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GAU Research Journal **45** (3) : 108-112 (July 2020) *Short Communication*

Comparative efficacy of different farmyard manure sources on growth and yield of castor (*Ricinus communis* L.)

A.L. JAT*, S.K. SHAH[2] AND A.G. DESAI[3]

Castor-Mustard Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat- 385506 (India)

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ABSTRACT

A field experiment was conducted at Castor-Mustard Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar in the North-Gujarat Agro-climatic region during *kharif* season of 2015-16. Results revealed that the plant height, 100 seed weight and oil content was recorded marginally higher with application of heap method FYM before one month of sowing and remains as pile for 15 days than incorporation into soil while length of main spike and seed yield of castor was registered higher under application of pit method FYM before one month of sowing and remains as pile for 15 days than incorporation into soil. Nutrient composition in FYM at the time of incorporation and soil fertility status after harvest of crop was also unaffected due to various treatments.

Key words: Farmyard manure, efficacy, castor, growth

Castor is an important non-edible oilseed crop of the arid and semi arid regions. It is the most useful and economically important oilseed crop having vast and varied industrial importance. Castor cake is considered to be excellent organic manure. At present, India is the World leader in castor production and export of castor oil, seed and some of its derivatives. Currently, the total castor production is 11.96 lakh tonnes obtained from 7.51 lakh ha with a productivity of 1593 kg/ha during 2018-19 in India. Gujarat is the largest castor growing state of India. Where, it's grown over an area of 5.21 lakh ha with the annual production of 9.44 lakh tonne with average productivity of about 1809 kg/ha and its shares about 69.5% of the total area and 78.9% of the total castor production of the country (Anonymous, 2018-19). Integrated nutrient management holds a great promise in maintaining yield stability and soil fertility with providing favourable soil physical condition. Farmyard manure (FYM) incorporation into soil as a source of nutrients and organic matter is an integral part of conventional crop production. Farmers produce the FYM by putting materials such as cattle dung, cattle shed wastes, kitchen wastes, ash, and house sweepings into the pit and heap on a daily basis. Hence, not much information was available on the heap and pit methods of FYM with its proper time of incorporation into the field and their influence on crop productivity. Therefore, present field experiment was planned to study the efficacy of heap and pit methods FYM on performance of castor under North Gujarat Agro-climatic region.

[1,2]Assistant Research Scientist, [3]Research Scientist, Castor-Mustard Research Station, S. D. Agricultural University, S.K. Nagar, Dist. Banaskantha, Gujarat- 385 506

*Email: aanandiagro508@gmail.com

MATERIALS AND METHODS

A field experiment was carried out during 2015-16 at Castor-Mustard Research Station, S. D. Agricultural University, Sardarkrushinagar, Gujarat to study the effect of heap and pit method FYM on performance of castor (*Ricinus communis* L.) in loamy sand soil of North Gujarat. The ten treatments consisted i.e. T_1: Application of heap method FYM before one month of sowing and remains as pile for 15 days than incorporation into soil, T_2: Application of pit method FYM before one month of sowing and remains as pile for 15 days than incorporation into soil, T_3: Application of heap method FYM before one month of sowing and incorporation into soil. T_4: Application of pit method FYM before one month of sowing and incorporation into soil, T_5: Application of heap method FYM before 15 days of sowing and remains as pile for 15 days than incorporation into soil, T_6: Application of pit method FYM before 15 days of sowing and remains as pile for 15 days than incorporation into soil, T_7: Application of heap method FYM before 15 days of sowing and incorporation into soil, T_8: Application of pit method FYM before 15 days of sowing and incorporation into soil, T_9: Application and incorporation of heap method FYM at the time of sowing and T_{10}: Application and incorporation of pit method FYM at the time of sowing. The experiment was laid out in randomized block design with three replications. Castor hybrid 'GCH 7' was sown in row of 150 cm apart with keeping plant to plant distance 120 cm. From the recommended dose of fertilizer (RDF) (180-37.5-20 kg N-P-S/ha), the full dose of phosphorus and sulphur with 1/4th part of nitrogen were supplied through urea, diammonium phosphate and elemental sulphur to all the plots as basal and remaining 3/4th dose of nitrogen applied in 3 equal splits at 30-35, 60-65 and 90-95 DAS. Weed management was done manually as well as interculturing by tractor operated cultivator. Other crop management practices were followed as per recommendations under irrigation situation. All the data were statistically analysed to draw a valid conclusion and logical interference.

RESULTS AND DISCUSSIONS

Growth and yield attributes:

An examination of the data presented in Table 1 indicated that the different sources of FYM & time of application and incorporation in the soil were failed to showed significant variation on growth (plant height and number of nodes/plant), yield attributing characters (effective branches/ plant, primary spike length, number of capsules on primary spike, 100 seed weight) of castor. Similar results were also reported by Saha *et al.*, 2008 and Basak *et al.*, 2012.

Seed yield and oil content:

Seed yield of castor was produced numerically higher under the application of pit method FYM before one month of sowing and remains as pile for 15 days than incorporation into soil (T_2), which was closely followed by application of heap method FYM before one month of sowing and remains as pile for 15 days than incorporation into soil (T_1) but it could not at the level of significance to make a significant variation among the treatments (Table 1). However, the minimum seed yield (2781 kg/ha) was obtained with the application of heap method FYM before 15 days of sowing and incorporation into soil (T_7). Oil content (51.45%) and oil yield (1742 kg/ha) of castor were observed marginally higher with the application of heap method FYM before one month of sowing and remains as pile for 15 days than incorporation into soil (T_1), respectively. These results are in agreement with the findings of Reddy *et al.*, (2010) and Basak *et al.*, (2012).

Nutrient content in FYM and Soil fertility status:

Nutrient content in FYM at the time of incorporation had unaffected due to different sources (heap and pit methods) of FYM. Soil analysis *viz*. bulk density, organic carbon, available phosphorus, potassium and sulphur after harvest of the crop indicated that no significant variation was observed due to different sources of FYM as well as their time of application and incorporation in the field (Table 2). These results are in close conformity with the findings of Pandit *et al*., (2020).

Thus, it can be concluded that the yield of castor and soil nutrient status after harvest of crop did not influenced significantly due to various sources of farmyard manure and its time of incorporation into the soil in North Gujarat Agro-climatic region.

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Table 1 Effect of heap and pit methods FYM application on growth and yield of castor

Treatments	Plant height (cm)	Nodes/plant (no.)	Effective branches/ plant	Length of main Spike (cm)	No. of capsules on main Spike	100-seed weight (g)	Seed yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)
T_1	84.27	19.47	32.00	75.20	100.87	35.10	3387	51.45	1742
T_2	81.40	18.20	33.33	79.00	100.27	33.55	3415	48.96	1675
T_3	79.67	18.93	29.67	78.60	107.73	34.11	3342	48.55	1624
T_4	75.87	19.47	29.40	76.27	99.07	31.95	3074	47.18	1449
T_5	77.80	18.60	28.33	75.53	91.47	34.36	3349	47.99	1606
T_6	73.40	18.27	31.67	72.47	95.20	33.38	2946	47.96	1410
T_7	78.27	19.00	34.33	76.67	96.93	33.55	2781	50.27	1395
T_8	76.13	18.13	34.87	74.33	95.87	34.14	2975	50.85	1512
T_9	81.67	19.40	33.67	72.53	104.00	32.81	3266	49.30	1609
T_{10}	80.33	19.73	34.33	75.80	104.13	32.89	2955	50.65	1497
SEm±	3.62	0.39	1.80	2.49	4.94	0.68	216.32	1.28	107.60
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	7.97	3.58	9.70	5.72	8.61	3.53	11.90	4.50	12.01

Table 1 Effect of heap and pit methods FYM application on growth and yield of castor

Treatments	Bulk density (g/cc)	Nutrient content in FYM at incorporation			Nutrient content in soil after harvest of castor			
		N (%)	P (%)	K (%)	Organic carbon (%)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available S (ppm)
T_1	1.59	0.48	0.21	0.46	0.32	50.00	262.00	12.33
T_2	1.65	0.45	0.21	0.47	0.33	49.00	266.00	12.67
T_3	1.63	0.50	0.21	0.46	0.33	50.00	264.67	11.67
T_4	1.63	0.48	0.22	0.48	0.33	48.67	262.33	13.00
T_5	1.62	0.47	0.21	0.46	0.33	48.67	262.67	11.67
T_6	1.58	0.46	0.21	0.47	0.32	50.67	263.33	12.67
T_7	1.64	0.51	0.21	0.46	0.33	49.67	264.00	12.33
T_8	1.60	0.48	0.22	0.48	0.33	49.67	267.33	11.33
T_9	1.59	0.50	0.21	0.46	0.33	49.67	263.00	12.67
T_{10}	1.62	0.48	0.22	0.48	0.33	50.33	260.00	11.67
SEm±	0.03	0.02	0.01	0.01	0.01	1.14	6.34	0.38
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	3.09	5.65	4.94	5.28	4.05	3.39	4.17	5.40

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Physicochemical properties of starch extracted from sorghum grains

NAZRINA NOURIN[1*] AND NEETU SINGH[2]

Department of Food and Nutrition, School for Home Sciences,
Babasaheb Bhimrao Ambedkar University, Lucknow-226025, India

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ABSTRACT

A wide-going farming advancement of starch has fixated on monetarily significant cassava, potato, maize and rice. Starch fundamentally adds to the finished properties of certain customer products and is every now and again utilized as a thickener, colloid stabilizer, solidified operator, building specialist and water holding specialist, in food and modern applications. The investigation centers around the characterization of the starch extracted from sorghum, an inadequately-used crop and that may substitute or upgrade the current supplies. The rate yield of sorghum starch was seen as 69.25% which was over the top than different sources. The amylose:amylopectin proportion was determined as 12.8:87.2 in this manner adding to a serious extent of swelling. The low estimation of moisture content could be a sign of improve timeframe of realistic usability and existence of certain minerals for expanded applications. The assessment of the physicochemical properties further helped in the utility of the extracted starch. The utilitarian properties of swelling power and water solubility index (WSI) expanded with increment in temperature. These properties show convincingly that the nature of starch got can be modernly used as potential beneficiaries by the food industry and drug industry.

Key words: Sorghum starch, rate yield, physicochemical properties, swelling power, water solubility index (WSI), food industry

In order to identify different and improved potential sources of compatible raw materials that may supplement; augment or enhance current supplies, the purpose of research has been extended. Natural resources provide botanical products high in certain raw resources, but are commonly left unused.

Starch being one of these botanical commodities is nowadays of immense value and importance to mankind. Starch had become a vital aspect of human nutrition and it is included in certain basic necessities such as cereals(e.g. rice, wheat, barley, sorghum, corn, oats); legume (e.g. lentil, bean, pea) and tuber (e.g. potato, sweet potato, yam, cassava, taro). Pure starch is a white, bland and inodorous powder which exists as water-insoluble granules with particular morphology in various plants; ranging from round, oval, ogival or lengthened to level, lenticular or polyhedral, and sizes ranging from 0.1- 200μm in width (*Hoover*, 2001; *Singh et al.*, 2003).

Sugar molecules composed of two forms of amylose and amylopectin α-D-glucan chains are known as starch. Different structures and compositions of the starch molecules formed for burgeoning vegetation types can differ considerably with protein and fat in storage systems. Therefore, starch differs depending on the source. This inherent functional diversity due to the different biological sources enlarges its

[1]Student, [2]Assistant Professor, Department of Food and Nutrition, School for Home Sciences, Babasaheb Bhimrao Ambedkar University, Lucknow

*Email: nazrina15@rediffmail.com

range of industrial uses (*Santana et al.*, 2014). The utility of starch in many food items is currently increasingly prominent. Starch significantly adds to the textured properties of certain consumer items and is frequently employed as a thickener, colloid stabilizer, frozen agent, bulking agent and water retaining agent, in food and industrial applications (*Moo et al.*, 2015; *Syahariza et al.*, 2017; *Zhou et al.*, 2018). While starch is present in many plant tissues, it is primarily extracted from cereal grains and tubers commercially (*Daudt et al.*, 2014).

A wide-ranging agricultural development of starch has centered on economically important cassava, potato, maize and rice.Nevertheless, a significant proportion of starch is similarly used as a source of staple foods from these crops. Sorghum has become a source of substitute starch in underutilized crops, and may be used as a substituting source of cereal grains. Sorghum is a subtle source of starch (Olayinka *et al.*, 2013). *Sorghum bicolor* is the fifth most significant grain crop after wheat, rice, maize, and grain regarding creation (*Beta et al.*, 2004; *Waniska et al.*, 2004). It is an imperative food crop for many individuals in parts of Africa, Asia and Latin America (Beta *et al.*, 2004; Dicko *et al.*, 2006).India grows the world's biggest acre of sorghum led by Nigeria and Sudan and the second highest tonnage behind the United States of America. This is grown as both rainy and post-rainy season crops in most regions of India (FAO, 2009; Nadia *et al.*, 2009).It continues the lives of the least fortunate provincial individuals and frequently alluded to as "coarse grain" or "needy individual's crop." However, with expanding total populace what's more, diminishing water supplies, it is anticipated as a significant future yield. Despite the fact that sorghum is major cereal crop and looks like maize when all is said in done organization, it is viewed as substandard compared to corn for food, feed what's more, modern use. Sorghum based food items possess a low situation in an eating regimen because of poor grain quality characteristics. The dim shading, high fiber content, articulated flavor, coarseness of flour and trouble to cook into the delicate items like bread, roll, pastries, cakes, baked goods, are a portion of the detriments (*Shinde et al.*, 2004).Unutilized stockpile sorghum could be used for the development of starch and starch-based sugars. The procedure is prone to be practical as sorghum is accessible on huge scope with minimal effort. Sorghum grain comprises 68-75% starch, based on cultivar, region and climatic conditions(Shinde, 2005; Singh *et al.*, 2009)..

This work is therefore intended at extracting and assessing starch from Sorghum grains in aspects of its functional characteristics to assess their usage in the industrial sector as a potential cheap source of starch.

MATERIALS AND METHODS

The experiment was carried out at Laboratory of Department of Food & Nutrition. The experiment was conducted over a period of six months. The Sorghum grains were purchased from the local general store of south city, Lucknow, India. All chemicals and equipments used for the extraction and analysis were of analytical grade.

Extraction of Starch:

The method used for extraction of starch was described by Shinde *et al.*, 2004, with certain modifications elaborated by Udachan *et al.*, 2012. Sorghum grains (250 g) was weighed and cleaned thoroughly in distilled water to remove the dirt and extraneous matter. The washed grains were soaked at the room temperature for 24 hours in 500ml of distilled water (1:2w/v) with another 2 ml of benzene. In addition a very low concentration (0.001M) mercuric chloride was added into the steeping water. The steeped grains were further washed and pulverized using a mixer grinder and the slurry was further steeped in 500 ml of NaOH (0.25% w/v).The steeped slurry was stirred for 2 hours using magnetic stirrer and then kept at 5°C for 24 hours. The slurry was filtered using muslin cloth completely while rinsing the residue with water. The filtrate obtained was allowed to stand for a couple of days in the refrigerator for comprehensive sedimentation of the crude starch. The upper supernatant was siphoned off and the crude

starch was obtained. The crude starch was filtered by suspending in distilled water (1:5 w/v) and NaCl was added to accomplish the last fixation to 0.1M. Further toluene was added to the suspending medium in the ratio of 3:1(v/v). The medium was continued shaking for 1-2 hours and then centrifuged at 4000rpm for 10minutes. The toluene layer with the protein part was discarded. Then the starch was refluxed with 80% aqueous methanol for 12 hours. It was washed with acetone and afterwards ether. The starch was washed with distilled water a few times and continued towards drying at 45°C for 4 hours in a dehydrator. The dried pure starch was stored in plastic zipper pouches until further use.

Physico-chemical Characterization of extracted starch:

Bulk density

A known weight of the starch was poured in a 10 ml graduated cylinder and the volume was noted. The bulk density was calculated as,

$$\text{Bulk density (g/ml)} = \frac{\text{weight of the starch (g)}}{\text{volume of the starch (ml)}}$$

True density

True density was determined by adding 5 g of starch powder in 25 ml toluene in 100 ml measuring cylinder. The final volume was noted and true volume of starch powder sample was determined from as,

$$\text{True density (g/ml)} = \frac{\text{weight of the starch (g)}}{\text{true volume(ml)}}$$

Porosity

Porosity is the level of air between the particles contrasted with a unit volume of particles.

Porosity of the extracted starch was estimated by,

$$\text{Porosity(\%)} = \frac{\text{True Denisty- Bulk Density}}{\text{True Density}} \times 100$$

Moisture Content

Using moisture analyser, the moisture contents were determined. 5 g of the sample is placed at 180°C in the moisture analyser. The process persisted until all moisture was dissipated.

pH

The 5g of the starch sample was weighed and blended appropriately with 15ml distilled water. The blend was poured into boiling distilled water to makeup 100ml of slurry.The slurry was permitted to cool. Utilizing a digital pH meter, the pH of the slurry was estimated.

Amylose:Amylopectin ratio

The method described by Muazu *et al.*, 2011was used to measure the amylose:amylopectin ratio.2g of the extract was suspended in 50ml distilled water. A 1:9 butanol:water mixture was added with continuous stirring and heating to boiling. Butyl and amyl alcohol (1:1) was added to the boiling suspension which was then allowed to cool in a cold water bath. The supernatant liquor was decanted and the microcrystalline precipitate formed was washed repeatedly with butanol saturated with water, dried in oven and weighed. The supernatant was precipitated with excess methanol and the precipitated was dried in an oven and weighed to determine the ratio of amylopectin.

Swelling Power & Water Solubility Index (WSI)

The estimation of swelling power and water solubility index was determined by Claver *et al.*, 2010. In a water bath, a suspension of 0.10 g of starch and 6 ml of distilled water was heated was acceptance of the food from consumer's standpoint. heated in the range of 30°C-80°C for 30 minutes. The suspension was quickly refreshed and centrifuged at room temperature at 8,000rpm for 20 minutes. The ratio of dry mater supernatant to dry starch was reported as WSI, whereas the proportion of swelling of starch granules from sediment to dry starch was reported as SP.

Oil Absorption Capacity (OAC)

Method of Sindhu and Khatkar 2016 was used for determining the oil absorption capacity.3ml refined groundnut oil was added to 0.5g of sample

and mixed for 1 minute. Following 30 minutes at room temperature the cylinders were centrifuged at 3200 rpm for 25 minutes. The volume of unabsorbed oil was resolved.

Data Analysis:

All the above mentioned procedures for characterization of the extracted starch sample were done in triplicate and their mean value was calculated as the final value.

RESULTS AND DISCUSSION

Starch Yield:

The individual weights of the isolated starch and the sorghum grains used were measured to assess the extracted starch yield.The assurance was done in triplicate and the mean value was considered. The percentage yield of sorghum starch was found to be 69.25%. It was observed that the starch yield of sorghum was significantly higher than the starch yield of the millet, wheat and rice varieties isolated by Verma *et al.* 2018.The yield percentage was compared to the percentage yield of potato (14.49%), cassava (29.41%) and maize (45.85%) starches found in the study conducted by Kundu *et al.*, 2011.

Physicochemical Properties:

Appropriates of production process, product design and development management, product formation, food quality assurance and food process mapping are essential to understand the characteristics of food. The physicochemical characteristics of a consumer commodity or an element decide the end-use. This explains the appearance, taste and feeling of ingredients during processing and cooking of the end products. The characterization of the utilitarian properties is fundamental to theoretical and applied investigations in Food Science and Technology. This is often the basis for establishing the nutritional value and overall The physicochemical properties of the extracted sorghum starch are compiled in table 1.

Table 1 Physicochemical Properties of Extracted Sorghum Starch

Parameter	Value
Bulk Density (g/ml)	0.78
True Density (g/ml)	1.63
Porosity %	31.96
Moisture Content %	8.40
Ph	6.3
Amylose: Amylopectin Ratio	12.8:87.2
Water Solubility Index(WSI) %	17.5
Swelling Power (g/g)	19.1
Oil Absorption Capacity(OAC) %	14.8

All the physico-chemical properties play a major role to swelling, pasting properties, viscosity and gelatinization temperature of the starch thereby describing its utility. The true and bulk density has an impact on the texture and mouthfeel of the food. Higher porosity brings about more noteworthy contact with climatic oxygen, along these lines higher pace of auto oxidation. In the current investigation the amylose and the amylopectin content of the separated sorghum starch was ascertains as 12.8% and 87.2% individually. This outcome was in conjuction with the outcomes determined by Udachan *et al.*, 2012 for starch separated from local assortments of sorghum(CSH-9, CSH-5, Dadar and Parbhani) produced in India. The moisture content and pH of the derived starch is close to those of the previous analysis. Among the two experiments was noticed a substantial connection.

It has been found that the swelling power has a temperature feature between 40°C-80°C and the graph is shown in Figure 1.The intensity and nature of the micellar network within the starch granule is the swelling power of the starch. With the rise in temperature, the starch granules were more profoundly jiggled, violating intermolar connections and allowing hydrogen linking sites to moleculate more water. A pattern similar to that of swelling power was also observed in the water solubility index(Figure2).

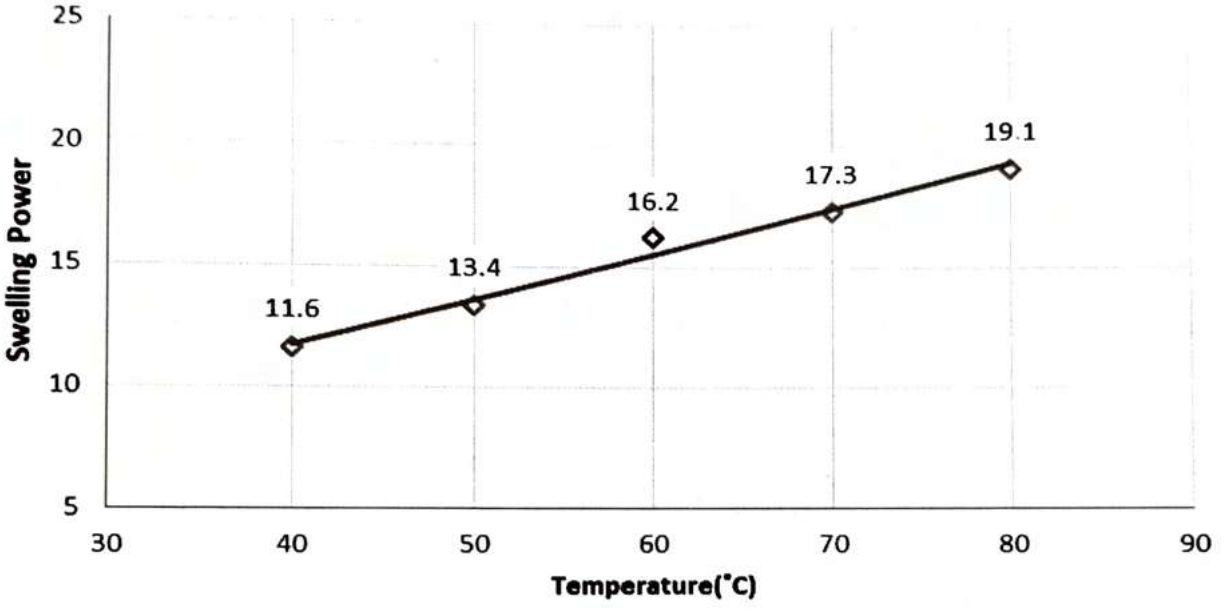

Figure 1 Effect of temperature on Swelling Power of extracted sorghum starch

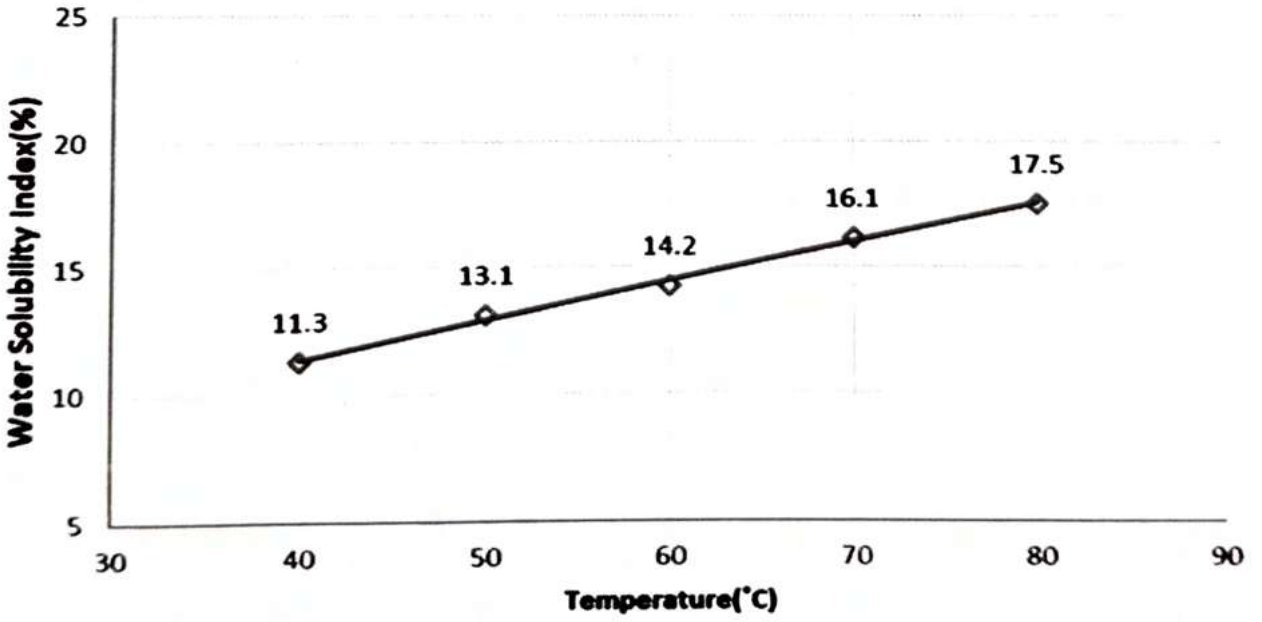

Figure 2 Effect of temperature on the water solubility index of extracted sorghum starch

A noteworthy contrast was seen between the consequences of the current examination and the discoveries of Mir *et al.*, 2017 regarding swelling power and the water solubility index. The growing intensity of corn starches differed from 10.79 to 13.55 g/g in the investigation by Mir *et al.*, 2017, though the growing intensity of the removed sorghum starch was 19.1g/g. The water solubility index for sorghum extracted starch was similarly higher than the values for maize starches determined by Mir *et al.*, 2017.

CONCLUSION

The convention followed in this investigation allowed a decent filtration just as partition of starch granules from the lattice and permitted to get an extraction yield of 69.25%. The yield of sorghum was exorbitant than the other sources of starch like potato, cassava, maize, millet rice and wheat. The yield rate finishes up sorghum as a business and practical wellspring of starch. The low amylose content recommends its compelling use in the arrangement of pie fillings and puddings. All the evaluated properties of the separated sorghum starch have significant job in deciding textural, sticking and thickening properties of starch based preparation. Furthermore adjustments during the extraction may prompt improvement in its utility. The physicochemical properties of the separated recommend that it might have expansive prospects as a fixing in food frameworks and other mechanical application. The present discoveries illuminate extraction and usage of starch from sorghum rather than corn for its business applications in different food enterprises.

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Footprint of agricultural inputs on trend of productivity in West Bengal

ANWESHA BANERJEE[1*], SUMAN BERA[2] AND RAMKRISHNA MAITI[3]

Department of Geography and Environment Management
Vidyasagar University, Midnapore- 721102, West Bengal, India

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ABSTRACT

Agricultural productivity is the synthetic reflection of agricultural efficiency in which different inputs are being used and it helps to recognize the regional inequalities in agriculture. The main focus of the present study is on the district wise variation of trends in agricultural productivity in West Bengal from 1991 to 2011 as well as its relation to agricultural inputs like rainfall, percentage of cropped area, irrigation and fertilizer consumption. Therefore, trend analysis has been done by *Mann-Kendall test*together with the Sen's Slope Estimator for the determination of trend and slope magnitude.Alsoa regression analysis is done in between productivity and various inputs for answering the causes behind positive and negative trends. Most of the districts have facing negative trend in productivity since 1990. In Hooghly, Burdwan and Nadia districts,agricultural productivity is well enough in comparison to Purulia, Bankura, Darjeeling districts.

Key words: Agricultural productivity, Agricultural inputs, Productivity Trend, Mann-Kendall test

Agriculture is the foremost economic activity in West Bengal which is one of the most fertile regions in India. Over 58 per cent of the rural households depend on agriculture as their principal means of livelihood (Indian Brand Equity Foundation, 2016). It contributes around 18.7% to 18.8% of the state's gross domestic product (GSDP) from 2009-2010 to 2015 (India Brand Equity Foundation, West Bengal, November 2011 & 2015).Also west Bengal took an important position in terms of the average annual growth rate of the gross state domestic product from agriculture over the ten year from 1994 to 2004 at 3.64 % which is much higher than the national average (1.53%) and highest among all other states (Government of West Bengal 2009; Planning Commission and Central Statistical organization 2008).So, agriculture is most important sector because it helps to achieve required self-sufficiency in food production at the macro level, though this state has facing food deficit in rural region till today due to low productivity. Agricultural productivity means the degree to which the agricultural inputs are able to produce resources of a area for agricultural production (Singh, 1979).It tries to assessthe relative effectiveness of an area in utilizing various inputs and comparing the output of that area to the neighbouring area. Itis closely controlled by some physical factors i.e. topography,climate, soils, surface drainage and ground water potentiality etc but Enhanced agricultural productivity usually comes as a outcome of the effective apaptation of improved

[1&2]Research Scholar, [3]Professor and Head, Vidyasagar University, Midnapore- 721102 West Bengal

*Email Id: anweshabanerjee2011@gmail.com

technologies (FAO, 1981). Among the all factorsas well as technologies, rainfall, percentage of cropped area, irrigation and fertilizer consumption is most relevant to agricultural productivity. By demarcating the high, medium and low productivity region, the causative factors behind agricultural retardation may be found out and evenagricultural planning may be formulated to minimise the regional inequalities (Kothari and Kohli, 1997).

Study Area:

West Bengal is an eastern state of India and is lying between 21°25□24□□and 27°13□15□□ north latitudes and 85°48□20□□ and 89°53□04□□ east longitudes.The state has essentially a flat, featurelessalluvial plain, a large portion of it being a part of the delta of river Ganga. Two-third of the total geographical area of the state consists of flat alluvial plains with an elevation below 30 metres. The climate is generally tropical, hot and humid, monsoon type except in the northern mountains, where the altitude is the controlling factor. Agriculture dominates both the landscape and the economy of West Bengal and it is the major economic activity of West Bengal. Its proportion of agricultural land is highest amongthe all other Indian states. As per 2002 estimates West Bengal accounts for approximately 18 per cent of total rice production, 1.2 per cent of total wheat production, 4.5 per cent of total rapeseed-mustard production, 30 per cent of total potato production, and 77 per cent of total jute production in India (Ghose& Bhattacharya, 2011).

MATERIALS AND METHODS

The present study is entirely based on secondary data sources which are collected from Bureau of Applied Economics and Statistics, Govt. of West Bengal, Kolkata. In the present work, Enyedi's (1964) formula of agricultural productivity has considered. The crops areselected according to their percentage share in area in each and every districts of West Bengal. Enyedi while describing geographical types of agriculture in Hungery refers to a formula for determining agricultural productivity. This technique is admirable in the sense that it determines the productivity index of an area with reference to national level.This formula for assessing productivity coefficient would be read thus:

Productivity Index = $Y/Y_n \div T/T_n$

Where, Y is the total production of selected crop in unit area;Y_n is the total production of the same crop on national scale; T is the total cropped area of the unit area, and T_n is the total cropped area at national scale.

Trend of agricultural productivity from 1990 to2000 and 2000 to 2010 has been measured by using Mann- Kendall test for each crop.In the study non-parametric methods, Mann-Kendall (MK) test (Mann, 1945; Kendall, 1955) and Sen's estimator (P. K.Sen,1968) are used to detect the nature of trends in the time series. Mann-Kendall's method is applied to test the presence of a monotonic trend and the statistical significance of the trend and Sen's slope estimator for estimating true change per year in the time series. No pre-whitening of the data series is carried out. MK test is not only used for rainfall trends, but also widely used for analysing different climatic variables (Hirsch *et al.*1982 &1984; Douglas *et al.* 2006; Chen *et al.* 2007) and analysis of various environmental data (Hipel *et al.* 1994).

The Mann-Kendall test is appropriate in cases when the data values x_i of a time series can be assumed to follow the model

$$X_i = f(t_i) + \varepsilon_i \qquad (1)$$

Where $f(t_i)$ is a continuous monotonic increasing or decreasing function of time and the residuals ε_i

can suppose to be from the same distribution with zero mean. It is therefore assumes that the variance of the distribution is constant in time.

The null hypothesis of no trend, H_0, assumes that the observations x_i are independently distributed in time and the alternative hypothesis, H_1, denoted an increasing or decreasing monotonic trend. The number of annual values in the considered data series is designated by n. Missing values are allowed and n can thus be smaller than the number of years in the time series.

The Mann-Kendall test statistic S is established using the following formula

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\,(x_j - x_k) \qquad (2)$$

Where, x_j and x_k are the annual values in years j and k, j> k, respectively, and

$$sgn\,(x_j - x_k) \equiv \begin{cases} 1 & if\ x_j - x_k > 0 \\ 0 & if\ x_j - x_k = 0 \\ -1 & if\ x_j - x_k < 0 \end{cases} \qquad (3)$$

The variance of S is computed by the following equation which takes into account that ties may be present

$$VAR(s) = 1\left[n(n-1)(2n+5) - \sum_{p=1}^{a} t_p(t_p-1)(2t_p+5)\right]/18 \qquad (4)$$

Where, n is the number of data points, q is the number of tied groups and t_p is the number of data values in the $_p^{th}$ group. Z statistics or Normal Approximation test generally used when the sample size is greater than 10. The Normal approximation test (Z test) is developed by both the values of S and VAR(S) (Equation 5).

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAR(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \dfrac{S+1}{\sqrt{VAR(S)}} & if\ S < 0 \end{cases} \qquad (5)$$

The statistically significant trend is assessed by this Z value. The positive and negative values of Z denotes increasing and decreasing trend respectively. The statistic Z has a normal distribution. To test for either an increasing or decreasing monotone trend (a two-tailed test) at α level of significance, H_0 is rejected if the absolute value of Z is greater than $Z_{1-\alpha/2}$, where $Z_{1-\alpha/2}$ is acquired from the standard normal cumulative distribution tables(Tabari and Talaee, 2011).

Sen's slope estimator

To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method is used. It can be in cases where the trend can be assumed to be linear. This means that f (t)in equation (1) is equal to

$$f(t) = Q_t + B \qquad (6)$$

Where, Q is the slope and B is a constant.

To get the slope estimate Q in equation (6) we first calculate the slopes of all data value pairs

$$Q_t = \frac{X_j - X_k}{j - k} \qquad (7)$$

Where, x_j and x_k are the data scores at times j and k ($j>k$) respectively. If there are n values x_j in the time series we get as many as $N = n_{(n-1)/2}$ slope estimates of Q_i. The Sen's estimator of slope is the median of these N values of Q_i. The N values of Q_i are ranked from the smallest to the largest and the Sen's estimator is

$$Q = Q_{(N+1)/2} \qquad \text{if N is odd}$$

Or (8)

$$Q = \frac{1}{2}\left(Q_{[N/2]} + Q_{[(N+2)/2]}\right) \qquad \text{if N is even}$$

Q is tested with a two-sided confidence interval at 100(1-α) % and the slope estimate is obtained by the nonparametric method.

The confidence interval at two different confidence levels; α= 0.01 and α= 0.05 as follows

$$C_x = Z_{1-\alpha/2}\sqrt{VAR(S)} \quad (9)$$

Where, VAR(S) has been defined in equation (4), and $Z_{1-\alpha/2}$ is obtained from the standard normal distribution.

After that, $M_1 = (N - C_\alpha)/2$ and $M_2 = (N + C_\alpha)/2$ are computed. The lower and upper limits of the confidence interval, Q_{min} and Q_{max}, are the M_1^{th} largest and the $(M_2+1)^{th}$ largest of the N ordered slope estimates Q_i. If M_1 is not a whole number the lower limit is interpolated. Correspondingly, if M_2 is not a whole number the upper limit is interpolated.

Then to show the relationship between Agricultural Productivity and agricultural inputs, a set of threeinputs have been taken into account to determine the degree of relationship. This inputs are cropped area, Irrigated area, fertilizer consumption,In order to achieve the degree of relationship Karl Pearson product movement correlation coefficient technique is used.The technique is as under:

$$\text{Correlation Coefficient}(r) = \frac{\sum XY - (\sum X)(\sum Y)}{\sqrt{[n\sum X2 - (\sum X)2] \times [n\sum Y2 - (\sum Y)2}}$$

Where,r is the co-efficient of correlation;X is Independent variable;Y is Dependent variable;n is the number of observation

RESULTS AND DISCUSSION

Spatial variation of Agricultural productivity:

Spatial variation means variationin a particular areal unitand which is so much important for making out the regional inequality.So, districtspecific change in some crop productivity has compared between two decades (1990-91 to 2000-01 and 2000-01 to 2010-10). Though this state is well known for rice cultivation, in the present study nine crops are selected according to their percentage share in cropped area. On the basis of crop productivity, a district wise sequential arrangement of five crops (out of nine crops) in 1990-91 and 2010-11 period has presented in table-1& table-2 respectively. In 1990-91 periods, Aus paddy wasthe 1st crop inBurdwan, Birbhum, Howrah, Hooghly, N 24 Paragana district but in allsaid districts except Birbhum, 1st crop has been changed from auspaddy to potato in 2010-11 perioddue to decrease of average aus cropped area from 4.95 to 2.83 %as well as increase of average potato cropped area from 5.76 to 10.74%. In Nine districts of this state (Bankura, Midnapore, Nadia, Murshidabad, Uttar Dinajpur, Malda, Jalpaigri, Coochbehar, Purulia), maize was the 1st crop in 1990-91 and it is changed in 2010-11. It may be due to increase of fertilizer consumption (45.58 to 105.31 thousand tonne). Highest productivity of aus paddy has shifted from N 24 Paragana to Burdwanin those two decades due to two fold increase (85.80 to 164.5 thousand tonne)of fertilizer consumption.On the other, Bardwan was highest in Amanpaddy productivity in 1990-91 but Hooghly isexceeded Bardwan in 2010-11 because of enhancement of irrigated area and fertilizer consumption. In case of boro productivity, Malda is in 1st position since 1990-91 because of holding more or less same cropped area, increament ofboth irrigated area and fertilizer consumption. DakhshinDinajpur is advanced from Uttar Dinajpur in wheat productivity in between aforesaid two periods. Maize productivity has been excessively diminishingin Bankura (highest) since 1990-91. The causes behind this diminution is mainly increase of cropped area, and fertilizer consumption. But Bankura has surpassed Howrah in jute productivity because of increasing cropped area from 4% to 12.63% and fertilizer consumption from 34 to 73 thousand tonne in between those two periods. From 1990-91, S 24 paragana is occupied its same highest position in Repseed-Mustard productivity.

On an average, the crop productivity of West Bengal have been facing changing pattern.Aus

Paddy (1.07 to 1.01), Aman Paddy (1.02 to 0.99), Wheat Paddy (0.94 to 0.92), Maize (1.76 to 0.98) and Jute (1.01 to 0.94) have experienced decreasing tendency from 1990-91 to 2010-11 periods and potato (0.74 to 1.14), rapeseed-mustard (0.94 to 0.96), Boro paddy (0.91 – 0.93) have experienced increasing tendency in same time period.

Relationship between Agricultural productivity (AP) & Agricultural Inputs (AI):

Agricultural production and efficiency are largely depends upon the agricultural inputs. Agricultural input means those technologies which have received increasing emphasis and breakthrough in agriculture.In this study four basic inputs have been chosen i.e. cropped area irrigated area, fertilizer consumption, and average rainfall in crop period.

Cropped area:

Cropped area means the total area sown once as a specific crop in a particular year. Agricultural productivity and the cropped area have a reciprocal relationship. Over the previous century, area occupied by agricultural landis nearly doubled globally (Houghton, 1994). The pace of cropland expansion has just increased by 10 % (Etter *et al.*, 2005). Here district wise change of cropped area has compared between two decades (1990-91 to 2000-01 and 2000-01 to 2010-11). Total cropped area of each crop (nine crops) has changed through time. The eleven districts of this state have been facing contraction of total cropped area and Bankura and Birbum has experiencedmaximum contraction. Alternatively Cropped area hasexpanded in Midnapore, Murshidabad, Hooghly, Uttar Dinajpur, Dakshin Dinajpur and Darjeeling districts and Midnapore is heighest among those. In crop specific analysis, cropped area of Aus Paddy and Aman paddy have decreased in most of the districts but the scenario has been changed in Boro paddy and Potato. Also the condition of Wheat, Jute and Sugarcane is not so well.

Irrigated area:

Irrigation connotes maintaining the water in the soil required for plant growth at particular time and place of deficient water supply. The agricultural aspect of irrigation denotes to use irrigation water for various cropping pattern and agricultural practices. Irrigation brings fourth 30 to 40% of World's food crops on only 17 % of all arable land (Seckler *et al.*, 1998). In water scarcity region,irrigation is deemed necessary for the extreme production of crops. So, if the percentage of irrigated area to the total cropped area has to be increased then the productivity of crops also enhance. In West Bengal, average irrigated area has reduced from 145.07 to 131.11 thousand hectares and in most of the districts, percentage of irrigated area to the total cropped area has reduced from 1990-91 to 2010-11. Only Burdwan, Birbhum, Bankura and Purulia have near about 50% irrigated area to the total cropped area and all other districts have no sufficient irrigated area to enhance the productivity.

Fertilizer Consumption:

Fertilizer,amaterial of natural and chemical origin is applied to soil to enhance the production ofagricultural crops. It provides three main macronutrient to the soil i.e. Nitrogen (N) for leaf growth, Phosphorus (P) for development of roots, flowers, seed and fruit and Potassium (K) for stem growth, movement of water in plants. These nutrients are needed for boosting plant growth as well as efficient crop production. In West Bengal, use of fertilizer has increased (752.90 to 1031.53 '000 tonnes) from 1990-91 to 2010-11 t. Also average fertilizer consumption per hectare cropped area also has raised from 120.48 kg to 242.70 kg in between these two decades. In spite of increasing the usage of fertilizer, the condition is turned around in the districts of Midnapore, Howrah and Darjeeling.

Cropped area, Fertilizer consumption, irrigated area and also rainfall is most important inputs in crop productivity. From table-3, it has been shown that in between two decades the relationship of agricultural inputs is varying with crop productivity. Irrigated area and fertilizer have strong influence on Aus Paddy, Aman Paddy, Potato and Sugarcane productivity. On the other hand, cropped area and irrigated area has influencing moderately on Boro Paddy, Wheat, Sugarcane productivity. But Rainfall has also strong positive relationship with Aus Paddy, Aman Paddy, jute, sugarcane productivity.

Trend of agricultural productivity:

Trend of agricultural productivity depicts the temporal changes in productivity which has computed between two decades (1990-91 to 2000-01 and 2000-01 to 2010-11). Also magnitude of productivitytrendsis obtained by the Mann–Kendall test, the Sen's slope estimator. Here both the positive and negative trend has recognized. Table 4 showing the crop wise significant positive and negative trend. Most of the districts has significant negative trends at the 95%, 99% and 99.9% confidence levels regarding various crop productivity.In the entire crop wise trend map, blue colour and green colour indicate the positive and negative trend respectively.

The average productivity of Aus paddy has been decrease by 6% since 1990-91.Out of eighteen districts(fig-5 & 6) only 4 districts i.e.Purulia, Malda, Murshidabad and Coochbehar have positive trend in aus paddy productivity (1990-91 to 2000-01) but except Murshidabad other aforesaid three districts has facednegative trend in in next decades because of so much decrease of crop area (Fig-2.a).

In 2010-2011 period,the scenario regarding productivity is well enough because there are about ten districts which have positive trend in Aus paddy prodctivity and especially Hooghly and Birbhum have gained positive trend for its strong relationship between Irrigation and fertilizer consumption (shown in table-3).Comperatively, Darjeeling, Jalpaiguri, S 24 Paragana, Midnapore district are in bad condition in Aus paddy productivity since 1990-91.

On the basis of cropped area and production, Aman paddy is the main crop in West Bengal. Like Aus Paddy the average productivity of Aman paddy also has declined 3% and most of the districts have facing despairing condition. In 1990-91 period eleven districts namely Medinipur, N & S 24 Paragana, Howrah, Hooghly, Burdwan, Murshidabad, Nadia, Darjeeling, Jalpaiguri and Coohbehar, have negative trend in Aman paddy productivity (Fig-7) because of decreasing cropped area but among those districts some districts has changed into positive trend in 2010-11 period due to increase of irrigation, fertilizer consumption and rainfall. Alongside, out of other six districts which have positive trend (1990-91), three districts (Purulia, Bankura, Birbhum) have changed their trend to negative for decreasing crop area in 2010-11 (Fig-2.b).

In case of Boro paddy productivity,the condition of West Bengal is not so well enough since 1990-91. The average productivity is declined by 3% because the increasing tendency of agricultural inputs (Cropped area, Irrigated area and Fertilizer consumption) is not sufficient to enhance the productivity. But if we go to district wise analysis, then it has been seen that Out of seventeen districts of this state,six districts (Midnapore, Howrah, Hooghly, S 24 Paragana, Malda and Jalpaiguri) have changed its productivity from negative to positive trend from 1990-91 to 2010-11 (Fig-9) and the causes behind this is increasing cropped area, irrigated area and Rainfall. Midnpur is one such district which was in negative trend in past decade,isin positive trendin

recent decade due to enhancing irrigated areato the total cropped area (33.1 to 40.13 %) and fertilizer consumption (81.48 to 183.83 kg/hectare). In Malda irrigated area to the total cropped area is increased which in turn enhance productivity. But overall, Boro paddy productivity in this state is better than the aus paddy and aman paddy because of Irrigation facilities and fertilizer consumption.

This state is stand in a receding status comparatively to the other states of India in regarding Wheat productivity since 1990-91 because of the average total cropped area under wheat cultivation (293.55 thousand hectare) is much more less than the other crops (Aman Paddy- 3853.55 and Boro paddy- 1164.15 thousandhactare). The average wheat productivity in this state is declined by 5 % since 1990-91. But in district wise scenario it has seen that (Fig-11) fourdistricts(Bankura, Murshidabad, Birbhum and Burdwan) have positive trend due to increasing cropped area, irrigation and fertilizer and rest of the districts have negative trend in 1990-91 to 2000-01 period due to less sharing of total cropped area (3.71% in 1990-91) than the other crops (59.54% in Aman paddy, 12.40 % in Boro Paddy and 8.44 % in Aus Paddy). In 2000-01 to 2010-11 most of the south Bengal districts namely paschim and PurbaMedinipur, Howrah, Hooghly, N & S 24 Paragan and northernmost districts i.e. Jalpaiguri, Coochbehar, Uttar &DakshinDinajpur, Malda get positive trend in wheat productivity for raisingthe use of fertilizer and irrigated area. Only two districts (Bankura and Murshidabad) have been kept its same productivity since 1990-91 to 2010-11 due to more fertilizer consumption, increasing cropped area and also irrigation facility.Purulia and Darjeeling districts have stood themselves in negative trend since 1990-91 for their very low sharing of cropped area.

In 1990-91 Maize was an important crop in West Bengal with respect to productivity but in 2010-11, the condition has been changed vastly because of cropped area contraction. The average productivity of maize has been decreased by 78 % because the percentage share of total cropped area is very low than the other crops.In this state among the 17 districts only 7 districts have positive trend of productivity in 1990-91 to 2000-01 periods and Malda, Murshidabad and Jalpaiguri have high positive trend of productivity among them due to increasing share of cropped area but in next decade due to both increase of fertilizer consumption and irrigated area, fourteen districts (fig-14) have positive trend of productivity. In time, only Hooghly, N 24 Paragana, Murshidabad and Uttar Dinajpur have been proceeding with its same productivity. Since 1990-91 period, maize productivityhas faced negative trend in Purulia, Birbhum and Darjeeling districts due to less cropped area (Fig- 2.e), poor irrigation facility and rugged terrain.

In West Bengal, potato is most important crop after rice and jute and the productivity of this crop is tremendously raised by 40% due to increasing percentage of cropped area since 1990-91 (2.71 % to 7.63 %). Also, it is seen from the fig-15 & 16 that, out of seventeen districts only five districts (Birbhum, Burdwan, Bankura, Howrah and hooghly) has positive trend and rest of the districts have negative trend (1990-91 to 2000-01) in potato productivity but that scenario has been change surprisingly in next decade. Except Darjeeling, all of sixteen districts have positive trend of productivity for their strong relation to cropped area and large scale use of irrigation and fertilizer (table-3). In all of the districts of this state, cropped area has been increased during 1990-91 to 2010-11 period. The area of potato cultivation has been increased tremendously in Darjeeling but the trend of productivity is till negative.

Though in India, West Bengal is the undisputed king of jute production, the productivity is continuously decreasing from 1990-91 to 2010-11. In fig-17 only two districts i.e. Murshidabad and Nadia have been recognized as negative trend and in spite of increasing cultivated area till those two districts have been facing negative trend in productivity in 2000-01 to 2010-11. Purulia is not being able to agricultural practice of jute because of its rain fed character. Fourteen districts of this state have been facing positive trend and out of them only seven has kept its same trend because of its strong relation with Fertilizer consumption, irrigated area and rainfall (Table-3). Murshidabad has highest cultivated area of jute among all other but has been facing negative trend in jute productivity since 1990-91 due to decrease of demand.

In Comparison to other sate of India, West Bengal is in a backward position in sugarcane productivity because of over emphasizing on rice, potato and jute cultivation and cropped area contraction. In 1990-91 to 2000-01 period, Midnapur was in first position of sugarcane productivity (table-1)but it has been faced negative trend due to decreasing cropped area. But this district have been replaced by Malda districts as a first position (table-2) and it has continued its positive trend since 1990-91 to 2010-11 because of increasing cropped area, irrigation facility. Out of seventeen districts, only five districts of this state have negative trend of productivity and the main cause behind this negative trend is loss of cropped area (Fig- 2.h) in 1990-91 to 2000-01 period but and in 2000-01 to 2010-11 period, negative trend has shown in ten districts due to cropped area contraction mainly. So, the sugarcane productivity in this state has been worsening on account of losing cropped area in all districts (except Murshidabad). Coochbehar, Malda, Birbhum, Burdwan has retained their positive trend due to large scale utilization of irrigation and fertilizer consumption.

Rapeseed-Mustard is an important crop in west Bengal. Since 1990-91. The productivity is raised by 2%. From the fig-21 & 22, it has been realized that in rapeseed-mustard productivity, six districts (Purulia, Burdwan, Birbhum, Murshidabad, Malda and Darjeeling) of this state have positive trend in 1990-91 to 2000-01 for their cropped area enhancement. But in 2000-01 to 2010-11among those six districts, Purulia, Bankura, Burdwan and Darjeeling has been experienced negative trend due to loss of cropped area. Since 1990-91, S 24 Paragana is in a top position but has been faced negative trend in 1990-91 to 2000-01 period. In Bankura, Howrah, S 24 Paragana, Uttar &DakshinDinajpur, jalpaiguri and Coochbehar, due to decreasing cropped area the productivity trend is negative since 1990-91. Nadia, Hooghly and PaschimMedinipur have experienced positive trend due to more irrigation facility, fertilizer consumption.

CONCLUSION

The entire studyinfers that most of the agricultural crops have been facing decrement of cropped area and average productivity except potato. Maximum cropped area is decreased in respect to Aus Paddy cultivation.AmanPaddy is considered as major crop of West Bengal on the basis of sharing cropped area and productivity. Average potato productivity has been spectacularly increased and fifteen districts are in a positive trend. Though there have an increase of cropped area in between recent two decades, the average productivity of Boro Paddy and Rapeseed-mustard also isexperienced decreasing trend. Maize crop is diminished subsequently over two decades in term of productivity but the trend is slowly positive. In case of wheat, also productivity is decreased and nine district districts have negative trend. Overall, crop productivity scenario has characterised that northernmost hilly districts i.e. Darjeeling, Coochbehar, Jalpaiguri and westernmost

undulating red-lateritic district i.e. Purulia and coastal saline zone i.e. S 24 Paragana has been experienced low productivity with reference to state level.Remaining districts have shown High productivity in agriculture.

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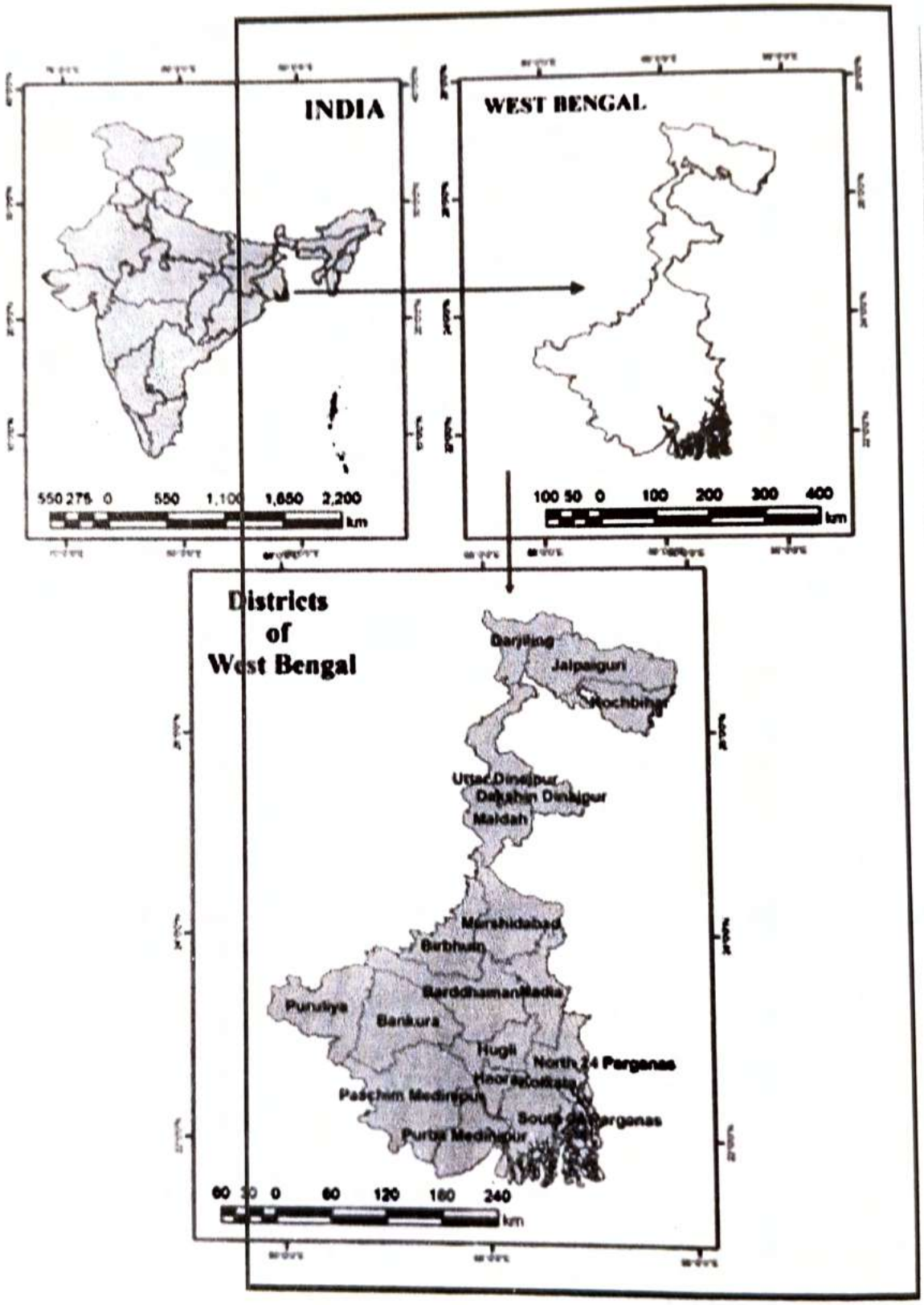
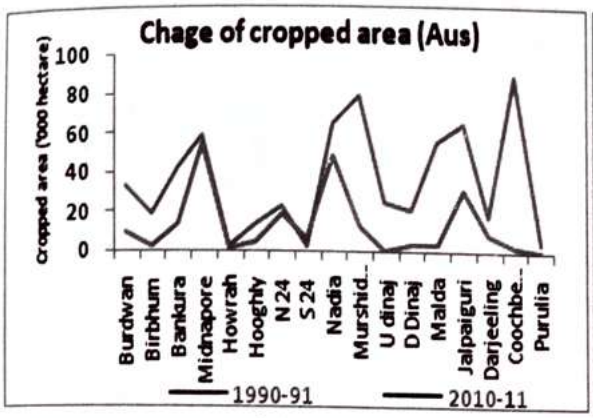
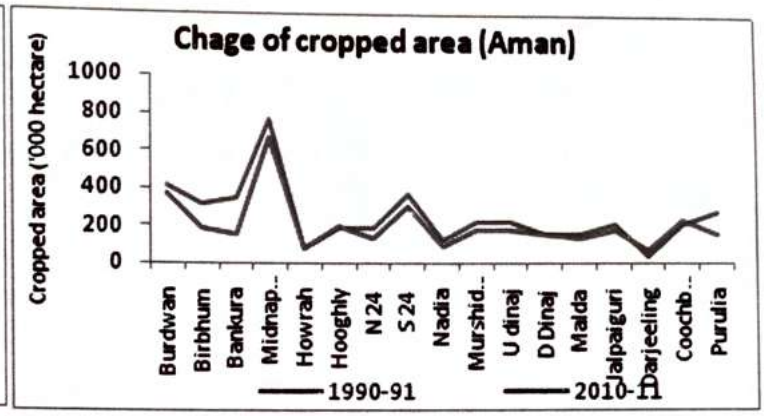


Fig 1 Study area



(a)



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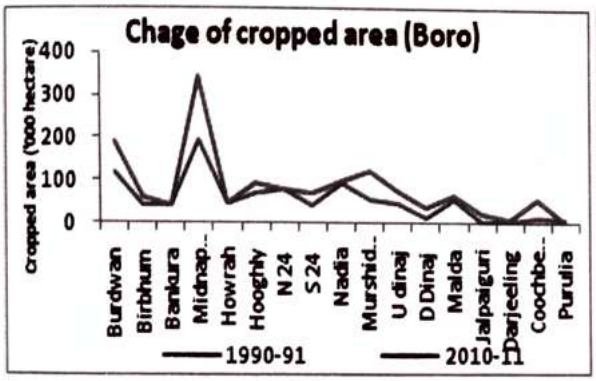

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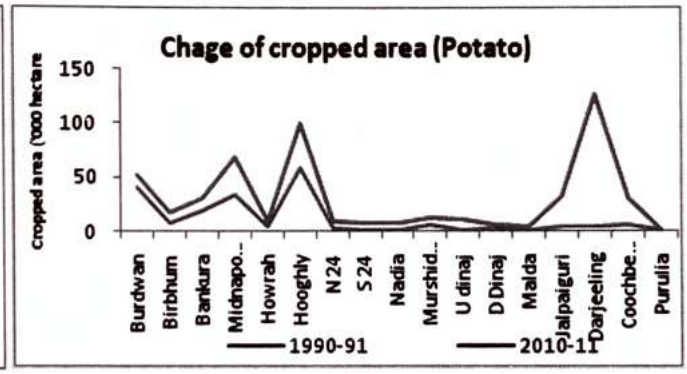

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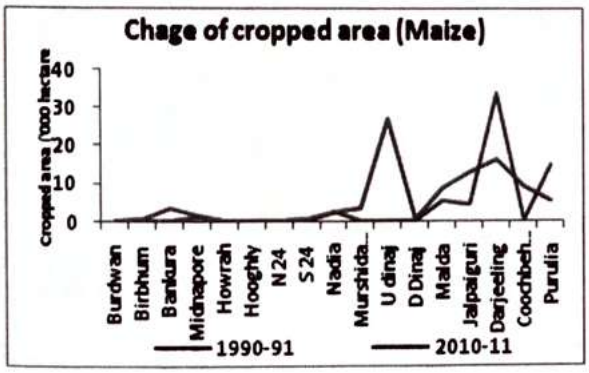

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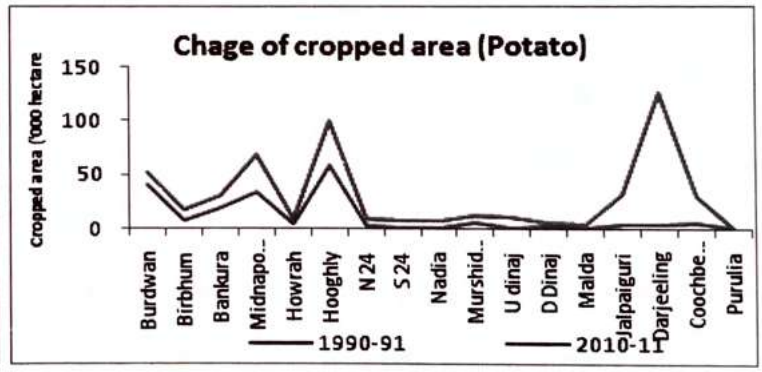

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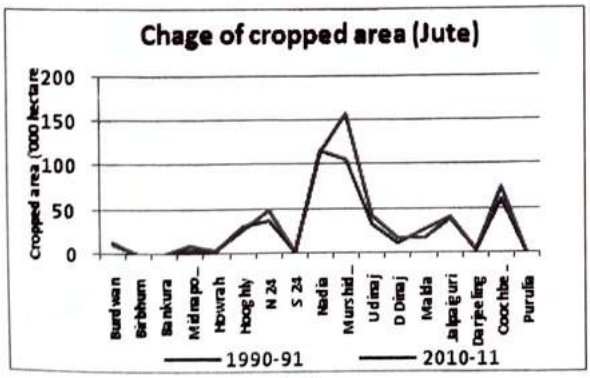

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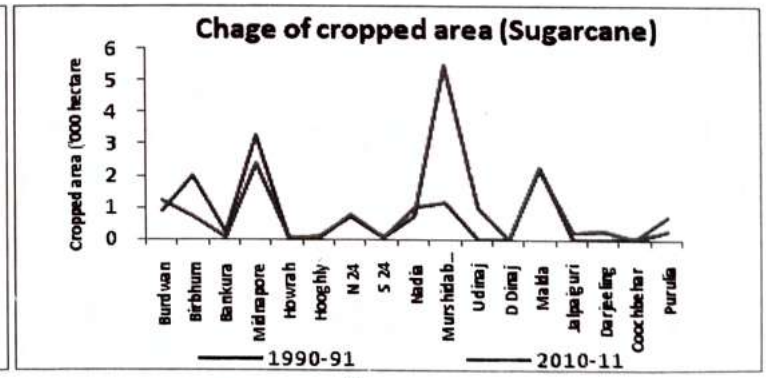


(h)

Fig 2 Districts wise changes of cropped area of some selected crops

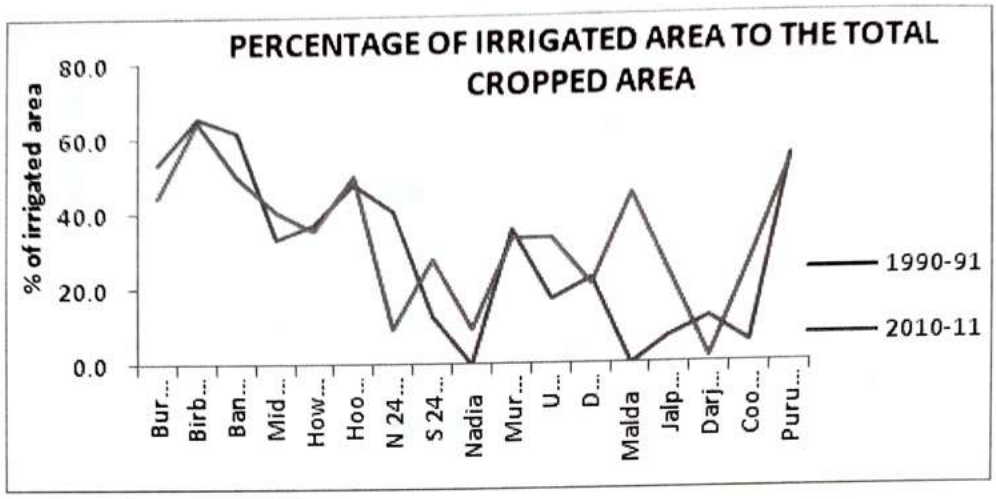


Fig 3 District wise change of irrigated area

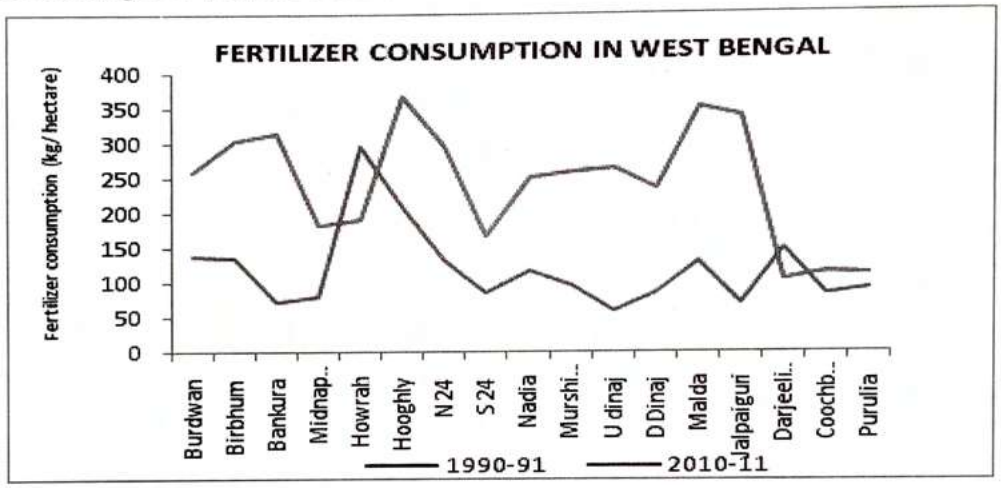
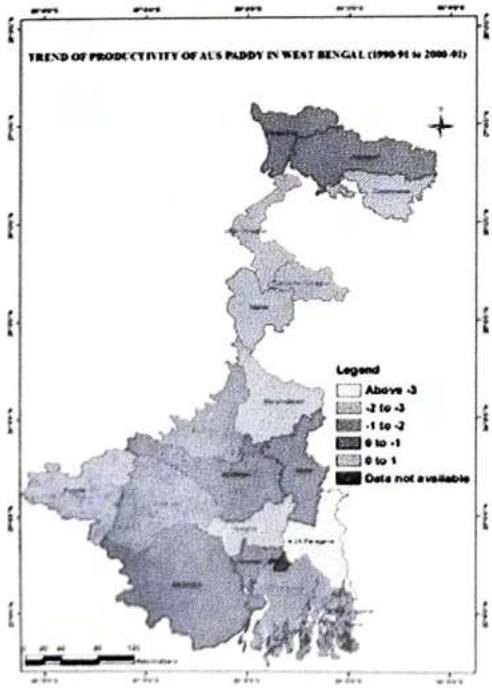


Fig 4 Fertilizer consumption per hectare cropped area



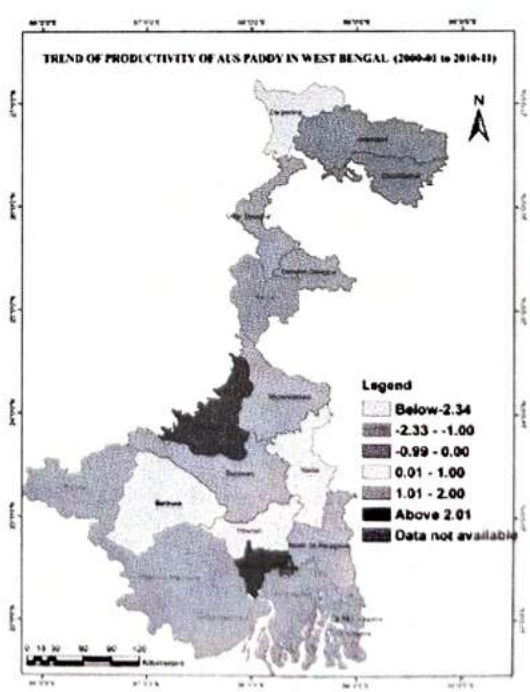


Fig 5 Trend of Aus productivity (1990-91 to 2000-01) Fig 6 Trend of Aus productivity (2000-01 to 2010-11)

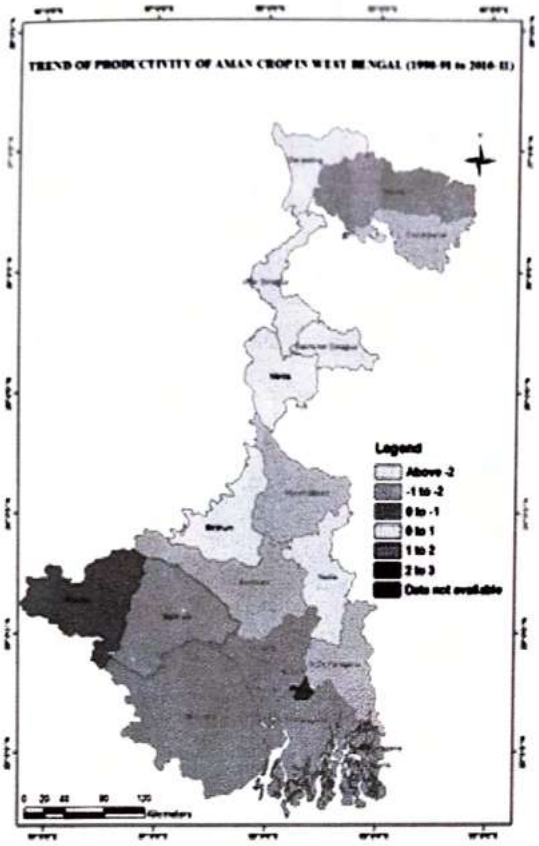


Fig 7 Trend of Aman productivity (1990-91 to 2000-01)

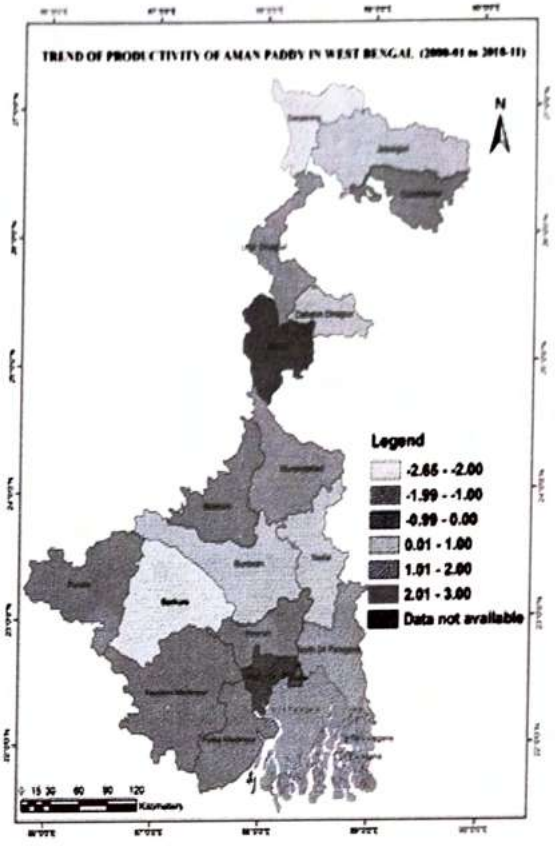


Fig 8 Trend of Aman productivity (2000-01 to 2010-11)

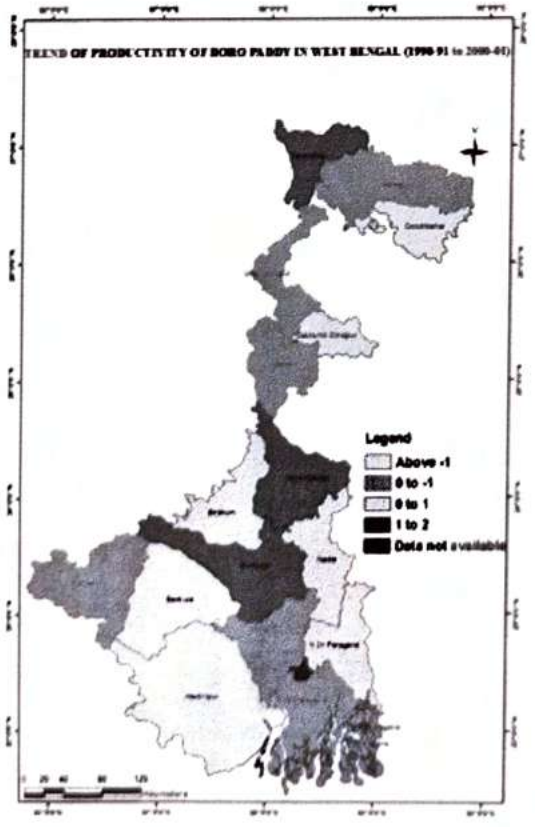


Fig 9 Trend of Boro productivity(1990-91 to 2000-01)

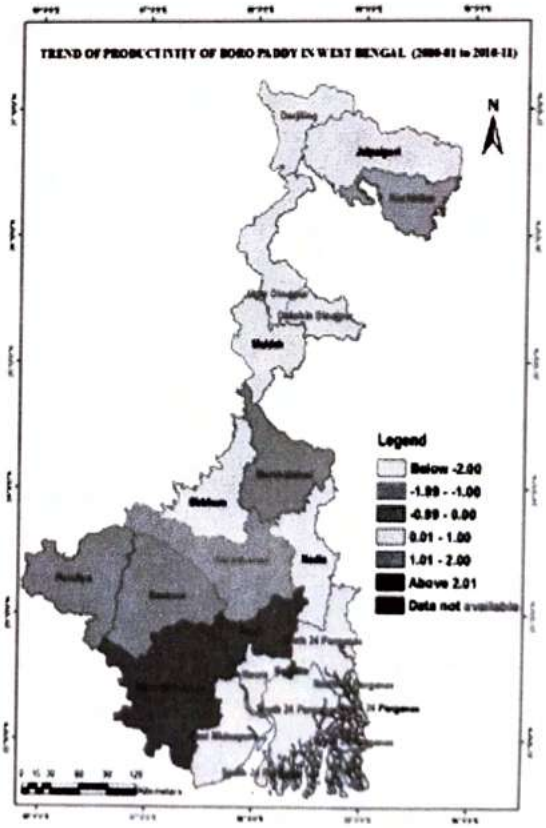


Fig 10 Trend of Boro productivity(2000-01 to 2010-11)

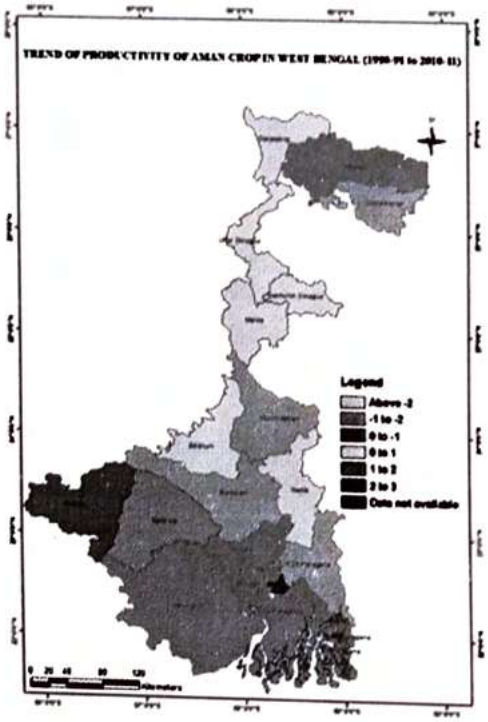


Fig 11 Trend of Wheat productivity(1990-91 to 2000-01)

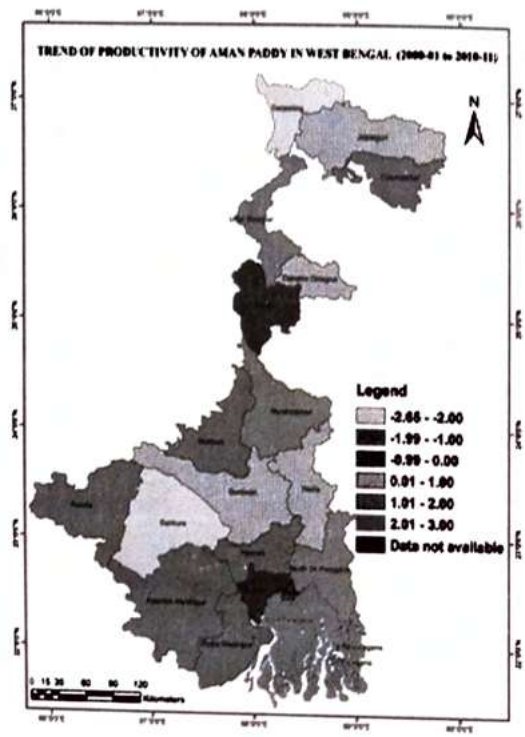


Fig 12 Trend of Wheat productivity(2000-01 to 2010-11)

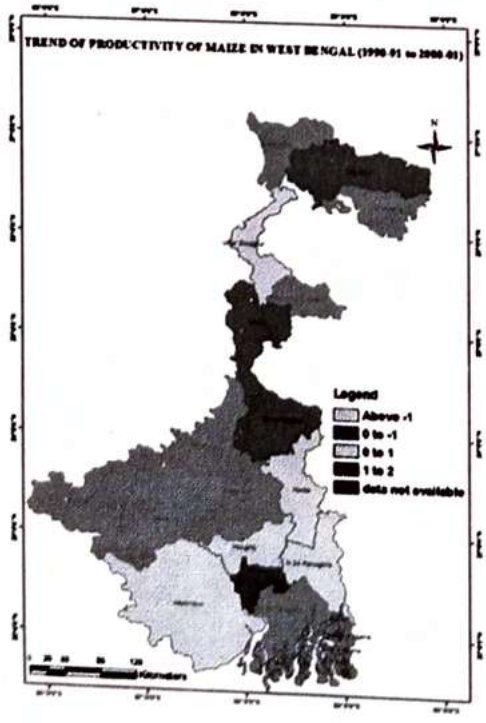


Fig 13 Trend of Maize productivity(1990-91 to 2000-01)

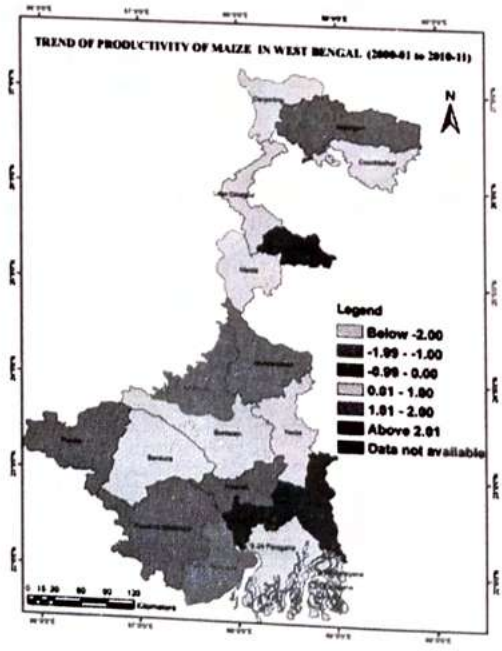


Fig 14 Trend of Maize productivity(2000-01 to 2010-11)

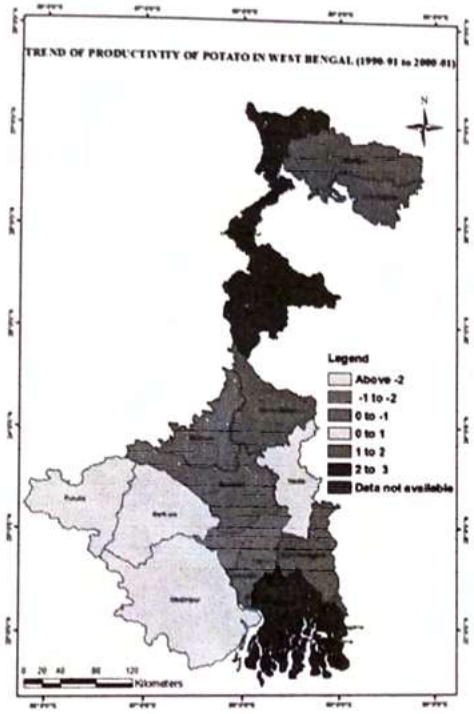


Fig 15 Trend of Potato productivity(1990-91 to 2000-01)

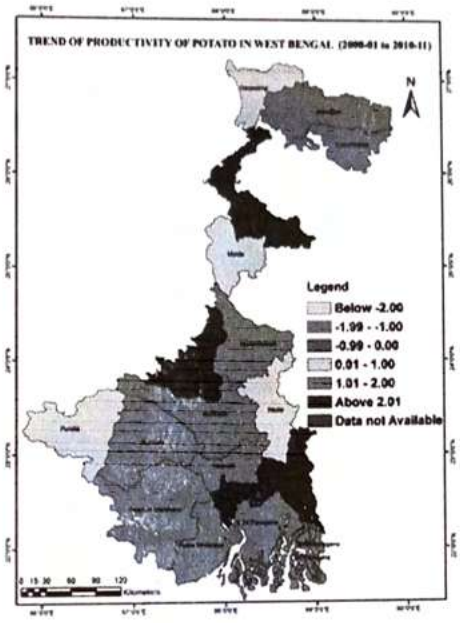


Fig 16 Trend of Potatoproductivity(2000-01 to 2010-11)

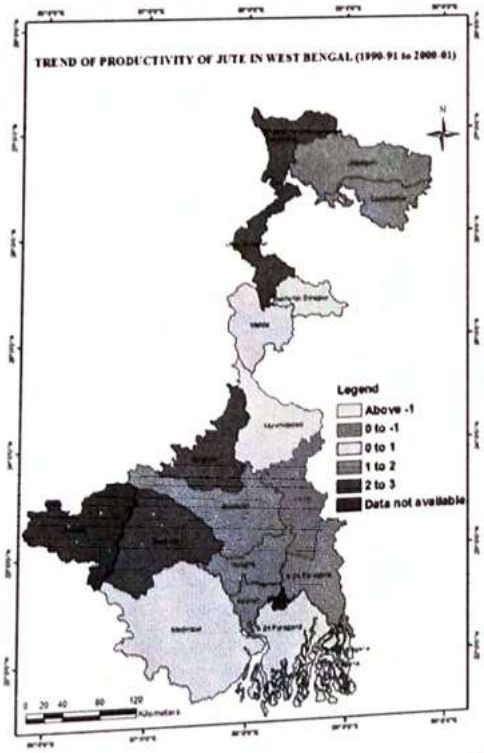


Fig 17 Trend of Jute productivity(1990-91 to 2000-01)

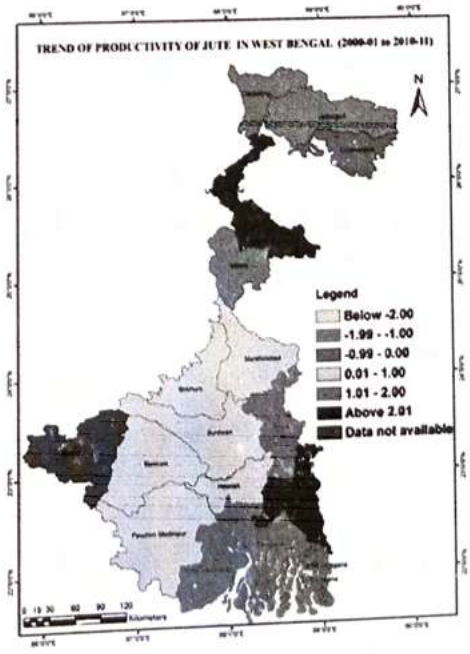


Fig 18 Trend of Jute productivity(2000-01 to 2010-11)

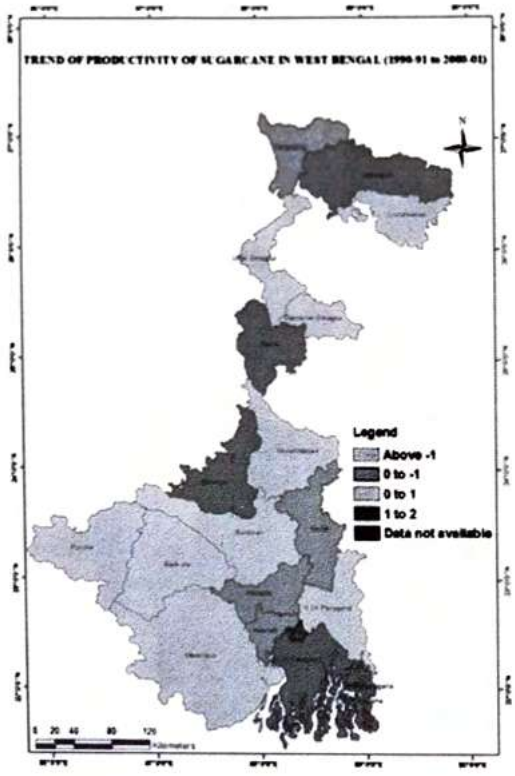


Fig 19 Trend of Sugarcane productivity (1990-91 to 2000-01)

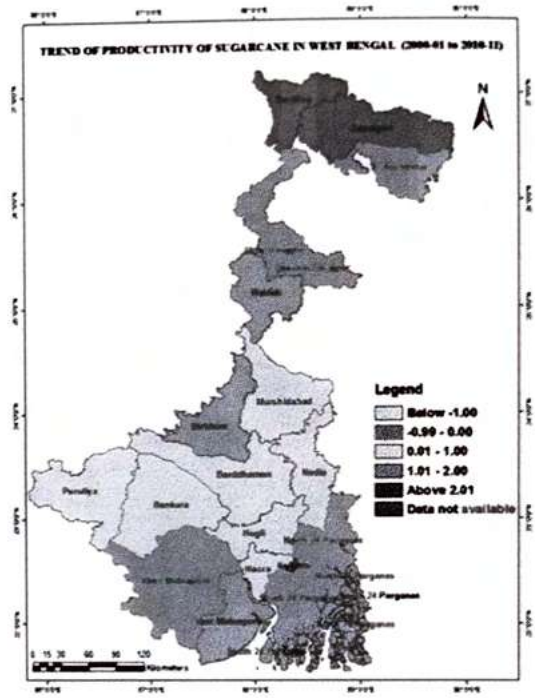


Fig 20 Trend of Sugarcane productivity (2000-01 to 2010-11)

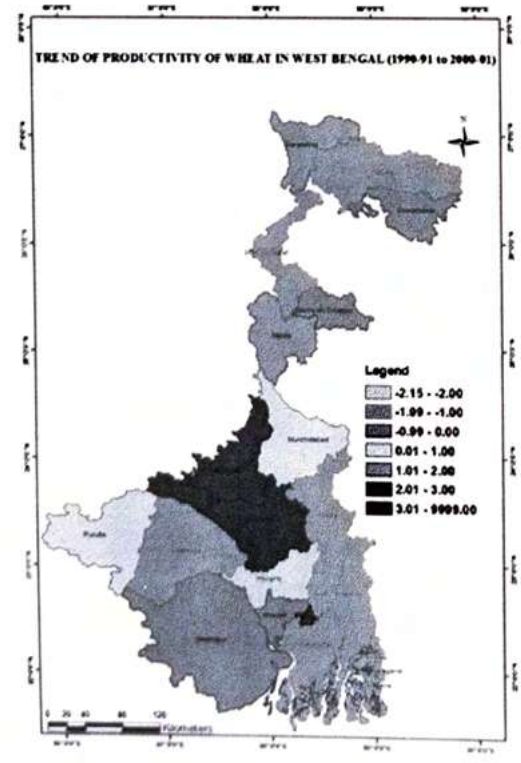


Fig 21 Trend of RM productivity (1990-91 to 2000-01)

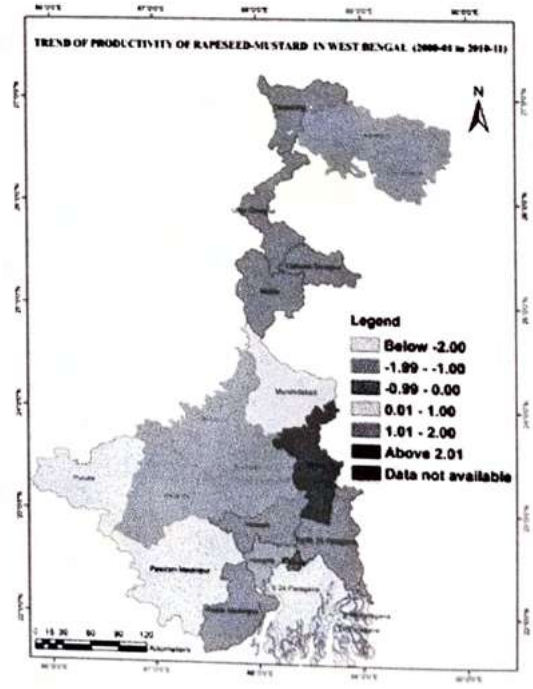


Fig 22 Trend of RM productivity (2000-01 to 2010-11)

Table 1 District wise sequential arrangement of crop in respect of productivity (1990-91)

Districts	DISTRICT WISE SEQUENTIAL ARRENGEMENT OF CROP(1990 1991)									
	1ST	Productivity	2ND	Productivity	3RD	Productivity	4TH	Productivity	5TH	Productivity
Burdwan	Aus	1.64	Aman*	1.57	Maize	1.57	Jute	1.25	Potato	1.12
Birbhum	Aus	1.72	Aman	1.30	Jute	1.23	Boro	0.96	Potato	0.93
Bankura	Maize*	4.62	Aus	1.60	Jute	1.29	Potato	1.15	Aman	1.14
Midnapur	Maize	2.30	Jute*	1.43	Sugarcane*	1.41	Aus	1.12	Boro	1.03
Howrah	Aus	1.65	Potato*	1.23	Jute	1.21	Wheat	1.01	Boro	0.97
Hooghly	Aus	1.42	Jute	1.30	Aman	1.29	Potato	1.12	RM	1.06
N 24 Paragana	Aus *	1.78	Aman	1.17	RM	1.12	Wheat	1.07	Jute	1.06
S 24 Paragana	RM*	1.41	Jute	1.12	boro	0.97	Aus	0.85	Wheat	0.85
Nadia	Maize	1.83	Aman	1.42	Jute	1.20	RM	1.20	Aus	1.11
Murshidabad	Maize	1.57	Aman	1.46	Jute	1.18	Boro	1.07	RM	1.04
U dinaj	Maize	3.15	Wheat *	1.24	boro	0.98	RM	0.89	Aman	0.81
D Dinaj	RM	1.28	Aus	1.16	Aman	1.11	Wheat	1.03	Boro	0.84
Malda	Maize	1.96	Wheat	1.20	Boro*	1.10	Aman	1.07	Sugarcane	0.99
Jalpaiguri	Maize	2.32	Boro	1.01	RM	0.81	Wheat	0.78	Aus	0.60
Darjeeling	RM	0.95	Aman	0.80	Jute	0.55	Wheat	0.52	Potato	0.41
Coochbehar	Maize	1.57	Aman	0.84	Wheat	0.84	Aus	0.81	Boro	0.81
Purulia	Maize	1.55	Sugarcane	1.10	Wheat	0.89	Boro	0.84	RM	0.79

Source: Prepared by the Author *Highest Productivity RM-Rapeseed-Mustard

Table 2 District wise sequential arrangement of crop in respect of productivity (2010-11)

Districts	DISTRICT WISE SEQUENTIAL ARRENGEMENT OF CROP(2010 2011)									
	1st crop	Productivity	2nd crop	Productivity	3rd crop	Productivity	4th crop	Productivity	5th crop	Productivity
Burdwan	Potato	1.48	Jute	1.47	Aus*	1.36	Sugarcane	1.29	Aman	1.17
Birbhum	Aus	1.31	Aman	1.16	Sugarcane	1.13	Potato	1.11	Boro	1.03
Bankura	Potato*	1.51	maize	1.51	Aus	1.10	Aman	1.00	Boro	0.91
E Midnapur	Jute	1.17	Wheat	1.10	RM	1.09	Boro	1.07	Potato	1.04
W Midnapur	Potato	1.51	Boro	1.10	Jute	1.08	Aus	1.05	Aman	1.00
Howrah	Potato	1.43	Jute	1.41	Aus	1.26	Boro	1.00	Aman	0.92
Hooghly	Jute*	1.49	Potato	1.38	Aman*	1.23	Aus	1.23	Maize	1.13
N 24 Paragana	Potato	1.42	RM	1.38	Jute	1.33	Sugarcane	1.14	Aus	1.09
S 24 Paragana	RM*	2.06	Potato	1.00	Boro	0.96	Wheat	0.95	Aman	0.85
Nadia	Sugarcane	1.12	Aman	1.08	Potato	1.07	Potato	1.07	RM	1.01
Murshidabad	Potato	1.19	Wheat	1.09	RM	1.08	Jute	1.04	Aman	1.04
U dinaj	Sugarcane	1.31	Potato	1.18	Aman	1.06	Maize	1.01	Wheat	1.00
D Dinaj	Maize*	1.58	Aman	1.19	Wheat*	1.11	Potato	1.06	Aus	1.05
Malda	Sugarcane*	1.37	Potato	1.16	Boro*	1.16	Aman	1.15	Wheat	1.11
Jalpaiguri	Sugarcane	1.09	Aman	0.91	Potato	0.91	Aus	0.89	Jute	0.84
Darjeeling	RM	0.98	maize	0.87	Jute	0.70	Aus	0.48	Aman	0.40
Coochbehar	Maize	0.95	Aman	0.92	Boro	0.88	Potato	0.85	Aus	0.79
Purulia	Maize	1.56	Boro	0.95	Aman	0.69	Potato	0.63	RM	0.54

Source: Prepared by the Author *Highest Productivity RM-Rapeseed-Mustard

Table 3 Relationship between productivity and agricultural inputs

AI →	Irrigated area (thousand hectare)		Fertilizer consumption (thousand tonne)		Cropped area (thousand hectare)		Rainfall (average in crop period in cm)	
Crops	1991	2011	1991	2011	1991	2011	1991	2011
Aus	0.57	0.43	0.54	0.54	0.19	0.10	0.52	0.11
Aman	0.55	0.54	0.49	0.64	0.02	0.30	0.44	0.51
Boro	0.36	0.41	0.40	0.32	0.40	0.50	0.34	0.57
Wheat	0.09	0.26	0.17	0.52	0.27	0.35	0.11	0.30
Maize	0.30	0.05	0.09	0.23	0.09	0.14	0.12	0.34
Jute	0.74	0.16	0.79	0.35	0.34	0.02	0.65	0.09
Sugarcane	0.73	0.17	0.51	0.45	0.58	0.34	0.65	0.76
Potato	0.67	0.49	0.72	0.55	0.63	0.42	0.02	0.14
Mustard	0.038	0.011	0.042	0.15	0.12	0.18	0.11	0.63

Source: Prepared by the author

Table-4 : values of statistics Z of the Mann–Kendall test and values of statistics Qmed of the Sen's slope estimator

1990-2001	Districts	Z	Signi fic.	Q	Signif ic.
Aman	N 24 Paragana	-1.97		-0.027	*
	Nadia	-2.50		-0.038	*
	Darjeeling	-2.33	*	-0.026	
	Purulia	2.15	*	0.020	
Aus	Hooghly	-2.15		-0.026	*
	N 24 Paragana	-3.58		-0.042	***
	U dinajpur	-2.15	*	-0.047	
	D dinajpur	-2.33	*	-0.026	
Jute	Birbhum	2.86		0.087	**
	Bankura	2.15		0.109	*
	U dinajpur	2.68	**	0.023	
	Darjeeling	2.50	*	0.032	
Mustard	Burdwan	2.33		0.016	*
	Birbhum	2.86		0.082	**
	Hooghly	-2.15		-0.052	*
	Nadia	-1.97		-0.020	*
	Malda	1.97	*	0.029	
Potato	Bankura	-2.33		-0.028	*
	S 24 Paragana	2.50		0.065	*
	U dinajpur	2.86	**	0.102	
	D Dinajpur	2.86	**	0.066	
	Malda	2.50	*	0.044	
	Jalpaiguri	1.97	*	0.049	
	Darjeeling	2.15	*	0.053	

2001-2011	Districts	Z	Significic.	Q	Significic.
Aman	Bankura	-2.65		-0.018	**
	Hooghly	2.65		0.012	**
	Malda	2.18	*	0.028	
	Darjeeling	-2.49	*	-0.038	
Aus	Birbhum	2.34		0.021	*
	E mid	-2.18		-0.039	*
	Hooghly	2.02		0.009	*
	Darjeeling	-2.34	*	-0.031	
Boro	W mid	2.49		0.016	*
	Hooghly	2.02		0.013	*
	U dinaj	-2.18	*	-0.011	
	Darjeeling	-2.96	**	-0.045	
Jute	Birbhum	-2.80		-0.070	**
	W mid	-2.49		-0.066	*
	N 24	2.65		0.020	**
	U dinaj	2.96	**	0.027	
Maize	Howrah	-1.97		-0.030	*
	Nadia	-2.49	*	-0.028	
	Malda	-3.27	**	-0.076	
	Darjeeling	-2.34	*	-0.062	
Potato	N 24	2.65		0.069	**
	U dinaj	2.49	*	0.059	
	Darjeeling	-2.02	*	-0.057	

* Trends statistically significant at the 95% confidence level.
**Trends statistically significant at the 99% confidence level.
*** Trends statistically significant at the 99% confidence level.

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Nutrient management with organic, inorganic and biofertilizers for yield attributes of soursop (*Annona muricata* L.)

T. UMA MAHESWARI[1]* AND P. DEEPTHI BERSHANI[2]

Department of Horticulture, Faculty of Agriculture,
Annamalai University, Annamalainagar- 608 002

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ABSTRACT

A field experiment was carried out to study the effect of organic, inorganic and biofertilizers in soursop (*Annona muricata* L.) at Department of Horticulture, Faculty of Agriculture, Annamalai University during 2017-2019. Two years old soursop plants were used for this study. The experiment was conducted in a Randomized Block Design with eight treatments in four replications. The treatments include chemical fertilizers (80:60:40 g of N:P:K; 60:45:30 g of NPK and 40:30:20 g of NPK), organic nutrients *viz.*, vermicompost @ 500 g, Biofertilizers (*Azospirillum* and Phosphobacteria) @ 50 g were applied per plant in the respective treatments. Humic acid @ 0.2 % spray was applied through foliar means once in 3 months.Totally 4 sprays were given starting from 2 years after planting in the respective treatments. The results revealed that among the various treatments tried, application of 80:60:40 g NPK/plant + Biofertilizer (50 g/plant) + Vermicompost (1/2 kg/plant) + Humic Acid (0.2 % spray) resulted in improving the yield atributes like minimum days taken for flowering, number of flowers per plant, minimum days taken for fruit set, number of fruits per plant, per cent fruit set (%), fruit length(cm), fruit width (cm), fruit weight (g). This was closely followed by the application of 60:45:30 g NPK/plant + Vermicompost (1/2 kg/plant) + Biofertilizer (50 g /plant) + Humic Acid (0.2 % spray).

Key words: Soursop, organic manures, biofertilizers, humic Acid

Soursop (*Annona muricata* L.) which belongs to Annonaceae family is an evergreen tree species and it has annonaceous acetogenins content. Soursop is known for its anti-cancer properties. Origin of this crop is Central America. It bears the largest fruit among Annonas. Annonaceous acetogenins content of soursop leaves exhibited significant inhibitory effects against six human cancer cell lines: lung, breast, colon, pancreatic, kidney carcinoma (Vieira *et al.*, 2010). Soursop Leaves Crude Extract (AMCE) exhibitedcytotoxicity towards breast cancer cell lines and reduced the tumor's size and weight in lab mice. Thus it is proved to be a promising candidate for cancer treatrnent especially in breast cancer as an alternative to conventional drugs (Najmuddin *et al.*, 2016). Such an amazing gift of nature should be utilized and commercialized for cultivation. Since it is an underutilized fruit crop, agro techniques are yet to be standardized. Hence a field experiment was conducted to study the effect of organic, inorganic and biofertilizers on the yield attributes of soursop.

[1]Assistant Professor, [2] Research Scholar, Department of Horticulture, Faculty of Agriculture, Annamalai University, Annamalainagar- 608 002

*Email: umahorti2003@gmai.com

MATERIALS AND METHODS

A field experiment was carried out to study the effect of organic, inorganic and biofertilizers in soursop at Department of Horticulture, Faculty of Agriculture, Annamalai University during the year 2017. Two years old soursop plants were used for this study. The experiment was conducted in a Randomized Block Design with eight treatments in four replications. The treatments included chemical fertilizers (80:60:40 g of NPK; 60:45:30 g of NPK and 40:30:20 g of NPK), organic nutrients *viz.*, vermicompost @ 500 g, Biofertilizers (*Azospirillum* and Phosphobacteria) @ 50 g were applied per plant in the respective treatments. Accrdingly total eight treatments were there *viz.*, 80:60:40 g NPK/ plant(T_1); 80:60:40 g NPK/ plant + Biofertilizer (50 g/ plant)(T_2); 80:60:40 g NPK/ plant + Vermicompost (1/2 kg/ plant)(T_3); 80:60:40 g NPK/plant + Humic Acid @ 0.2 % spray (4 spray once in 3 month)(T_4); 80:60:40 g NPK/plant + Biofertilizer (50 g/plant) + Vermicompost (1/2 Kg/plant) + Humic Acid (0.2 % spray)(T_5); 40:30:20 g NPK/plant + Vermicompost (1/2 Kg/plant) + Biofertilizer (50g/plant) + Humic acid (0.2 % spray)(T_6); 60:45:30 g NPK/plant + Vermicompost (1/2 Kg/plant) + Biofertilizer (50 g/plant) + Humic Acid (0.2 % spray)(T_7);Control(T_8). The chemical fertilizers were applied in the form of urea, single super phosphate and muriate of potash as per treatments by forming a trench around the tree at 30 cm away from the trunk. 80:60:40 g ; 60:45:30 g and 40:30:20 g of NPK were applied in the respective treatments. Phosphorous and potash were applied as basal. Nitrogen was applied in two split doses at 3 months interval. Humic acid @ 0.2 % spray was applied through foliar means once in 3 months during the mnths of July, Ocober, January and April, 2017. Totally 4 sprays were given starting from 2 years after planting in the respective treatments. Irrigations were given through basin method. Observatins recorded were , number of days for flowering, number of days for fuit set, number of fruits, fruit set(%), fruit length(cm), fruit breadth(cm) and fruit weight(g).

RESULT AND DISCUSSION

The results revealed that among the various treatments tried, application of 80:60:40 g NPK/plant + Biofertilizer (50 g/plant) + Vermicompost (1/2 kg/plant) + Humic Acid (0.2 % spray) (T_5) resulted improving the yield atributes like minimum days taken for flowering, minimum days taken for fruit set, maximum number of flowers per plant, maximum number of fruits per plant, per cent fruit set (%), fruit length(cm), fruit width (cm), fruit weight (g). This was closely followed by application of 60:45:30 g NPK/plant + Vermicompost (1/2 kg/plant) + Biofertilizer (50 g /plant) + Humic Acid (0.2 % spray) (T_7).

The reproductive growth in terms of number of flowers, number of fruits and per cent fruit set was also significantly influenced due to the application of 100% of NPK, bio fertilizers, vermicompost and humic acid. The maximum number of flowers per tree, maximum number of fruits per tree(Table 1) and per cent fruit set were recorded in the treatment T_5 (80:60:040 g NPK/ plant + Biofertilizer (50 g /plant) + Vermicompost (1/2 Kg /plant + Humic acid (0.2 % spray). Minimum days required for flowering, fruit set, and High fruit set %, maximum value for fruit length, fruit breadth, and fruit weight were recorded in the same treatment. The results are in agreement with the findings of Suresh Kumar *et al.* (2017) in custard apple, who reported the enhanced growth characters of custard apple due to the integrated nutrient practices. The effect of integrated nutrient management on yield parameters of soursop *viz.*, days taken for flowering, percent fruit set, was evident that it

might be due to the altered C: N ratio which helped in balanced management of vegetative and reproductive stages and induce early flowering.

It is clear from the results, that 100 % NPK, vermicompost, biofertilizer and humic acid recorded significantly the maximum number of flowers per plant as compared to control. The increased number of flowers per plant might be due to increased continuous supply of nutrients and growth promoting substance from vermicompost and biofertilizers. The fact that increased number of fruits set percent was obtained with the same treatment might be due to supply of all the nutrients in balanced proportion right from starting of the experimentation to the harvesting of the crop, which induced the more flowering and fruits set due to production and supply of photosynthates at critical requirement. These results are in accordance with the findings of Singh and Mithra(2017) in bael.

The results revealed that 100 % of N, P and K with organic nutrients significantly increased the number of fruits per tree and this was similar to the results of Suresh Kumar *et al.*(2011) in custard apple.

The increase in fruit length, fruit breadth and fruit weight (Table 2) might be attributed to elongation of individual cells. This might be possible through better translocation of soluble ions under optimum level of nutrients. Fruit weight and fruit size are highly correlated with biomass and balanced level of hormones. Improved fruit quality might be due to the fact that, organic manures and microbial fertilizers enhance the nutrient availability by enhancing the capacity of the plant. The above findings are in accordance with Meena (2016) in sapota. Application of vermicompost provides adequate supply of macro and micronutrients to the metabolic activities of plants. Indirectly, it increases the photosynthetic activities of plants and ultimately increased the fruit length and fruit girth. Moreover vermicompost are rich in microbial activity and plant growth stimulants, and possessing pest repellence attributes as reported by Gandhi *et al.*, (1997). Better fruit quality with respect to fruit length, diameter, and fruit weight might be due to fact that chemical fertilizers along with biofertilizers application caused accumulation of more food reserves in the trees and lead to an efficient utilization of the food materials for development of fruit. The marked effect of nitrogen on various characters of fruits showed that, it increased the efficiency of metabolic processes of the tree in various parts of the plant which might have resulted in high rate of photosynthesis and in higher carbohydrate accumulation in fruits thereby increasing in fruit length, diameter and weight. As the application of NPK significantly enhanced the plant growth and through its beneficial effects, which in turn resulted in increased fruit size as reported by Athani *et al.* (2007) in Guava. Humic acid also influenced the increase in number of fruits. This might be due to enhanced uptake of mineral nutrients and increase of cation exchange in soil as well as growth hormone like activity of humic acid. Similar results were also reported by Ngullie *et al.* (2014) in mango.

Organic manures and biofertilizers have direct role in nitrogen fixation, production of growth hormones like substances and more uptake of nutrients hence enhanced the fruit quality. These observations are in agreement with the findings Sharma and Bhatnagar (2014) in custard apple. Experimental findings stated that integration of organic, inorganic nutrients and biofertilizers studies will increase the productivity of crops by providing balanced nutrients in optimum quantity.

CONCLUSION

Based on the above observations, it could be concluded that among the various treatments, application of 80:60:40 g NPK/plant + biofertilizer (50 g /plant) + vermicompost (1/2 kg/plant) + humic acid (0.2 % spray) (T_5) was adjudged as the best treatment for enhancing the various yield parameters of soursop.

Table 1 Effect of Integrated nutrient management on yield parameters of soursop

Treatments	Number of days for flowering	Number of flowers	Number of days for fruit set	Number of fruits
T_1 - 80:60:40 g NPK/ plant	233.25	15.25	71.25	10.15
T_2 - 80:60:40 g NPK/ plant + Biofertilizer (50 g/ plant)	238.25	13.25	67.45	8.25
T_3 - 80:60:40 g NPK/ plant + Vermicompost (1/2 kg/ plant)	218.35	21.25	59.35	16.15
T_4 - 80:60:40 g NPK/plant + Humic Acid @ 0.2 % spray (4 spray once in 3 month)	228.15	18.15	64.25	12.58
T_5 - 80:60:40 g NPK/plant + Biofertilizer (50 g/plant) + Vermicompost (1/2 Kg/plant) + Humic Acid (0.2 % spray)	200.00	31.35	48.00	27.35
T_6 - 40:30:20 g NPK/plant + Vermicompost (1/2 Kg/plant) + Biofertilizer (50g/plant) + Humic acid (0.2 % spray)	212.25	24.25	55.25	19.25
T_7 - 60:45:30 g NPK/plant + Vermicompost (1/2 Kg/plant) + Biofertilizer (50 g/plant) + Humic Acid (0.2 % spray)	206.05	27.35	51.05	22.76
T_8 - Control	251.42	12.25	75.64	6.55
S.Ed	1.63	0.58	0.82	1.45
C.D(P=0.05)	3.26	1.16	1.64	2.90

Table 2 Effect of Integrated nutrient management on fruit characters of soursop

Treatments	Fruit set (%)	Fruit length(cm)	Fruit breadth(cm)	Fruit weight (g)
T_1 - 80:60:40 g NPK/ plant	66.55	23.53	16.52	449.66
T_2 - 80:60:40 g NPK/ plant + Biofertilizer (50 g/ plant)	62.26	24.55	17.55	464.22
T_3 - 80:60:40 g NPK/ plant + Vermicompost (1/2 kg/ plant)	76.00	25.06	18.05	476.52
T_4 - 80:60:40 g NPK/plant + Humic Acid @ 0.2 % spray (4 spray once in 3 month)	69.31	24.05	17.05	456.22
T_5 - 80:60:40 g NPK/plant + Biofertilizer (50 g/plant) + Vermicompost (1/2 Kg/plant) + Humic Acid (0.2 % spray)	87.24	26.54	19.53	500.00
T_6 - 40:30:20 g NPK/plant + Vermicompost (1/2 Kg/plant) + Biofertilizer (50g/plant) + Humic acid (0.2 % spray)	79.38	25.55	18.55	484.32
T_7 - 60:45:30 g NPK/plant + Vermicompost (1/2 Kg/plant) + Biofertilizer (50 g/plant) + Humic Acid (0.2 % spray)	83.21	26.05	19.05	490.32
T_8 - Control	53.46	23.05	16.03	443.22
S.Ed	1.08	0.13	0.13	2.60
C.D(P=0.05)	2.17	0.27	0.26	5.20

Soursop fruit

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Effect of plumbagin on midgut amylase in *Dysdercus cingulatus* Fab. (Heteroptera: Pyrrochorridae)

MRINMAYEE DATAR[1] AND SUJATA MAGDUM[2]*

PG Department of Zoology and research Centre,
KRT Arts, BH Commerce and AM Science College (K T H M College), Nashik

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ABSTRACT

India has an agro-based economy where there is a constant struggle between using pesticides and maintaining healthy crop yield. Often, the use of pesticides takes a priority to achieve a good quantity of crop yield. This has now triggered a renewed interest in assessing the role of natural products in insect growth regulation. Naphthoquinone Plumbagin is one such natural compound extracted from *Plumbago* spp. In the current study, the role of Plumbagin in interfering with the amylase activity was assessed. The assay was done using the DNSA reagent. It was found that as the activity of amylase decreased with the progressive increase in the dose and duration of treatment

Key words: *Dysdercus cingulatus*, Plumbagin, Amylase, Naphthoquinone, secondary metabolite

Insects form an integral part of any ecosystem. They are of great economic importance as they act as pollinators, decomposers, also add aesthetic beauty to the environment. Many of the insects act as pests and cause great economic loss by destroying the agricultural yield or stored grains. Since India has an agro-based economy, controlling the insect pests has been the focal point of research. Of all the methods known to control insect pests, striking a balance between the advantages and disadvantages of these methods to efficiently control pest infestation is a challenge. The age-old practice of using synthetic pesticides has resulted in the development of resistance in pests as well as causing aggravated human health hazards. In this context, many of the natural products are screened for understanding the biological activities like insect growth regulators, allohormones, antifeedants etc.

[1]Research Scholar, [2]Assistant Professor, Department of Zoology, KRT Arts, BH Commerce and AM Science College, Nashik

*Email: sujata_magdum@yahoo.com

Natural products are organic compounds isolated from plants, animals, algae, fungi etc. Albrecht Kossel, in 1891, proposed the classification of natural products in two major classes– Primary and secondary metabolites. Primary metabolites are essentially present in each cell of the organisms in the form of carbohydrates, amino acids, lipids and nucleic acids, and play a vital role in the survival of organisms which produce them. Similarly, secondary metabolites are present in very small amounts in an organism and are essential to support/protect organism within its environment, through the modulation of biochemical and signal transduction pathways.

There are many secondary metabolites are known to show biological activities. Naphthoquinone is widely occurring secondary metabolites of some actinomycetes, fungi, lichens and higher plants. These are highly cytotoxic compounds known to be affecting mitochondria, cytoplasmic proteins and microsomes in the form of free radicals and damage DNA and RNA. Some of the secondary

metabolites have been reported for their insecticidal properties and inhibitors of larval development. Plumbagin, one such naphthoquinone extracted from Bamboo –*Plumbago* spp. is known to possess a wide range of biological properties which primarily include antimicrobial (Krolicka *et. al.*, 2009, Sharma et al 2013), anti-tumour (Bhasin *et al.* 2013) and insecticidal properties (Pavela R, 2013). Plumbagin has been reported to be acting as insect growth regulator by acting as a chitin synthesis inhibitor (Gnanamani and Dhanasekaran, 2013). The cuticle of the insects treated with Plumbagin becomes stiff, consequently hampering feeding and thereby resisting moulting. Preliminary studies on the control of *Dysdercus koenigii* have been done using the naphthoquinones Plumbagin, Juglone and their synthetic analogue Menadione along with 24 other naphthoquinones and benzoquinones by (Magdum, 1999).

Insects are ubiquitous and possess different enzymatic tools specific for circumventing the plant defences and for metabolizing the nutrients. The detection and characterization of digestive enzymes in the insects is an active field of research. Various aspects of digestion in insects is reviewed by Day and Waterhouse 1953; Wigglesworth 1972; Silva and Terra 1994; Terra and Ferreira 2012.

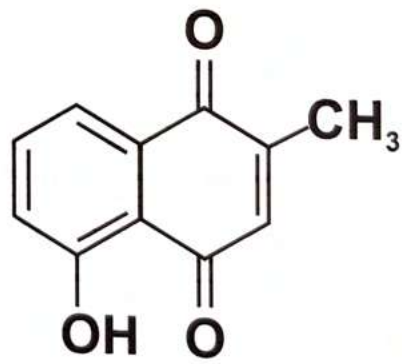
Midgut is most prominent region for digestion and absorption. In *Dysdercus cingulatus* the midgut is differentiated into four distinct ventriculi and are denoted as first, second, third and fourth ventriculus (V_1-V_4). Based on this, here an attempt is made to study the effects of Plumbagin on amylase in particular in *Dysdercus cingulatus*. Amylases are glycosyl hydrolases that break down 1,4 glycosidic bonds inside a malto-polysaccharide linear chain, mainly in starch and glycogen, resulting in maltose, maltotriose, and residual branched maltodextrins as final products. (Jean-Luc Da Lage, 2018).

This paper deals with understanding the quantitative changes in the midgut amylase due to topical application of important naphthoquinone-Plumbagin in *Dysdercus cingulatus*.

MATERIALS AND METHODS

Insect Culture: Insects were handpicked from cotton fields in Ankai village of Manmad, Nashik district. They were then transferred to plastic jars containing 5-6 cm of moist soil and the mouth of the jars was covered with a muslin cloth. The ambient temperature was maintained at 25°C ± 5°C. The insects were fed with cotton seeds soaked in water, which were changed on alternate days. The walls of jars were wiped clean every day to prevent fungal and bacterial contamination. Freshly moulted 24-36 hours old adults were separated from the culture and were used for experimentation.

Test compound: Plumbagin is 5-hydroxy-2-methyl-1, 4-hydroxy naphthoquinone obtained from Sigma (1 gm) was dissolved in acetone (1mg/ml)



Plumbagin (5-hydroxy-2-methyl-1, 4-hydroxy naphthoquinone)

Treatment: Freshly moulted 24-36 hrs old adults were treated with varying sub-lethal doses of Plumbagin (2, 4, 6, 8 µg/ml). The doses were administered topically on the ventrolateral side with the help of Hamilton microlitre syringe. Topical application was chosen as the mode of treatment so that the haemolymph does not ooze out. The insects were treated in a group of 20 for every dose keeping controls for each group.

Extraction of amylase: Insects were dissected in ice-cold Citrate Phosphate buffer (6.2) under the stereoscopic dissecting microscope and alimentary canal was pooled out of the body and the additional tissue adhering to it was removed. Foregut, midgut and hindgut were homogenised separately at 0°C for 3 minutes and the tissue was screened for detection of the active amylase in the alimentary canal as mentioned by Pickford and Dorris (1934). Amylase was extracted by the method described by Hemlata *et al* (2014)

Enzyme quantification: Enzyme quantification with respect to the amylase was done using the methods described by Sadasivam and Manickam, 2008. 2 % soluble starch was used as a substrate for quantification of the enzyme.

Data Analysis: Two factor ANOVA was carried out in Excel.

RESULTS AND DISCUSSION

Identification of amylase in alimentary canal: The alimentary canal of *Dysdercus cingulatus* measured about5.2±1 cm long and as seen in other insects consisted of anterior foregut, middle midgut and posterior hindgut. The midgut is the largest part of the alimentary canal in *Dysdercus cingulatus* and measured about 3.5±0.2 cm long. It showed the presence of four ventriculi namely $V_1$to V_4. V_1 appeared sac-like and forms nearly one-fourth part of the midgut(0.8±0.1cm). Second Ventriculus (V_2) is thin long and slender and measures 1.5. Third ventriculus (V_3) is again sac-like with a smaller size (0.4±0.1 cm) than V_1. The third ventriculus is curled which joins to the fourth ventriculus which is tube-like(0.5±0.1cm) and joins posteriorly to the hindgut. At the junction of V_4 and hindgut, two rows of gastric caeca are present in the female which is lacking in males.

For analysis of amylase foregut, midgut with V_1, V_2, V_3, V_4 and hindgut of 4 insects were separately placed. 2 drops of 0.2 M Sodium Chloride was added to the incubation mixture to activate the enzyme. Along with normal control, a positive control of a 0.2 % diastase solution is added instead of gut extract for comparison. The micro method described by Pickford and Dorris (1934) for the detection of amylase confirmed the absence of amylase in the foregut, V_2 – V_4 and hindgut extract. Very feeble weak reaction was noted in the extract obtained from the foregut region and hindgut region.

Table 1 Distribution of amylase in positive control and Normal control in different regions of the alimentary canal of *Dysdercus cingulatus*
(+ means Present,++ more amount of amylase reaction, - means absent,* feeble amount)

	Foregut	Midgut				Hindgut
		V1	V2	V3	V4	
Positive control	+	++	-	-	-	+
Control(Normal)	*	++	-	-	-	*

Majority of insects in this infra order are predators and seed sucking insects with few exceptions, showing feeding on phloem-sap. Due to this reason variation is seen in their digestion. Absence of amylase in foregut, V_2 – V_4 of midgut and hindgut could be due to the nature of feeding in *Dysdercus*. Major insect enzymes are amylase, maltase, invertase, tryptase, peptidase and lipase.

Food that is taken in by insects defines the type of enzymes they possess in the digestive tract. Adaptation to a particular food by insects, its digestive processes and mechanism of digestion is understood only by the detailed study on its digestive enzymes. Predominantly it is found that carnivore insects possess proteolytic and lipolytic digestive enzymes and lacks amylase and saccharases. Omnivore and herbivore insects possess carbohydrase. *Dysdercus* feeds on cotton seeds. Nearly 45% of carbohydrates are glucose and small oligosaccharides especially disaccharides are more important sugars in cotton seeds. These are soluble forms and starch is totally absent (Silva, 1994). Even though lipids and proteins are the major constituents of seeds, their digestion is not discussed here.

Quantification of enzymes amylase: The activity of an enzyme is a measure of its catalytic ability which converts oligosaccharides to reducing sugars. The Amylase concentration in the gut of *Dysdercus cingulatus* was assayed using the protocol described by Sadasivam and Manickam, 2008. The spectrophotometric the analysis was carried out and total amylase in both the control and different doses of plumbagin treated insects were recorded in µg/ml of tissue extract. As shown in table 2, amylase activity decreases with the progression of dose and duration of treatment. There is a dose-dependent effect observed in treated groups.

Table 2 Amountof amylase (µg/mg of tissue) in control and Plumbagin treated *Dysdercus cingulatus*

Days	Control	2µg/ml	4 µg/ml	6 µg/ml	8 µg/ml
1	0.82±0.05	0.79±0.1	0.75±0.13	0.64±0.02	0.57±0.07
2	0.82±0.07	0.81±0.09	0.79±0.02	0.69±0.11	0.66±0.05
3	0.82±0.04	0.80±0.02	0.78±0.05	0.71±0.01	0.68±0.01
4	0.81±0.05	0.79±0.07	0.77±0.02	0.75±0.06	0.69±0.03
5	0.83±0.02	0.79±0.05	0.76±0.08	0.73±0.02	0.72±0.04
6	0.82±0.03	0.78±0.01	0.75±0.02	0.74±0.01	0.73±0.01
7	0.83±0.02	0.79±0.05	0.74±0.06	0.71±0.01	0.69±0.03

2µg/ml of Plumbagin/adult: There was a reduction in amylase concentration in 2µg/ml of Plumbagin per treated *Dysdercus cingulatus* when compared to control. After 24 hours of post-treatment period, 96.34% of amylase observed which reduced to 90.00% on the seventh day of the post-treatment period. Not much difference was noted on the second and third day of the post-treatment period. It was found to be 95.29% and 95.51% respectively on the second and third day of treatment. Subsequently, on the fourth, fifth and sixth day, the amount of amylase was less than the control group.

4µg/ml of Plumbagin/adult: With 4µg/ml dosage, it was observed that there was a further reduction in amylase concentration when compared to control. Hereafter one day of post-treatment period, 91.46% of amylase was observed. This further reduced to 87.88% on the seventh day of the post-treatment period. Throughout the course of the experiment, there was an increase in the amylase concentration noted in this group but the amount was less than control as well as the previous dose (2µg/ml).

6µg/ml of Plumbagin/adult: With a slight increase in dosage *i.e.*,6 µg/ml it was observed that there after 24 hours of post-treatment period, 78.05% of amylase was observed. The trend of amylase concentration in the midgut of Dysdercus *cingulatus* was the same as that found in control and previous doses. There was an increase in the concentration of amylase noted on subsequent days of post-treatment period but this concentration was found to be lesser than the both 2 and 4 µg/ml dosage. This further reduced to 72.88% of amylase was found on the seventh day of the post-treatment period.

8µg/ml of Plumbagin/adult: Amylase concentration was further seen to be lesser in the insects treated with 8µg/ml of Plumbagin. On the first day of the post-treatment period, it was 69.51%; which was 26.83 % less than 2µg/ml dosage. From table 2 it can be seen that on the fourth and fifth day of post-treatment period there was no change found in the amylase concentration in this particular dose. Maximum reduction was found on the seventh day of treatment (60.00%)

Data Analysis: From Anova Analysis using excel was carried out and it was found that concentration in amylase was varying amongst different doses. This supports the effect of Plumbagin. The data were considered to be significantly different within the treatments as the P□0.05 (Annexure I)

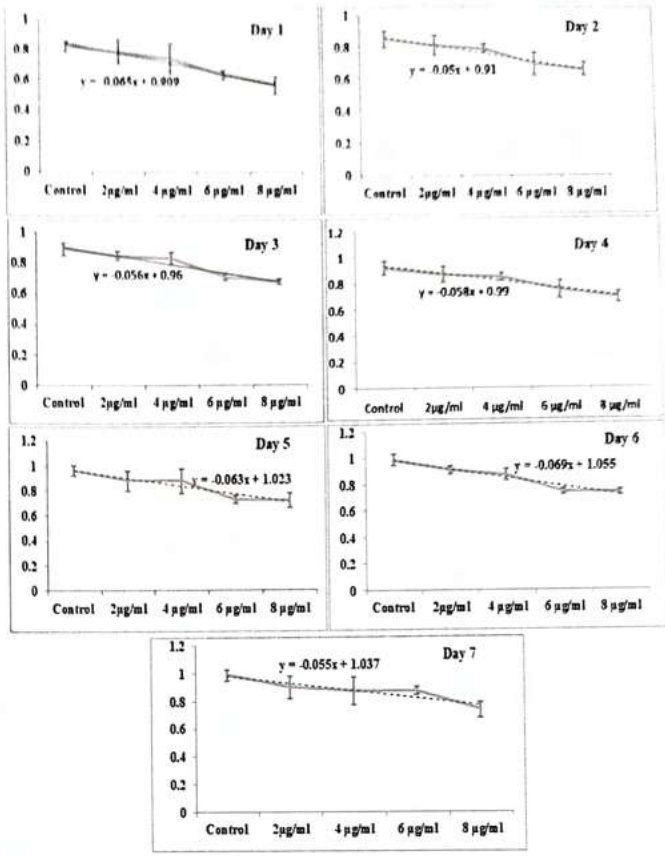
Characterisation and quantification of enzymes in insects is carried out by many of the workers like Ford (1962), Saxena (1955), Herzog (1967).

An attempt is made here in the present study to elucidate the effect of plumbagin on carbohydrate digestion by amylase. This is because plumbagin exhibits antifeedant activity in third instar larvae of

Achaea janata and Spodoptera litura (K Rajendra Prasad et al., 2012).Similar results were found in Dysdercus koenigii when treated with plumbagin and Juglones (Magdum,1999) Earlier studies have also shown that Plumbagin interferes in the growth of insects (Singh-Gupta et al., 2015, Kumar et al., 2002, Banerjee et al., 2001). As a result of this, Dysdercus koenigii were found to be flattened abdomen, indicating loss in feeding, (Singh-Gupta S et al., 2015).

From the present observation can be seen that there is less amount of amylase in the midgut of Dysdercus cingulatus in the entire treated group. The decrease is dose-dependent and time-dependent. The maximum loss in amount of amylase was noted in 8µg/ml dosage. This could be presumed due to the following reasons (1) Dysdercus is sap feeder and so food source itself lacks carbohydrate polymers, so there is a possibility of low synthesis of amylase itself. (2) Dysdercus is a discontinuous feeder (Chapman, 1985), and as the synthesis of the digestive enzyme depends on the presence of food. There are chances which will affect the synthesis of amylase. Amylase is found in a soluble form (Silva, 1994) Major carbohydrate digesting enzymes α- and β-mannosidase are found in the midgut of Dysdercus and is associated with membranes. (3) In Dysdercus, NSC stimulate intake of food and through the secretagogue, mechanism enzymes are released (Muraleedharan and Prabhu, 1979), disruption in this mechanism can also hamper the release on amylase enzyme. Magdum in 1999 reported the presence of low in the secretory granules in the neurosecretory cell of plumbagin treated Dysdercus koenigii. The lower level of amylase in the treated group could be thus correlated with this.

Symbiotic bacteria also play a major role in digestion. These bacteria by their enzymatic action help in digestion of food in the organism. Here this part was not considered and is planned for future studies.



Graph 1 Graphical representation of amount of amylase(µg/mg of tissue±SD) in control and Plumbagin treated *Dysdercus cingulatus*

CONCLUSION

Plumbagin a natural quinone adversely affects the amylase concentration in *Dysdercus cingulatus* and is dose-dependent. Further analysis dealing with proteomic studies will help in understanding the changes in amylase synthesis.

From the present study, it can thus be concluded that Plumbagin interferes in the metabolism of *Dysdercus cingulatus* and can be used as a means to control its infestation.

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Annexure I:

Anova: Two-Factor Without Replication

SUMMARY		*Count*	*Sum*	*Average*	*Variance*
	1	5	3.57	0.714	0.01113
	2	5	3.8	0.76	0.0066
	3	5	3.96	0.792	0.00842
	4	5	4.08	0.816	0.00878
	5	5	4.17	0.834	0.01098
	6	5	4.24	0.848	0.01252
	7	5	4.36	0.872	0.00872
Control		7	6.42	0.91714	0.00452
2µg/ml		7	6.01	0.85857	0.00201
4 µg/ml		7	5.84	0.83429	0.00233
6 µg/ml		7	5.13	0.73286	0.00502
8 µg/ml		7	4.78	0.68286	0.00319

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	0.08887	6	0.01481	26.1175	2.11045E-09	2.50819
Columns	0.25499	4	0.06375	112.401	3.55394E-15	2.77629
Error	0.01361	24	0.00057			
Total	0.35747	34				

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Ground water irrigation: Its gain and risk: A review study on some districts of West Bengal, India

P. PAUL AND A. DAS[2]

Department of Anthropology
West Bengal State University, Barasat-700126, India

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ABSTRACT

Irrigation is an essential component for agricultural production in India. To produce high yield crops good amounts of irrigation is needed. India has a good amount of ground water which used for irrigation over the few decades. West Bengal is one of the highest food productive State in India. For the successful agricultural production, it needs enough irrigation. In case of cropping intensity West Bengal holds a reputed rank in all over India. Ground water irrigation is considered as an important source of agricultural production in West Bengal. But over exploitation of the groundwater, fill the water bodies for rapid urbanization makes stress upon ground water and reached in scarcity level in sone regions in West Bengal. This paper is a review paper which focus on the ground water scenario in West Bengal, it is importance in increasing crop intensity in the several districts of West Bengal and to maintain the healthy level of ground water sustainability. Several research papers, journals and newspaper reports used as a source of the data.

Key words: Ground water, irrigation, crop intensity, sustainability.

With the development of agriculture farming, management of water supply in agriculture was also continuously in progress. To maintain the water supply for agricultural production is a challenge for each country. Thus, irrigation constitutes an important agenda in the planning to Government. Proper irrigation consists of utilizing the water in the nature in such a way that it becomes most beneficial for agricultural production. This becomes necessary because of the unpredictable nature of rainfall, which fluctuates year to year, sometimes leading to extreme situations like flood or drought. Again, some regions in India have great geographical and geological advantage towards crop production, due to land quality, rainfall, infrastructural facilities, etc. High yield crops and development of industries require enough water supply. To fulfill the demand of water supply both surface and ground water are needed to be utilized properly. But India lacks enough surface water storage, though there are some dams. There are also some canals to take the river water to the fields. Shortage of surface water or rather shortage of utilization of surface water necessitates extraction of ground water. But ground water exploitation has many shortcomings. First too much of ground water exploitation leads to fall in the water level. So, one has to dig deeper and deeper. Depletion of ground water also leads to other hazards like more absorption of surface water by earth, earthquakes, etc. Second, there is a danger of arsenic poisoning. Many areas in India have been seen to be arsenic affected. Due to prolonged use of arsenic affected water, people develop skin disease and ultimately it may result into mortality.

Research Scholar, [2]Associate Professor, Department of Anthropology, West Bengal State University, Barasat
*Email-priyanka1jhoom@gmail.com

Because of ground water irrigation, the growth of irrigated area has also increased over last few decades in India. Around 70% of the agricultural food grain production area irrigated through ground water as the major source of irrigation. From the 1998 census it is found that the estimated replenishable ground water availability in India was 43.57%, in which only 7.15% was used for domestic, industrial, and other purposes, 36.42% of water available ground water resources for irrigation in net terms. Out of the total available ground water resources utilizable ground water for irrigation is about 32.77% and the ground water development is 32.07% from its useful aggregate (Central Ground Water Board, India 2003). River basin wise irrigation system shows' that out of the total replenishable groundwater resources of 431.42 billion cubic meters, the Ganga basin alone accounts for nearly 40 percent. From the 2001-02 Ministry of water sources census it is found that in West Bengal the ground water irrigation potential is 6918 ha, in which ground water potential were 3318 ha. West Bengal has 48% Share of ground water in total ultimate irrigation potential (India, Ministry of Water Resources 2007). This paper aims to do thorough reviews of papers on benefits and disadvantages of ground water irrigation in West Bengal and then highlights the needs to manage and preserve the vital natural source, which has one of the major roles in Sustainable Development.

MATERIALS AND METHODS

As envisaged in the proposed aims and objectives, the data have been collected through secondary sources only, namely books, journals, newspapers, internet sources and administrative materials.

RESULT AND DISCUSSION

Ground water Scenario in the states of West Bengal:

West Bengal consists of 20 districts and 341 blocks and the entire area is covered by three major river basins – Brahmaputra, Ganga, and Subarnarekha Basins. The major source of ground water recharge is the monsoon rainfall. West Bengal has good potential of ground water storage because of its geographical location and high rainfall. The state has 2.7% land area and it covers 6% of total replenishable ground water in India. In West Bengal ground water is the most exploited sources for agriculture. From 1986 to 2001 shallow and deep tube well has increased rapidly and over exploitation of the ground water has resulted into decrease in the ground water level, but the condition is not yet severe (Table-1). In 1993 restriction on low duty tube wells were imposed in several states of West Bengal. In 2002 the minor irrigation census reveals that the ground water exploitation increased in many folds because of the privately owned low duty tube wells. In 2005 West Bengal ground water bill has been imposed and the Government has taken some initiatives to control and restrict the placing of tube wells with submersible pumping devices (Ghosh, A. K. 2007).

In Table-2 sector wise percentage of projected water requirements in West Bengal are given for the years 2000, 2011 and 2025. It can clearly be seen that agricultural sector holds not only the dominant position in West Bengal, but also captures more than 50% of the requirements almost from the beginning of this millennium. In 2025 it will exceed 60%.State Irrigation Department, 1987 estimated that the whole availability of ground water (1.46 million-hectare meter) utilized in West Bengal.

From the District-wise groundwater resource of West Bengal, 2009 it is found that the annual replenish able ground water resource in monsoon season was 18.16 bcm from rainfall and 2.17 bcm from other sources. Paschim Medinipur district show the highest frequency of replenishment of ground water from rainfall and district Bardhhaman shows the highest frequency of replenishment of groundwater from other water sources (viz. canal seepage, return flow from irrigation, recharge from tanks, ponds etc.) among the states of West Bengal (Table-3). In non-monsoon season ground water replenishment from other sources is higher when the rainfall decreases (Table-4).

Among the districts of West Bengal, Paschim Medinipur (3.39 bcm) and Barddhaman (3.06 bcm) show the highest frequency of net ground water availability whereas Haora (0.33 bcm) and Darjiling (0.47 bcm) show the least amount of net ground water availability. District Nadia show highest amount of 2011 ground water draft for irrigation (1.68 bcm) though the net ground water availability was 1.99 bcm. Purulia, Darjiling and Jalpaiguri show an alarming situation in case of existing ground water draft for irrigation. Paschim Medinipur and Jalpaiguri show the highest frequency of net ground-water availability for future irrigation development though existing ground water draft for irrigation is poor (Table-5). Groundwater irrigation in West Bengal: Gains, Costs, and Risks:

Barker *et al.*, (2002) concentrated on the lower Gangetic plains in order to see the ground water irrigation scenario in West Bengal. This study was based on the minor irrigation report of the government of West Bengal in the year 2000-2001. It reveals that the use of ground water is maximum in Murshidabad (1.92 lakh ha), Medinipur (1.88 lakh ha), Bardhaman, Nadia, North 24 Parganas and Hooghly districts of West Bengal, India. The number of tube wells has been seen to increase rapidly in an alarming rate (10% annually) and canal irrigation, tank irrigation and other sources of irrigation have decreased rapidly over the few decades. Ground water irrigation in summer for the Boro rice cultivation was maximum in Midnapore (1.08 lakh ha) and Burdwan (0.99 lakh ha). Overexploitation of ground water in summer causes serious drinking water crisis in the districts of West Bengal. Arsenic contamination in ground water drags the people towards serious health problems in those areas. The study also reveals that in West Bengal the ground water depth reaches maximum to the limit of 5-6 meter below ground level (mbgl) during May and June in the highland areas where in low land areas it reaches 1.5 – 5 mbgl depending upon the ground water exploration for cultivating summer rice. The fall of the ground water level is seen to be faster in winter months (November – February) while in the low land areas it happens in pre-monsoon seasons (February May) and in summer the fall is maximum because of the surface water evaporation (Barker *et al.*, 2002).

Hooghly district is another major crop producing district of West Bengal and bounded with two rivers – Hooghly River in the east and Damodor River in the west. A study on the availability and utility of ground water for irrigation on the Hooghly district reveals that high rate of utilization of ground water is seen in a single block Pursurah in that district. The study reveals that the percentage of increased cropping intensity and net sown area are not only the result of economic factors but also several other factors like socio-cultural, human and natural factors. The exploitation of ground water for irrigation has taken place at a medium rate of 35-40% of the total available resource, which needs to be controlled. Nevertheless, surface water and rainwater utilization for the irrigation purpose need to be increased in those areas (Dutta, 2013).

A study on the ground water potential for irrigation has been taken place in Durgapur – a semiarid climatic region in West Bengal. In this region surface water resources are insufficient so that ground water is the major source of water supply. From the calculation of electrical conductivity and Sodium Adsorption Ratio it is found that salinity hazards in the water sample were 31% and 26% good in pre and post monsoon season while 52% and 57% of water classified as the unsuitable water for irrigation under normal condition during pre and post monsoon season in some areas. Sodium hazards in water is greater in the pre monsoon season making water unsuitable for irrigation in few areas in Durgapur but the overall ground water quality for irrigation is good and safe (Chakraborty *et al.*, 2012).

The economy of Mursidabad district in West Bengal is exclusively supported by agriculture. There was an excessive population growth over the few decades in this area. Moreover, the farmers left the traditional multi cropping pattern and adopted water intensity monoculture for production. The study on dependency upon the cropping intensity and irrigation intensity reveals that it has decreased over the time from 1994-95 to2010-11. Barwan and Bharatpur-I blocks showing high changes in cropping intensity and irrigation intensity than other blocks in Mursidabad. With increase in the irrigation the exploration of ground water also increased and Musirdabad district have a high chance of ground water scarcity for future generation which needs an integrated water resource management approach. It is found that ground water in the Mursidabad district has declined at the rate of 0.1 to 0.4 meters per year and it is rising at the rate of 0.01 to 0.18 meter per year (Ghosh, 2007). The focus of the water management project should not only the management mechanism but also sustainable utilization of the resources. (Haque, 2015).

A study in comparison of the growth of agricultural land through ground water and surface water irrigation has been carried out in the four districts of Burdwan, Nadia, Hooghly and Birbhum in West Bengal. Based on 1990-91 and 2010-11. It is found that some areas of Burdwan and Birbhum districts reveal negative compound growth rates of the agricultural area because of surface water irrigation but some areas of Nadia and Hooghly district show positive compound growth rates through surface water irrigation. It is observed that all the districts show positive compound growth rates because of ground water irrigation. From the study of the combined area the compound growth rates are estimated to be-0.16% for surface water irrigated area and +1.66% for the ground water irrigated area. (Konar and Dey, 2015).

A study on the ground water quality and sustainability for irrigation in Rajnagar block, Birbhum district, West Bengal, India has been carried out in which pre and post monsoon dissolved solids in the water like Ca, Mg, Na, K and anions like Cl, HCO3 and SO4 etc. have been examined. The study reveals that pH level of the water ranges from 6.32 and 7.26 during pre-monsoon season and around 6.3 to 7.33 in post-monsoon season, which shows slightly acidic in nature. The total harness ranging also varies which shows moderately hard to awfully hard. Different calculated values of Sodium Absorption Ratio (SAR) indicate permissible range of water use for irrigation but Magnesium Adsorption Ratio (MAR) in water prohibits its use for agricultural purposes (Nag and Suchetana, 2016)

Irrigation is the key to any kind of crop production. After the green revolution, Indian agriculture faced drastic change in terms of high-quality cropping, which needs developed. A study on the blocks of Birbhum district shows that there is a moderate and positive association between cropping intensity and irrigation intensity. It is also found that the surface water irrigation (like river lift irrigation, canal, tank etc.) and ground water irrigation (like shallow tube well, deep tube well, open dug well etc.) have positive impact on cropping intensity rather than other sources of irrigation. Behind the corresponding relation between irrigation and cropping intensity, there are several other factors such as socio-cultural, political, economic, technological and infrastructure behind cropping pattern and intensity. Overexploitation of ground water for irrigation can be the major water problem in that area in near future (Ganguly and Patra, 2016).

Reason for declining ground water quality:

West Bengal has a diverse geological feature. It has enough rainfall in the rainy season. There is a great variation in ground water level despite great geographical advantages. The quality and amount of ground water are suitable for drinking,

agricultural and industrial use. But in coastal tracts the ground water is saline and rich with fluoride, arsenic, iron, bacteria, and other heavy metals. For the over exploitation of ground water for agriculture in those areas, contaminations in the ground water are increasing at alarming rate. There is industrial influence too for the over exploitation of ground water.

Impact of land acquisition in irrigation:

Acquisition of agricultural land for rapid urbanization in West Bengal is the major concern because of the corrosion of irrigation system and its effects on the ground water recharge. The Kolkata New Town planning project in Rajarhat, West Bengal, is a planned township project which aims to solve the increase of crowding and squalor problems in the metropolitan city of Kolkata. This area consists of 68.36% of water bodies. For the purpose of the project 3075 hectors of agricultural land have been acquired. It will have a tremendous impact on the livelihood of the local people who were involved in agriculture. In the year 1975 the River Lifting Irrigation (RLI) scheme was introduced in the local canals by the Central Government of India in which Bagjola, Krishnapur and Nowaicanals are important. After the installation of RLIs scheme almost all the cultivated land become three cropped land. Till 1999, three kinds of rice crops (Aush, Aman, Boro paddy), vegetables were cultivated and during the monsoon season fishing were another source of their livelihood. The annual average rainfall of the area during 1970-97 was 1679.10 mm and afterwards the annual average rainfall has come down to 1431.15 mm. This is possibly because of land acquisition in 1999 and rapid urbanization. This change also affects the ground water level which decreases from 6.06 mt to 4.1 mt in that area. Rapid town planning and decreasing RLI scheme effect on the recharge of ground water and scarcity of safe drinking has taken place (Sengupta *et al.*, 2017).

Initiatives taken for Ground water management:

In West Bengal, ground water is declining rapidly, and alternative water resource is not yet developed. The quality of ground water needs planned development; also it is necessary to restrict exploitation of ground water to fulfill the future needs. Ministry of water resources initiated several bills and circulated them since 1990 to 2005 to manage the ground water. Some initiatives have already been taken in some rural areas. In urban areas, rainwater harvesting seems to be beneficial and it helps recharge the ground water. Several states of India including, West Bengal made the law of mandatory roof top rainwater harvesting structure in the buildings. According to the 'The West Bengal Ground Water Resources (Management, Control and Regulation) Act, 2005' three authorities must be formed at the Indian States to manage ground water resources. These authorities can be formed district and corporation level in West Bengal. If any person flinches to get along with the provisions of the act made by government bodies, he/she shall be punishable and must give fine one the basis of rules.

Ground water level monitoring through Tape and Plopper technique:

Focusing on ground water it found that it is a complex form of water than surface water because it is invisible so, that the exploitation and over exploitation is not so clear for the users. So first we need to adopt some equipment's that can easily measure the level of ground water and local people can measure and understand the ground water level that will help the users to understand when to use and when to stop using. The Tape and Plopper measuring technique give accurate results of ground water level bore well/tube well within 1 cm. If the tape found the water level below the ground the record shows as negative (-) and if it is above the ground it shows positive (+) result, which helps very time saving and low cost ground water monitoring with authentic results.

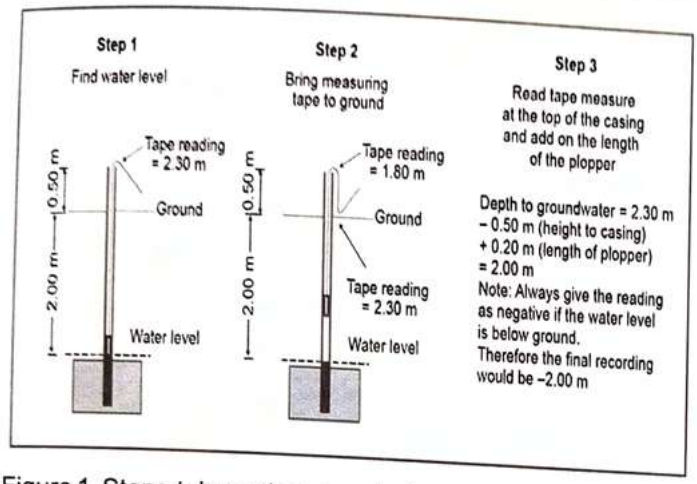

Figure 1 Steps taken when monitoring ground water levels (@ 2020 State of Western Australia) Source: https://www.agric.wa.gov.au/soil-salinity/monitoring-groundwater

CONCLUSION

It is clear, from the above discussions, that ground water has become almost inevitable for high yield crop cultivation and increase productivity in agriculture. Rapid increase in productivity by exploiting ground water, should keep pace with the increase in population. In short, the ground water situation in West Bengal is approaching an alarming state due to over-exploitation. The situation is not different in other States in India. Ground water inanition and erosion have become the burning issue for many of the states and planned township in India.

Several impurities like arsenic, fluoride, bacteria etc. contamination in ground water are in increasing trend and harmful for human use. In West Bengal, industrial growth is not much, but rapid urbanization has much impact upon ground water. Government should explore ways to take artificial methods to recharge ground water. New acts may be enacted to preserve the ground water resources. In case of agriculture, other irrigation systems such as surface water, rainwater, canal water irrigation etc. should be stressed. If necessary, incentive schemes may be introduced in irrigation systems other than ground water irrigation.

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Table 1 Estimate of water resource availability and utilizabilty in West Bengal in 1987

Surface and Ground water	Availability (million-hectare meter)	Utilizable (million-hectare meter)
Surface water	13.29	5.31
Ground water	01.46	1.46
Total	14.75	6.77

Source: State Irrigation Department, 1987

Table 2 Sector Wise Percentage of Projected Water Requirements in West Bengal in 2000, 2011 and 2025

Sectors	2000	2011	2025
Agriculture	49.6	59.3	62.4
Domestic	2.4	2.2	2.2
Industry (including thermal)	5.3	2.9	3.4
Inland Navigation	33.5	27.9	20.6
Forestry	0.1	0.1	5.7
Ecology, Environment and Others	9.2	7.7	5.7
Total	100	100	100

Source: WBPCB (2009)

Table 3 Annual reprehensible ground water resources in monsoon season in bcm (as in 2009)

Name of District	Recharge from Rainfall	Recharge from other sources
Maldah	0.96	0.05
Nadia	1.12	0.18
Koch Bihar	1.58	0.04
North 24 Parganas	0.95	0.08
Dakshin Dinajpur	0.69	0.05
Uttar Dinajpur	1.18	0.07
Bankura	1.07	0.30
Purulia	0.53	0.11
Jalpaiguri	1.99	0.02
Bardhhaman	1.72	0.37
Murshidabad	1.34	0.19
Birbhum	0.71	0.25
Haora	0.19	0.03
Darjiling	0.39	0.01
Hugli	0.88	0.18
Purba Medinipur	0.55	0.02
Paschim Medinipur	2.31	0.22
State Total	18.16	2.17

Source: CGWB and SWID, 2011

Table 4 Annual reprehensible ground water resources in non-monsoon season in bcm (as on 2009)

Name of District	Recharge from Rainfall	Recharge from other sources
Maldah	0.25	0.18
Nadia	0.42	0.49
Koch Bihar	0.61	0.10
North 24 Parganas	0.27	0.23
Dakshin Dinajpur	0.19	0.15
Uttar Dinajpur	0.32	0.20
Bankura	0.28	0.50
Puruliya	0.13	0.06
Jalpaiguri	0.60	0.04
Barddhaman	0.50	0.78
Murshidabad	0.41	0.46
Birbhum	0.19	0.47
Haora	0.06	0.09
Darjiling	0.11	0.02
Hugli	0.25	0.36
Purba Medinipur	0.15	0.08
Paschim Medinipur	0.70	0.52
State Total	5.44	4.73

Source: CGWB and SWID, 2011

Table 5 Ground water sources availability and development for future irrigation in West Bengal

Name of District	Net Annual Ground-water availability (bcm)	Existing Gross Groundwater draft for irrigation (bcm)	Net ground-water availability for future irrigation development (bcm)
Maldah	1.31	0.49	0.74
Nadia	1.99	1.68	0.35
Koch Bihar	2.10	0.38	1.68
North 24 Parganas	1.37	0.77	0.51
Dakshin Dinajpur	0.98	0.42	0.54
Uttar Dinajpur	1.62	0.71	0.85
Bankura	1.95	0.54	1.35
Puruliya	0.75	0.01	0.68
Jalpaiguri	2.37	0.07	2.26
Barddhaman	3.06	1.45	1.55
Murshidabad	2.18	1.63	0.61
Birbhum	1.47	0.30	1.11
Haora	0.33	0.05	0.27
Darjiling	0.47	0.01	0.45
Hugli	1.50	0.49	0.94
Purba Medinipur	0.72	0.19	0.49
Paschim Medinipur	3.39	0.93	2.37
State Total	27.56	10.12	16.75

Source: CGWB and SWID, 2011

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Review Paper

Dirty money as a carrier of corona virus and other pathogens: a survey article

MOON MOON HUSSAIN[1] AND RASHMI REKHA BORAH[2*]

School of Social Sciences and Languages,
Vellore Institute of Technology, Chennai

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ABSTRACT

Money makes the world go round and corona virus could go round with it. Money in the form of paper currency or coins might be considered as the most dreadful carrier of different viruses or infections as it is one of the most often used items passing from hand to hand. Can dirty money spread the virus? Cash handling is a concern. Covid-19 which is the latest series in the corona virus family survives on surfaces for several hours or days and when we mean surfaces; it can be paper surface too. According to the World Health Organization, the use of dirty banknotes could pass around the corona virus or Covid-19 from one person to another. This paper draws attention to the studies conducted by researchers both at the national and international level on the impact of dirty money on human health. The present study also gives an insight into the theory of heterotopia where money occupy a public space and travels from one space to another as a potential carrier of pathogens .It also provides an interesting channel from various research studies to create awareness on growing health risks that may arise due to the use of currency and also suggest measures to overcome the same.

Key words: coins, paper money, forrmites, COVID-19, transmissible disease

Different people may interpret the term "dirty money" in different ways. However, according to microbiology, dirty money can be a transmitter of pathogens that can cause various diseases in humans. With the outbreak and spread of COVID-19, institutions around the world are contemplating the use of currencies as a harbinger of bacteria, viruses, or microorganisms that are harmful to human health. Cash, notes or coins, is perceived as a least hygienic everyday item. People who handle money regularly from business registers can expose themselves to a myriad of germs and there is a high possibility of spreading pathogens that are harmful to the human body. Pathogens are bacteria, viruses, or microorganisms that can cause disease. Some of the bacteria like salmonella, staphylococcus, and streptococcus are commonly found on money and credit cards as evident from various studies that can cause serious illness to individuals handling cash. With COVID-19 (Corona Virus Disease-19) as the pandemic continues to evolve real-time training during global emergencies is critical for effective preparedness and response. As money is a potential carrier of pathogens, it cannot be ignored how we "handle" it Pandemic preparedness calls for urgent and aggressive actions to combat disease like COVID-19.

Throughout history, as human spread across the world diseases have universally threatened the survival of human beings (Ackerman, Hill, & Murray, 2018; Schaller & Park, 2011). Infectious diseases have been a constant companion. Even

[1]Assistant Professor, School of Social Sciences and Humanities B.S. Abdur Rahman Crescent Institute of Science and Technology, Chennai-48, [2]Assistant Professor, School of Social Sciences and Languages, Vellore Institute of Technology, Chennai
*Email:profedu2@gmail.com

in this modern era, outbreaks are nearly constant. Smallpox came to North America in the 1600s. The USA in the period between 1832 and 1866 had a dangerous three waves of cholera which is an infection of the intestine while New York faced "Spanish Flu" in 1918. In fact, the world had to face several other pandemics like Bubonic Plague, Polio, Measles, to name a few.

In response to such threats, humans engaged in behavioural responses to avoid contact with pathogens to ensure survival such as lowering their sociability and movement at the interpersonal level (Mortensen, Becker, Ackerman, Neuberg, & Kendrick, 2010). But how to distance ourselves from dirty money which is colonised with various pathogens remains a debatable question.

Foucault (1986) introduced the concept of heterotopia which has been explored to understand the aspects of money as a public space. Foucault describes heterotopias as a heterogeneous space where certain institutional and cultural spaces are by some means disturbing and incompatible because it creates a world inside a world. Money form heterotopias, when their utopic purity orbits around the public space which is juxtaposed with the private spaces.

Currency passes from one space to another which becomes a potential site for contagion. Heterotopias of crisis are created which are spaces that can accommodate often violently contradictory differences like prisons and luxury hotels simultaneously. Money travels from one space to another from cardboard boxes of homeless to the people residing in skyscrapers. If a new form of money is designed, a new form of society will rise from this design which would probably change the premises on which all economic activities takes place in a capitalist system. Money occupies such a space where it transcends all boundaries. It goes round and with it the virus travels all spaces, around the most elitist to someone who has nothing. In "The Poetics of Space" Bachelard (1964) introduces his concept of topo - analysis as the systematic psychological study of the spaces of our intimate lives. The house, he says is the most intimate of all spaces, and now with post- Covid, dirty currency will occupy a space in our house intimate yet distant.

Bachelard underlines the ways in which ambiguous spaces in our world require perceptual alertness and acute flexibility. According to him society has turned a blind eye to the dystopia. The journey into intimacy is skilfully evoked in 'The Poetic of Spaces' by drawers, cupboards, wardrobes and above all locks. He warns, as it should not be used as gratuitous metaphors. Money as a space has twofold significance involving internal diversity versus external connectedness and a carrier of potential pathogens that can emerge as a pandemic like Covid-19.

METHODOLOGY

The study is based on secondary data and relevant information and data have been collected from various publications in journals, articles, newspapers, editorials, analytical pieces, media houses, etc., available online. Whatever relevant articles or studies were available in the electronic form were examined and put to review. The findings of the available studies are summarized and are presented in the following discussions.

LITERATURE REVIEW

A brief review of the related study involves opinions of different authors, scholars and economists, and also evaluates reports of research work related to actual research proposed to be undertaken. Dirty currencies can create health havoc on human lives. This study provides a solid ground for the necessity and desirability of undertaking an anatomy of the various studies conducted across the globe by researchers to create awareness and encourage further research on the ill effects of dirty money. A brief review of the related study involves opinions of different authors, scholars and economists, and also evaluates reports of research work related to actual research proposed to be undertaken. In this connection, the studies of some authors who have contributed to research in the field of the proposed problem are enumerated below.

Studies on Dirty Money in the International Level:

The analysis of dirty money remained a neglected discipline and was not recognized as a distinct field of research till the 1970's. However, after 1970, there has been a large volume of publications and several attempts have been made to investigate the microbial population in currency notes in various parts of the world. The earlier studies on dirty money dates back to 1972 carried out by Abrams and Waterman who considered the possibility of currency notes acting as environmental vehicles or fomites for the transmission of potential microorganism.[6]

In order to analyse the degree of faecal contamination of currency notes with enteric bacterial in a local market in Rangoon, samples of the notes that were in circulation were collected from butchers and fish mongers and examined bacteriologically to count the number of total bacteria and faecal coliforms (TC, FC) using standard methods and tools. Enteric pathogens, such as *Enterotoxigenic Escherichia Coli*, *Vibrio*, and *Salmonella* were isolated from paper-money samples. The study reveals that isolation rates of pathogens increased during the hot wet season where the count of the number of total bacteria and faecal coliforms ranged from 0 to 2.9x107/sq cm of currency notes. The study suggests that currency notes may carry enteric pathogens.

A probable cause for bacterial and parasitic transmission by paper currency in 4 major cities of Nigeria was conducted by collecting 250 currency notes obtained from butchers and beggars. The study concludes that 21.6% were contaminated with enteric parasites including *Ascaris lumbricoides, Enterobius vermicularis, Trichuris trichiura* and *Taenia* spp.

A study was conducted in Nepal concerning the possible transmission of bacteria through Nepalese currency, the Rupee. In order to examine the prevalence of contamination in Nepalese rupee, 28 samples of the same were collected consisting of notes in all seven denominations (Rupees 5, 10, 20, 50, 100, 500 and 1000). Coins were not tested as the rate of coin circulation in Nepal is declining. Bacteriological analysis was conducted on 24 currency notes. The results reveal 75% of various kinds of pathogenic bacteria. In fact this analysis established 84.8 % contamination in notes acquired from conductors of local microbuses, 78.0 % from butchers and 62.1 % from food sellers. The notes which were collected from banks and tested were free from bacterial contamination.

In order to investigate the hygiene status and bacterial content on banknotes, a total of 1280 banknotes were obtained from food outlets in 10 different countries namely the United States Australia, United Kingdom, Ireland Burkina Faso, New Zealand, China, the Netherlands, Nigeria and Mexico. After laboratory simulations, a strong correlation was found between the number of

bacteria per square centimetre and a series of indicators of the economic prosperity of the mentioned countries. The strongest correlation was found with the "index of economic freedom. The study concludes by indicating that bacterial content on the banknotes was higher when the index of economic freedom was low.

Another study was aimed at determining the prevalence and load of bacteria on Kenyan currency notes in circulation in the Nairobi CBD area which is the centre of the Kenyan economy. A total of 7 Banknotes were sampled randomly and isolated for bacteria using Nutrient agar, Eosin Methylene Blue agar and Mannitol Salt agar. The samples were collected from a Public service vehicle conductor of Route 23 (Nairobi - Kangemi), a Vegetable vendor from City Market, a butcher from City market, a teller from a supermarket and the Central Bank of Kenya. Both notes and coins were sampled. Various denominations of money were sampled; 100 shilling notes, 50 shilling notes, and 10 shilling coins. After appropriate media preparation, culturing, isolation, gram staining and microscopic observation, various genera of bacteria were isolated. They included the predominant *Staphylococcus* sp., *Bacillus* sp.,

Escherichia coli and possibly *Salmonella* or *Shigella* sp. *Staphylococcus aureus* and *Staphylococcus epidermidis* were also isolated. It was therefore concluded that Kenyan banknotes on circulation could act as a route for the transmission of potential pathogenic microorganisms that could lead to the manifestation of serious diseases. It is therefore important to maintain proper hygiene to reduce these high risks of infection.

In order to establish the survival status of bacteria including *Staphylococcus aureus*, *E. coli*, and *Vancomycin-Resistant Enterococci (VRE)* on banknotes from countries around the world and deliberate how money can transmit bacteria to volunteers getting in contact with contaminated banknotes, a study was conducted in the Netherlands. For this experiment, various currencies across the globe like Euro, US Dollar, Canadian Dollar, Croatian Luna, Romanian Leu (RON), Moroccan Dirham, and Indian Rupee banknotes were included and all of them yielded microorganisms.

Parasitological analysis of the Pakistani currency reveals 92.5% of Pakistani currency to be contaminated with pathological microorganisms. A parasitological, fungal, aerobic and anaerobic microbial analysis was conducted by using various microbiological techniques. For this, a total of 81 Pakistani currency notes and coins in circulation were randomly collected from different shopkeepers, vendors, canteen owners and restaurant cashiers in Lahore. The results reveal that Pakistani currency is contaminated with pathological microorganisms namely staphylococcus spp., *Micrococcus* spp., *bacillus cepacia*, *klebsiella pneumoniae* , *serretia rubideae*, *Bacteriodes* spp. and yeast and mold.

A cross-sectional study was conducted in Saudi Arab to assess the presence of microbial pathogens of paper currency collected from ten selected public places of Al-Kharj. The results from the study suggest that the higher microbial contaminations were found in lower currency denominations. The most significant source of contaminated currencies came from small eating outlets. The various microorganisms present in the currency notes were *Bacillus spp.* (56.84%), *Staphylococcus spp.* (25.03%), *Klebsiella spp. (13.40%) and E. Coli* (04.71%).

In order to determine bacterial contamination of paper currencies in Iran, 337 currency notes of different value were collected from markets, shops, restaurants, bus stations and banks in Kashan, Iran during April 2015 to March 2016. By using standard microbiological methods, antibiotic resistance patterns of isolated bacteria

were determined by the disk diffusion method. Out of 337 currency notes, 262 (77.7%) were identified with bacterial contamination like *bacillus* spp. *coagulase-negative staphylococci, escherichia coli 20* (7.6%), *enterococci species, Staphylococcus aureus, Klebsiella* spp., *shigella species,* and *Pseudomonas species*. The most and least contaminated currency notes were 50000 and 500 Rials, respectively.

A similar research was conducted in Pakistan from 4/3/2010 to 31/1/2011. Around 720 samples of currency of different denominations were collected from various sources - 243 sample were collected from bank, 50 samples from ATM Machine 80 samples from meat shops, 92 samples from milk seller, 35 samples from medical store, 94 samples from food seller, 63 samples from grocery shop, 36 samples from road side mechanics, 4 samples from bus conductor and 23 sample from beggars. Standard methods were used to process all the samples. 100%, microorganisms were found from denominations collected from bus conductors, 82.6% from beggars and 28% found from the bank counter. The presence of microorganisms is lowest in denominations collected from bank counter might be because of the supply of the cleaner currency notes in comparison with currencies collected from other sources

Another study concentrated on the hygienic and microbial status of Sudanese banknotes, Khartoum State, Sudan. Fifty samples of Sudanese banknotes were collected randomly from handlers through (March - April / 2015). These samples were microbiologically tested for quantify bacteria, identification of bacteria and fungi (Yeasts and Moulds) by using biochemical tests for bacteria and phenotypical characteristics for fungi.

The study showed that the mean of total viable count (CFU/cm^2) of bacteria contaminated of banknotes between (4.5 – 8.3) x 10^5 CFU/cm^2. the study indicated 12 different types of bacteria and 5 types of fungi was identified from banknotes with different percentages. Of 50 questionnaires that were statistically analysed; 76% of handlers knew contaminated banknotes as being a source of infection; 94% educated handlers at different levels; 64% of the handlers washed hands after using toilets and before dealing with banknotes again.

A pilot study was conducted in New York City to study the presence of microbes found on circulating currency. The researchers obtained $1 bills from a New York City bank in February (winter) and June (summer) 2013. They used basic culture conditions and shotgun metagenomic sequencing to test viable microbes on their surface. The results confirmed high levels of human eukaryotic DNA with high incidences of *E. caballus* (horse), *S. scrofa* (wild boar), and *C. lupis* (grey wolf) on currency, however the same was found particularly less in the summer bills.

Research in Rwanda Frank attempted to analyse the bacterial, fungal and protozoan contamination and source of infection in currency notes and coins. For this experimental purpose a microbiological analysis was done by randomly collecting 108 paper currency notes of Rwanda Frank and 55 of coins were from vegetable sellers in market places in Musanze district (Rwanda) during November 2017. The results of the study indicate the presence of a huge number of pathogens. Out of 108 paper currency notes, 23% of *E. Coli* was reset in 25 notes, 36% of *Staphylococcus aureus* in 40 notes, 18% *Klebsiella pneumonia*, and *Pseudomonas* in 20 notes, 29.5% *Clostridium* spp in 32 notes, 41% of *Streptococcus pyogenes* in 45 notes, 21% *Bacillus subtilis, Vibrio* spp in 22 notes, 35% *penicillium* spp in 38 notes, 18% *Aspergillus* spp in 20 notes, 16% *Rhizopus, Candida* and *Alternaria* in 18 notes, 27% *Entamoeba hystolytica* in 29 notes, et, to name just a few.

Studies on Dirty Money in the National Level

At the national level, a study of its kind was carried out in Bhopal in the mid-90s to study the microbial contamination of Indian currency. 180 Indian currency notes including each of Rs. 5, Rs. 10, Rs. 20, Rs. 50, Rs. 100 and Rs. 500 denominations, were collected from peoples of various social strata. The study concluded that among the total 180 Indian currency notes 169 (93.89%) were contaminated, both with pathogenic and non-pathogenic organisms that risk and generate public health hazards to the individuals and community as a whole.

A research was carried out in the North East part of India, Assam to test whether paper currencies act as a potential carrier of pathogenic microorganisms. To conduct the microbial analysis, dirty paper currencies comprising 500 rupee, 100 rupee, 50 rupee, 20 rupee, 10 rupee, 5 rupee were collected from the butchers, sweepers & fish mongers. The results of the study show the presence of pathogenic bacteria namely *Pseudomonas* spp., *E. coli, Klebsiella* spp., *Staphylococcus* spp., and *Streptococcus* spp. The study concludes by stating that the deposition of the moisture on the paper currencies provided favourable conditions for the microorganisms to grow on it.

A research using metagenomics and high-throughput DNA sequencing technique was carried out in New Delhi to examine the presence of microbes in currency notes. They collected notes from random spots such as street vendors, grocery shops, snack bars, canteen, tea shops, hardware shops and chemists across New Delhi. Investigation of the data revealed the presence of species 78 pathogens including *Staphylococcus aureus*, *Corynebacterium glutamicum*, *Enterococcus faecalis*, and 75 *cellulose degrading organisms including Acidothermus cellulolyticus*, *Cellulomonas flavigena* and *Ruminococcus albus* belonging to both eukaryotic and prokaryotic genera. In addition, 78 antibiotic resistance genes were identified and 18 of these were found in all the samples. Furthermore, six out of 78 pathogens harboured at least one of the 18 common antibiotic resistance genes.

A study was undertaken in Lucknow city to confirm microbial contamination of currency and also introduce the nature and levels of contamination of the Indian currency. To conduct the study, total 96 paper currency and 48 coins of different denominations were randomly collected from vegetables seller, chemist store, butcher shop, auto rickshaw and rickshaw man, tuberculosis chest outpatient department (OPD) and general OPD from the different areas of Lucknow city in a sterile paper bags. The results suggest the presence of contaminated microbes like bacterial and fungal isolates which play a vital role in transmitting antibiotic resistant or potentially harmful organisms.

A prospective study was carried out in a tertiary care hospital in Tirunelveli City, Tamil Nadu, India to assess the microbial contamination of paper currency notes. The investigation was carried out by collecting 121 Indian paper currency yielding 6 different types of bacterial species. Assessment of the study revealed the presence of pathogenic micro-organisms like *Escherichia coli, Bacillus* spp, *Klebsiella* spp, *Staphylococcus aureus, Micrococci* and *Pseudomonas* spp. The study also revealed that lower denominations like Rs. 5, Rs.10, Rs.20 were moderately contaminated, higher denominations like Rs.500 and Rs.100 were less contaminated and Rs.100, Rs.50 notes were more contaminated.

An online questionnaire-based study was conducted through a survey planet link to conform that money acts as a vector for transmissible diseases. The respondents who undertook the survey are undergraduate students of various medical and dental colleges,

school students, and other professionals in the working industry. The 22 questions were based on their awareness on the diseases that could be spread through currency and coins. The study concluded that currency in the form of cash and coins transmit diseases and suggest resorting to digital transactions and washing hands after handling currency.

RESULTS AND DISCUSSIONS

What is evident from the above studies is that microorganisms or pathogens might appear on currencies due to several reasons namely poor handling, moisture deposition due to application of saliva on fingers while counting money or through open wounds or scratches on the hands, etc. Further, contamination from nasal discharge, sneezing and coughing are major sources of transfer of bacteria or virus to currency notes during handling, etc. Currency notes are often kept warm by our body heat and even absorb our body moisture, helping bacteria to grow faster. To support the studies, an instance can be cited of 2016 demonetization in India when due to the surge in cash transactions, bankers were forced to do manual counting which led to a host of health hazards like allergies and breathing problems besides rashes on their fingers.

The Covid-19 pandemic has raised public apprehension that the corona virus could be transmitted by cash. In fact the research on novel COVID-19 concerning the transmission of the virus is gaining momentum. Research in microbiology proves the presence of pathogens on coins and banknotes. Some viruses can last for hours on banknotes when diluted with mucus while some bacteria and viruses can be readily transmitted through non porous surfaces. A recent study on corona virus reveals that Covid-19 can persist for three hours in the air, 24 hours on cardboard and even longer on other hard surfaces. In fact, according to a German disease expert as cited in Reuters 2020, the virus survives best on non-porous materials, such as plastic or stainless steel indicating that debit or credit card terminals or PIN pads could transmit the virus too. To date, there are no known cases of Covid-19 transmission via banknotes or coins.

Even though there is no conclusive scientific evidence to stand as a testimony to the fact that corona virus can spread through contaminated currency notes, the World Health Organisation has recommended following adequate hygienic measures after handling hard cash.

CONCLUSION

It is certain that cash could spread pathogens, though it has not been proved so far whether it carries the corona virus or not. Hence, a realistic appraisal of the risks of transmission of corona virus through cash is particularly important. With the ongoing pandemic, the payment behaviour would change definitely. The apprehension of using cash comes as the global number of people infected by the corona virus numbers around 11,635,939 as on 8th July, 2020.

Although till date, there are no known cases of Covid-19 transmission via banknotes or coins, with the outbreak of COVID-19, many nations across the globe are undertaking suitable measures to sterilize currency in banks by using ultraviolet light, supersonic and chemicals means to trim down the risk of transmission of infection or virus through dirty money. Central Bank of South Korea resorted to extreme steps of taking all banknotes out of circulation for two weeks and even burning some for containing the virus. Initially since China was the epicentre of the virus and most of the cash got circulated from high risk infected areas and hospitals, it took enormous initiative of sanitizing and disinfecting potentially infected cash with ultraviolet light and high temperatures, and even to the extent of destroying cash .The Central bank of Kuwait, Hungary, South Korea and many other countries ensure that the cash were sterilize before leaving

the bank. While the Central bank of Georgia, Indonesia and India encouraged cashless payments.

The COVID-19 outbreak killing countless people across the globe has made people aware of the menace of handling and using currency notes. Hence replacing traditional methods of trading with electronic money transactions would of course be a good resolution for the problem. Contactless card payments like Google Pay, Samsung Pay, Paypal Apple Pay, Paytm, to name a few can act an effective tool to curtail physical contact and minimise physical contact. The pandemic which has created havoc worldwide might compel people to shun the use of cash and resort to digital payments like net banking, debit and credit card payments. Lockdown and social isolation which have compelled many businesses to shut down; cash is no longer a feasible mode of payment for many. However imagining a world not using cash at all sounds utopian particularly for a nation like India where people are yet not digitally educated enough for resorting to electronic mode of transactions. Being alert and alarmed with the prevailing situations, sanitizing hands and following hygienic practices after handling currency notes might prevent transmission of microbes or corona virus from spreading through dirty money.

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