days. Oil content is 41 percent.

RCC-4: The plants are medium tall, solid & with more branches. Seeds are medium in size & dark brown in colour. This variety is suited for sowing with wheat. Its maturity period is 155-160 days, oil is 40% & average yield is 10.5 q/ha.

Soroma (RW-85-59), Sanjukta, Pusabold, Sita (B-85) are some rai varieties.

Unirrigated condition: Binoy, Subinoy, Sita, Sanjukta

Late var.: Binoy, Soroma (RW-85-59), Sanjukta

1. Selection of seed by the farmers from their own land

Generally, growers keep their own seed from the previous crop. Some field area, 3-5 sq m from other rapeseed-mustard crops, is demarcated for the production of seed. This selected area is given special attention as regards to weed and rouging. The seed from this area is used for seed purpose only. The quantity of seed required depends mostly on seed size, seed viability and soil moisture

2. Seed treatment

Seed treatment is a useful practice for healthy plant growth. To isolate the healthy seed, total seed materials are dipped into 5% salt solution. The healthy and heavy seeds settle down on the bottom of the salt solution. They are thoroughly washed, shed dried and stored. Before sowing the seed is treated with Thiram or Captan or Carbendazim @ 2.5 g/kg seed as protection against seed-borne diseases.

3. Seed rate

Raya: When sown as pure crop, the seed rate of 6 kg ha-1 may be advised for all rapeseed and mustard crops.

Toria: The seed rate is 2.5-3.0 kg ha-1.

4. Time of sowing

Sowing time is the most vital nonmonetary input to achieve target yields in mustard. Production e?ciency of different genotypes greatly di?ers under di?erent sowing dates. Soil temperature and moisture in?uence the sowing time of rapeseed-mustard in various zones of the country. Sowing time in?uences phenological development of crop through temperature and heat unit. Sowing at optimum time gives higher yields due to suitable environment that prevails at all the growth stages. Normal sowing time is 1st fortnight of October and continues up to 1st fortnight of November.

5. Methods of sowing

a. Broadcast method

Since the seeds of rapeseed and mustard are small in size, therefore, growers find broadcasting method of sowing very convenient. They spread the seeds over the field as even as possible and plough or harrow and then plank the field. This method is not generally recommended. In this method of sowing, one or two thinning are required for getting optimum plant population.

b. Line sowing method

Seeds are sown in lines with the help of seed drill or para. The recommended spacing between lines, among plants and seed depth are given in Table-I.

Table 3. Recommended spacing for rapeseed and mustard

Sl. No.	Crop	Space between lines (cm)	Space between plants (cm)	Depth of sowing (cm)
1	Sarson	30-35	10-12	3-4
2	Toria	25-30	8-10	2-3
3	Rai	40-45	10-15	2-3

The total number of plant per m^2 should be 35-40 numbers for getting optimum yield.

6. Manures and Fertilizers

If available, apply 15-20 tonne ha^{-1} farm yard manure or compost during field preparation. For good crop stand and better yield, apply 60-90 kg nitrogen, 60 kg P_2O_5 and 40 kg K_2O per hectare.

Rapeseed and mustard crops, being broad leaved crops, respond well to the foliar spray of urea. About 2% solution of urea is sprayed from early stage of plant growth to flowering stage, at an interval of 20 days. At the time of commencement of flowering urea is not sprayed.

For *Toria*: Before last tillage 30 kg Nitrogen, 37.5 kg Phosphate and 37.5 kg Potash should be incorporated. Top dressing of 35 kg nitrogen at 25-30 days after seed sowing.

White / yellow Sarson and *Rai*: Before last or final land preparation, Nitrogen, Phosphate and Potash will be given @ 60 kg ha^{-1}. During first split application (25-30 days after sowing) 30 kg ha^{-1} is to be applied. Second split application of nitrogenous fertilizer @ 30 kg ha^{-1} is normally done during siliqua formation. If there is deficiency of micro nutrient then 11 kg Borux should be applied with the organic manures before final land preparation to get good yield.

Micronutrients: Mustard, in general is very sensitive to micronutrient deficiency, specially zinc and boron. The increase in seed yield was 8.5% after application of 12.5 kg $ZnSO_4$ ha^{-1}. The harvest index (HI) was significantly affected by Zn application, although seed yield showed diminishing return with additional $ZnSO_4$ doses.

7. Irrigation

Generally, the rapeseed and mustard are grown under rainfed conditions and growers do not provide irrigations to these crops. To

get high yield, judicious application of irrigation water is necessary in the absence of rains. Single irrigation given at vegetative (branching) stage (25-30 Days after sowing) is found to be most critical, as irrigation at this stage produces the highest yield. When two irrigations are given, the irrigation at vegetative (branching) and siliqua development stages is of maximum benefit. The irrigation at vegetative (branching), flowering, and siliqua development stages resulted in the highest yield, where three irrigations were given. Oil and protein yield were also significantly affected by number and stages of irrigation. For rai crop, one irrigation at 75% flowering may be given.

8. Weed Control

The most common weeds which grow in the fields of rapesed and mustard are deep rooted broad leaved weeds like bathua (*Chenopodium album*), chattari mattari (*Lathyms spp.*), kateli (*Cirsium arvense*), gajri (*Fumariapal vijlora*) etc. Weeds are removed mostly by hand-hoeing with khurpi. This method is advantageous since it removes the weeds thoroughly during early stages of growth. It pulverizes the soil and creates mulch over the soil and reduces moisture loss. It also allows some soil to be earthed up along the base of the plant and protects it from windbreak and finally make the channel in between the rows to allow drainage. First hand weeding should be done 15-20 days after sowing and the second weeding is done 35-40 days after sowing.

Chemical herbicides like Pendimethalin @ 1.5 kg/ha or Nitrofen @ 1.5 kg a.i. per hectare as pre-emergence spray or Isoproturon @1.0 kg a.i. per hectare at 30 days after sowing mixed in 700- 800 liters of water and spray to control weed population.

Common disease and insect of mustard and their control

Alternaria blight

Causal Organism

Alternaria brassicae Sacc., A. alternanta

Damage

The disease attacks on the lower leaves as small circular brown necrotic spots which slowly increase in size. Damage may occur throughout crop growth. Period of activity is Nov-March. Formation of spots takes place in the plant leaves and siliquae. The spots produced by this disease are brownish or grayish. Many spots coalesce to cover large patches showing brightening and defoliation in severe cases. Circular to linear, dark brown lesions also develop on stems and pods, which are elongated at later stage. Infected pods produce small, discoloured and shriveled seeds.

Survival & Favourable Conditions

The pathogen survives through spores (conidia) or mycelium in diseased plant debris or weed host. Moist (more than 70% relative humidity) and warm weather (12-25 C temp) and intermittent rains are favours disease development.

Cultural Control

- Use of resistant/tolerant varieties
- Timely sowing between 10-25th October.
- Removal of weeds like bathua.

Chemical Control

Spray the crop with Mancozeb 75 % WP at the rate 2 gm per litre. If the infection persists then repeat the spray after 15 days interval.

OR Three or four spray of Iprodione (Rovral) or Mancozeb (Dithane M 45) 75% WP.

OR Zineb at 2 g/litre per ha just at the appearance of the disease.

Downy mildew

Causal Organism

Peronospora parasitica

Damage

- The most susceptible stage for the disease development is the flowering stage.
- Symptoms appear on all aerial parts but usually on leaves and inflorescence.
- Grayish white irregular necrotic patches develop on the lower surface of leaves.
- The most conspicuous and pronounced symptom is the infection of inflorescence causing hypertrophy of the peduncle of inflorescence.
- The affected inflorescence does not produce any siliqua or seed.
- The extent of damage is 17-32 % in mixed infection.

Survival & Favourable Conditions

- The pathogen survives as oospores on the affected plant tissues and on weed hosts.
- Cool (10-20 C temp) and wet weather (90%) humidity favours disease development.

Cultural Control

- Destroy the diseased crop debris.
- Follow at least three years crop rotation.
- Varieties of *Brassica napus* group are resistant to this disease.
- Timely sowing between 10 - 25th October.
- Use healthy certified seeds.
- Field sanitation is a must.
- Destruct the crop residues.
- Crop rotation
- Application of potash in recommended doses reduce disease index.

Chemical Control

- Seed treatment with 6g Metalaxyl (Apron) per kg seed followed by single spray with Metalaxyl (Ridomil MZ) at 2.5 g/litres at 60 days after sowing is effective in managing the disease.
- Spray the crop with Mancozeb 75 % W.P. at the rate of 2 gm per litre of water at the onset of the disease.
- Repeat the spray after 15 days interval.
- Apply potash in recommended dose.
- Seed treatment with Apron-35, followed by first spray of Ridomil (0.25%) at 60 days after sowing and second and third sprays of Rovral (0.2%) at 80-100 days after sowing provide effective control of diseases.

Powdery Mildew

Causal Organism

Erysiphe cruciferarum

Damage

- This disease occurs at the reproductive stage during Feb-March.
- Symptoms appear as dirty white, circular, floury patches on either sides of the leaves.
- Under favourable environmental conditions, entire leaves, stems and siliquae are affected.

Survival & Favourable Conditions

- The pathogen survives through cleistothecia present in the crop debris in the field.
- High temperature (15-28^{0}C), low humidity (less than 60% humidity) and low or no rainfall with wind favours disease development.

Cultural Control

- Field sanitation is a must.
- Timely sowing between 10-25th October.
- Destroy crop residues.
- Application of potash in recommended doses reduces disease index.

Mechanical Control

Destruct the crop residues.

Insect

Diamondback moth (*Plutella xylostella*)

Identification & Monitoring

- Adult is a small greyish moth with three white triangular spots along the inner-margin of the forewings.
- When at rest the triangular markings of opposite wings appear as diamond shaped markings and hence the name.
- Larvae is pale green, body tapering slightly at both ends.
- Monitor the adult by installing pheromone trap.

Damage

- Caterpillars feed on the foliage. The leaves give a withered appearance but in later stages larvae bore holes in the leaves may be eaten up completely.
- It also bores into pods and feeds developing seed.

Mechanical Control

- Installing pheromone trap to control the adult pest.
- Collection and careful destruction of the larvae at gregarious stage at least twice a week.

Biological Control

- Conserve *Cotesia plutellae*, as it is an important parasitoid for diamond back moth.
- *Diadegma insulare* is the most important parasitoid of the diamondback moth

Chemical Control

- For control of grown up larvae apply 5% malathion dust @ 37.5 kg/ha.
  OR
- 940 ml Trichlorfon in about 625 liter water.
  OR
- 925 ml Endoslfan 35 EC or 750ml Diazinon 20 EC in 600-700 liter water
- The insect shows high tolerance to a number of insecticides, however, triazophos is effective.

Mustard saw fly (*Athalia lugens proxima*)

Identification & Monitoring

- Adults are orange bodied with smoky transparent wings.
- Larva is greenish black with wrinkled body and eight pairs of pro-legs. On slightest touch the larva falls to round and feigns death.
- The pest is active during seedling stage of the crop i.e. October - November.

Damage

- Initially the larva nibbles leaves, later it feeds from the margins towards the midrib.
- The grubs cause numerous shot holes and even riddled the entire leaves by voracious feeding.
- They devour the epidermis of the shoot, resulting in drying up of seedlings and failure to bear seeds in older plants.
- The yield losses up to 5 to 18 %. In severe case at the seedling stage, the crop have to be resown.

Cultural Control

- Summer ploughing to destroy the pupa.
- Early sowing should be done.
- Maintain clean cultivation.
- Apply irrigation in seedling stage is very crucial for sawfly management because most of the larvae die due to drowning effect.
- Severe cold reduce pest growth.

Mechanical Control

- Collection and destruction of grubs of saw fly in morning and evening

Biological Control

- Conserve Perilissus cingulator (parasites the grubs), and the bacterium Serratia marcescens Bizio infect the larvae of sawfly.
- Use of bitter gourd seed oil emulsion as on anti-feedent.

Chemical Control

- Spray the crop with 1000 ml/ha malathion 50 EC OR
  625 ml/ha Endosulphan 35 EC
  OR
  Quinolphos 25 EC 625ml/ha. All this should be applied in about
  600 to 700 litres of water per ha.
  OR
  Endosulfan 4% dust OR methyl parathion 2% @25 kg/ha.
- Methyl preparation or carbaryl dust or spray formulations are effective.

Mustard aphid (*Lipaphis erysimi*)

Identification & Monitoring

- Aphids are small, soft-bodied, pearl-shaped insects that have a pair of cornicles (wax-secreting tubes) projecting out from the fifth or sixth abdominal segment.
- There are four nymphal stages (instars).
- Wingless, female, aphids are yellowish green, gray green or olive green with a white waxy bloom covering the body.

- The waxy coating is denser under humid conditions.
- The winged, female, adult aphids have a dusky green abdomen with dark lateral stripes separating the body segments and dusky wing veins.
- Male aphids are olive-green to brown in color.
- The aphid attacks generally during 2nd and 3rd week of December and continues till March.
- The most favourable temperature is in between 8 to 24°.
- Rainy and humid weather help in accelerating the growth of insects.
- Set up yellow stick trap to monitor aphid population.

It is a serious pest of mustard.

Damage

- Plants are infested at all the stages.
- Both nymph and adults suck the sap from leaves, buds and pods.
- Curling may occur for infested leaves and at advanced stage plants may wither and die.
- Plants remain stunted and sooty molds grow on the honey dew excreted by the insects.
- The infected filed looks sickly and blighted in appearance.

Cultural Control

- Use tolerant varieties like JM-1 and RK-9501.
- The crops sown before 20th October escape the damage.
- 70 to 80 % humidity is favourable for faster multiplication of aphid.

Mechanical Control

- Destroy the affected parts along with aphid population in the initial stage.

Biological Control

- Ladybird beetles viz., Cocciniella septempunctata, Menochilus sexmaculata, Hippodamia variegata and cheilomones vicina are most effcient pradators of the mustard aphid. Adult beetle may feed an average of 10 to 15 adults/day.
- Several species of syrphid fly i.e., Sphaerophoria spp., Eristallis spp., Metasyrphis spp., Xanthogramma spp and Syrphus spp. are predating on aphids.
- The braconid parasitoid, Diaretiella rapae a very active bio control agent cause the mummification of aphids.
- The lacewing, Chrysoperla carnea predates on the mustard aphid colony.
- Predatory bird Motacilla cospica is actively feeding over aphids in February-March.
- A number of entomogenous fungi, Cephalosporium spp., Entomophthora and Verticillium lecanii infect aphids.

Chemical Control

- Spraying should be done only insect population is more than ETL level.
- Spraying should be done in evening.
- Spray the crop with one of the following in the flowering stage; Oxydemeton methyl, Dimethoate@ 625 - 1000 ml per ha.

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ANNEXURE - I

District wise area, production and productivity of rapeseed and mustard in West Bengal are shown here through following figures.

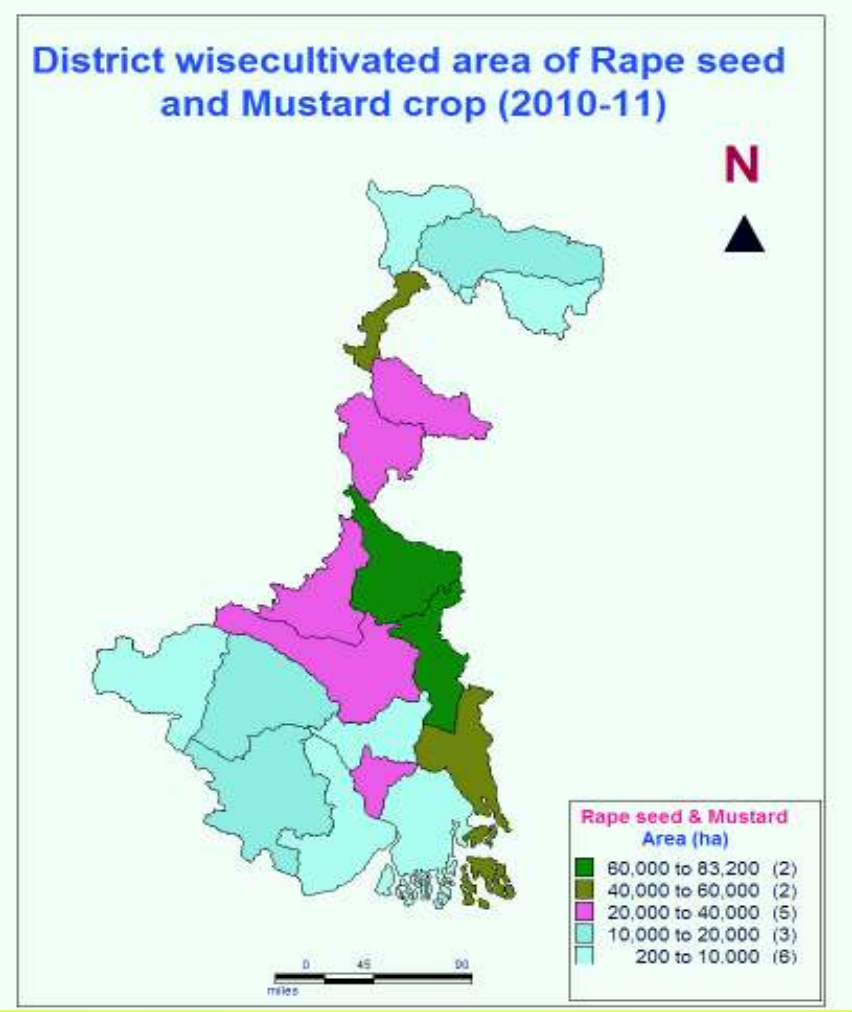

Fig. A-1: District-wise cultivated area of rape seed and mustard during 2010-11 of West Bengal

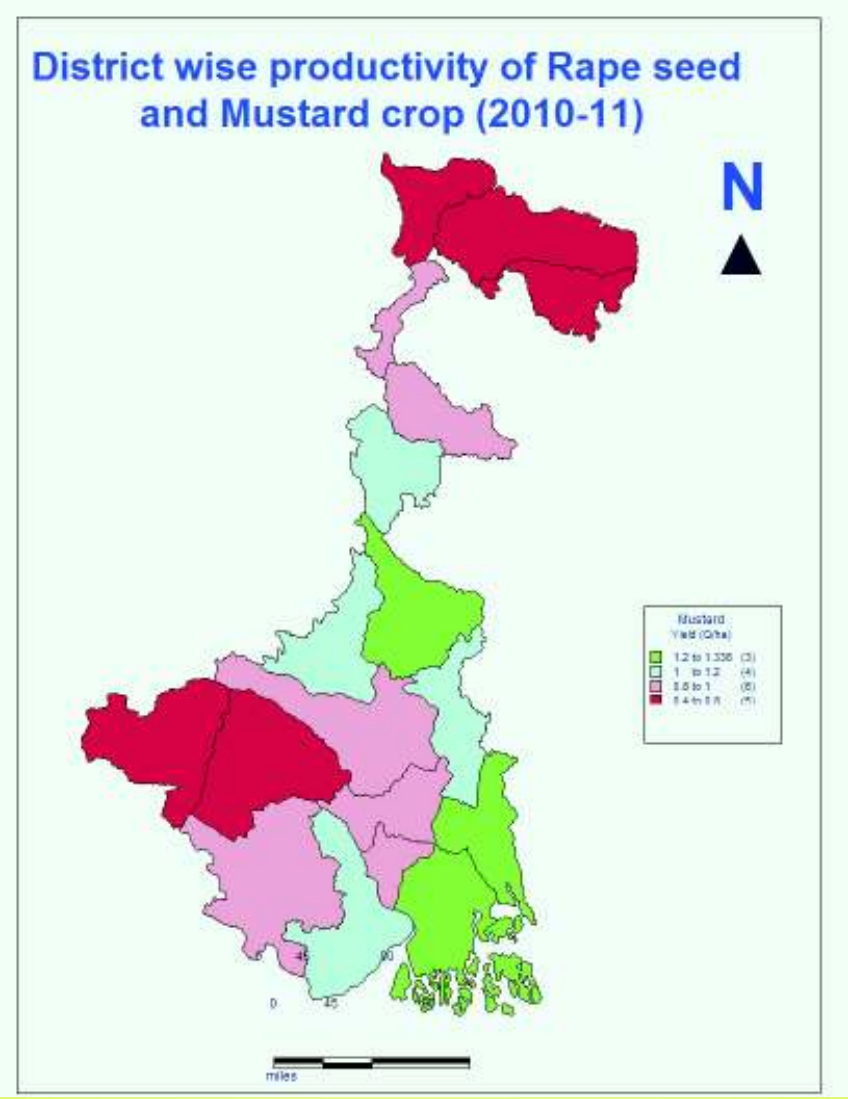

Fig. A-2: District-wise change in cultivated area of rape seed and mustard during last 10 years in West Bengal

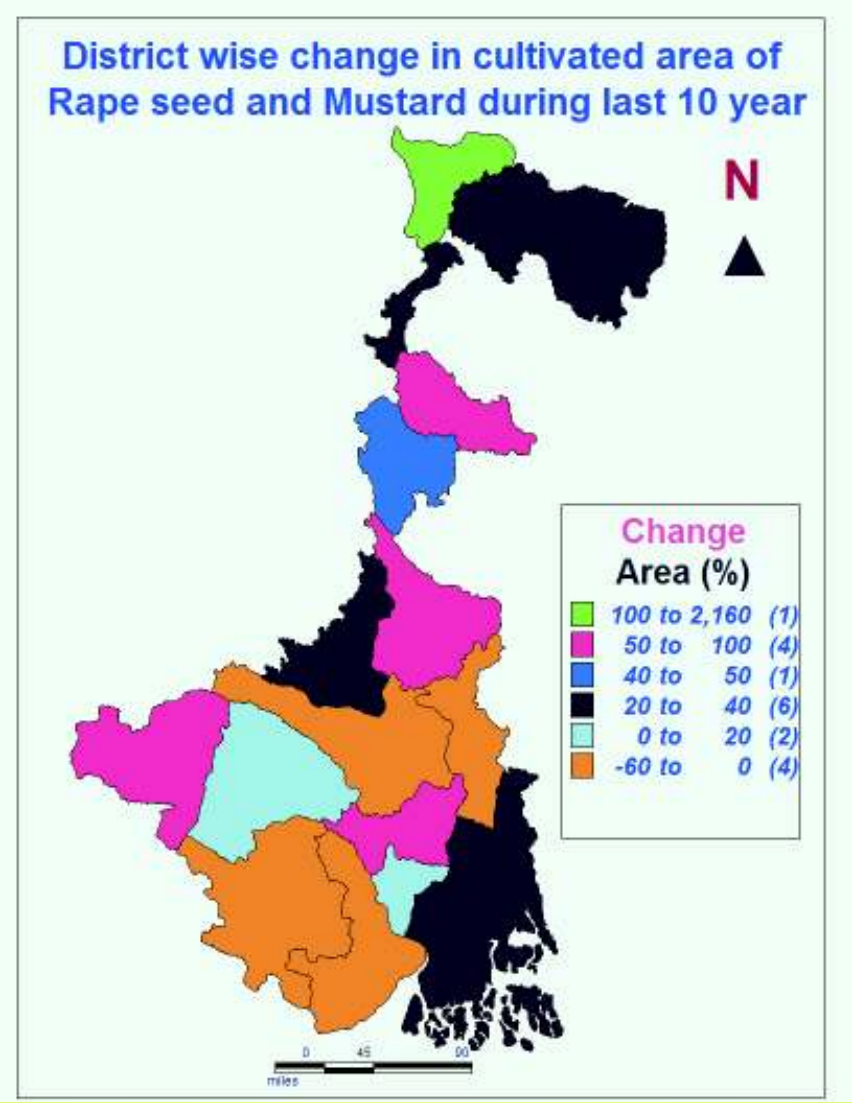

Fig. A-3: District-wise productivity of rape seed and mustard during 2010-11 of West Bengal

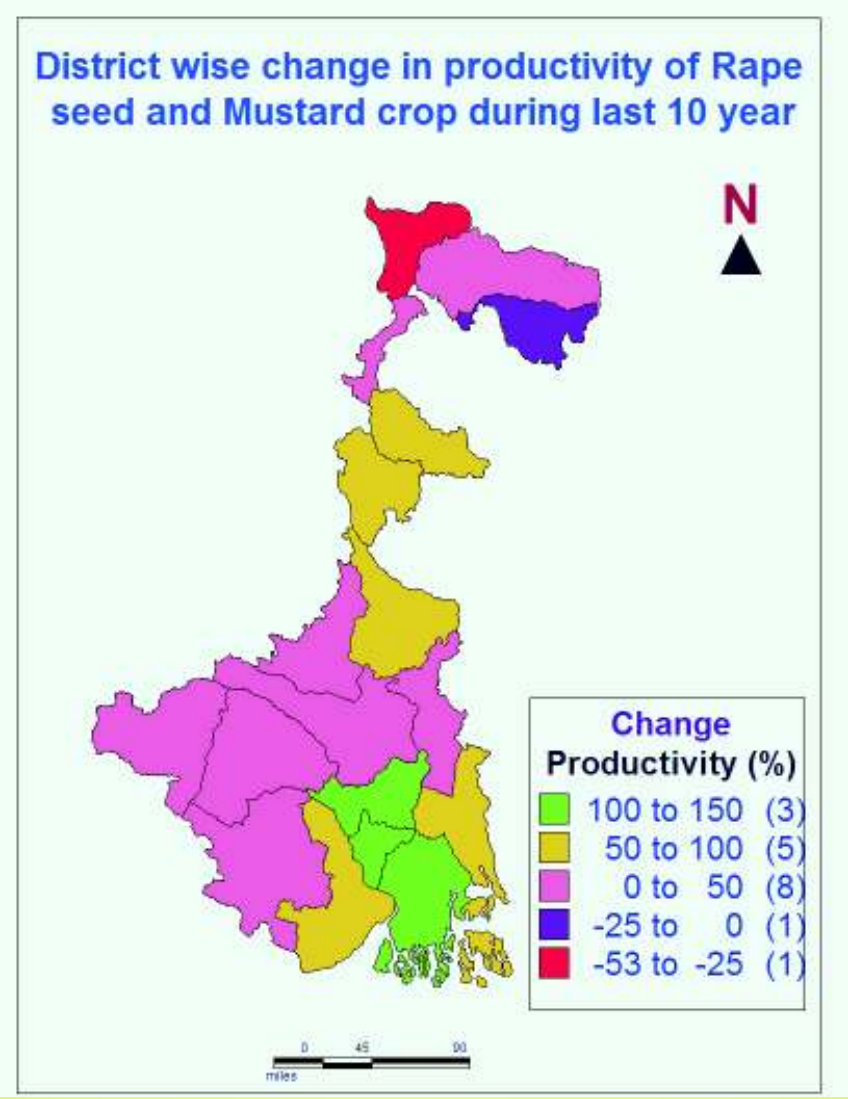

Fig. A-4: District-wise change in productivity of rapeseed and mustard during last 10 years in West Bengal

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