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Effect of Sulphur on Yield and Yield Attributes of Rice and Subsequent its Residual Effect on Mustard and Green Gram Crops

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Abstract

The experiment was initiated in the year 2014-15 and repeated for three years to evaluate the immediate effect of sulphur in rice and thereafter the residual effect of sulphur on succeeding mustard and green gram crops. The experiment was conducted at farmer's field; Deganga Block of North 24-Paraganas district in West Bengal. The soil of the experimental plot was deficient in sulphur. Sulphur was applied once in a year through SSP & elemental S during rice transplantation and the NPK were applied at recommended dose of the respective crops. The NPK fertilizers were applied in the form of urea, SSP & MOP during the rice planting and Urea, DAP & MOP during the mustard and green gram crops. The application of sulphur have the direct effect on plant characters and as well as on yield parameters of rice. The significant improvement of yield attributes and yield of mustard and green gram noticed due to the residual effect of sulphur applied in the form of single super phosphate and remaining from elemental sulphur. In all cases the control treatment received no sulphur produced the lowest yield. The mustard yield varied from 1075 $kgha^{-1}$ to 1295 $kgha^{-1}$. The highest seed yield of mustard was observed in the T_3 treatment i.e. 45 kg S/ha and the lowest yield in the control. Like seed yield, the stover yield of mustard responded significantly to residual sulphur. The stover yield ranged from 3064 to 3465 $kgha^{-1}$ over the treatments. The highest residual effect of sulphur was recorded 45 kg S ha^{-1}applied in the succeeding green gram crop and the seed yield recorded was 894 kg ha^{-1}. The residual sulphur also significantly influenced the growth and yield attributing parameters of mustard and green gram crops i.e. plant height, number of siliquae $plant^{-1}$, number of seeds $siliqua^{-1}$, number of pods $plant^{-1}$ and number of seed pod^{-1}. Like seed yield, there was a significant and positive effect of residual sulphur on the stover yield of mustard and green gram. The stover yield of green gram varied from 1967 to 2381 kg ha^{-1} and the highest stover recorded 2381 kg ha^{-1}.

Keywords **:** sulphur, rice, mustard, green gram, yield.

Introduction

Sulphur is the fourth most important nutrient after nitrogen, phosphorus and zinc in Indian agriculture (Sakal and Singh, 1997). Sulphur is best known for its role in the synthesis of proteins, oils, vitamins and flavoured compounds in plants. It is a constituent of three amino acids viz. Methionin (21% S), Cysteine (26% S) and Cystine (27% S), which are the building blocks of protein. About 90% of plant sulphur is present in these amino acids (Tandon and Massick, 2002). Sulphur is also involved in the formation of chlorophyll, glucosides and glucosinolates (mustard oils), activation of enzymes and sulphydryl (SH-) linkages that are the source of pungency in onion, oils, etc (Mengel and Krikby 1987)

Sulphur is considered to be one of the most important major nutrients along with nitrogen phosphorus and potassium for balanced fertilization. In some crops particularly oilseeds, pulses, potato, onion, garlic, soybean have sulphur requirement almost in same amount as phosphorus is needed, being constituent of several amino acids like methionine, cystine, cysteine, it not only help to increase the crop yield but also quality of crop produce.

Rice (*Oryza sativa*) is one the important staple food of India and it plays important role to our national food security system and therefore, it largely depends on the production of rice ecosystem. The 2nd largest agricultural produce in India is an oilseeds crop next only to food grains. Mustard being deep rooted crop performs well after rice due to better exploitation of nutritional pool from the deeper layer (Singh *et al.*, 2002).

The adequate and balanced supplies of fertilizers are critical importance in improving the productivity of rice and mustard in a particular zone. Due to high cost of chemical fertilizer, the marginal and small farmers do not apply the recommended doses of nutrient to these cereals and oil seeds corps.

Information on Sulphur for balance fertilization in Rice-Oilseeds-Pulse cropping sequence and their residual effect in alluvial soils is lacking. Therefore, the present investigation was undertaking to assess the i) balance use of Sulphur containing fertilizers at least once in a cropping sequence, ii) residual effect in the succeeding crop and iii) role of sulphur in increasing quantity and quality of crops.

Materials and Methods

The present investigation was carried out at farmer's field at Village Biswnathpur, Deganga Block in North 24-Paragansa district, West Bengal. The experimental plot is geographically situated at 22.699423 N latitude and 88.629789 E longitude and falls in the Gangetic Alluvial zone (Lower Gangetic plain region) agro-climatic region of West Bengal. The experiment was initiated in the year 2014-15 and repeated for three years to evaluate the immediate effect of sulphur in rice and thereafter the residual effect of sulphur on succeeding mustard and green gram crops.

The results of physico-chemical analysis revealed that the soil was sandy loam in texture, neutral in soil reaction, high in organic carbon and low in available nitrogen, available phosphorus, potassium and sulphur available.

Sulphur was extracted from soil by 0.15 % CaCl2 (William and Stainbergs, 1959) from soil. Nephalometer measured the "SO4-S" content in soil on the basis of turbidity. Cropping system during the years of study (2014 to 17) was Rice-Mustard-Green gram. Considering the sulphur deficiency in the experimental site, S was applied through single super phosphate (SSP) during the

Table 1. Soil physico-chemical properties of the experimental site

The trial was conducted on Hari Sardar's farm at Village Biswnathpur, Block Deganga in North 24-Paragansa District

Texture	Sandy loam
pHW (1:2.5)	6.9
EC (dsm^{-1})	0.17
Organic Carbon (%)	1.01
Available nitrogen (kg ha^{-1})	260
Available P2O5	24.36
Available K_2O	165.5
Available Sulphur as $SO_4^{=}$	7.65
DTPA -extractable zinc (mg kg^{-1})	
DTPA-extractable copper (mg kg^{-1})	
DTPA -extractable iron (mg kg^{-1})	
DTPA -extractable manganese (mg kg^{-1})	
Where irrigated or rainfed	Irrigated

TABLE 2. Particulars of experiment

Parameter	First Crop	Second Crop	Third Crop
Season	Kharif	Rabi	Pre-Kharif
Crop	Rice	Mustard	Moong
Variety	Gotra Bidhan 1	B-9	Sweta
Seed rate	20 kg/ha	6 Kg/ha	4 Kg/ha
Plot Size	6m x 3m	6m x 3m	6m x 3m
Fertilizer doseN:P:K (Kg/ha)	80:40:40	100:50:50	20:40:40
Fertilizer type	Urea, SSP, MOP, DAP, elemental Sulphur	Urea, MOP, DAP	Urea, MOP, DAP

sowing of the first crop i e Rice and its residual effect was observed on mustard and green gram where no sulphur containing fertilizer was used.

Results and Discussion

Effect of sulphur on rice yield and yield component

Effect of different levels of sulphur on yield of rice for three consecutive years is represented in Table 3. The increased grain yield was significant for the three consecutive years over the control one but there were no of significant differences among the treatments and highest mean grain yield (5590 kg/ha) was recorded at T_2 treatment i.e. 30 kg S/ha. Islam and Hossain (1993), Rashid et *al* (1992) and Chandel *et al.* (2003) also reported the increased grain yield of rice with sulphur application. Sulphur application increased the straw yield of rice for the three consecutive years but yield increase was not significant and the maximum straw yield i.e. 6355kg/ha recorded in the 30 kg S/ha treatment. Similarly, the biological yield of rice increased with increased of sulphur application and maximum yield increase recorded at T_2 treatment. Maximum increase in yield was recorded in all the three years by application of S @ 30 kg/ha & 45 kg/ha, indicating that application of S through SSP can eliminate the S deficiency. The studied of Sriramchandra Sekharan *et al* (2004) reported the yield response of rice after sulphur application.

TABLE 3. Effect of different levels of sulphur on grain yield of rice and sulphur use efficiency (Pooled data of three years)

Treatments	Grain yield (kg/ha)			Pooled	Percent (%) response	S-use efficiency (kg/ha)
	2014-15	2015-16	2016-17			
T_1 ($NPKS_{15}$)	5508	5568	5528	5535	2.7	9.6
T_2 ($NPKS_{30}$)	5543	5623	5603	5590	3.7	6.6
T_3 ($NPKS_{45}$)	5546	5612	5610	5589	3.7	4.4
C (NPK)	5340	5402	5432	5391	—	—
SEM	38.5	55.0	61.3			
CD at 5%	118.7	169.4	188.7			
CV (%)	8.4	9.0	10.2			

The effects of sulphur on percent response of rice grain were 2.7, 3.7 & 3.7 for 15, 30 & 45 kg of sulphur application respectively and the maximum response was 3.7 for both 30 & 45 kg/ha of sulphur application. Similarly, the maximum sulphur use

Table 4. Effect of different levels of sulphur on straw yield of rice and sulphur use efficiency (Pooled data of three years)

Treatments	Straw yield (kg/ha)			Pooled	Percent (%) response	S-use efficiency (kg/ha)
	2014-15	2015-16	2016-17			
T_1 ($NPKS_{15}$)	6316	6325	6356	6332	1.2	5.2
T_2 ($NPKS_{30}$)	6371	6384	6308	6355	1.6	3.3
T_3 ($NPKS_{45}$)	6318	6304	6420	6347	1.5	2.1
C (NPK)	6239	6280	6245	6255		
SEM	44.7	38.1	47.6			
CD at 5%	137.9	117.4	146.5			
CV (%)	9.4	8.2	10.5			

Table 5. Effect of different levels of sulphur on biological yield of rice and sulphur use efficiency (Pooled data of three years)

Treatments	Biological yield (kg/ha)			Pooled	Percent (%) response	S-use efficiency (kg/ha)
	2014-15	2015-16	2016-17			
T_1 ($NPKS_{15}$)	11747	11796	11734	11759	1.9	14.7
T_2 ($NPKS_{30}$)	11914	11960	11882	11919	3.3	12.7
T_3 ($NPKS_{45}$)	11913	11933	11888	11911	3.2	8.3
C (NPK)	11512	11526	11576	11538		
SEM	62.5	76.3	103.4			
CD at 5%	192.7	235.1	318.7			
CV (%)	10.1	9.3	8.8			

Table 6. Effect of different levels of sulphur on 1000 grain weight of rice and harvest index (Pooled data of three years)

Treatments	1000 grain weight (gram)				Hervest index			
	2014-15	2015-16	2016-17	Pooled	2014-15	2015-16	2016-17	Pooled
T_1 ($NPKS_{15}$)	18.2	18.3	18.4	18.3	0.47	0.47	0.47	0.47
T_2 ($NPKS_{30}$)	18.4	18.5	18.5	18.5	0.47	0.47	0.47	0.47
T_3 ($NPKS_{45}$)	18.4	18.5	18.4	18.4	0.47	0.47	0.47	0.47
C (NPK)	18.1	18.3	18.4	18.3	0.46	0.47	0.47	0.47
SEM	0.1	0.2	0.2		0.00	0.00	0.00	
CD at 5%	0.3	0.6	0.5		0.01	0.01	0.02	
CV (%)	1.1	2.1	1.7		1.16	1.42	2.07	

efficiency for rice grain was 9.6 kg/ha of 'S' applied at T_1 treatment and it decreased with increase of 'S' applied. In case of rice straw yield, the maximum percent response was 1.6 at T_2 treatment and the maximum sulphur use efficiency was 5.2 at T_1 treatment. The similar kind of yield response was reported by Sakal *et al* (1996), Misra (1995) and Mukhopadhyay & Mukhopadhyay (1995).

There were no significant differences among the treatments for test weight and harvest index of rice on sulphur application. The lowest test weight recorded 18.1 g at control and the highest test weight 18.5 g at T_2 & T_3 treatments. The harvest index value ranges from 0.46 to 0.47.

Residual effect of sulphur on growth, yield attributes and yields of mustard

The application of sulphur through SSP has a significant residual effect on yield attributing character of mustard like plant height and number of siliquae/ plant over control but there was significant difference on number of seeds/siliqua. The maximum plant height recorded 95.8 cm at 45 kg/ha 'S' applied and the minimum plant height was 86.2 cm at control plot.

TABLE 7. Residual effect of different levels of sulphur on seed yield of mustard and sulphur use efficiency (Pooled data of three years)

Treatments	Seed yield (kg/ha)			Pooled	Percent (%) response	S-use efficiency (kg/ha)
	2014-15	2015-16	2016-17			
T_1 ($NPKS_{15}$)	1186	1168	1124	1159	7.9	5.6
T_2 ($NPKS_{30}$)	1268	1266	1246	1260	17.2	6.2
T_3 ($NPKS_{45}$)	1298	1298	1290	1295	20.5	4.9
C (NPK)	1070	1092	1062	1075	—	—
SEM	23.1	25.9	22.5			
CD at 5%	71.2	79.8	69.4			
CV (%)	9.8	8.3	8.8			

TABLE 8. Residual effect of different levels of sulphur on stover yield of mustard and sulphur use efficiency (Pooled data of three years)

Treatments	Stover yield (kg/ha)			Pooled	Percent (%) response	S-use efficiency (kg/ha)
	2014-15	2015-16	2016-17			
T_1 ($NPKS_{15}$)	3294	3366	3216	3292	7.4	15.2
T_2 ($NPKS_{30}$)	3418	3464	3336	3406	11.2	11.4
T_3 ($NPKS_{45}$)	3474	3488	3432	3465	13.1	8.9
C (NPK)	3152	3020	3020	3064	—	—
SEM	60.9	54.0	69.4			
CD at 5%	187.7	166.4	213.9			
CV (%)	9.7	8.2	9.3			

The highest number of siliqua/plant was 300 and the minimum number recorded 287.

The residual effects of sulphur significantly increase the mustard grain and straw yield. The maximum increase in grain and straw yield was recorded with application of 'S' @45 kg/ha. This indicates that application of 'S' through SSP once in a cropping sequence can supplement the 'S' need of the crops in sequence. Sakal et al (2001) reported the yield increase of succeeding crop in wheat and rice crops.

The residual effects of sulphur on percent response of mustard seed were 7.9, 17.3 & 14.8 for 15, 30 & 45 kg of sulphur application respectively and the maximum response was 17.3 for both 30 kg/ha of sulphur application. Similarly, the maximum sulphur use efficiency for mustard seed was 6.2 kg/ha of 'S' applied at T_2 treatment ie 30 kg S /ha. Sen et al (2002) also observed the residual effect of sulphur on mustard yield in rice –mustard cropping sequence. Sen et al (2008) also reported the residual effect of sulphur in the succeeding crop.

In case of stover yield of mustard, the residual effects of sulphur on percent response of mustard seed were 7.5, 11.2 & 13.1 for 15, 30 & 45 kg of sulphur application respectively and sulphur use efficiency were 15.2kg/ha, 11.4kg/ha & 8.9 kg/ha of S' applied and the maximum percent response was 13.1 at T_3 treatment and the maximum sulphur use efficiency was 15.2 kg/ha 'S' applied at T_1 treatment.

Table 9. Effect of different levels of sulphur on biological yield of mustard and sulphur use efficiency (Pooled data of three years)

Treatments	Biological yield (kg/ha)			Pooled	Percent (%) response	S-use efficiency (kg/ha)
	2014-15	2015-16	2016-17			
T_1 ($NPKS_{15}$)	4480	4534	4340	4451	7.5	20.8
T_2 ($NPKS_{30}$)	4686	4730	4582	4666	12.7	17.6
T_3 ($NPKS_{45}$)	4772	4786	4722	4760	45.0	13.8
C (NPK)	4222	4112	4082	4139		
SEM	67.3	63.5	72.1			
CD at 5%	207.3	195.8	222.2			
CV (%)	9.0	8.8	8.3			

Table 10. Residual effect of different levels of sulphur on growth of mustard (Three years mean data, 2014-15 to 2016-17)

Treatments	Plant height (cm)	Number of siliquae/plant 2014-15	Number of seeds/siliqua 2015-16	Harvest index 2016-17
T_1 ($NPKS_{15}$)	90.4	292	11.4	0.26
T_2 ($NPKS_{30}$)	93.6	296	12.2	0.27
T_3 ($NPKS_{45}$)	95.8	299	12.6	0.27
C (NPK)	86.2	287	10.6	0.25
SEM	2.6	2.9	0.8	0.00
CD at 5%	7.9	9.0	2.3	0.01
CV (%)	8.6	8.0	12.9	3.66

Residual effect of sulphur on yields attributes and yields of green gram

The residual effect of sulphur on yield attributing character of green gram like plant height and number of pods/plant, number of grain/pod has significant effect over control. The maximum plant height recorded 43.4 cm at 45 kg/ha 'S' applied and the minimum plant height was 39.6 cm at control plot. The highest number of pods/plant was 22 and the minimum number recorded 16.8.

The residual effects of sulphur significantly increase the green gram seed yield and stover yield. The maximum increase in seed and stover yield was recorded with application of 'S' @45 kg/ha. The increased seed yield was significant for the three consecutive years over the control and the highest seed yield was recorded at T_3 treatment (903 kg/ha) and also increased the stover yield of green gram. The biological yield of green gram increased with increased of sulphur application and the highest yield recorded was 3287kg/ha at T_3 treatments.

The mean percent response of seed yield of green gram of three consecutive years were 7.5, 16.5 and 16.0 for three doses of 'S' i.e. 15, 30 and 45 kg respectively and the highest sulphur use efficiency was 4.1 kg/ha of 'S' applied at T_2 treatment i.e. 30 kg/ha 'S' applied. Similar trend was noted in percent response. The highest response (16.5) was observed with 30 kg S/ha. Sen et al (2008) reported the similar kind result in black gram-mustard cropping system.

TABLE 11. Residual effect of different levels of sulphur on growth, yields attribute and yield of green gram (1st year, 2014-15)

Treatments	Plant height (cm)	Number of pods/plant	Number of grain/pod	Harvest index
T_1 ($NPKS_{15}$)	40.4	18.2	8.4	0.27
T_2 ($NPKS_{30}$)	42.8	20.2	8.8	0.27
T_3 ($NPKS_{45}$)	43.2	22.0	9.0	0.27
C (NPK)	39.6	16.8	7.8	0.26
SEM	0.7	0.7	0.3	0.01
CD at 5%	2.1	2.1	0.8	0.02
CV (%)	3.3	7.0	6.2	4.79

TABLE 12. Residual effect of different levels of sulphur on seed yield of green gram and sulphur use efficiency (Pooled data of three years)

Treatments	Grain yield (kg/ha)			Pooled	Percent (%) response	S-use efficiency (kg/ha)
	2014-15	2015-16	2016-17			
T_1 ($NPKS_{15}$)	792	790	790	791	7.6	3.7
T_2 ($NPKS_{30}$)	851	867	852	857	16.6	4.1
T_3 ($NPKS_{45}$)	895	903	894	897	22.0	3.6
C (NPK)	732	738	736	735	—	—
SEM	20.0	19.2	18.1			
CD at 5%	61.5	59.0	55.8			
CV (%)	9.9	8.6	9.4			

Conclusion

The application of sulphur had the direct effect on rice plant parameters and as well as on yield parameters of rice. The significant improvement of yield attributes and yield of mustard and green gram noticed due to the residual effect of sulphur applied in the form of single super phosphate and remaining from elemental sulphur. In all cases the control treatment received no sulphur produced the lowest result due to lack of residual sulphur.

The main finding of this experiment was that the application of sulphur in the rice-mustard-green gram cropping sequence had the residual effects on the following crops and significant yield increased was recorded at 45 kg S ha^{-1}applied. Babu and Hegde (2002) in the rice-sunflower cropping sequence reported the similar kind of findings. Henceon the basis of this experiment it can be recommended that in a Sulphur deficient soil S @ 45 kg/ha may be applied for better crop quality and quantity.

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Table 13. Residual effect of different levels of sulphur on Stover yield of green gram and sulphur use efficiency (Pooled data of three years)

Treatments	Stover yield (kg/ha)			Pooled	Percent (%) response	S-use efficiency (kg/ha)
	2014-15	2015-16	2016-17			
T_1 ($NPKS_{15}$)	2229	2181	2131	2180	10.9	14.2
T_2 ($NPKS_{30}$)	2370	2340	2278	2329	18.4	12.1
T_3 ($NPKS_{45}$)	2392	2386	2366	2381	21.1	9.2
C (NPK)	2028	1946	1926	1967		
SEM	75.2	44.1	53.4			
CD at 5%	231.7	136.0	164.5			
CV (%)	8.7	8.0	8.9			

Table 14. Effect of different levels of sulphur on biological yield of green gram and sulphur use efficiency (Pooled data of three years)

Treatments	Biological yield (kg/ha)			Pooled	Percent (%) response	S-use efficiency (kg/ha)
	2014-15	2015-16	2016-17			
T_1 ($NPKS_{15}$)	3021	2921	2921	2954	9.6	17.3
T_2 ($NPKS_{30}$)	3221	3145	3130	3165	17.4	15.7
T_3 ($NPKS_{45}$)	3287	3269	3260	3272	21.4	12.8
C (NPK)	2760	2664	2662	2695		
SEM	77.6	53.4	61.4			
CD at 5%	239.2	164.4	189.1			
CV (%)	8.1	9.6	10.1			

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Nutrition Security in the Context of Climate Change : a Review

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Abstract

In the present changing climate condition, nutrition security, which exists when food security is combined with a sanitary environment, adequate health services, and proper care and feeding practices to ensure a healthy life for all household members, is of great importance. The four fundamental components of food security, which is in turn a component of nutrition security, include food availability, food accessibility, food utilization and food systems stability; various factors contribute directly or indirectly in ensuring these components and the nutrition security as a whole. On the other hand, climate change, determined by long-term changes in average weather conditions, all changes in the climate system, including the drivers of change, the changes themselves and their effects, and human-induced changes in the climate system, has been responsible for about 0.6° C rise in ambient temperature during the 21st century. An attempt, in this backdrop, has been made to review the impacts of climate change on nutrition security issues and the existing mechanisms, strategies, and policies to address them. The pathways through which climate change is leading towards food security threat have been identified and the mechanisms of management strategies have been analyzed. It has been found that climate extreme, variability and changes are directly impacting food security, livelihoods, household food access and many socioeconomic factors that contribute food security. In recent times, although nutrition sensitive adaptation measures are being implemented, there exists a visible gap between research and practice, knowing-doing or science-policy. Coherence of both adaptation and mitigation approaches is required to face the nutritional security challenge posed by climate change. It may be concluded that climate change phenomenon has direct impacts on nutrition security resulting into under-nutrition, one of the most serious but least addressed public health challenge. An integrated multi sectorial approach of direct climate-smart nutrition interventions coupled with nutrition sensitive policy formulation and implementation can address the threats to food and nutrition security in the present changing environment.

Keywords **:** adaptation, climate-smart technologies, food access, under-nutrition, vulnerability.

1.0 Introduction

The number of people suffering from chronic hunger has increased from under 800 million in 1996 to over a billion

[1]. Under-nutrition, including hidden hunger, caused mainly by inadequate dietary intake and diseases, still remains a major public health challenge worldwide, with the number of people suffering from hunger stood at 925 million in 2010 [2], in spite of adopting multi-sectorial attempts to ensure food security. For a more inclusive purpose, the concept of food security, which exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and

nutritious food that meets their dietary needs and food preferences for an active and healthy life, has been modified to a newer concept of 'nutrition security' with some additional components like sanitary environment, adequate health services, and proper care and feeding practices to ensure a healthy life for all household members [3, 2]. To achieve these, countries need to develop rapidly and as the modern world is witnessing developmental activities at a fast pace, the impact is leading to many crises; climate change is one of the most important of them. Climate Change phenomenon caused, inter alia, due to Global Warming (GW), i.e. rise in mean temp of the earth's atmosphere, has been responsible for about 0.6°C rise in ambient temperature during the last few decades [4]. GW is expected to continue at ever growing rates in the current century, and some scenarios indicate a global temperature rise by up to 6°C by 2100 [5,6] depending on actions to limit greenhouse gas (GHG) emissions, geographic, local conditions and adaptation measures. In this present changing climate condition, nutrition security is of great importance. An attempt, in this backdrop, has been made to review the impacts of climate change on nutrition security issues and the existing mechanisms, strategies, and policies to address them.

2.0 Methodology

The pathways through which climate change is leading towards food security threat have been identified and the mechanisms of management strategies have been analyzed. A literature search was carried out using the key terms under-nutrition, food security, nutrition security, climate variability, adaptation, mitigation, food access and like.

3.0 Findings

The process of global warming, mainly due to the burning of fossil fuels (coal, oil and gas) to meet increasing energy demand and deforestation for the sake of the spread of intensive agriculture to meet increasing food demand, shows no signs of abating and is expected to bring about long term changes in weather conditions; which in turn is causing more complex climatic problem. Food availability, food accessibility, food utilization and food system stability - all four dimensions of food security [7] are being affected, as visible in global food market, by climatic change phenomenon. Broadly climate change has been found to be affecting nutrition security through different causal pathways that impact food security, livelihoods, household food access, maternal and child care, health, water and sanitation, and many other socioeconomic factors that determine nutrition security. Climate extremes, variability and change influence maternal and child under-nutrition and its three main determinants: household food access, maternal and child care and feeding practices, and access to health services and environmental health, which in turn, is regulated directly and indirectly by other factors, such as livelihoods, formal and informal institutions, economic, political, and ideological structures, resources, and structural transformations. The negative effects of changing temperatures and precipitation on agricultural production, and therefore, on food security and under-nutrition in developing countries, constitute the largest single negative impact of climate change on health due to the very large numbers of people who may be affected [8, 9]. IPCC further predicts that the climate change over the next century will affect rainfall pattern, river flows and sea levels all over the world and consequently the agricultural yield will likely be severely affected in near future resulting into threat to nutrition security. Specific impacts of climate change on nutrition security issues have been explained below.

3.1 As a result of climate change, the pattern, timing and intensity of environmental events have changed a lot. Rise in temperature and changes in precipitation have direct impacts on water availability and other factors required for crop yield. IPCC assessment report demonstrated that global mean crop yields of rice, maize and wheat are projected to decrease between 3% and 10% per degree of warming above historical levels [10]. Another study estimated global wheat yield reductions of 6% per degree of warming [11]. Not only quantity, further, study explains that reduced quality of crop production is also due to decreases in leaf and grain Nitrogen, protein and macro and micro-nutrients like Fe, Zn, Mn, Cu and like concentrations associated with increased CO2 concentration as a result of warmer climate [12].

3.2 Climate change-related extreme events like heat waves, droughts, storms, heavy precipitation, and floods, which are expected to aggravate in coming decades, are negatively affecting institutions critical for food and nutrition security, e.g., through physical damage to health infrastructure and overburdening of social services, safety nets, and other social policies, hence multiplying many of the same socioeconomic factors that make people vulnerable to climate change [2]. Studies have repeatedly shown that flood, drought and other climate related extreme events are leading to malnutrition, wasting, stunting and like problems in children due to reduced access to food, increased difficulties of providing proper care, and greater exposure to contaminants [13]. It will not possibly absolutely out of context to mention that our history is replete with instances where extreme events like famine in 1943 (1.5-3 million people died) and back to back drought in 1960s in post independent India(grain production in MMT decreased from about 90 in 1964-65 to 72 in 1965-66) seriously raised question about nutritional security.

3.3 Although impacts of climate change predominate on agricultural crop production, fisheries and livestock production, important sources of animal protein, are no less serious [14]. Impacts of climate change on livestock systems are expected to be mediated through reduced feed quantity and quality, changes in pest and disease prevalence and impairment of production due to physiological stress. Egg, milk and meat yield decrease as temperature go beyond 30°C due to reduced feed intake [15]. Changes in distribution of fish and plankton are expected to be affected due to increase in ocean temperature, changes in wind pattern, ice thickness, pH and nutrient supply [16].

3.4 Climate-related disasters are also a major cause of displacement. It has been reported that a huge number of people are still being displaced by climate-related disasters, losing their livelihoods and their access to nutritious food [17].

3.5 Climate change phenomenon is expected to affect people's ability to access food [18]. Reduction in agricultural crop yield may increase the food price and reduce the purchasing capacity of vulnerable population of the society resulting into a threat for not fulfilling the recommended calorie requirement. Physical access to food may be affected by climate change via effects on transport system and physical wellbeing.

3.6 Extreme climate variability has impacts on food utilization, mainly through two dimensions – food safety through supply chain and health impacts from climate change that mediate nutritional outcomes – also. Climate change is likely to reduce food safety due to higher rates of microbial growth at increased temperature [19], especially in fresh fruits, vegetables and also in fisheries supply chain. In addition, climate change impacts health via vector borne diseases, heat stress and natural disasters, which in turn affect people's nutrition [20]. Indirect effects of climate change on health include loss of jobs and livelihood which in turn can aggravate the nutritional insecurity.

3.7 In addition to direct impact on agriculture, food systems and food security, climate change negatively affects the nutritional value of plant foods, e.g. elevated carbon dioxide results in a reduction in protein concentration in many human plant crops [21, 22]

3.8 Climate change can have an impact on environmental health issues such as sanitation- water availability, access, and quality; and the transmission of waterborne, food-borne, vector-borne, and other diseases [23]. Such diseases, in turn, reduce the body's absorption and utilization of essential nutrients, effectively increasing overall nutritional needs.

3.9 Climate extreme may have negative impacts on occupational health also [24], and thus on the performance of the agricultural workforce, either directly due to increased worker exposure to heat [25-31] and extreme weather, or indirectly due to workforce vulnerability to climate-related diseases.

3.10 One of the most vulnerable sections expecting to suffer from impacts of climate change and resulting nutrition security threat include women. Climate change can put strain on the existing heavy workload of women, with negative impacts on their health as well as on their ability to provide proper care to infants and young children, thus further increasing the risk of under-nutrition [32]. In addition to it, there is an age old practice of discrimination on the basis gender even within the household at the time of intake of food, that itself could be in short supply, which can further lead to nutritional insecurity [33].

3.11 Storage, distribution and management of food crops can be severely affected through climate variability.

Potential management strategies: Current management strategies to achieve optimum food security in turn leading to nutrition security challenge posed by climate change have focused mainly on three aspects. These are -

- Accelerated adaptation to progressive climate change
- Management of agricultural risks associated with increasing climate variability and extreme weather events
- Mitigation actions that involve both carbon sequestration and reduction of emission

  To reduce the adverse impacts of climate change on nutrition security, adaptation is considered as one of the vital components of any management policy. Climate change adaptation strategies, although some are highly localized and cannot be directly adopted and implemented in all cases, especially for agricultural production broadly include –

- Micro-level options, e.g. crop diversification and changing the timing of operation
- Market responses, e.g. income diversification and credit schemes
- Institutional changes mainly through government responses, e.g. subsidies and taxes and improvement in agricultural market
- Technological developments, e.g. development and promotion of new crop varieties and advances in water management techniques [34]

Another important aspect to ensure nutrition security is to focus on the vulnerable groups. In this context, the poor people, marginal communities, women and children are at greatest risk for suffering from the potential impacts of climate change due to their high exposure to natural hazards, direct dependence on climate-sensitive resources, and limited capacity to adapt to and cope with climate change impacts. With local production declining and probable disruptions caused by climate hazards, income-generating opportunities and purchasing power will decrease for vulnerable populations. In addition to it, simultaneously, decreases in production can lead to price increases for staple crops which may increase the degree of severity of suffering. Therefore, certain initiatives for direct nutrition interventions to build resilience to climate change impacts have been taken. These include promotion of good nutrition, care, and hygiene practices, such as breastfeeding, complementary feeding for infants over 6 months of age, improved hygiene practices, and deworming programs; micronutrient supplementation for young children and their mothers; provision of micronutrients through food fortification for all (e.g., salt iodization, iron fortification, etc.); and therapeutic feeding of malnourished children with special foods. Overall, food assistance (e.g. school lunch program, various schemes related to nutrition security and like) must be targeted directly to meet immediate food and nutritional requirements of vulnerable people, to increase their productive potential and adaptive capacity, and to protect them from climate-related disasters.

Discussion

Ensuring nutrition security and maintaining it uninterruptedly is one of the biggest challenges worldwide. The issue of concern is that current climate change-related policies and practices have not considered under-nutrition and related issues as a major threat of public health; they consider nutrition insecurity possibly as a “peripheral” issue in the climate change related agenda. As a result of extreme climate variability, food supply chains are getting disrupted, market prices increase, assets and livelihood opportunities are being lost, purchasing power is falling, human health is getting endangered, and affected people are unable to cope with such challenges. Now, while considering the management aspects, concentrating only on under-nutrition will be insufficient if the impacts and threats of climate change to nutrition security are not properly addressed. On the other hand, climate change adaptation and mitigation have been addressed separately in the agriculture, food security, social protection, health, and nutrition contexts, when in fact a more integrated approach is needed. In one study, four immediate challenges have been identified to address nutrition insecurity induced by climate change – changing the research culture to become more action oriented, identifying climate smart options, addressing social inequality and addressing the mitigation challenge (Campbell). In this context, in spite of adopting and implementing climate resilient crop production, emphasis on nutritional quality and health promotion is still lacking. To address this issue, agricultural policies should go beyond staples foods and increase the availability and affordability of a diverse range of nutritious foods like vegetables, fruits, legumes, animal and dairy products, small fish, under-utilized nutrient-rich indigenous foods and like.

CONCLUDING NOTE

It may be mentioned that climate change phenomenon may have impacts on nutrition security resulting into under-nutrition, one of the most serious but relatively less addressed public health challenge. Thus, climate change related phenomenon challenges the realization of the fundamental human rights to health and adequate nutritious food. An integrated multi sectorial approach of direct climate-smart nutrition interventions coupled with nutrition sensitive policy formulation and implementation can address the threats to food and nutrition security in the present changing environment.

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Impact of Organic and Synthetic Mulch Materials on Tomato (*Lycopersicon Esculentum* Cv. Pusa Ruby)

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Abstract

A field study was conducted to evaluate the effect of different mulch materials on growth, yield and different qualitative characters of tomato (var. Pusa Ruby). Different mulches used during the study were black polythene mulch, yellow polythene mulch, transparent polythene mulch, mango leaf, paddy straw, saw dust and sun grass along with bare soil as the control. Different mulches generated higher soil temperature and moisture regimes over the control. Weed population was significantly suppressed under black polyethylene mulch. Days to 50 percent flowering followed by days to first harvest were recorded at 41.23 and 80.03 days after transplanting under black polyethylene mulch as compared to rest of the treatments. Plant height, number of primary branches per plant, number of leaves, fruit yield, and average fruit weight recorded higher values under black polythene mulches. However, it failed to have significant impact on fruit quality parameters.

Introduction

Tomato (*Lycopersicon esculentum)* is the most important and popular solanaceaous vegetable crop grown commercially throughout the country. It is usually cultivated during early and late winter in humid tropical condition of West Bengal, India. In spite of its wide cultivation in India, the average yield is very low due to heavy weed infestation. Scarcity of water resources and competition for water in many sectors reduce its availability for agricultural use. This leads to competition for soil nutrients, depletion of soil moisture during summer and nutrient losses due to leaching during rainy season. The situation thus demands evaluation of proper technology for improving the hydrothermal regime of soil to a level which is not injurious to crop growth. Use of mulches offer great scope in such a situation to conserve soil moisture and improves soil temperature (Bhella 1988; Kwon *et al.,*1988; Chakarborthy and Sadhu,1994; Hooda *et al.,* 1999; Pinder and Rana, 2016).

Organic mulch (plant materials) and synthetic mulches (plastic of different colours) are widely used in vegetable production for their efficacy to conserve soil moisture by monitoring water distribution between soil evaporation and plant transpiration, and modifies soil temperature. Mulching reduces the deterioration of soil by way of preventing the runoff and soil loss, minimizes weed infestation and checks water evaporation. Thus, it facilitates better retention of soil moisture and helps in control of temperature fluctuations, improves physical, chemical and biological properties of soil and ultimately enhances the growth and yield of crops (Dilipkumar *et al*., 1990). Therefore, the present study was conducted to determine the effect of various mulches on growth and yield of tomato. Taking the consequences, an investigation was undertaken to have knowledge on enhancing the productivity of tomato through use of synthetic and organic mulches. The study includes investigation on differentiation of morphological and yield related characters in tomato grown under different mulching materials, variation in the major qualitative traits under different sets of mulching, biomass of the weed in terms of dry weight gathered from the mulch plots, average temperature of the soil under different mulch materials and its linkage to water conservation in the crops under study.

Materials and Methods

The experiment was conducted at Agricultural Experimental Farm of Calcutta University at Baruipur, 24- Parganas (South) (88 28‘ E, 22 N during winter to early monsoon (November – June) of 2012-2013.The soil type of experimental site was uniform with medium fertility and clay loam texture. The soil samples from the experimental plots were collected from a depth of 25 cm before transplanting and analysed for physical and chemical properties. The field experiment was laid out in a randomized block design (RBD) having three replications. The seeds treated with Bavistin @ 2gm/kg seeds were sown in challi pots in December, 2012. The experimental land was ploughed and cross ploughed 2 to 3 times. Split application of NPK was applied @ 110:60:60kg/ha. Full dose of phosphorus, potassium and one third of nitrogen was applied after preparation of pits. The remaining nitrogen was applied in 2 split doses successively at one month interval from transplanting. Mulched layers were placed before date of transplanting and an “x” cut was given at a spacing of 45 x 45 cm, to maintain a population of thirty plants per plot. Transplanting was carried out after 45 days of sowing in the mulched field. Requisite cultural practices in term of timely irrigation, weeding and pesticide application were done. When the plants attained an optimum height, bamboo stakes were tied with the help of jute ropes to support the crops for proper stand. The data were recorded on five randomly selected plants in each plot for morphological feature, and yield attributing characters as well as some qualitative parameters. For qualitative characters, the observations were recorded from composite samples of five fruits in each plot.

Qualitative parameters like total chlorophyll content of leaves, ascorbic acid content and lycopene content was estimated following the method of Arnon and Witham, 1949., Rangana 1986. Data collected on various parameters were statistically analysed (Panse and Sukhante, 1978) to evaluate the treatment effects on morphological traits, yield and qualitative performance of tomato. For weed count half square metre area (0.5m X 0.5m) was fixed randomly before emergence of weeds. Total amount of weeds growing within the area were weighed on fresh weight basis. These observations were recorded 45days after transplanting. Soil temperature was measured by use of Fisher band bimetal dial thermometer. Thermometers were installed between rows in centre of one replication of each treatment at 10cm depth. The temperatures in °C were recorded daily for maximum at 12.30 hrs. Soil moisture estimation was carried out through gravimetric method.

Results and Discussion

Organic as well as synthetic mulches significantly increased plant height, number of primary branches per plant, leaf area and fruit yield over the control (Table 1 and Table 2). The effect of synthetic mulches was more pronounced on fruit yield than the organic mulches. Higher fruit yield under black polythene was ascribed to favourable and integrated effect of moderation in hydrothermal regime that enhanced the root growth for better uptake of water nutrients and lesser weed population thus enhancing height and plant spread (Gollifer 1993; Munguia *et al.*, 1998).

Minimum days to 50 percent flowering (41.23 days) and days from fruit set to fruit maturity were observed in plants grown under black polythene mulch. Organic mulches and control exhibited delayed flowering. It is a well-known fact that mulches create favourable conditions such as higher temperature, soil moisture and reduce weed population, which accelerates plant growth and early flowering. These results are in agreement with Zhang *et al.*,(1992) and Wien and Minotti (1993). Early harvest was recorded in the treatment mulched with black polythene (80.03 days) which may be attributed to early flowering due to improved crop growth as well as warming effect of soil by the use of mulch, reduced weed population and better soil moisture retention. Similar results were observed by Bhella (1988) and Teasdale and Abdul-Baki (1995). Number of fruits per plant was high under black polythene (22.94) followed by transparent polythene mulch(22.61). Individual fruit weight was high under black plastic mulch(40.13g) and minimum

TABLE 1. Effect of different mulch materials on morphological traits of tomato (*Lycopersicon esculentum,* Mill) var. Pusa Ruby

Treatment	Plant height (cm)	No. of primary branches/plant	Total no. of leaves/plant	Leaf length (cm)	Leaf width (cm)	Leaf area (cm²)	Days to 50% flowering	Days to first harvest
T_1	74.39	3.72	24.93	14.61	6.96	68.44	41.23	80.03
T_2	69.19	3.16	20.13	14.35	6.80	67.62	43.39	83.41
T_3	74.26	3.50	24.33	15.46	6.93	68.26	42.43	81.18
T_4	68.99	2.66	21.11	14.25	6.67	68.36	43.18	83.00
T_5	70.83	3.55	23.22	14.39	6.84	67.96	42.56	82.74
T_6	57.30	3.03	18.11	14.34	6.83	66.89	44.43	82.44
T_7	59.03	2.86	19.16	14.02	6.88	66.35	44.76	83.16
T_8	58.72	2.33	13.77	14.17	6.61	66.32	52.35	90.74
CD at 5%	1.38	0.63	2.14	NS	NS	NS	2.47	2.44
SE(d)	0.63	0.29	0.98	0.26	0.24	0.92	1.14	1.13

Note: T_1- Black polythelene mulch, T_2- Mango leaf mulch, T_3- Yellow polythelene mulch, T_4- paddy straw mulch, T_5- Transparent polythelene mulch, T_6- Sawdust mulch, T_7- Grass mulch, T_8- Control (without any mulch)

TABLE 2: Effect of different mulch materials on fruit characters and yield of tomato(*Lycopersicon esculentu,*Mill.) var. Pusa Ruby

Treatment	Total number of fruits/plant	Individual fruit weight (g)	Polar diameter of fruit (cm)	Equatorial diameter of fruit (cm)	Average fruit weight/plant (kg)
T_1	22.94	40.13	12.49	12.98	0.95
T_2	20.53	38.48	11.92	12.11	0.88
T_3	22.61	39.51	12.26	12.40	0.92
T_4	21.16	37.74	11.85	12.08	0.89
T_5	21.54	38.49	12.19	12.87	0.90
T_6	20.38	37.01	11.27	12.06	0.76
T_7	20.10	38.09	11.14	12.15	0.74
T_8	15.50	29.44	10.41	11.74	0.54
C.D. at 5%	1.34	1.55	0.69	0.19	0.12
SE(d)	0.62	0.72	0.32	0.09	0.05

Note: T_1- Black polythelene mulch, T_2- Mango leaf mulch, T_3- Yellow polythelene mulch, T_4- paddy straw mulch, T_5- Transparent polythelene mulch, T_6- Sawdust mulch, T_7- Grass mulch, T_8- Control (without any mulch)

in control (29.44g). Mulching with yellow polyethylene was statistically at par with black polyethylene mulch as herein there was similar less crop weed competition, optimum supply of moisture and nutrients which resulted in better plant growth and increased individual fruit weight. Both polar (12.47) and equatorial diameter (12.98) was maximum in fruits under black polyethylene mulch (Table 2). Yield per plant was significantly high under black polyethylene mulch (0.95 kg/plant) followed by yellow polyethylene mulch (0.92

kg/plant). Organic mulches like paddy straw showed higher yield.

The present study showed that different mulch materials had no significant effect on TSS content. However, Total soluble solids (TSS) was more in fruits of plants mulched with black mulch and minimum under transparent mulch. The results are in accordance with the findings of Srivastava and Aggarwal, 1965.

Estimation of important qualitative components viz, total chlorophyll content of leaf (mg/g), ascorbic acid content (mg/g) and lycopene content (mg/g) are depicted in Table 3. Chlorophyll is one of the major chloroplast components for photosynthesis and relative higher content (stay green) had a positive relationship with photosynthesis (Shangguan *et al.*, 2000). In tomato, mulching with black polythene exhibited higher total chlorophyll content followed by paddy straw mulch. Least chlorophyll content was observed in transparent polythene mulch. Similar findings were reported earlier by Bahadur *et al*., (2009) where they observed significant increase in chlorophyll content. An optimum soil moisture and hydrothermal soil regime with relative water content might have contributed for improved physiological attributes of plant under mulched condition. The experimental findings for ascorbic acid content are presented in Table 3. Highest ascorbic acid was found under black polythene mulch(11.00mg/g)) and the least was recorded under control(10.16 mg/g). Rest of the treatments containing ascorbic acid varied in between grass mulch(10.83 mg/g) and mango leaf mulch(10.33 mg/g), though none exhibited significance. Data pertaining to the titrable acidity (%) content in tomato of various treatments are presented in Table 3. None of treatments were found to be significant. However, the highest titrable acidity was observed under white polythene sheet (0.332%) followed by mango leaf mulch (0.328%). The least titrable acidity percentage was obtained under paddy straw mulch (0.295%). Maximum lycopene content (Table 3) was observed under black polythene sheet mulch (0.355mg/g) followed by white polythene sheet mulch (0.341mg/g)). The least was observed under sawdust mulch. However, the treatments pertaining to this qualitative trait showed no significant result.

Weed is an important factor related to crop growth as it determines the amount of essential nutrients taken up by the weed plants thus checking crop growth, reduces moisture supply to the main crop and finally creates a space crunch for robust growing leading to crop weed competition. The data is represented in Table 4. The dry weight of weeds was significantly influenced by different mulch materials. Black polythene mulched plants showed minimum dry weight of (16g) followed by yellow mulch (17.18g). Transparent polythene mulch showed higher average dry weight of weed (29.93g). Among organic mulches, straw mulch showed least dry weight content of weed (19.63g) followed by mango leaves mulch (19.66g). Rest of the treatments effectively reduced weed population as compared with control in a variable manner.

Soil temperature at 10cm depth was markedly influenced by different mulch materials (Table 5). The maximum increase in soil temperature at noon was observed under transparent polythene mulch by 3.61^0C. Increase in soil temperature under transparent polythene mulch may be attributed to its greenhouse effect (Hanks *et al*., 1961; Mahrer *et al*., 1984). It was also observed that transparent mulch permits the incoming short wave radiation to pass through but its transmissivity to longwave radiation is highly reduced to formation of water droplets on its lower surface (Gupta and Acharya, 1993).

Application of different mulch materials significantly influenced the soil moisture content during the cropping season (Table 6). Black polythene was found most effective in conserving higher moisture level than control, followed by yellow and transparent mulch. Among the organic mulches paddy straw was found most effective followed by mango leaf. The higher effectivity of polythene mulch as compared to organic mulches may be attributed to the impermeabilty of such materials to vapour at the soil surface as compared with organic mulch which being porous allows diffusion of water under vapour pressure gradient. Beneath the polythene mulches, soil water gets condensed and the droplets are again absorbed by

TABLE 3. Effect of different mulch materials on qualitative characters of tomato (*Lycopersicon esculentum*Mill.) var. Pusa Ruby

Treatment	Total soluble solids (°Brix)	Ascorbic acid content (mg/100g)	Titratable acidity (%)	Lycopene content (mg/100g)	Total chlorophyll content of leaf (mg/1gm)
T_1	6.06	11.00	0.327	0.355	0.826
T_2	5.73	10.33	0.328	0.331	0.652
T_3	5.93	10.50	0.306	0.321	0.572
T_4	5.80	10.83	0.295	0.330	0.809
T_5	5.33	10.83	0.332	0.341	0.564
T_6	5.73	10.83	0.305	0.316	0.590
T_7	5.66	10.83	0.315	0.338	0.762
T_8	5.73	10.16	0.306	0.337	0.758
C.D at 5%	NS	NS	NS	NS	0.050
SE(d)	0.43	0.70	0.01	0.01	0.02

Note: T_1- Black polythelene mulch, T_2- Mango leaf mulch, T_3- Yellow polythelene mulch, T_4- paddy straw mulch, T_5- Transparent polythelene mulch, T_6- Sawdust mulch, T_7- Grass mulch, T_8- Control (without any mulch)

TABLE 4. Effect of different mulch materials on weed population of tomato (Lycopersicon esculentum) var. Pusa Ruby

Treatments	Weed content (g)
T_1	16.00
T_2	19.66
T_3	17.18
T_4	19.63
T_5	29.93
T_6	21.23
T_7	21.22
T_8	41.00
CD at 5%	2.00
S.E (d)	0.92

Note: T_1- Black polythelene mulch, T_2- Mango leaf mulch, T_3- Yellow polythelene mulch, T_4- paddy straw mulch, T_5- Transparent polythelene mulch, T_6- Sawdust mulch, T_7- Grass mulch, T_8- Control (without any mulch)

the soil surface. The results are in accordance to the findings of Mahrer *et al*., (1984).

Conclusion

On the basis of the conducted experiment it may be concluded that use of black polyethylene mulch was found superior among all mulching materials used in this study. Similarly, use of organic mulches also had significant effect on growth, yield and yield attributing characters of tomato. The study also demonstrated that for higher fruit yield as well as higher net returns, paddy straw mulch among the organic mulches was the most suitable for commercial cultivation of tomato under humid tropical condition of West Bengal, India. During the study, use of black polyethylene mulch reduced

Table 5. Effect of different mulch materials on soil temperature(in °C) below the mulch in tomato (*Lycopersicon esculentum* Mill.) var. Pusa Ruby

Treatment	February	March	April	May
T_1	29.31	34.80	36.50	35.41
T_2	27.46	32.31	34.41	34.08
T_3	29.40	35.00	36.81	35.90
T_4	27.38	32.00	34.25	33.88
T_5	32.61	37.00	39.37	39.40
T_6	27.50	32.80	34.55	34.10
T_7	27.64	32.93	34.56	34.25
T_8	29.00	35.00	36.81	36.30
CD at 5%	0.08	0.09	0.10	0.06
S.E (d)	0.02	0.04	0.04	0.02

Note: T_1- Black polythelene mulch, T_2- Mango leaf mulch, T_3- Yellow polythelene mulch, T_4- paddy straw mulch, T_5- Transparent polythelene mulch, T_6- Sawdust mulch, T_7- Grass mulch, T_8- Control (without any mulch)

TABLE 6: Effect of different mulch materials on soil moisture(in %) 15cm below the mulch in tomato (*Lycopersicon esculentum*) var. Pusa Ruby

Treatment	February	March	April	May
T_1	18.45	17.31	14.61	14.64
T_2	16.29	14.62	12.63	12.62
T_3	18.10	16.71	14.35	14.40
T_4	16.21	14.71	12.72	12.43
T_5	17.93	15.51	13.00	12.95
T_6	16.07	14.52	12.58	12.60
T_7	16.00	14.50	12.53	12.54
T_8	14.12	12.63	10.46	11.44
CD at 5%	0.06	0.09	0.08	0.09
S.E (d)	0.02	0.04	0.03	0.04

Note: T_1- Black polythelene mulch, T_2- Mango leaf mulch, T_3- Yellow polythelene mulch, T_4- paddy straw mulch, T_5- Transparent polythelene mulch, T_6- Sawdust mulch, T_7- Grass mulch, T_8- Control (without any mulch)

weed intensity, conserved soil moisture, increased the availability of the nutrients by reducing the crop weed competition and ultimately resulted in increased growth, development and yield of tomato. The field-experiments during the study suggests that sub-soil temperature and soil water conservation of mulched beds were affected by the optical characteristics of the mulch shading of the bed by the developing crop canopy probably moderated differences between mulches and weed on the general effect of mulching. Data presented under the study can provide background information that can be used to develop and verify numerical models which would help in simulating the field temperature regime under plastic/ organic mulch culture. These modes may be used to evaluate the cumulative effects of mulch properties, the plant canopy, drip irrigation and other factors on crop productivity.

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Influence of Organic Soil Amendment on Production Potential of Okra (*Abelmoschus Esculentus* L. Moench) Cv. Avantika

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Abstract

An experiment was carried out to study the influence of organic amendment on production potential of Okra. The experiment comprised of nine treatments: T_1(FYM@25t/ha+100%RDF),T_2(FYM@25t/ha+75%RDF+BF),T_3(FYM@25t/ha+50%RDF+BF),T_4(FYM@15t/ha+MC@1t/ha+100%RDF),T_5(FYM@15t/ha+MC@1t/ha+75%RDF+BF),T_6(FYM@15t/ha+MC@1t/ha+50%RDF+BF),T_7(FYM@10t/ha+MC@1t/ha+100%RDF),T_8(FYM@10t/ha+MC@1t/ha+75%RDF+BF)andT_9(FYM@10t/ha+MC@1t/ha+50% RDF+BF) which were laid out in randomized block design with three replications.The treatments applied were Recommended dose of fertilizer (RDF) @150:100:80(N-P_2O_5-K_2O), Farm Yard Manure (FYM) @10, 15, 25t/ha, Mustard Cake (MC) @ 1t/ha and Biofertilizer (BF)(Azotobacter, Phospho Solubilizing bacteria)@ 3kg/ha).The results revealed that treatment T_4 gave consistent performance for all studied traits viz. early flowering, plant height, number of fruits per plant, average fruit weight, fruit length and girth, highest yield per plant and per hectare. The treatment also gave a yield benefit of 11.4% over the application of FYM @ 25t/ha+ 150:100:80 kg/ha NPK which is the recommended dose of crop nutrients. Highest net income was also registered for the treatment T_4. Thus, it was concluded FYM @ 15t/ha+ MC @ 1t/ha+ 150:100:80 kg/ha NPK may be advocated to local growers for boosting okra productivity. However, equivalent yield response of recommended dose of crop nutrient (25t/ha+ 150:100:80 kg/ha NPK) was recorded with the application of FYM @ 25t/ha+ 75% RDF+ BF (114.5), FYM @ 15t/ha+ MC@ 1t/ha+ 75% RDF+ BF and FYM @ 15t/ha+ MC @1t/ha+ 50% RDF+ BF. Thus, it was observed that equivalent yield of recommended dose of crop nutrient may also be achieved by either inclusion of bio-fertilizers and reduction of 25% of chemical fertilizers in recommended dose or by inclusion of mustard cake and bio-fertilizers and reduction of farm yard manure followed by 25% to 50% of chemical fertilizers in crop nutrition programme.

Key Words: okra, soil amendment, organic, economics of production.

Introduction

Okra is a warm season, annual vegetable crop belonging to the *Malvaceae* family. It is an oligo purpose crop, but is usually consumed for its green tender fruits as a vegetable in a variety of ways (Nuruzzaman*et al*., 2003; Ndunguru and Rajabu, 2004). These fruits are rich in vitamins, calcium, potassium and other mineral matters (Adewole and Ilesanmi, 2011). The mature okra seed is a good source of oil and protein (Oyelade*et al*., 2003) and has been known to have superior nutritional quality. The mature fruit and stems contain crude fibre, which is used in the paper industry. Okra does very well in humid tropics with a temperature range of 25-30° C and the optimum temperature for seed germination is 29°C. Loose, friable and well-manured loam soils with pH 6.0 to 6.8 are suitable for okra cultivation. Its cultivation has gained much importance for its desirable characteristics as: short growth period, day neutral nature, heat and drought tolerance (Nuruzzaman *et al*., 2003).

The use of high yielding crop varieties and chemical fertilizers has resulted in rapid increase in agricultural production, especially in irrigated areas. But complete reliance on the use of fertilizers ignoring bio-organic materials affects the soil environment. Organic manure supplies important plant nutrients, organic matter favours aggregation of fine soil particles, thereby promoting good structure, improved tilth, aeration, moisture movement and retention. These properties in turn, enhance seed germination, root development, nutrient uptake, plant growth and yield in cyclic order. It also contributes to the formation of soil humic compounds. Addition of organic matter in the soil cause the soil life to flourish.

The integrated approach of applying fertilizers and manures not only meets the crop requirements but also adds organic matter to the soil which acts as a buffer in maintaining the soil environment and thus allows the healthy growth of the plants. Okra requires heavy amount of nutrients for its successful cultivation. Dependence on chemical method of nutrient supplementation not only makes the cultivation cost intensive, but creates so many environmental hazards along with depletion of soil health. Hence, based on the above issues the present research focussed on the effect of various soil amendments in okra and derivative in terms of its production economics.

Materials and Methods

The present experiment was conducted at Agricultural Experimental Farm of Calcutta University at Baruipur, 24-parganas (South) [88° 28' east, 22° 22' latitude] during summer of 2014.Topography of experimental field was uniform with medium fertility, clay loam texture and nearby neutral pH. Soil samples were collected from different locations of the entire experimental field before the basal application of fertilizers and physico- chemical analysis of the composite soil sample was done (Table: 1) in the Soil Science laboratory of the Institute of Agricultural Science, University of Calcutta following standard methods.

The field was laid out in Randomized Block Design (RBD) having three replications each having nine plots of 3.0m X 2.0m size representing nine treatments viz. T_1(FYM@25t/ha+100%RDF), T_2(FYM@25t/ha+75%RDF+BF), T_3(FYM@25t/ha+50%RDF+BF), T_4(FYM@15t/ha+MC@1t/ha+100%RDF), T_5(FYM@15t/ha+MC@1t/ha+75%RDF+BF), T_6(FYM@15t/ha+MC@1t/ha+50%RDF+BF), T_7(FYM@10t/ha+MC@1t/ha+100%RDF), T_8(FYM@ 10t/ha+MC@1t/ha+75% RDF+BF) and T_9 (FYM@10t/ha+MC@1t/ha+50% RDF+BF). The treatments applied were Recommended dose of fertilizer (RDF) @150:100:80(N-P_2O_5-K_2O), Farm Yard Manure (FYM) @10, 15, 25t/ha, Mustard cake (MC) @1t/ha and Bio fertilizer (BF) (Azotobacter, Phosphate Solubilizing Bacteria)@ 3kg/ha. The treatments were allocated randomly to different plots with the help of random number table (Fisher and Yates, 1948). FYM and MC (as required) were applied 10 days before sowing. BF cultures were applied with organics. Half the dose of nitrogen (as urea) along with entire phosphate (Single Super Phosphate) and potash (Muriate of Potash) fertilizers were given as basal and rest of the urea was top dressed in two split doses at 30 and 50 days after transplanting. All necessary cultural operations like irrigation, weeding and earthing up were carried out as per recommendations. The okra cultivar used was Avantika (228) (F_1 hybrid; Shriram Bioseed Genetics, Hyderabad, A.P.).

The replicated mean data were subjected to statistical analysis. The total variation for different treatments was tested for significance by 'F' test using analysis of variance (ANOVA) technique.

The cost of cultivation for fruit yield of okra was worked out by taking all the important practices of cultivation for each treatment. In this experiment, the total cost of cultivation was same for all the treatment combinations, except manure and fertilizer cost. The gross income was worked out by multiplying the produce under each treatment and selling price of okra. Net income was worked out by deduction of gross income from total cost of cultivation. Finally, benefit-cost ratio was worked out by division of net profit and total cost of cultivation.

Results and Discussion

The mean sum of squares of all characters under study was highly significant. Treatments T_5

Table 1. Physico-chemical analysis of soil of the experimental site

Sl. No.	Parameters	Data
1	Apparent density	1.24 g/cc
2	Absolute specific gravity	2.56
3	Maximum water holding capacity	53.80 %
4	Soil texture	Clay loam
5	Soil pH	6.7
6	Organic carbon	0.7869
7	Available nitrogen	305 kg ha-1
8	Available phosphorus	25.104 kg ha-1
9	Available potassium	149.626 kg ha-1
10	Electrical conductivity	0.15 ds ms-1
11	CEC	27.00 m.e/ 100g of soil

(36.7days), T4 (37days) and T_7 (38 days) were early to 50% flowering (Table:2), all being statistically significant. On the other hand, T_1 (42.0 days) and T_3 (40.9 days) took maximum days to 50% flowering. Early flowering enables early harvest which is advantageous for the market. Hence, switching to any of the treatment combination (T_5, T_4 or T_7) may be advantageous to the okra grower of the region for early harvest. The data agree with the previously reported data on the integrated application of either 50% or 75% RDF with vermicompost or neem cake that resulted in early flowering (Tripathy *et al*., 2004). Similar reports were observed on treatment with 50% RDF+50% N through neem cake that resulted in minimum days to 50% flowering (Bharadiya *et al*., 2007).Plant height is an important character for increase of yield in okra. The data for plant height of different treatments is represented in Table 2. Comparison of treatments revealed that statistically significant maximum plant height producing treatments were T_4 (107.2cm), T_1 (99.5cm) and T_5 (98.1cm). The overall mean for the trait was 92.0 cm. The data agree with the previously reported data where greatest plant height was recorded with Azospirillum + 50% of recommended N rate (Sankarnarayan *et al*., 1996). Maximum plant height was also reported previously with the application of NPK (80:60:50) + 20t of FYM per hectare (Naidu *et al*., 2000).

Significant differences for the number of fruits per plant were observed among the treatments (Table: 2). Comparison of treatments revealed that T_4 (15), T_5 (15.4) and T_1 (15.1) showed significantly higher number of fruits per plant. T_9 (11.8) followed by T_3 (13.1) gave lower number of fruits per plant. The overall mean for this trait was 14.3. The results are in agreement to those of Sankarnarayan *et al*., 1996 and Naidu *et al*., 2000.Comparison of treatments revealed that T_4 (14.3g) and T_1 (13.1g) produced significantly maximum average fruit weight, whereas T_9 (10.1g) and T_3 (10.9g) were significantly less in fruit weight. The overall mean for this trait was 12.1g.Maximum weight of fruits per plant was reported previously with the application of NPK (80:60:50) + 20t of FYM per hectare (Naidu *et al*., 2000). The data also agree to the reported data on the integrated application of either 50% or 75% RDF with vermicompost or neemcake that resulted in better fruit weight of okra (Tripathy *et al*., 2004).

The potential vegetables for export and quality specifications were recommended to okra has green, tender, 6-8cm, 4-5 ridges slender and roundish with

Table 2. Parameters studied for Okra cultivation under different organic soil amendments

Treatments	50% flowering	Plant height (cm)	No.of fruits per plant	Average fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Fruit yield per plant (g)	Yield per hectare (q)
T_1	42.0	99.5	15.1	13.1	10.3	4.7	178.7	119.2
T_2	40.7	91.6	14.3	12.2	9.2	4.2	165.8	114.5
T_3	40.9	82.0	13.1	10.9	8.7	4.0	150.2	101.3
T_4	37.0	107.2	17.5	14.3	11.9	5.1	195.6	135.9
T_5	36.7	98.1	15.4	12.8	10.1	4.8	184.6	121.7
T_6	39.0	93.2	14.0	12.3	8.9	4.3	162.7	113.1
T_7	38.0	92.8	14.3	12.1	9.1	4.2	158.1	109.2
T_8	39.7	87.5	13.6	11.5	8.5	4.2	154.2	97.7
T_9	40.0	76.3	11.8	10.1	7.7	3.9	145.8	90.4
Mean	39.3	92.0	14.3	12.1	9.4	4.4	166.2	111.4
SE (d)	0.8	4.4	1.3	0.7	0.5	0.2	6.8	5.3
CD (5%)	1.9	10.2	2.9	1.6	1.2	0.4	15.7	12.3
CV (%)	2.5	5.9	10.8	7.0	6.6	5.3	5.0	5.9

T_1(FYM@25t/ha+100%RDF),T_2(FYM@25t/ha+75%RDF+BF),T_3(FYM@25t/ha+50%RDF+BF),T_4(FYM@15t/ha+MC@1t/ha+100%RDF),T_5(FYM@15t/ha+MC@1t/ha+75%RDF+BF),T_6(FYM@15t/ha+MC@1t/ha+50%RDF+BF),T_7(FYM@10t/ha+MC@1t/ha+100%RDF),T_8(FYM@10t/ha+MC@1t/ha+75%RDF+BF),T_9(FYM@10t/ha+MC@1t/ha+50% RDF+BF)

pointed tips. However, strong local preferences govern the market specifications of okra in India. Average fruit length of 9.4cm was recorded under this experiment (Table:2) which was highly acceptable in Kolkata and nearby markets. Treatment T_4 (11.9cm) produced maximum fruit length, whereas T_9 (7.7 cm) and T_8 (8.5cm) exhibited significantly less fruit length. The results do confirm to the findings of Prasad and Naik, 2013 who recorded significant fruit length in the plant receiving 50% RDF+ Azotobacter+ Azospirillum+ PSB+ FYM. Regarding fruit girth, T_4 (5.1cm) followed by T_5 (4.8cm) and T_1 (4.7cm) had significantly high fruit girth thus confirming the findings of Prasad and Naik, 2013.

The data for fruit yield per plant under different treatments is represented in Table 2. Comparison of treatments revealed that T_4 (195.6g) followed by T_5 (184.6g) produced highest yield per plant. On the other hand, T_9 (145.8g) and T_3 (150.2g) showed low significant yield. Previous reports agree to the data obtained where it was reported that application of 60% RDF through inorganic fertilizers+ neem cake+ vermicompost+ azotobactor + PSB resulted in significantly maximum fruit yield (Bairwa *et al.*, 2009).Regarding yield per hectare, it was revealed that T_4 (135.9 q) produced highest yield per hectare. T_5, T_1, T_2 and T_6 were statistically significant to each other and next best treatments after T_1. Treatment T_9 (90.4q) and T_8 (97.7q) showed significantly low yield. The overall mean for this trait was 111.4 q/ha. The data agree to the reported data where inoculation of okra seed with Azospirillum significantly increased fruit yield (Garhawal *et al.*, 2010).

The cost of cultivation of okra and the

economics of fruit production of okra is represented in Table 3 and Table 4. The general cost of cultivation for fruit production was worked out to Rs. 29,385.00. The cost of manures and fertilizers for different treatments was separately worked out. A whole sale price of Rs. 1500.00 per quintal was kept to work out the figure. Highest net income was calculated to Rs. 1,34,813.70 for the treatment T_4. However, highest output-input ratio was 2.03 for treatment T_1.Previous reports agrees to the data obtained wherein it was reported that application of 60% RDF through inorganic fertilizers+ neem cake+ vermicompost+ azotobacter + PSB resulted in significantly maximizing fruit yield along with highest benefit: cost ratio for the treatment (Bairwa *et al.*, 2009).

Conclusion

The study revealed that treatment T_4 (FYM @ 15t/ha +MC@ 1t/ha+ 100% RDF) gave consistent performance for all studied traits. The treatment also gave a yield benefit of 16.7q (11.4%) over the application of FYM @ 25t/ha+ 150:100:80 kg/ha NPK which is the recommended dose of crop nutrients. Highest net income (Rs. 1,34,813.7) was also registered

TABLE 3. Cost of cultivation for okra (excluding manures and fertilizers)

Operations	Amount (Rs)
Land preparation	4680
Planning material	2325
Irrigation	14,400
Intercultural operations	1440
Plant protection	5100
Harvesting	1440
Total (A_1)(Rs/ha)	**29,385**

TABLE 4. Economics of fruit production in okra

Treatment	Cost A_1 (Rs. ha^{-1})	Cost A_2 (Rs. ha^{-1})	Cost A (Rs. ha^{-1})	Yield (q ha^{-1})	Gross Income (Rs. ha^{-1})	Net income (Rs. ha^{-1})	Output Input ratio
T_1	29385.00	29651.29	59036.29	119.2	178800	119763.7	2.03
T_2	29385.00	40884.39	70269.39	114.5	171750	101480.6	1.44
T_3	29385.00	39721.64	69106.64	101.3	151950	82843.4	1.20
T_4	29385.00	39651.29	69036.29	135.9	203850	134813.7	1.95
T_5	29385.00	50884.39	80269.39	121.7	182550	102280.6	1.27
T_6	29385.00	49721.64	79106.64	113.1	169650	90543.4	1.14
T_7	29385.00	34651.29	64036.29	109.2	163800	99763.7	1.56
T_8	29385.00	45884.39	75269.39	97.7	146550	71280.6	0.95
T_9	29385.00	44721.64	74106.64	90.4	135600	61493.4	0.83

A_1= Cost of cultivation for okra (excluding manures and fertilizers); A_2= Cost of manures and fertilizers for different treatments in okra cultivation; A=Total cost of cultivation for okra (Cost A_1+ Cost A_2)
Note: Okra was sold @ Rs. 1500 per quintal.

for treatment T_4. Thus, this treatment combination may be advocated to local growers for boosting okra productivity. However, equivalent yield response (119.2 q/ha) of recommended dose of crop nutrient (25t/ha+ 150:100:80 kg/ha NPK) was recorded with the application of FYM @ 25t/ha+ 75% RDF+ BF (114.5), FYM @ 15t/ha+ MC@ 1t/ha+ 75% RDF+ BF (121.7) and FYM @ 15t/ha+ MC @1t/ha+ 50% RDF+ BF (113.1). Thus, equivalent yield of recommended dose of crop nutrient may also be achieved by either inclusion of bio-fertilizers and reduction of 25% of chemical fertilizers in recommended dose or by inclusion of mustard cake and bio-fertilizers and reduction of FYM and 25% to 50% of chemical fertilizers in crop nutrition programme.

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Heterosis Study in Sunflower (*Helianthus Annuus* L.) Through Line X Tester Matting Design for Yield Attributing Traits

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Abstract

Heterosis is the increase or decrease in vigour of F_1over its mid or better parental value. One of the objectives of present study was to estimate the extent of heterosis for various characters and to isolate promising hybrids over standard check hybrids for seed yield and oil content for commercial exploitation on basis of SCA study. The development of new high yielding and stable sunflower hybrids based on hybridization which requires information on the heterotic effects for agronomically important traits in the F_1 generation. SCA effects for seed yield and it's attributing traits were studied in the sunflower hybrids developed by the line x tester method. There are significant differences among the sunflower genotypes (inbred lines and F1 hybrids) we tested with regard to the mean values of all the traits involved.

From the experiment it was revealed that the average heterosis of 8.9% for days to 50% flowering, 65.1% for plant height; 80.3% for head diameter;139.8% for seed yield(kg/ha);107.5% for number of filled seed/head; 5.9% for seed filling %; 10.8% for 100 seed weight, 12.1%for 100 seed kernel weight, 6.5% for hull content; 4.7% for volume weight(g/100 cc); 0.1% for oil content (%;) and 140.4% for oil yield (kg/ha) respectively. In all cross, seed and oil yield (kg/ha) traits and other desirable traits, P-2-7-1A, CMS-10 A, P-89-1A, EC-601958, R-104, EC-601978, R-138-2, R-630 and R-6D-1 were involved more frequently.

The studies revealed that, as regards performance *per se*, the best cross combination for semi-dwarf plant height coupled with good seed yield and high oil content, the superior cross combinations were P-2-7-1A X R-138-2 (66 days to flower, seed yield of 1932kg/ha and oil yield of 678 kg/ha,), P-89-1A X R-12-96(68 days to flower, seed yield of 1818 kg/ha and oil yield of 667 kg/ha), CMS-10A X R-630(66 days to flower, seed yield of 1798 kg/ha and oil yield of 662 kg/ha), P-2-7-1A X R-104(66 days to flower, seed yield of 1752 kg/ha and oil yield of 628 kg/ha) respectively showed significantly positive heterosis for seed yield, oil yield and other some yield attributing traits.

***Key words*: Sunflower, Heterosis, Seed yield, Yield components**

Introduction

Sunflower is an important oilseed crop with high quality of edible oil in the world. Sunflower hybrids are preferred by farmers, because of their uniformity, high yield performance, better quality and resistance to disease. Identification of superior parents for hybridization is an important step in plant breeding. Combining ability of parental lines should be estimated to find the best hybrid combinations. Furthermore, estimation of gene effects could be done by analyzing combining ability values based on F_1 mean values (Mijic *et al.* 2008). Combining ability of inbred lines could be estimated with various methods such as top cross. Line × tester analysis is an extension of this method in which several testers are used (Kempthorne 1957).

Heterosis of sunflower has been exploited only over the past few decades. Hybrid sunflower became a reality with the discovery of cytoplasmic male sterility and effective male fertility restoration system during 1970. Hybrid vigor has been the main driving force for acceptance of this oilseed crop. Utilization of heterosis has allowed sunflower to become one of the major oilseed in many countries of Eastern and Western Europe, Russia and South America and is an important crop in the USA, Australia, South Africa, China, India and Turkey. Sunflower hybrid breeding has thus played a vital role in improvement of this crop. Increasing seed and oil yields is the top priority of most sunflower breeding programs. Getting benefit from use of heterosis is the main purpose in sunflower hybrid breeding.

In India, the sunflower is grown on about 0.55 million ha (Anonymous, 2018) and mostly grown in the states of Karnataka, Maharastra, AP and Tamil Nadu with potential scope of growing in the non-traditional areas like West Bengal (Dutta, 2011). In West Bengal, Sunflower is second important oilseed crop after rapeseed-mustard during *rabi*-summer season and it was grown on about 16,000 ha in last *rabi* season, 2016-17(Annual Report, Dept. of Ag, GOWB). Due to short winter spell and delayed and heavy rainfall during rainy season, the sowing of mustard was delayed which ultimate reduced the production of rapeseed-mustard. The delayed sowing also invites the insect pests in most of the years. Sunflower being a photoperiod natural crop has wide scope to replace the rapeseed-mustard cultivation with high yield potentiality. Here Sunflower proved to be fitted with good seed and oil yield potentiality.

The main objectives of sunflower breeding programs are the development of productive F1 hybrids with high seed and oil yield. Sunflower oil yield is determined as the product of seed yield per unit area and the oil percentage in grains. Therefore, consideration of both components is important when breeding for high oil yield (Fick and Miller, 1997). National sunflower hybrid (development of new hybrid) breeding programme is a continuous programme which started in our country early 1980s. Sunflower hybrid breeding was started economically in discovering **CMS** by Leclercq in 1960 and restorer genes by Kinman in 1970 (Miller and Fick, 1997).

Materials and Methods

The crossing was affected in the line x tester fashion and the resultant hybrids were subjected to combining ability studies. The experiment was conducted in randomized complete block design with three replicates for two years 2015-16 and 2016-17 at AICRP-Sunflower, Nimpith Centre.

Specific combining ability (SCA) effects for seed yield and other yield attributing agronomic traits were studied in the sunflower hybrids. Four cytoplasmic male sterile lines were used as female lines while nine new male inbreds were introduced as testers in the form of fertility restorers. The female lines were introduced from IIOR-ICAR, Hyderabad and from other AICRP Centers, while the male restorer inbreds with good combining abilities were used as testers in the form of fertility restorers. F_1 hybrids were obtained by crossing each tester with each female inbred. The inbred lines and their F_1 hybrids differed significantly in their mean values of the traits under the present study.

The genotypes (parents and hybrids) were raised in Randomized Block Design with two replications where in each replications were represented by three rows of three meter length. The soil texture was clay loam in "On station" plots. Three irrigations were provided during the cropping period. One foliar spray was given with Boron (@ 2g/lit. of water in ray floret stage. The row per plot were five in number with a row spacing of 60 cm and plant to plant spacing was 30 cm. Uniform dose of fertilizer @80 kg N,40 Kg P_2O_5 and 40 kg K_2O per ha was applied. The germinated seed of sunflower used and one per hill were maintained throughout the cropping period. The data was recorded in ten randomly selected plants from each plot of all replications on the following characters *viz.,* days to 50% flowering, days to maturity, plant height at harvest (cm), head diameter per plant (cm), seed weight per head (g), 100-seed weight (g), husk (hull) content (%), volume weight (g/100cc). The seed yield (kg/ha), oil percentage and oil yield (kg/ha) were estimated on plot basis. The mean values were subjected to statistical analysis. In the very first year (2014-15), 36 of hybrids (developed from Line X tester matting design) were evaluated and next year, 2015-16 and 2016-17, 36 hybrids were evaluated for performance at research farm under AICRP Sunflower, Nimpith Centre in Randomized complete block design

Table 1. Combined analysis of variance for line X tester for yield and yield attributing traits

Source of variation	d.f.	Days. to 50% flowering	Plant height (cm)	Head Diameter. (cm)	No. of filled Grain/hd.	Autoga-my%	100.seed wt(g)	100 kernel Wt(g)	Hull Cont%	Vol. Wt. (g/ 100CC)	Seed. yield/ Plant(g)	Seed yield / (Kg/ha)	Oil cont. %	Oil Yield (Kg/ha)
Location	1	24.25**	1729.7**	13.45**	33467.8**	260.3**	0.612	0.97	1.85	207.41**	289.0**	528696.2**	59.64**	66543.5**
Repl./Loc.	2	17.02	283.9*	2.00	10101.5**	19.34**	0.78	0.027	2.57	11.10**	76.49**	240075.5**	3.05	36602.7**
Parents	12	54.83**	356.1**	2.28*	32009.7**	44.14**	2.59**	0.832	7.97**	4.03	34.48**	74735.3**	8.37**	14864.8**
Line	3	28.36**	313.4**	4.02*	1843.1**	13.93**	2.03**	0.554	8.94**	1.76	10.94**	32852.2**	3.54	26755.0**
Tester	8	38.46**	374.0**	1.90*	38434.6**	39.27**	1.81	0.807	8.43**	3.64	42.51**	99355.5**	11.18**	18374.5**
L *vs* T	1	265.1**	340.1**	0.142	71110.3**	173.8**	10.53**	1.870*	1.42	13.96**	40.86**	3424.0**	0.351	23354.0**
Hybrid	35	35.48**	438.6**	2.48**	38861.2**	36.28**	1.66	1.085	41.42**	9.88**	41.80**	127157.2**	10.63**	14507.3**
Parents *vs* F_1s	1	730.2**	120811.2**	1617.7**	380513.6**	1266.4**	22.33**	10.54**	179.1**	139.5**	11346.2**	39053520.1**	0.324	4193951.2**
Parents X Loc.	12	3.36	198.2**	0.685	1685.7**	2.45	0.0037	0.008	1.98	12.25**	8.19**	7206.2**	0.191	2277.0**
Line X Loc.	3	5.70	121.4**	0.005	153.7*	0.200	0.0009	0.002	0.511	13.75**	0.171	536.0	0.042	66.62
T X Loc.	8	0.005	127.4**	1.02	2272.7**	0.0008	0.006	0.001	0.0005	5.95	6.77	10055.4**	0.0045	1597.5**
(L *vs* T) X Loc	1	23.2**	995.3**	0.013	1585.5**	28.74**	0.037	0.08	22.22**	58.20**	43.69**	4423.9**	2.38	14347.2**
Hybrid X Loc	35	0.09	0.278	0.009	2842.1**	0.022	0.0014	0.0004	2.28	22.24**	41.85**	565.1**	0.143	326.46**
(Parents *vs* F_1) X Loc	1	13.30**	319.1**	2.81**	13364.6**	15.25**	0.018	0.007	1.51	15.87**	79.67**	10039.8**	1.05	23653.4**
Error	96	0.192	3.34	0.028	224.2	0.268	0.24	0.145	0.87	3.16	0.726	180.4	0.145	33.6

*, **: Significant at P=0.05 and 0.01, respectively

Table 2. Comparison of overall mean performance of parents and F_1s and average heterosis for yield attributing traits in sunflower

Character	**Parents** Mean	Range	F_1 Mean	Range	Mean F_1- Mean P	Average heterosis(%)
Days to 50% Flowering	62.50	56.7-70.16	68.08	62.68-73.15	5.58	8.9
Plant height(cm.)	88.78	78.3-100.6	146.60	142.90-176.5	57.82	65.1
Head Diameter (cm.)	8.11	7.10-9.45	14.62	13.30-15.80	6.51	80.3
Seed yield(kg/ha)	739.30	625-941	1772.51	1484.5-2303.4	1033.21	139.8
No. of filled seeds /Head.	309.32	251-450	641.82	444.45-880.50	332.5	107.5
Autogamy (Seed Filling) %	81.12	75.3-85.3	85.94	80.28-90.12	4.82	5.9
100 Seed weight(g)	4.62	3.16-6.10	5.12	4.26-5.76	0.5	10.8
100 kernel weight(g)	2.94	2.02-3.65	3.32	2.57-4.16	0.38	12.9
Hull content%	33.91	31.05-36.15	36.1	30.97-41.50	2.19	6.5
Volume Weight(g)	34.86	32.68-36.28	36.5	34.50-39.62	1.64	4.7
Oil%	35.38	33.25-37.60	35.4	34.53-37.40	0.02	0.1
Oil yield (kg/ha)	260.68	198.6-301.2	626.7	507.6-795.5	366.02	140.4

with three replications. The data pertaining to seed yield and other yield attributing traits for these test hybrids are presented in Table 4.

Results and Discussion

Heterosis is the increase or decrease in vigour of F_1over its mid or better parental value. One of the objectives of present study was to estimate the extent of heterosis for various characters and to isolate promising hybrids over standard check hybrids for seed yield and oil content for commercial exploitation. For our purposes, we will define heterosis or hybrid vigour as the difference between the hybrid and the mean of the two parents (Falconer and Mackay, 1996) that is mid-parent heterosis and better-parent heterosis which is preferred in some circumstances, particularly in self-pollinated crops, for which the goal is to find a better hybrid than either of the parents. The nature and magnitude of heterosis for seed yield and its component characters is helpful in heterosis breeding. The maximum utilization of heterosis is possible when the variance due to both additive and non additive gene actions are fully exploited since they play a significant role in determining the magnitude of expression of yield and its component.

Among the sunflower 36 hybrids, the heterosis was observed from 1.07 per cent (P-2-7-1A X R - 104) to 12.11 per cent (CMS-10A X EC-601958) for days to 50% flowering; 31.46 per cent (P-2-7-1A X R-630) to 87.26 per cent (CMS-10A X EC-601978) for plant height; 54.07 per cent (CMS-107 AX EC-601958) to 120.3 per cent (CMS-10A X EC-601978) for head diameter; 81.50 per cent (P-2-7-1A X R-630) to 233.15 per cent (CMS-10 A X R-104) for seed yield(kg/ha); 54.5 per cent (P-89-1A X R-630) to 252.2 per cent (CMS-10A X EC-601958) for number of filled seed/head; -3.14% per cent (CMS-10 AXR-138-2) to 13.38% per cent (P-2-7-1A X R-1-1) for seed filling % ; -15.3 per cent (CMS-10A XR-6D-1) to 13.38 per cent (P-2-7-1A X R-1-1) for 100 seed weight(g); -19.35 per cent (CMS-10A XR-6D-1) to 46.7 per cent (CMS-10 A X R-104) for 100 seed kernel weight(g); -16.2 3 per cent (CMS-10A X R-107) to 30.54 per cent (P-89-1A X R-1-1) for hull content; -9.13 per cent (CMS-10 A X R-630) to 15.24 per cent, (CMS-107A X R-104) for volume weight(g/100 cc); -9.80

Table 3. Performance *per se* of the sunflower hybrids (F_1) for yield attributing traits in sunflower

Sl. No	Hybrid combination	Days. to 50% flowering	Plant height (cm)	Head Diameter (cm)	Seed yield (kg/ha) Head	No .of filled seeds/	Autogamy (seed %	100 seed Filling) (g)	100 Kernel weight	Hull content wt (g)	Vol. Wt. (g/100cc) (%)	Oil content %	Oil Yield (Kg/ha)
1.	P-2-7-1A X R-6D-1	70.2	151.0	15.6	1927.8	789.2	87.2	5.45	3.67	37.0	39.9	37.6	723.9
2.	P-2-7-1A X R-12-96	66.2	155.2	15.2	1739.0	528.5	85.2	5.97	3.79	36.6	38.0	35.6	618.2
3.	P-2-7-1A X R-630	65.7	143.4	14.1	1692.8	679.8	84.2	4.65	2.91	39.3	37.8	35.5	600.9
4.	P-2-7-1A X R 601958	73.2	159.6	15.1	2303.4	691.5	88.2	6.25	4.15	34.7	36.4	34.5	795.4
5.	P-2-7-1A X EC-601978	69.7	150.3	14.2	1837.0	597.3	87.2	6.04	3.95	36.2	37.5	35.3	649.0
6.	P-2-7-1A XR-138-2	66.2	146.8	15.4	1932.8	628.6	87.2	5.37	3.44	36.5	37.7	35.1	678.4
7.	P-2-7-1A X R-1-1	67.7	146.0	13.7	1622.0	444.4	89.2	6.63	4.41	34.2	36.6	35.5	575.8
8.	P-2-7-1A x R -107	70.2	159.4	14.4	1798.0	563.7	88.2	5.44	3.53	36.0	37.5	35.7	641.9
9.	P-2-7-1A X R -104	66.2	145.0	13.8	1752.8	480.7	89.2	6.58	4.35	34.1	37.1	35.8	627.5
10	P-89-1A XR-6D-1	64.2	142.9	13.6	1573.0	558.5	88.2	4.93	3.12	36.3	39.7	37.5	589.9
11.	P-89-1A XR-12-96	67.7	161.5	14.1	1817.7	637.8	85.2	5.10	3.22	36.3	38.8	36.7	667.1
12.	P-89-1A X R-630	64.2	150.7	14.3	1484.5	604.1	80.3	5.01	3.22	37.5	38.1	34.2	507.0
13.	P-89-1A XEC-601958	72.2	153.4	15.1	2020.0	772.7	86.2	4.70	3.12	34.0	38.0	37.1	749.4
14.	P-89-1A X EC-601978	68.7	145.7	13.5	1682.00	606.0	90.1	5.36	3.59	33.7	37.8	37.7	633.6
15.	P-89-1A XR-138-2	64.2	152.9	13.2	1660.7	556.3	80.3	5.13	3.27	37.9	40.3	36.5	606.2
16.	P-89-1A X R-1-1	70.2	148.7	15.3	1910.2	703.9	84.2	4.80	2.84	41.5	38.1	35.8	682.9
17.	89-1A XR-107	68.7	160.4	14.3	1647.5	679.9	89.2	4.49	2.78	38.5	38.8	35.5	584.9
18.	P-89-1A X R-104	70.2	162.0	15.2	1967.7	799.1	84.2	4.45	2.76	36.8	39.3	36.7	722.1
19.	CMS-10A XR-6D-1	62.7	160.7	14.2	1521.7	677.0	87.7	4.10	2.50	39.3	39.8	35.3	536.4
20.	CMS-10A X R-12-96	71.2	168.0	15.7	1982.7	810.5	84.2	4.55	2.80	38.2	37.4	34.6	685.4
21.	CMS-10 A XR-630	66.3	159.8	13.8	1798.0	658.2	83.3	5.31	3.70	30.9	33.0	36.8	661.7
22.	CMS-10A X EC-601958	71.0	147.1	14.2	1859.0	793.3	86.2	4.76	3.14	38.3	37.5	34.2	635.8
23.	CMS-10A X EC-601978	70.0	152.9	15.4	1848.0	787.5	88.2	4.59	2.84	39.1	38.0	35.0	645.9
24.	CMS-10 AXR-138-2	63.0	161.0	14.8	1622.0	538.8	78.3	5.39	3.71	32.3	36.1	36.9	598.5
25.	CMS-10A XR-1-1	63.5	156.2	14.4	1547.0	527.7	89.2	5.36	3.57	34.1	37.6	36.9	570.8
26.	CMS-10A X R-107	65.5	152.1	14.0	1673.5	606.7	87.2	4.95	3.57	28.8	35.7	36.5	630.4
27.	CMS-10 A X R-104	69.5	157.9	15.4	2175.2	701.0	86.2	5.62	3.28	35.7	37.6	34.6	751.5
28.	CMS-107 A X R-6D-1	67.5	162.3	14.7	1791.7	734.3	84.2	4.55	3.06	33.7	35.4	35.6	636.9
29.	CMS-107A X R-12-96	73.5	178.6	15.8	1643.0	677.8	85.2	4.30	2.61	40.6	38.1	33.0	541.4

Contd.

Sl. No	Hybrid combination	Days. to 50% flowering	Plant height (cm)	Head Diameter (cm)	Seed yield (kg/ha) Head	No .of filled seeds/	Autogamy (seed %	100 seed Filling) (g)	100 Kernel weight	Hull content wt (g)	Vol. Wt. (g/100cc) (%)	Oil content %	Oil Yield (Kg/ha)
30.	CMS-107A XR-630	70.5	175.9	15.4	1864.5	781.5	80.3	4.26	2.61	39.6	40.2	35.7	665.6
31	CMS-107 AX EC-601958	70.5	148.7	13.8	1781.7	557.0	89.2	5.74	3.90	33.4	38.2	36.8	655.7
32	CMS-107A X EC-601978	70.5	145.1	13.3	1778.0	563.5	89.3	5.60	3.85	32.3	37.1	36.3	645.4
33	CMS-107A X R-138-2	66.5	168.1	14.4	1610.7	636.3	89.1	4.70	3.11	34.7	36.8	37.4	602.4
34	CMS-107A X R-1-1	65.5	161.1	15.3	1622.0	588.6	86.2	5.26	3.57	33.4	35.7	34.5	560.1
35	CMS-107A XR-107	69.5	169.0	15.4	1685.7	629.3	85.2	4.85	3.14	37.1	36.6	35.5	597.6
36	CMS-107A X R-104	70.6	176.0	15.7	1638.7	515.2	84.8	5.76	4.16	31.0	40.3	36.4	596.8
	G. Mean	68.0	146.6	14.6	1772.5	641.8	85.9	5.1	3.3	36.1	36.5	35.4	626.7
	Lowest	62.68 10A XR-6D-1	142.90 P-89-1A XR-6D-1	13.20 P-89-1A XR-138-2	1484.5 P-89-1A X R-630	444.45 P-2-7-1A X R-1-1	80.28 107A XR-630	4.10 10A XR-6D-1	2.50 10A XR-6D-1	28.84 10A X R-107	32.95 10 A X R-630	32.95 107A X R-12-96	507.6 P-89-1A X R-630
	Highest	73.50 107A X R-12-96	178.50 107A X R-12-96	15.80 107A X R-12-96	2303.4 P-2-7-1A X R 601958	810.50 10A X R-12-96	90.12 P-89-1A X EC-601978	6.63 P-2-7-1A X R-1-1	4.41 P-2-7-1A X R-1-1	41.50 P-89-1A X R-1-1	40.30 P-89-1A XR-138-2	37.55 P-2-7-1A X R-6D-1	795.5 P-2-7-1A X R 601958

per cent (1P-89-1A X R-1-1) to 7.02 per cent (CMS-10A X R-107) for oil content % and for oil yield (kg/ha) from 46.0 per cent (P-89-1A X EC-601978) to 199.6 per cent (CMS-10A X EC-601958).

From the experiment it was revealed that the average heterosis of 8.9% for days to 50% flowering, 65.1% for plant height; 80.3% for head diameter; 139.8% for seed yield(kg/ha); 107.5% for number of filled seed/head; 5.9% for seed filling %; 10.8% for 100 seed weight, 12.1%for 100 seed kernel weight, 6.5% for hull content; 4.7% for volume weight(g/100 cc); 0.1% for oil content (%;) and 140.4% for oil yield (kg/ha) respectively(Table 2).

Among the 36 sunflower hybrids, significant negative heterosis and lower values of performance *per se* for days to 50% flowering was recorded in sunflower hybrids *viz.,*P-2-7-1A X R-138-2 (66days), P-2-7-1A X R-104(66 days), P-89-1A X R-12-96(68 days) and CMS10A XR-630(68 days), where as fourteen crosses displayed significant positive heterosis. Higher values of performance *per se* for days to 50% flowering was recorded in sunflower hybrids *viz.,* P-2-7-1A X EC-601958 (73 days), P-89-1A X EC-601958(72 days) followed by P-2-7-1A X R-6D-1(70 days) and CMS-10 A X R-104 (71 days) respectively (Table-3). It was revealed that positive heterosis and lower values of performance *per se* for plant height was observed in sixteen cross combinations, among them P-2-7-1A X R-630(143.3 cm), P-2-7-1A XR-138-2(146.7 cm), P-2-7-1A X EC-601978(150.2 cm), P-2-7-1A X R-104(152cm), P-89-1A X EC-601958(153cm), CMS-10A X R-104(157cm),CMS-10A X EC-601958(147 cm),CMS-10A X EC-601978(152 cm), CMS-107A X EC-601958(148cm), CMS-107 A X EC-601958(145 cm) were found promising ones (Table 4).

Seventeen crosses displayed significant positive heterosis for head diameter, as per the positive heterosis and performance *per se,* the highest value was recorded in P-2-7-1A X R-138-2 (15.4cm), followed by CMS-107A X R-12-96 (15.8Cm), CMS-107A X R-104(15.7cm), CMS-10A X R-12-96(15.7cm), CMS-107A X R-630(15.4cm), CMS-10 A X R-104(15.4cm), P-89-1A X R-1-1(15.3cm) respectively which were found promising ones (Table 3 and 4). For number of filled seeds per head, significant positive heterosis were recorded in fifteen crosses among them, as per the performance *per se,* CMS-10A X R-12-96(810),P-89-1A X R-104(798), CMS-10A X EC-601958 (793), CMS-10A X EC-601978(787), CMS 107A XR-630(781), P-2-7-1A X R-6D-1(789) and P-89-1A X EC-601958(772) are found promising ones. For autogamy (seed filling) (%), significant positive *sca effects* and positive heterosis were recorded in twelve crosses among them, as per the performance *per se*, P-89-1A X EC-601958(90.2),CMS-10A X R-1-1(89.2), CMS-107AX EC-601958(89.2), CMS-107A X EC-601978(89.2) and CMS- 107A X R-138-2(89.2) are found promising (Table 3 and 4).

For 100 seed weight, very few crosses (eleven) displayed significant and positive heterosis. Among them, as per the performance *per se*, P-2-7-1A X R-1-1 (6.6) and P-2-7-1A X R-104 (6.6) followed by P-2-7-1A X EC-601978(6.2) and P-2-7-1A X EC-601958(6.04g) were found promising ones. For 100 seed kernel weight, positive heterosis was observed only thirteen crosses. Among them, as per the performance *per se*, the hybrids, *viz.,* P-2-7-1A X R-1-1(4.41), P-2-7-1A X R-104(4.35g), and P-2-7-1A X EC-601978(4.25g) are found very promising ones (Table 3 and Table 4).

For hull content (%), the lower values are desirable because hull content (%) has negative association with oil content and seed yield. Among the hybrids, very few (only twelve) crosses displayed significant negative heterosis for the same trait. Among the hybrids, as per the negative heterosis *and* performance *per se*, the hybrids *viz.,* CMS-10A X R-107(28.8), CMS-10A X R-630(30.8%), CMS-107A X R-104(30.9%), CMS-10A X R-138-2(32.2), CMS-107A X EC-6019178(32.2%) were found very promising. For volume weight (g/100cc), it was revealed that only seven crosses displayed significant positive heterosis. With regards to performance *per se,* P-89-1A XR-138-2(40.3) and CMS-107 X R-630 (40.2) followed by P-2-7-1A X R-6D-1 (39.8), CMS-10A X R-6D-1(39.8), P-89-1A X R-6D-1(39.7),CMS-107 X R-104 (39.6), P-89-1A X R-104(39.3) were found promising ones.

For seed oil content (%), only seventeen crosses displayed significant positive heterosis for the said trait, among them, with regards to performance *per se*, the hybrids,*viz.,*P-2-7-1A X R-6D-1(37.6), P-89-1A X EC-601978(37.7), P-89-1A X EC-601958(37.1), and CMS-10A X R-107(37.7) sunflower hybrids were the promising ones (Table 3 & 4). Among the 36 sunflower hybrids, as regards to the seed yield and oil yield (kg/ha), fifteen crosses displayed significant positive heterosis. Among them, with regards to performance *per se*, P-2-7-1A X EC-601958(seed yield of 2304 kg/ha, oil yield of 795 kg/ha), CMS-10 A X R-104 (seed yield of 2175 kg/ha, oil yield of 722 kg/ha), P-89-1A X EC-601958(2020 kg/ha, oil yield of 750 kg/ha), P-2-7-1A X R-6D-1(1927 kg/ha, oil yield of 724kg/ha), P-89-1A X R-104(1968 kg/ha, oil yield of 722kg/ha) were found very promising ones (Table 3 and Table 4).

The studies revealed that, as regards to heterosis and performance *per se*, the best cross combination for semi-dwarf plant height coupled with good seed yield and high oil content, the superior cross combinations were P-2-7-1A X R-138-2 (66 days to flower, seed yield of 1932kg/ha and oil yield of 678 kg/ha), P-89-1A X R-12-96(68 days to flower, seed yield of 1818 kg/ha and oil yield of 667 kg/ha), CMS-10A X R-630(66 days to flower, seed yield of 1798 kg/ha and oil yield of 662 kg/ha), P-2-7-1A X R-104(66 days to flower, seed yield of 1752 kg/ha and oil yield of 628 kg/ha) respectively negative heterosis for days to 50% flowering and significantly positive heterosis for seed yield and were involved type H x L and L × H (the parents with low *gca effects*).The above said crosses involved at least one parent with high *gca effects* with high seed yield at *per se* performance. The hybrid vigour and significant heterosis for economic trait can be exploited for commercial purpose. Such type of good with significant heterosis for yield attributing in sunflower was reported by Gourishankar *et al.,*(2007), Parmeshwarappa *et al.*, (2008), Binodh *et al.*, (2008),Mohanasundaram *et al.* 2010; Karasu *et al.* (2010), Chandra *et al.,*(2011), Patil *et al.,* (2012), Nandini 2013; Tyagi *et al* (2013), Suresha *et al.,* (2016).

Table 3. Heterosis (Mid Parent) of the Sunflower hybrids (F1) for yield and yield contributing characters : Pooled:-2015-16 and 2016-17

Sl. No	Hybrid combination	50% Flowering	Pl. Ht (cm)	Hd. Dia.(cm)	Seed Yield (kg/ha)	No. of Filled Grain/Hd	Autogamy %	100 seed wt(g)	100 Kernel Wt (g)	H.Cont. %	Vol. Wt. (g/100cc)	Oil%	Oil Yield (Kg/ha)
1.	P-2-7-1A XR-6D-1	3.15	**53.97****	84.08**	122.1**	108.94**	8.70*	5.9*	7.37*	4.39	3.35	-0.56	123.5**
2.	P-2-7-1A XR-12-96	4.91	**51.74****	67.62**	112.3**	128.15**	9.17*	-11.9**	-18.15**	23.14**	11.96**	-7.61**	80.9**
3.	P-2-7-1A XR-630	1.16	**31.46****	79.62**	81.5**	82.42**	4.18	-5.7*	-5.52*	14.17**	6.11*	5.81*	72.4**
4.	P-2-7-1A x R 601958	4.75*	**55.10****	68.45**	165.8**	165.93**	6.53*	9.2*	15.84**	1.43	4.82	-0.20	157.4**
5.	P-2-7-1A X EC-601718	8.71**	**66.63****	97.64**	211.4**	145.64**	7.72*	27.6**	35.18**	0.20	0.09	-3.41	182.3**
6.	P-2-7-1A XR-138-2	3.29	**52.73****	105.0**	129.0**	79.08**	10.51**	13.1**	17.41**	3.69	3.81	0.86	106.4**
7.	P-2-7-1A XR-1-1	4.22	**46.81****	64.07**	111.5**	63.85**	13.38**	27.3**	33.23**	1.64	3.91	3.20	107.4**
8.	P-2-7-1A xR -107	6.63*	**61.79****	67.83**	118.9**	89.11**	7.07*	5.4*	11.01**	1.26	2.72	4.69	114.6*
9.	P-2-7-1A XR -104	1.07	**40.06****	65.91**	130.0**	53.48**	13.02**	42.1**	53.71**	-5.07*	3.17	6.23*	117.4**
10	P-89-1A XR-6D-1	2.49	**63.58****	72.41**	112.2**	105.99**	11.06**	-1.2	-3.11	9.33**	8.60*	2.60	119.3**
11.	P-89-1A XR-12-96	3.50	**76.27****	68.06**	109.8**	75.17**	5.39*	15.9**	13.78**	9.70**	9.03*	5.01*	103.0**
12.	89-1A X R-630	1.25	**59.45****	89.91**	66.7**	54.55**	-1.89	17.1**	16.25**	15.08	7.17*	-0.58	48.7**
13.	P-89-1A XEC-601958	5.52*	**50.50****	67.08**	159.0**	149.56**	8.81**	9.8*	15.81**	-0.71	5.90*	4.06	168.9**
14.	P-89-1A X EC-601718	9.65**	**73.60****	106.2**	189.4**	157.78**	4.08	10.6**	13.45**	3.44	5.02*	1.50	46.0**
15.	P-89-1A XR-138-2	2.56	**72.98****	71.88**	107.0**	50.67**	0.51	25.1**	25.29**	13.50**	11.46**	2.53	88.8**
16.	P-89-1A XR-1-1	10.59**	**61.82****	90.54**	163.4**	143.18**	5.78*	5.3*	-5.33*	30.54**	8.75*	-9.80*	125.0**
17.	**89-1A XR-107**	6.77*	**76.07****	73.33**	111.3**	114.96**	7.00*	-0.4	-2.80	13.86**	6.72*	1.72	100.9**
18.	P-89-1A XR-104	9.59*	**69.83****	90.00**	173.2**	141.11**	5.45*	11.8**	9.96**	7.89*	9.89*	6.38*	157.2**
19.	CMS-10A XR-6D-1	2.89	**73.54****	87.34**	125.8**	167.04**	9.12**	-15.3**	-19.35**	15.78**	7.25*	-4.34	117.7**
20.	CMS-10A XR-12-96	11.77**	**84.93****	94.17**	148.1**	133.90**	2.95	7.1*	3.32	12.94**	3.43	-1.93	123.9**
21.	CMS-10 A XR-630	7.51*	**59.45****	91.94**	118.4**	76.35**	0.54	28.6**	39.62**	-7.19*	-9.13*	6.20*	107.7**
22.	CMS-10A XEC-601958	12.11**	**65.20****	83.23**	219.4**	252.23**	2.88	0.6	5.37*	10.76**	3.53	-6.30*	199.6**
23.	CMS-10A XEC-601718	9.24*	**87.26****	120.3**	193.0**	179.11**	5.20*	12.0**	7.58*	16.66**	3.38	-10.58*	141.9**
24.	CMS-10 AXR-138-2	3.57	**84.01****	101.4**	120.7**	53.22**	-3.14	36.5**	48.40**	-5.13*	-1.88	2.79	100.2**
25.	CMS-10A XR-1-1	2.92	**71.68****	87.01**	135.1**	94.10**	10.62**	21.5**	23.96**	5.02	5.42*	3.94	130.6**
26.	CMS-**10A XR-107**	4.67	**67.43****	76.92**	134.9**	103.11**	3.42	13.5**	29.82**	-16.23**	-3.69	7.02*	134.3**

Contd.

Sl. No	Hybrid combination	50% Flowering	Pl. Ht (cm)	Hd. Dia.(cm)	Seed Yield (kg/ha)	No. of Filled Grain/Hd	Autogamy %	100 seed wt(g)	100 Kernel Wt (g)	H.Cont. %	Vol. Wt. (g/100cc)	Oil%	Oil Yield (Kg/ha)
27.	CMS-10 AXR-104	3.55	**66.33****	100.5**	233.1**	123.38**	6.63*	46.7**	36.67**	16.96**	3.47	-3.59	182.3**
28.	CMS-107 A X R-6D-1	7.11*	**60.06****	68.00**	140.6**	169.53**	7.45*	-8.8*	-4.38	-1.23	-2.87	-7.70*	123.9**
29.	CMS-107A XR-12-96	11.77**	**82.98****	71.00**	88.9**	85.49**	6.70*	-2.3	-7.12*	19.37**	8.05*	-5.18*	65.1**
30.	CMS-107A XR-630	10.52**	**65.08****	83.77**	108.5**	99.29**	-0.69	-0.5	-5.09*	18.52**	14.24**	4.54	95.9**
31	CMS-107 AX EC-601958	7.75*	**51.81****	54.76**	172.9**	128.14**	8.95*	17.6**	26.62**	-3.88	7.82*	2.22	178.8**
32	CMS-107A XEC-601718	6.53*	**59.60****	62.8**	153.6**	87.19**	8.95*	31.8**	41.03**	-4.16	3.37	-0.14	136.1**
33	CMS-107A xR-138-2	5.67*	**75.94****	68.82**	99.9**	71.73**	13.02**	14.6**	20.08**	1.17	2.24	5.65*	87.9**
34	CMS-107A X R-1-1	2.66	**65.95****	72.30**	122.6**	102.43**	7.11*	15.4**	19.80**	2.24	2.47	-1.34	108.0**
35	CMS-107A XR-107	7.45*	**70.58****	69.23**	115.2**	98.13**	3.49	7.5*	10.56**	7.13**	1.26	-3.60	93.9**
36	CMS-107A X R-104	9.68*	**70.90****	76.84**	126.4**	54.84**	3.68	44.7**	67.07**	-11.44**	15.24**	6.18*	117.5**
	SEm (±) **MD.P**	**0.26**	**1.12**	**0.10**	**26.01**	**29.00**	**0.31**	**0.30**	**0.231**	**1.73**	**1.08**	**0.23**	**11.23**
	Lowest	**1.07**	**31.46**	**54.76**	**66.7**	**53.22**	**4.18**	**-15.3**	**-19.35**	**-16.23**	**-9.13**	**-10.58**	**46.9**
	Highest	**12.11**	**87.26**	**120.3**	**233.1**	**252.23**	**13.38**	**46.7**	**67.07**	**30.54**	**15.24**	**7.02**	**199.6**

Conclusion

From the experiment it was revealed that the average heterosis of 8.9% for days to 50% flowering, 65.1% for plant height; 80.3% for head diameter;139.8% for seed yield(kg/ha);107.5% for number of filled seed/head; 5.9% for seed filling %; 10.8% for 100 seed weight, 12.1%for 100 seed kernel weight, 6.5% for hull content; 4.7% for volume weight(g/100 cc); 0.1% for oil content (%;) and 140.4% for oil yield (kg/ha) respectively. In all cross, seed and oil yield (kg/ha) traits and other desirable traits, P-2-7-1A, CMS-10 A, P-89-1A, EC-601958, R-104, EC-601978, R-138-2, R-630 and R-6D-1 were involved more frequently.

The studies revealed that, as regards to *sca effects* and performance *per se*, the best cross combination for semi-dwarf plant height coupled with good seed yield and high oil content, the superior cross combinations were P-2-7-1A X R-138-2 , P-89-1A X R-12-96, CMS-10A X R-630, P-2-7-1A X R-104 respectively showed significantly high *sca effects* (negative) for days to 50% flowering, and significantly positive *sca effects* for seed yield and were involved type H x L and L × H (the parents with low *gca effects*).

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Evaluation of Promising Pigeon Pea Genotypes During *Rabi* in Coastal Odisha

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Abstract

Pigeonpea always face challenges from natural calamities, aberrant weather condition, severe attack of pod borer complex and competitive remunerative rainfed crop during *kharif* season. Need for horizontal expansion of pigeonpea encouraged for searching new niche. Hence effort has been made to find out suitable genotypes of pigeonpea for *rabi* condition . A Field experiment was conducted over two years (2016-17 and 2017-18) at the Centre for Pulses Research (OUAT), Berhampur-761001 to evaluate the performance of promising pigeonpea genotypes during *rabi* under irrigated medium land condition. Altogether 16 genotypes of Pigeonpea such as BRG-2, Laxmi (ICPL 85063), TTB-7, Asha (ICPL 87119), CO-6, Maruthi (ICP -8863), Surya (MRG-1004), PUSA-855, CORG-9701, UPAS-120, GC-11-39, Manak (H-77-216), TJT-501, PRG-176, GJP-1 and Sarita (ICPL- 85010) were taken in Randomized Block Design with two replications. The data revealed that pigeonpea variety Laxmi (ICPL 85063) performed best during both the years and recorded maximum number of fruiting branches / plant (7.88), pods/plant (46.5) and the grain yield (1742.4 kg/ha). Though variety BRG-2 recorded maximum seeds per pod (4.3) and 100seed weight (14.1g) as compared to all other varieties, but could not yield more due to less branching and number of pods per plant. *Bhusa* yield, stick yield and total dry matter production (TDMP) followed the same trend as the grain yield. Maximum harvest index (HI) was recorded with Laxmi (0.43) followed by CO-6 and TJT-501 (0.41). Significant variation was observed among pigeonpea genotypes in growth, yield attributes and yield parameters during both the years. Maximum gross return per hectare (Rs. 91473), net profit (Rs. 61,473/-), per day productivity (12.91 kg/ha/day), per day net return (Rs.455/ha/day) with B:C ratio (3.05) were obtained with variety Laxmi. Strong positive association was found between grain yield and number of effective pods per plant of pigeonpea (r=0.74). In general, reduction in plant height was observed with *rabi* sown pigeonpea crop as compared to *kharif* crop with delayed date of sowing, which might be due to agronomic dwarfing.

Key words: *rabi* pigeonpea, agronomic dwarfing, harvest index, net return, B:C ratio.

Introduction

Pulses are important for both soil and human health due to its inherent BNF capability with richness in protein and micro nutrients. In developing country like India, the small holder, resource poor and dry land farmers could not afford to derive their protein requirement from animal sources. Pulses are considered as the cheapest sources of dietary protein for these poor farmers. The rapid strides in population growth further aggravate the situation coupled with decrease in arable land available for pulses. Pigeonpea fits very well in various production niches. Pigeonpea (*Cajanus cajan* L.) always face challenges from natural calamities, aberrant weather condition, severe attack of pod borer complex and competitive remunerative rainfed crops during *kharif* season. Need for horizontal expansion of pigeonpea encouraged for searching new niche. Pigeonpea can be grown as *rabi* crop in areas with mild and short winter (Sharma et. al. ,1980). Puste and Jana (1990) recommended September sowing of pigeonpea in West Bengal. Venugopal and Rao (1999) recommended September sowing of *rabi* pigeonpea in Andhra Pradesh. Panda et.al. (2003) studied on the effect of NK fertilization on performance of yambean-pigeonpea intercropping system during pre-*rabi* and its residual effect on succeeding mung in West Bengal. Babu and Kalra (1989) studied nutrient management of rabi pigeonpea in Maharastra. Kanwar (1981) indicated the importance of early maturing pigeonpea for post-monsoon sowing. Mahalakshmi *et. al.* (2011)

reported the positive response of *rabi* pigeonpea to drip irrigation. Hence effort has been made to find out suitable genotypes of pigeonpea for *rabi* condition after harvest of early-medium paddy(120-125 days) or finger millet in up-medium land with irrigation facility in coastal Odisha.

Materials and Methods

A field experiment was conducted during rabi 2016-17 & 2017-18 under AICRP on Pigeonpea at the Centre for Pulses Research, OUAT, Berhampur(O) which comes under East and South Eastern Coastal Plain Zone of Odisha. Altogether 16 genotypes of Pigeonpea such as BRG-2, Laxmi (ICPL 85063), TTB-7, Asha (ICPL 87119), CO-6, Maruthi (ICP -8863), Surya (MRG-1004), PUSA-855, CORG-9701, UPAS-120, GC-11-39, Manak (H-77-216), TJT-501, PRG-176, GJP-1 and Sarita (ICPL- 85010) were taken in Randomized Block Design with two replications. The crop was sown on 10th of November during both the years at 30 X 10cm spacing in plot size 4mX3.6m (12lines of 4m) after harvest of finger millet in medium land in RBD with three replications. The soil was sandy loam with pH 5.8, low Organic Carbon (0.41 %), medium available Phosphorus (21.38kg/ha) and medium potassium (132.7kg/ha). The crop was received 6.75 mm &75mm rainfall (3 & 6 rainy days) during 44th standard week (29 Oct.-04 Nov.) to 13th standard week (25- 31Mar.) of 2016-17 &2017-18, respectively. Five number of irrigations were given at critical stages of growth. Recommended package of practice for *kharif* crop was followed in *rabi* crop. Observations on days to flowering, Plant height, yield attributes, grain yield, *bhusa* yield and stick yield were taken at harvest and analysed as per statistical procedure described by Panse and Sukhatme(1985). Total dry matter production (TDMP), harvest index and duration of the crop were also calculated. Economics including gross return, net return, per day productivity, per day net return and benefit-cost ratio were calculated and compared for economic feasibility. The correlation study was also made between yield and yield attributes for identification of strength of relation among variables.

Results and Discussion

Plant height

In general plant height of pigeonpea during *rabi* season found to be shorter than that of the *kharif* crop. Significant variation was observed in plant height of pigeonpea genotypes during *rabi* season. Data depicted in Table-1 revealed that maximum plant height of 120.1 cm was recorded with pigeonpea genotype Laxmi (ICPL85063) followed by Asha (118.2 cm), TTB-7 (113.6) and Maruthi (113cm). Dwarf plants were found with BRG-2 (76.9 cm), GC 11-39 (92.8 cm), PUSA-855 (96.8 cm) and Sarita (99 cm).

Yield attributes

Various yield attributes of pigeonpea genotypes were taken at harvest and placed in table-1. Number of primary fruiting branches showed significant variation due to different genotypes. The highest number of fruiting branches per plant (7.88) was recorded with Laxmi followed by TJT-501 (7.08). Significant variation on the number of effective pods/ plant was also observed among the pigeonpea genotypes. The maximum number of pod /plant (46.5) was obtained from Laxmi followed by CO-6 (41). Number of seeds/pod was also found to differ significantly as per genotypes. The maximum seeds/ pod was obtained from BRG-2 (4.3) and the lowest from UPAS-120 & Sarita (2.86). Boldest seed was recorded with BRG-2 (14.1g/100 seeds) and the smallest seeds with UPAS-120 (9.9g/ 100 seeds) (Table-1).

Yield

Conspicuous variation in Pigeonpea grain yield was observed with different genotypes of pigeonpea (Table-1). Significantly highest grain yield (1742.4 kg/ ha) was obtained from Laxmi followed by CO-6 (1510 kg/ha) and TJT-501 (1481.7kg/ha). Bhusa and stick yield followed the same trend. Maximum total dry matter production was registered with Laxmi (4056.1kg/ha).

Harvest Index (HI)

Harvest Index was calculated on proportion of grain yield to biological yield ie, total dry matter production of above ground parts to find out the dry

Table 1. Growth, yield and yield attributes of Pigeonpea genotypes during *rabi* in coastal Odisha. (Pooled of two year 2016-17&2017-18)

Sl.No.	Genotypes	Plant height (cm)	Primary fruiting Branches /plant	Pods /plant	Seeds /pod	100 seed wt.(g)	Grain Yield	Bhusa yield (kg/ha)	Stick yield (kg/ha)	TDMP (kg/ha) (kg/ha)	HI
V1	BRG-2	76.9	3.78	25.4	**4.30**	**14.1**	1107.6	498.8	1194.6	2801.0	0.40
V2	**LAXMI**	**120.1**	**7.88**	**46.5**	**3.37**	12.4	**1742.4**	**694.1**	**1619.6**	**4056.1**	**0.43**
V3	TTB-7	113.6	6.08	35.9	3.10	11.9	1281.6	566.7	1459.8	3308.1	0.39
V4	ASHA	**118.2**	6.43	36.4	3.30	12.5	1255.7	555.1	1431.3	3242.1	0.39
V5	CO-6	106.0	5.75	**41.0**	3.13	12.8	**1510.0**	**639.6**	**1560.2**	**3709.8**	**0.41**
V6	MARUTHI	113.0	6.00	33.8	3.10	11.6	1303.4	576.5	1433.7	3313.6	0.39
V7	SURYA	110.0	5.45	28.5	2.90	11.8	1040.1	568.6	1544.6	3153.3	0.33
V8	PUSA855	96.8	5.90	29.9	3.06	11.2	1204.5	532.2	1325.0	3061.7	0.39
V9	CORG9701	105.5	6.65	35.5	3.13	11.7	1404.6	582.1	1505.1	3491.8	0.40
V10	UPAS120	104.4	6.43	32.2	2.86	9.9	1310.7	562.2	1441.7	3314.6	0.40
V11	GC-11-39	92.8	5.88	33.8	2.41	10.2	841.4	416.2	1407.2	2664.8	0.32
V12	MANAK	102.4	6.05	35.9	2.87	10.6	1346.4	580.9	1441.1	3368.4	0.40
V13	TJT501	107.1	**7.08**	37.3	2.98	11.1	1481.7	571.3	1524.9	3577.9	0.41
V14	PRG-176	108.1	6.45	31.7	3.02	11.7	945.4	525.4	1339.6	2810.4	0.34
V15	GJP-1	110.7	6.55	33.1	3.13	**13.2**	878.9	495.5	1266.8	2641.2	0.33
V16	SARITA	99.0	5.65	30.5	2.86	10.2	985.8	506.4	1284.3	2776.5	0.36
	SEd	6.7	0.69	3.6	0.36	1.21	202.6	92.8	229.2	496.7	
	CD(5%)	14.4	1.48	7.7	0.77	2.59	434.2	198.9	491.2	1064.4	

Table 2. Economics of *rabi* pigeonpea in coastal Odisha. (Average of two year 2016-17&2017-18)

Sl.No.	Genotypes	Days to flower 50%	100% /plant	Duration (days)	Grain Yield (kg/ha)	Gross return (Rs/ha)	Cost of production (Rs/ha)	Net return (Rs/ha)	Per day productivity (kg/ha/day)	Per day net return (Rs/ha/day)	B:C ratio
V1	BRG-2	73	84	129	1108	58146	30000	28146	8.59	218	1.94
V2	**LAXMI**	75	86	135	1742	91473	30000	61473	12.91	455	3.05
V3	TTB-7	75	86	133	1282	67284	30000	37284	9.64	280	2.24
V4	ASHA	73	85	133	1256	65924	30000	35924	9.44	270	2.20
V5	CO-6	74	84	131	1510	79272	30000	49272	11.53	376	2.64
V6	MARUTHI	68	79	132	1303	68429	30000	38429	9.87	291	2.28
V7	SURYA	78	86	133	1040	54605	30000	24605	7.82	185	1.82
V8	PUSA855	73	86	133	1205	63236	30000	33236	9.06	250	2.11
V9	CORG9701	70	81	131	1405	73742	30000	43742	10.72	334	2.46
V10	UPAS120	70	81	131	1311	68809	30000	38809	10.00	296	2.29
V11	GC-11-39	78	87	135	841	44171	30000	14171	6.23	105	1.47
V12	MANAK	75	85	133	1346	70683	30000	40683	10.12	306	2.36
V13	TJT501	77	88	136	1482	77789	30000	47789	10.89	351	2.59
V14	PRG-176	73	85	134	945	49634	30000	19634	7.06	147	1.65
V15	GJP-1	77	88	136	879	46142	30000	16142	6.46	119	1.54
V16	SARITA	70	81	129	986	51752	30000	21752	7.64	169	1.73

Price of pigeonpea grain as per MSP 2016-17= 50.50/kg & 2017-18= Rs. 54.50/kg, Avg. Price=52.50/kg

matter partitioning to grain or the reproductive efficiency of crop as influenced by varying genotypes of pigeonpea during *rabi* season (Table-1). The maximum (0.43) being recorded with genotype Laxmi followed by CO-6 & TJT-501(0.41). Low vegetative growth of pigeonpea during *rabi* season as compared to *kharif* crops leads to lower stick yield and lower biological yield *i.e.* total dry matter production or above ground biomass without reducing per hectare grain yield. Higher plant density compensated the lower grain yield per plant and higher harvest index.

Economics

Economics for each genotypes was computed and presented in Table-2. The gross return was calculated on genotype basis by multiplying average grain yield of both year with average minimum support price (MSP) for both years (Rs.52.50/kg) and cost of cultivation was computed as Rs 30,000/ha. The highest gross return (Rs. 91,473/ha), net return (Rs 61,473/ha) and B:C ratio (3.05) was obtained from Laxmi followed by CO-6 (79272/ha, 49272/ha & 2.64 respectively). Per day productivity and per day net return were also calculated and the maximum (12.91kg/ha/day and Rs. 455/ha/day, respectively) being recorded with Laxmi followed by CO-6 (11.53kg/ha/day & Rs. 376/ha/day, respectively). Shortening of duration of same pigeonpea genotypes during *rabi* as compared to *kharif* results in higher per day productivity and per day net return, indicating its more economic feasibility.

Correlation study

Correlation refers to measure the strength and direction of linear relationship between two variables. Correlation among grain yield and growth & yield attributing characters such as plant height, fruiting branches per plant, pods per plant, seeds per pod and 100 seed weight were computed and the coefficient values placed in Table-3. The data revealed that there was strong positive association (r=0.74) between pods/plant and grain yield of *rabi* pigeonpea. Moderate positive associations of grain yield were found with plant height (0.4), fruiting branches/plant (0.47) and 100 seed weight (0.36). Strength of relationship between grain yield and seeds/pod was found weak (0.21). Plant height has strong positive association with fruiting branches/plant (0.77) & pods/plant (0.64). Pods/plant has positive strong association with fruiting branches/plant (0.75).

Conclusion

Agronomic dwarfing (dwarfed plant height with delayed sowing towards shorter day length), shortening of maturity period and synchronous maturity were noticed with *rabi* sowing of pigeonpea irrespective of genotypes. The maximum values of growth and yield attributing factors and ultimately maximum grain yield, TDMP and harvest index were registered with genotype Laxmi (ICPL 85063) followed by CO-6 & TJT-501. Highest gross return, net return, per day productivity, per day net return and B:C ratio was also obtained from same genotype (Laxmi). It can be concluded that after harvest of *kharif* paddy (120-125 days) or finger millet in up-medium land with irrigation facility in coastal Odisha, pigeonpea genotype Laxmi, CO-6 and TJT-501 should be recommended to farmers for higher profitability and soil health.

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TABLE 3. Correlation of grain yield with growth & yield attributes of pigeonpea during *rabi* season

Variables / *Variables*	Plant Height (cm)	Primary Fruiting branches/pl	Pods/pl	Seeds/pod	100seed weight (g)	Grain yield (kg/ha)
Plant height (cm)	1					
Fruiting branches/pl	0.767753	1				
Pods/pl	0.640092	0.751956	1			
Seeds/pod	-0.28288	-0.40369	-0.14436	1		
100seed weight(g)	0.246748	-0.04402	0.031678	0.698056	1	
Grain yield (kg/ha)	0.399137	0.473847	**0.740123**	0.214894	0.361787	1

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Assessment of Cardiac Strain in Male Paddy Cultivators Using Two Different Type of Paddy Thresher: a Comparison

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Abstract

Agriculture is one of the important occupations in India and also in the focal state of West Bengal, providing livelihood to a large number of our countrymen; the human resources are exposed to multiple environmental and occupational stressors that can contribute to adverse personal health outcomes. In the context of climate change becoming a reality, and reports of adverse health consequences including performances getting affected in different occupational settings in different parts of India, a study has been undertaken to assess the effect of workplace heat exposure on cardiac strain among the paddy cultivators. Cardiac strain indicators-heart rate $_{peak}$, estimated energy expenditure, human physical drudgery index, and discomfort indexwere estimated. From the study it may be concluded that, the agricultural workers experienced 'heavy' to 'very heavy' degree of physiological strain during the threshing task.

Key words: agriculture, WBGT, DI, PSI, cardiovascular strain.

Introduction

Paddy cultivation involves - ploughing, transplanting, reaping, threshing and parboiling and in India are to large extent non - mechanized tasks; requiring substantial physical involvement of a large number of human resources [1-2]. Moreover, the agricultural work is generally seasonal, and during summer harvest, workers often spend long hours under direct sun, in intense heat, performing arduous physical labour [3-4]. These manual tasks may be physically demanding through their energy requirements and are commonly regarded as a source of the drudgery [5-6]. In this backdrop, a study has been undertaken to assess the effect of workplace heat exposure on cardiac strain among male paddy cultivators primarily engaged in paddy threshing task using mechanical only type of paddy thresher and compare it with the human resources of comparable age engaged in traditional manual threshing task during the period of 'Boro' type of paddy cultivation.

Methodology

Human resources engaged in agricultural task in the district of Hooghly were approached for participation in the study. 39 adult male agricultural workers (age range of 21 – 30 years)primarily engaged in paddy threshing task using mechanical only type of paddy thresher and 47 male agricultural workers, of comparable age group, and same ethnic background engaged in traditional manual threshing task i.e. separating the grains from the rice straw by beating on hard or wooden object respectively constituted the threshing group 1 (TG1) and threshing group 2 (TG2). Information regarding their age (year), ethnicity, socio – economic status (SES) - assessed by using the Kuppuswamy's socioeconomic scale [7], working experience (year), and average working time (hr. day^{-1}) were recorded. Ambient temperature (T_a) (ºC), wet bulb temperature (T_{WB}) (ºC), globe temperature (T_g) (ºC) and natural wet bulb temperature (T_{nwb}) (ºC) were periodically noted. The values of wet bulb globe temperature (WBGT) (ºC) [8], corrected effective temperature (ºC) [9],discomfort index (DI) (ºC) and physiological strain index (PSI) [10] were found out.Stature (cm) and body weight (BW) (kg) were measured. Body mass index (BMI) and body surface are (m^2) were calculated. The pre work heart rate ($HR_{Pre-work}$) (beats. min^{-1}), systolic and diastolic blood pressure ($SBP_{Pre-work}$) and ($DBP_{Pre-work}$) (mm Hg) were recorded using automated blood pressure monitor. Physiological strain indicators - peak heart rate (HR_{peak}) (beats.min^{-1}) [11], estimated energy expenditure (EEE) (kcal.min^{-1}) [12], human physical drudgery index (HPDI) and drudgery index[13] were found out. The 'heaviness' of workload has also been adjudged. Different working postures adopted by the agricultural workers during the threshing task were analyzed with the rapid upper limb assessment (RULA) [14] and rapid entire body assessment (REBA) [15] methods. Data were collected during the period of April – middle of May. The environmental and cardiovascular response data were collected at regular intervals during morning [6 - 9am], around noon [9.30 -10.00 am to about 1pm] and [3.00pm-5 pm] respectively referred to as first (S1), second (S2) and third spell (S3). The thermal environmental conditions were assessed in terms of several indices, the correlation between them was found out. Cardiac strain was adjudged by several indices, the Analysis of variance (ANOVA) was carried out. P value lower than 0.05 ($P<0.05$) was considered significant.

Results

The general characteristics of the study participants of both the groups are presented in Table 1.

Discussions

In the present study the mean values of BMI of TG 1 and TG 2 individuals are were in 'normal weight' category as per WHO [16]. This finding is in agreement with the findings of earlier studies [17-22]. In terms of thermal working environment status in the first spell, there is no restriction on 'light' type of work, for 'moderate' type, upto 75%, for 'heavy' type, upto 50%, for very heavy', upto 25% of time, each hour work is allowable in work rest cycle. In the second and third spell, no work is ideally allowable [23]. In terms of CET in the first spell, there is no restriction recommended against carrying out of the work. Whereas in second spell, no work is ideally allowable; and during the third spell upto 'moderate' category of work can be carried out [24]. In terms of DI in the first, second and third spell of the working hours heat load is considered severe, and human resources engaged in physical work are at increased risk for heat illness[25]. Whereas in terms of PSI the second and third spells, no work is ideally allowable [26]. The trend of the result regarding thermal working environment in terms of WBGT, CET, DI and PSI in agreement with the findings of earlier studies [27-29]. However, the values of these four indices are indicating similar environmental condition. This is further affirmed by significant positive correlation among these four heat indices. The environmental heat load might be one of the reasons for increased physiological strain.

In the present study the HR_{peak} value for the TG 1 individuals was 138.2, ± 8.05 beats. min^{-1}. The HR_{peak} value for the TG 2 individuals was 158.4, ± 8.14) (beats. min^{-1}) [Fig. 2 (a)]. On the other hand, average EEE values in TG 1 individuals ranged between 6.9, ± 1.15 kcal.min^{-1} whereas in case TG 2 individuals, it ranged between 7.69, ± 1.57 kcal.min^{-1} [Fig. 2(b)], this finding was in consonance with the finding of an earlier study [30]. The trend of the result in consonance with the findings of an earlier study carried out in male agricultural workers engaged in manual paddy threshing task [31]. Cardiac strain of the study participants was also assessed using HPDI and drudgery index. HPDI score was significantly higher in all the three working spells in TG 2 individuals compared to their age matched TG 1 counterpart. Higher values of HPDI score denoting the less working effectiveness. Another important marker of the human physical performance is drudgery index. The values of drudgery index were significantly higher in case of TG 2 individuals compared

TABLE 1. General characteristics of study participants

Variables	TG1	TG2
Age (years)^	25.8 ± 3.52	27.0 ± 3.55
Ethnic background	Bengalee	Bengalee
SES^	Lower Middle	Lower Middle
Working experience (year)^	7.7 ± 1.89	8.3 ± 1.25
Working time ($hr.day^{-1}$)^	7.5 ± 0.81	7.3 ± 0.55

AM ± SD, ^ns

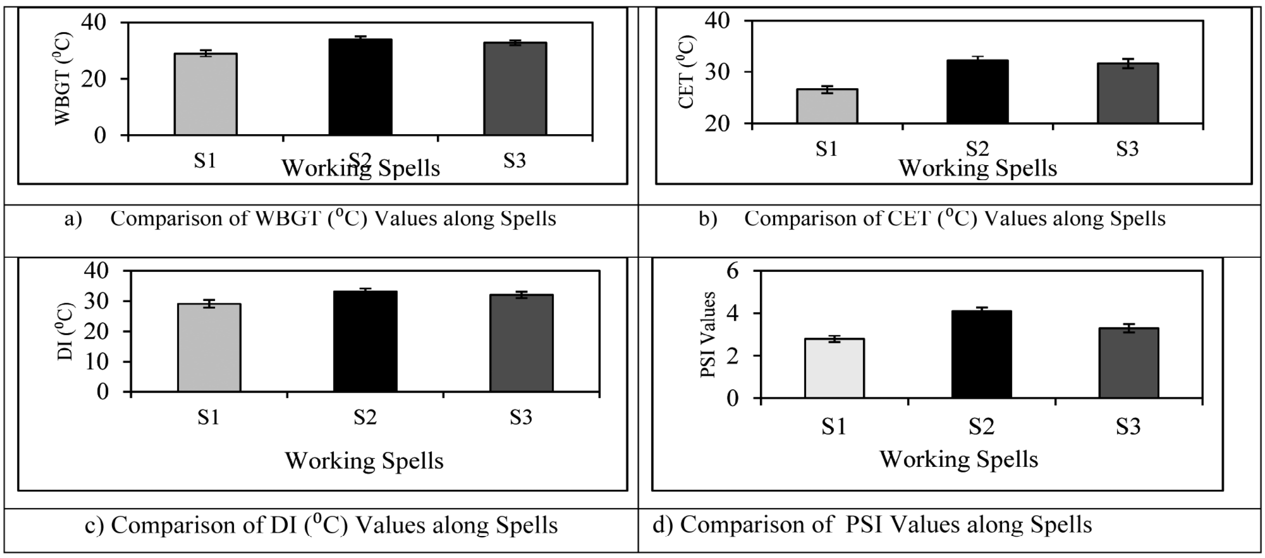
The physical and physiological variables of the study participants are presented in Table 2.

TABLE 2. Physical and physiological characteristics of the study participants

Variables	TG1	TG2
Stature (cm)^	164.7 ± 5.15	163.0 ± 4.95
BW (kg)^	55.0 ± 7.17	57.1 ± 5.11
BMI^	20.6 ± 3.17	21.7 ± 4.07
BSA^	1.61 ± 0.072	1.63 ± 0.092
$HR_{Pre\text{-}work}$ ($beats.min^{-1}$) ^	69.0 ±5.09	71.0 ± 6.14
$SBP_{Pre\text{-}work}$ (mm Hg)^	121.0 ± 8.19	122.0 ± 9.11
$DBP_{Pre\text{-}work}$ (mm Hg)^	71.0 ± 7.15	73.0 ± 6.19

AM ± SD, ^ns, *P<0.05

Thermal environmental status- WBGT, CET, DI and PSI are presented in figure 1.



a) Comparison of WBGT (°C) Values along Spells

b) Comparison of CET (°C) Values along Spells

c) Comparison of DI (°C) Values along Spells

d) Comparison of PSI Values along Spells

Figure 1: Comparison of Indicators of Thermal Environmental Status along the Working Spells S1 , S2, and S3

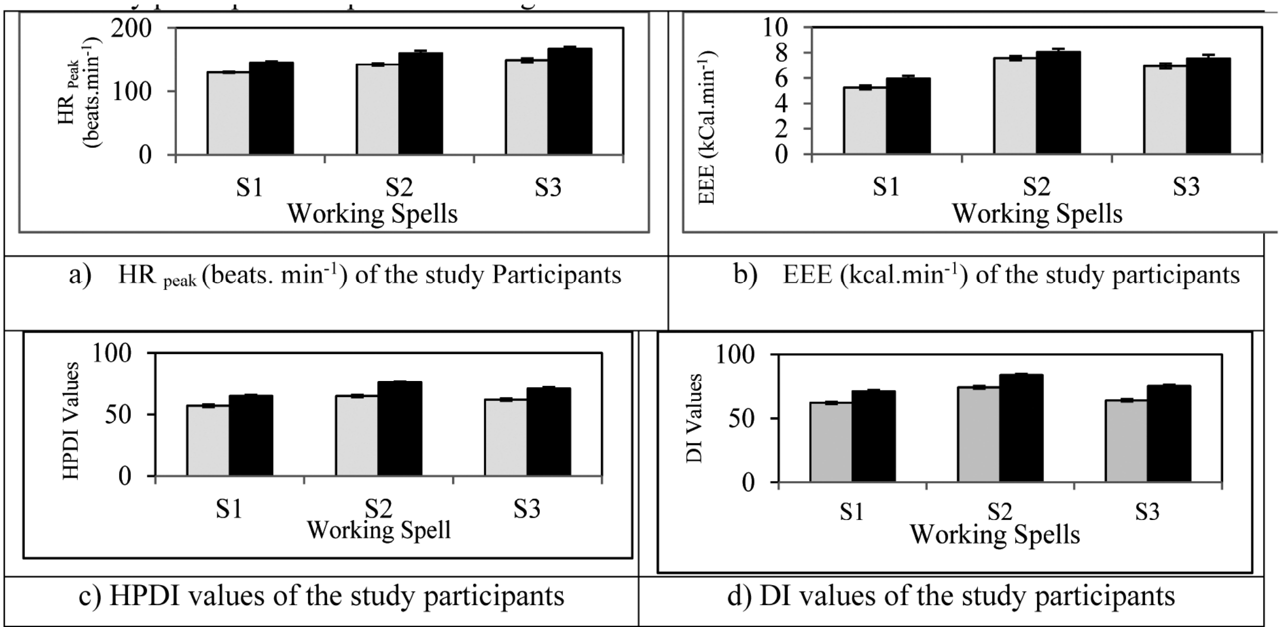
The heaviness of workload in terms of different indices of physiological strain is presented in Table 3.

Table 3. Heaviness of workload in terms of indices of physiological strain

Indices of Physiological Strain	TG 1 Working Spell			TG 2 Working Spell		
	S1	**S2**	**S3**	**S1**	**S2**	**S3**
HR_{peak} (beats. min^{-1})	H	VH	H	VH	EH	EH
NCC (beats. min^{-1})	H	H	H	H	H	H
EEE (kcal.min^{-1})	H	VH	H	VH	EH	EH
ACC (beats.min^{-1})	M	H	H	H	VH	VH

H- Heavy, VH- Very Heavy, EH- Extremely Heavy

The indices of cardiac strain in terms of HR_{peak} (beats. min^{-1}), EEE (kcal.min^{-1}), HPDI and drudgery index score of study participants are presented in figure 2.



a) HR_{peak} (beats. min^{-1}) of the study Participants

b) EEE (kcal.min^{-1}) of the study participants

c) HPDI values of the study participants

d) DI values of the study participants

Figure 2: Comparison of Indices of Cardiac Strain along the Working Spells TG1 G 2

to their age matched TG 1 counterpart. The finding of the present study regarding the human performance was also in consonance with the findings of earlier studies [32-34]. In so far as assessment of intensity of workload is concerned, the TG 2 group has been found to be most stressful in terms of indicators of physiological strain. It was observed that the human resources experienced highest degree i.e. 'extremely heavy' degree of physiological strain while engaged in manual (beating the panicles on a hard or wooden surface) paddy threshing task compared with the other task during paddy cultivation period- ploughing (dry and wet ploughing) [1, 4, 27-29, 34], transplanting (manual) [1. 2, 30, 35], reaping (manual) [1, 32], threshing (manual threshing and /or by mechanized thresher and electrically driven paddy thresher) [1, 5, 31] [and, parboiling (manual) [1, 33]. The working posture of each subject was studied by using RULA and REBA method. In the present study in case of RULA and REBA methods the postural score was significantly higher in case of TG 2 compared to their age matched TG 1 counterpart.Similar trend of results also observed among the agricultural workers occupationally engaged in threshing task during the period of paddy cultivation [6]. The finding of the present study regarding the cardiac strain was in consonance with the finding of an earlier study conducted among the paddy cultivators occupationally engaged in threshing task (by mechanized paddy thresher or electrically driven paddy thresher) during 'Aman' type of paddy cultivation that reports threshing task was found to be a heavier task of paddy cultivation [31]. This is further affirmed by the finding of the present study carried out during the 'Boro' type of paddy cultivation. The results of the present study indicated that, work in a warm humid condition is more stressful than doing the same in lower environmental temperature.

Conclusion

From the result of the present study it may be concluded that, cardiac strain was significantly higher in TG 2 individuals compared to their age matched TG 1 counterparts; as adjudged by the indices of cardiac strain. Agriculture being an open sky occupation and manual threshing is one of the strenuous tasks in paddy cultivation there is need for attempt to use more human factor designed devices than absolutely being dependent on manual effort. The strain could be minimized by implementing- sufficient work-rest pauses, water intake, and required some personal protective equipment.

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Evaluation of Yield Potential and Standardization of Seed Production and Storage Technique in Okra Under West Bengal Condition

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Abstract

Out of five varieties under evaluation, Pusa A 4 has been identified as the automatic choice for cultivation in West Bengal for its yield potential and resistance to yellow vain mosaic virus. The variety recorded higher yield of green vegetable and seed along with higher seed quality when sown dring 20th February to 1st April and also on 30th July for the 2nd time in the year. The seeds collected from fruits of node number 4 to 14 showed better quality. Seed longevity was higher when it was kept in metal container under ambient temperature.

Key Words: *Okra, Vegetable Yield, Seed Yield, Seed Quality.*

Introduction

Okra is one of the most important and popular delicious summer vegetable of West Bengal. Being comparatively cheap, easy availability and nutritional quality, it is an essential vegetable in Indian diet. The young tender fruits are good source of vitamins A,B,C and rich in protein, minerals and iodine. The crop is profitably grown in West Bengal but there is a big gap in between demand and supply of quality seeds. Keeping this in view the present work aimed at identification of suitable variety for profitable cultivation along with standardization of its quality seed production in West Bengal condition.

Materials and Methods

Experiments were conducted during February, 2014 to April, 2018 at Regional Research Station, Barrackpore (22R 46'N, 88R 24'E & 7.5 m above MSL), North 24 Parganas, West Bengal, India, Five varieties were evaluated for their yield potential in randomised block design with three replications in the year 2014 & 2015. Plots size was 30 square metre. The selected variety i.e., Pusa A 4, was again evaluated under different dates of sowing to identify the optimum time of crop production for vegetable yield, seed yield and seed quality in the following year i.e., in 2016. For this purpose seeds were sown in six splits at 40 days intervals following RBD design with three replication in each. Seeds were collected from different nodes separately (starting from 1 to 18) to identify the position of fruits on the plant which contain seeds with higher quality.

Farm Yard Manure @ 15 t/ha and N.P.K @ 90:60:60 kg/ha was used as basal dose. To quantity virus (Yellow Vain Mosaic) infection a scale of 0-5 was used where 0 and 5 indicate no infection and severe infection respectively. To protect the crop from insect-pests and fungal diseases standard measures were taken. Harvested seeds were properly sun dried for 3-4 days, graded, treated with thiram @2g/kg and kept in six kinds of containers made of cloth, jute, polythene, plastic, metal and glass and stored under ambient temperatures. Standard germination test was carried out at required intervals adopting paper towel method (Anonymous, 1985). Speed of germination and vigour index were assessed following Maguire (1962) and

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Abdul Baki and Anderson (1973) respectively. The period of seed viability or useful life-span of seed was calculated as follows:

Useful life-span of seed = Date up to which a seed lot maintains its germination as low as 65% (the standard of okra) - date of seed extraction.

Result and Discussion

Out of five varieties under study, Pusa A 4 and Parvani Kranti performed better with respect to their fruit and seed yield (Table 1). But due to susceptibility of Pravani Kranti to yellow vein mosaic virus it may not be recommended for cultivation in southern West Bengal. As regard to vegetable yield of Pusa A 4, it was observed that seed sowing during 20th February to 1st April and again on 31st July were ideal for profitable cultivation as individual fruit weight, fruit length and number of fruit/plant were higher as compared to those observed in remaining sowings schedules (Table 2). As regards to seed yield and seed quality, seed sowing in between 20th February and 1st April proved to be the ideal. During this period of sowing seed yield along with number of mature fruits/plant and test-weight of seeds were higher than those of other sowing schedules. For seed quality parameters like germination (%), speed of germination, seedling length, vigour index, field emergence and finally useful life-span of a seed lot, the 1st, 2nd and 5th date of seed sowing had recorded better performance.

It was also observed that higher vegetable yield didn't correspond to higher seed yield (Table 2). Though the 6th date of seed sowing (i.e., 10th September) recorded higher vegetable yield but its seed yield was very poor. On the other hand, the 3rd date of sowing (i.e., 10th May) produced higher seed yield than the 6th (i.e., 10th September) but its vegetable yield was lower than the latter. It seems that for higher vegetable and seed yield the crop needs differential environmental requirements. In the present study, 20th June and 10th September sowing not only produced poor seed yield, but their quality parameters were also not upto the mark. Even seeds produced under these two sowing schedules didn't show standard germination (i.e., 65%). The prevailing frequent and heavy rainfalls along with cloudy weather in the former and cooler weather in the latter during grain filling stage might have adversely affected seed yield and seed qualities.

The node –wise fruit collection for assessment of seed content and seed quality showed that fruits collected from 4th to 15th nodal position produced seed of higher quality as reflected from their germination (%), vigour index, period of seed viability etc (Table 3). It was observed that fruits developed at younger stage (at nodal position 1, 2 & 3) and at older stage

Table 1. Yield potential of different varieties of okra (Average of 2014 & 2015)

Characteristics	Pusa A-4	Parvanti Kranti	Pasupati	Anamika	Abhay	CD(at 5%)
Days to 50% flowering	34	27	30	31	24	1.5
Days to plucking of green fruit	43	34	38	40	31	1.8
Weight of green fruit(gm)	17.82	20.37	17.94	16.28	18.00	0.8
Length of green fruit (cm)	15.88	17.61	17.96	15.69	16.80	0.7
Plant height(cm)	118.80	134.40	135.50	125.60	132.50	5.8
Number of fruits/plant	22.21	17.28	15.03	15.12	11.79	1.8
Number of seeds/fruit	31.50	42.60	32.10	43.70	37.10	2.6
Vegetable yield (t/ha)	15.455	13.772	10.379	10.127	9.318	1.450
Expent of virus(YMV) infestation	1	4	0	5	4	-
Seed Yield(t/ha)	0.785	0.990	0.603	0.610	0.524	0.105

Date of seed sowing= 15th March of 2014 & 2015

TABLE 2. Effect of time of seed sowing on fruit yield, seed yield and seed quality in Pusa A 4 in 2016

Characteristics	Dates of sowing						C.D. (at 5%)
A. Fruit yield parameters							
1.Date of seed sowing	Feb. 20	Apr. 1	May 10	Jun. 20	Jul. 31	Sep. 10	
2.Days to 50% flowering	49	40	38	41	36	39	1.3
3.Days to picking of green fruits	54	45	46	48	42	45	1.5
4.Plant height(cm)	162	164	152	167	154	115	4.5
5.Fruit weight(g)	14.5	15.4	13.2	13.8	14.1	13.5	0.8
6.Fruit length(cm)	11.1	14.1	13.2	12.7	13.9	12.2	1.0
7.Fruit /plant (No.)	22	24	14	13	18	15	1.8
8.Fruit yield(t/ha)	13.89	15.13	10.96	7.01	12.41	8.60	1.15
B. Seed yielding parameters							
1.Date of picking of mature fruits	122	113	106	95	96	106	3.7
2.Mature fruits/plant (No.)	20	21	12	11	15	10	1.2
3.Total seeds/fruits(No.)	34	38	31	26	31	30	1.5
4.1000 seed weight(g)	72	69	54	51	60	58	1.6
5.Seed yield (t/ha)	0.940	0815	0.482	0.347	0.671	0.271	0.27
C. Seed quality parameters*							
1.Germination (%)	86	85	70	52	76	56	3.1
2.Speed of germination	14.6	16.9	16.4	9.3	18.6	11.4	1.2
3.Seedling length(cm)	8.6	6.9	6.9	7.8	8.0	6.7	0.8
4.Vigour index	7396	5865	4830	4056	6080	3752	314
5.Field emergence(%)	72	74	54	20	62	43	4.5
6.Seed viability (months)	15	14	06	-	12	-	1.7

*Tested after three months of seed harvest

(nodal position 16 to 20) produced seeds in less number with sub-standard quality. The poor seed quality of the fruits developed at older stage of plant growth may be due to shrinkage of source size (photosynthetic leaf area) of the plants hampering grain filling and others. However, on the other hand, the cause (s) of poor seed quality of fruit developed at younger stage needs elaborate study.

It was observed that okra seeds stored in vapour-tight containers like polythene, plastic jar, glass or metal showed longer period of seed viability as compared to other moisture permeable containers (Table 4). The moisture permeable containers allowed water vapour to move inside the seed, which are being hygroscopic in nature, especially during the rainy periods. It might have accelerated deterioration of seed quality. Among the vapour tight containers, metal box proved to be the most ideal for keeping okra seeds for a longer period under good condition.

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Table 3. Position of fruits showing seed content and seed quality in Pusa A 4(2016)

Nodal position	Seeds/ fruit (No.)	1000 seed weight(g)	Seed quality tested after three months of seed extraction					
			Germination (%)	Speed of germination	Seedling length (cm)	Vigour index	Field emergence (%)	Useful life-span of seed (month)
1st	23.1	20.1	77	35.5	6.3	4851	65	14.3
2nd	24.9	70.3	81	40.0	5.9	4779	68	14.3
3rd	26.2	69.9	80	39.3	6.8	5440	68	14.0
4th	37.5	71.2	84	42.0	7.4	6216	78	15.6
5th	41.7	69.5	86	43.0	8.2	7052	69	15.3
6th	43.3	68.7	82	41.5	7.1	5822	72	17.6
7th	42.4	68.8	75	39.3	5.9	4425	68	17.0
8th	43.5	71.5	89	39.5	5.8	5162	78	17.3
9th	44.7	71.0	89	39.8	6.6	5874	84	16.0
10th	43.0	68.2	90	36.2	6.4	5760	85	16.6
11th	42.8	70.3	91	40.5	6.5	5915	82	17.0
12th	41.6	68.6	83	41.5	7.4	6142	75	16.0
13th	39.6	70.1	83	38.5	5.8	4814	75	17.3
14th	42.8	71.2	89	39.5	6.5	5785	80	16.6
15th	38.3	68.9	84	40.2	6.7	5628	81	16.0
16th	30.2	65.2	75	35.4	6.4	4800	70	16.3
17th	38.6	63.4	67	32.6	6.9	4623	62	14.0
18th	21.7	59.8	68	30.4	6.5	4420	50	12.6
19th	17.4	54.6	71	30.6	6.5	4615	55	12.6
20th	13.0	53.8	66	31.2	6.3	4158	48	12.0
CD (at 5%)	2.2	1.8	4.3	2.1	0.4	515	3.0	1.0

Date of sowing=15th March
For study of shelf -life seeds were tested at three month interval

Table 4. Effect of storage container on seed viability in Pusa A 4

Storage container	GERMINATION (%)					
	3 MAH	6 MAH	9 MAH	12 MAH	15 MAH	18 MAH
1. Gunny (moisture permeable) (thickness=1.0 mm)	75+	75+	76+	57	20	00
2. Cloth (moisture permeable) (thickness=0.5 mm)	74+	72+	78+	56	29	00
3. Polythene (vapour tight) (thickness=700 gauge)	74+	76+	73+	71+	63	17
4. Plastic (vapour tight) (thickness=1.0 mm)	72+	76+	84+	77+	70+	31
5. Glass (vapour tight) (thickness=2.0 mm)	75+	82+	86+	86+	74+	49
6. Metal (vapour tight) (thickness=0.5 mm)	73+	81+	87+	85+	81+	66+
C.D. (at 5%)	3.4	3.1+	3.5	3.8	4.2	4.3

'MAH' stands for Month After Harvest,
'+' stands for germination (%) higher than standard i.e.,65%

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Effect of Organic Matter on the Changes in P Content under Waterlogged Soil Conditions

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Abstract

An incubation experiment has been conducted in the laboratory of Department of Agricultural Chemistry and Soil Science, University of Calcutta to find the effect of organic matter on the changes in P content under waterlogged soil conditions. After application of all treatments, maintaining waterlogged condition, the soils were allowed to incubate at room temperature (30±2)º C for a period of 10, 20, 30, 40, 50 days interval and analyzed for different fractions of P. The amount of Soluble and Loosely bound P fractions has been recorded highest (47.50 mg kg^{-1}) in the treatment P_2OM_2 at 30 days of incubation. As regards to the interaction effect between P and organic matter it was observed that the amount of Al-P was recorded enhanced, being highest with their highest level of application. The individual application of P increased the amount of Fe-P content, being highest (56.96 $mgkg^{-1}$) at 30 days of incubation with its highest level, while the application of organic matter at its highest level recorded highest amount of Fe-P (55.30 $mgkg^{-1}$) content. The absolute amount of reductant soluble P was recorded a lower value than Fe-P. The results suggest that Ca-P fraction was the dominant inorganic P fraction among other fractions.

Key words: phosphorus fractions, waterlogged, organic matter, incubation.

Introduction

Phosphorus is an essential element for plant growth and development. Because of its sparingly soluble nature it is present in very less proportion in the soil for plant uptake. A major proportion of soil-P remains interlocked in various insoluble forms and not available for plant use. To circumvent the P-deficiency, large amount of chemical P fertilizers are applied to attain reasonable crop yields. Indiscriminate use of P-fertilizers deteriorates the soil quality as well as cause negative impact in respect to both environment and economy. Consequently, it is important to search for sustainable strategies to alleviate the detrimental effects of chemical fertilizer on soil. Waterlogging is a condition of land in which the soil profile is saturated with water either temporarily or permanently. In waterlogged lands, the water table rises to an extent that the soil pores in the crop root zone are saturated resulting in restriction of the normal circulation of air. Organic matter causes soil to clump and form soil aggregates, which improves soil structure. With better soil structure, permeability (infiltration of water through the soil) improves, in turn improving the soil's ability to take up and hold water. So in this experiment an effort has been created to increase the different fraction of P availability in waterlogged soil under laboratory condition by using only small doses of inorganic P fertilizers and organic matter.

Materials and Methods:

An incubation experiment has been conducted in the laboratory of Department of Agricultural Chemistry and Soil Science, University of Calcutta to find the effect of organic matter on the changes in P content under waterlogged soil conditions. For this experiment, the surface soil was collected (0-15cm depth) from the cultivated field of Baruipur Experimental Farm of University. Before analysis, the soil was air dried, ground and passed through 2mm sieve. The physico-chemical properties of the soil were: pH 6.46, EC: 0.05 dSm^{-1}; Organic Carbon: 0.65%; CEC: 15.76 cmol(p+) kg^{-1}; Available N: 250.88 mg kg^{-1}; Available P: 15.33 mg kg^{-1}; Available K: 290.08 mg kg^{-1}; Available Zn: 0.55 mg kg^{-1}. In this present investigation, the source of P used was Potassium dihydrogen phosphate (22% P_2O_5) and the source of organic matter was Farm Yard Manure (FYM) in which Total N content was 0.96%, Total P content was 0.65%, Total K content was 1.02% and Total Zn content was 0.15%. After application of all treatments, maintaining waterlogged condition, the soils were allowed to incubate at room temperature (30±2)º C for a period of 10, 20, 30, 40, 50 days interval and analyzed for different fractions of P by following the procedure of Kuo, 1996.

Treatments details:

P_0OM_0 – No Phosphorus + No Organic Matter (OM)

P_0OM_1 – No Phosphorus + Application of Organic Matter (OM) 0.5% on soil weight basis

P_0OM_2 – No Phosphorus + Application of Organic Matter (OM) 1% on soil weight basis.

P_1OM_0 – Application of P at 10 mg/kg t soil + No Organic Matter (OM)

P_1OM_1 – Application of P at 10 mg/kg soil + Application of Organic Matter (OM) 0.5% on soil weight basis

P_1OM_2 – Application of P at 10 mg/kg soil + Application of Organic Matter (OM) 1% on soil weight basis.

P_2OM_0 – Application of P at 15 mg/kg soil + No Organic Matter (OM)

P_2OM_1 – Application of P at 15 mg/kg soil + Application of Organic Matter (OM) 0.5% on soil weight basis

P_2OM_2 – Application of P at 15 mg/kg soil + Application of Organic Matter (OM) 1% on soil weight basis.

Results and Discussion:

The results (Table. 1) show that the amount of loosely bound phosphorus fraction has been found to be increased initially and thereafter the amount of the same decreased with the progress of water logging. However, the magnitude of such pattern of changes varied with levels of both P and organic matter. The amount of such fraction was recorded highest (42.66 mg kg^{-1}) in the treatment when P at 15 mg kg^{-1} was applied which might be due to increasing levels of P application. As regards to the application of organic matter, it was found that the amount of loosely bound fractions of P was also recorded a highest amount with its increasing levels. Such increase might be partly attributed to amount of P present in the organic matter as well as solubilisation of insoluble P in the soil. With regards to the interaction effect between P and organic matter it was observed that the mount of such fractions of P has been found to be further increased, being highest (47.50 mg kg^{-1}) in the treatment P_2OM_2 at 30 days of incubation suggesting a positive relationship between P and organic matter in releasing soluble P in the soil solution. Singaram *et. al.* (1993) also reported similarly who found that the application of increasing amount of P up to 90 kg P_2O_5 ha^{-1} enhance the water soluble forms of P in soil *vis-à-vis* saloid P.

The results (Table. 2) show that the amount of Al-P fraction has been found to be increased initially and thereafter, the amount decreases with the progress of incubation irrespective of treatments. The magnitude of such changes, however, varied with treatments. The application of P at its different levels increased the amount of Al-P fraction, being recorded a highest amount with its increasing level, while the amount of

TABLE 1. Periodic changes in Soluble and Loosely bound P content (mg kg^{-1}) in soil under waterlogged condition affected by different treatments

Treatments	Days after incubation 10	20	30	40	50	Mean	% Over control
P_0OM_0	17.03	19.54	22.51	20.52	14.00	**18.72**	
P_0OM_1	30.08	32.52	36.07	33.54	22.50	**30.94**	**65.28**
P_0OM_2	33.00	38.06	42.08	36.50	29.00	**35.73**	**90.87**
P_1OM_0	31.55	33.00	35.00	27.57	21.50	**29.72**	**58.76**
P_1OM_1	34.00	35.40	39.82	36.08	32.50	**35.56**	**89.96**
P_1OM_2	38.00	41.00	44.86	38.70	34.50	**39.41**	**110.52**
P_2OM_0	32.55	39.08	42.66	40.55	36.22	**38.21**	**104.11**
P_2OM_1	36.88	39.75	44.90	41.20	37.82	**40.11**	**114.26**
P_2OM_2	39.50	42.55	47.50	42.80	40.50	**42.57**	**127.40**
Mean	**32.51**	**35.66**	**39.49**	**35.27**	**29.84**	**34.55**	
LSD (0.05)							
P	**0.663**	**0.330**	**0.021**	**0.015**	**0.024**		
OM	**0.663**	**0.330**	**0.021**	**0.015**	**0.024**		
P × OM	**1.147**	**0.573**	**0.036**	**0.027**	**0.042**		

TABLE 2. Periodic changes in Al-P content (mg kg^{-1}) in soil under waterlogged condition affected by different treatments

Treatments	Days after incubation 10	20	30	40	50	Mean	% Over control
P_0OM_0	21.00	25.60	28.75	24.48	20.25	**24.02**	
P_0OM_1	37.00	39.68	43.55	37.85	29.78	**37.57**	**56.45**
P_0OM_2	38.00	41.22	45.30	39.54	34.50	**39.71**	**65.36**
P_1OM_0	39.88	43.28	46.80	41.28	36.98	**41.64**	**73.40**
P_1OM_1	41.00	46.68	48.90	43.76	39.44	**43.96**	**83.03**
P_1OM_2	44.54	49.20	51.21	46.88	43.55	**47.08**	**96.02**
P_2OM_0	40.10	44.78	49.96	43.28	38.66	**43.36**	**80.53**
P_2OM_1	45.76	48.77	52.20	45.80	41.38	**46.78**	**94.80**
P_2OM_2	47.80	49.88	56.78	48.68	45.68	**49.76**	**107.21**
Mean	**39.45**	**43.23**	**47.05**	**41.28**	**36.69**	**41.54**	
LSD (0.05)							
P	**0.042**	**0.042**	**0.042**	**3.809**	**0.045**		
OM	**0.042**	**0.042**	**0.042**	**3.809**	**0.045**		
P × OM	**0.071**	**0.074**	**0.068**	**6.599**	**0.077**		

such fraction was also found highest with increasing level of organic matter. As regards to the interaction effect between P and organic matter it was observed that the amount of Al-P was recorded further enhanced, being highest with their highest level of application. The result of the present investigation finds support with the results reported by Jatav *et. al.* (2010) who found that significant increase in saloid P and Al-P as a result of inorganic fertilization and FYM.

The results (Table. 3) reveal that the amount of Fe-P content increased initially and the amount of the same decreased gradually with the progress of incubation irrespective of treatments. However, the magnitude of such changes varied with individual applications of P, organic matter and their interactions. The individual application of P increased the amount of Fe-P content, being highest (56.96 $mgkg^{-1}$) at 30 days of incubation with its highest level, while the application of organic matter at its highest level (1% on soil weight basis) recorded highest amount of Fe-P (55.30 $mgkg^{-1}$) content. As regards to the interaction effect, it was observed that the amount of Fe-P has been found to be further enhanced, being highest with their highest level of interactions. Sharma and Verma (1980) and Sharma *et. al.* (2000) also confirm the results of the present investigation in which the application of *Lantana* as green manure under rice – wheat cropping system. Among inorganic P-fractions Fe-P was the most important P-fractions contributing to P-nutrition of rice. The results also find support with the finding of Sihag *et. al.* (2005) where the higher amount of P recovered in saloid P, Al-P and Ca-P as well as Fe-P fractions significantly with the application of organic material over control.

The results (Table. 4) show that the amount of reductant soluble (RS) P showed a similar pattern of changes to that of Fe-P fraction. But the absolute amount of reductant soluble P was recorded a lower value than Fe-P. Mishra *et. al.* (2007) reported that on an average Reductant soluble (RS) P contributed 31 per cent of the total inorganic P. The results also indicated that RS-P and Fe-P were present in almost equal proportion.

The results (Table. 5) show that the amount of Ca-P fraction has been found to be increased initially and thereafter, the amount of the same decreased with progress of incubation. However, the pattern of changes in the amount of Ca-P was similar to that of Loosely bound P, Fe-P, Al-P and reductant soluble P fractions with respect to individual applications of P and organic matter and simultaneous application of both P and organic matter, but varied with its absolute value where the amount of Ca-P fraction was far greater among other P fractions. The results suggest that Ca-P fraction was the dominant inorganic P fraction among other fractions. Khan *et. al.* (1973) also reported similarly where the amount of Ca-P fraction ranged from 15.62 to 292.50 ppm, and was recorded the major constituents of the inorganic fractions. Singh and Singh (1976) also reported that the application of organic matter under waterlogged soil conditions favoured the significant reduction in Ca-P fractions after three months which also confirms the results of the present study.

Conclusions

From the results the fractions of P shows the increasing trend up to 45 days after incubation then they all show the decreasing trend. From the experiment we can say organic matter can be very effective in releasing the plant available P under waterlogged soil condition as it shows the synergistic effect with phosphorus, contributing relatively higher amount of loosely bound plant available P. The absolute amount of reductant soluble P was recorded a lower value compare to other fractions. It was found from the experiment that the combined effect of organic matter with phosphatic fertilizer showed the highest value in all P fractions compared to only application of P fertilizers irrespective of levels. The absolute value of Ca-P was was recorded highest out of all inorganic P fractions under study. From the results it has been observed that all P fractions especially Ca-P fractions increased significantly with increasing levels of P fertilization which indicates that the applied P fertilizer has been found to be transformed into different P fractions especially to Ca-P fraction.

TABLE 3. Periodic changes in Fe-P content (mg kg^{-1}) in soil under waterlogged condition affected by different treatments

Treatments	Days after incubation 10	20	30	40	50	Mean	% Over control
P_0OM_0	26.00	31.60	33.75	39.28	26.25	**31.38**	
P_0OM_1	41.00	43.68	48.25	42.80	34.58	**42.06**	**34.06**
P_0OM_2	43.30	47.22	55.30	46.54	40.50	**46.57**	**48.43**
P_1OM_0	45.88	49.28	56.80	47.28	42.98	**48.44**	**54.40**
P_1OM_1	46.70	51.68	54.90	49.76	45.44	**49.70**	**58.39**
P_1OM_2	51.54	56.20	59.21	52.88	47.55	**53.48**	**70.44**
P_2OM_0	45.10	49.78	56.96	48.28	44.66	**48.96**	**56.03**
P_2OM_1	46.76	51.77	57.20	50.80	46.38	**50.58**	**61.21**
P_2OM_2	52.80	55.88	62.78	55.68	51.68	**55.76**	**77.73**
Mean	**44.34**	**48.57**	**53.91**	**48.14**	**42.22**	**47.44**	
LSD (0.05)							
P	**0.030**	**0.039**	**0.056**	**0.027**	**0.045**		
OM	**0.030**	**0.039**	**0.056**	**0.027**	**0.045**		
P × OM	**0.051**	**0.065**	**0.095**	**0.074**	**0.074**		

TABLE 4. Periodic changes in Reductant soluble P content (mg kg^{-1}) in soil under waterlogged condition affected by different treatments

Treatments	Days after incubation 10	20	30	40	50	Mean	% Over control
P_0OM_0	22.40	23.40	26.75	25.28	23.85	**24.34**	
P_0OM_1	35.40	39.68	45.25	41.80	32.58	**38.94**	**60.02**
P_0OM_2	39.10	45.22	53.30	43.54	38.50	**43.93**	**80.52**
P_1OM_0	42.88	46.28	48.80	44.28	40.98	**44.64**	**83.45**
P_1OM_1	43.70	48.68	52.90	43.76	41.44	**46.10**	**89.41**
P_1OM_2	46.54	54.20	57.71	48.88	44.55	**50.38**	**107.00**
P_2OM_0	45.20	48.78	54.96	46.28	43.66	**47.78**	**96.32**
P_2OM_1	45.76	49.77	56.80	49.80	46.38	**49.70**	**104.23**
P_2OM_2	51.80	55.84	61.78	53.68	49.68	**54.56**	**124.18**
Mean	**41.42**	**45.76**	**50.92**	**44.14**	**40.18**	**44.48**	
LSD (0.05)							
P	**0.033**	**0.039**	**0.056**	**0.021**	**0.056**		
OM	**0.033**	**0.039**	**0.056**	**0.021**	**0.056**		
P × OM	**0.056**	**0.065**	**0.062**	**0.033**	**0.095**		

Table 5. Periodic changes in Ca-P content (mg kg^{-1}) in soil under waterlogged condition affected by different treatments

Treatments	Days after incubation 10	20	30	40	50	Mean	% Over control
P_0OM_0	42.40	48.40	51.75	46.28	41.85	**46.14**	
P_0OM_1	55.40	49.68	55.25	51.80	44.58	**51.34**	**11.28**
P_0OM_2	59.10	68.22	73.30	53.54	48.50	**60.53**	**31.20**
P_1OM_0	62.88	71.28	86.20	64.28	54.98	**67.92**	**47.23**
P_1OM_1	64.70	69.68	72.90	62.76	51.44	**64.30**	**39.36**
P_1OM_2	66.54	74.20	89.71	68.88	61.55	**72.18**	**56.44**
P_2OM_0	65.20	73.78	87.96	66.28	53.66	**69.38**	**50.37**
P_2OM_1	65.76	75.77	86.80	69.80	62.38	**72.10**	**56.28**
P_2OM_2	71.80	81.84	93.78	74.68	69.68	**78.36**	**69.84**
Mean	61.53	68.09	77.52	62.03	54.29	**64.69**	
LSD (0.05)							
P	**0.036**	**0.051**	**0.039**	**0.027**	**0.045**		
OM	**0.036**	**0.051**	**0.039**	**0.027**	**0.045**		
P × OM	**0.059**	**0.086**	**0.065**	**0.048**	**0.077**		

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