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Performance of integrated farming system models for economic viability, water productivity, employment generation, energy balance and soil health improvement under irrigated conditions of western Maharashtra.

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Abstract

Three farming system research models were selected with an aim to study the economic viability, water productivity, employment generation, energy balance and soil health improvement. A research farm integrated farming system model (Model-I) was carried out in All India Co-ordinated Research Project on Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri. Model-II as on-farm integrated farming system model was taken in the village Digraj, Tahsil - Rahuri and model-III as research farm sequence cropping model on soybean-wheat was taken at F-Block, Central Campus, Mahatma Phule Krishi Vidyapeeth, Rahuri, District- Ahmednagar. Each farming system model consisted of 2.0 ha area. The research farm IFS model-I under irrigated conditions proved to be more remunerative with highest average net returns of Rs.1,99,848/- indicating better economic viability, higher water productivity (991 Rs./ha.cm), better employment generation capacity (1275 man days/ha/year^{-1}), highest energy balance (4,11,949 MJ) and improvement in soil fertility status as compared to on-farm IFS model-II and research farm sequence cropping model-III. The adoption of research farm IFS model-I on large scale under irrigated conditions of Maharashtra is recommended. On the basis of this, Government of Maharashtra has implemented IFS models in Western Maharashtra, Vidharbha and Marathwada region of Maharashtra on large scale under irrigated conditions on farmer's field.

Key words: Integrated farming system, Water productivity, Economics, Energy balance, Employment generation and Soil health.

Introduction

Farming System is a complex inter-related matrix of soil, plants, animals, implements, power, labour, capital and other inputs controlled by farming families and influenced to varying degrees by political, economical, institutional and social forces that operate at many levels (Mahapatra, 1992).

The human population of India has increased to 1210.2 million at a growth rate of 1.76 per cent in 2011 over 2001 (1028.7 million) and is estimated to increase further to 1530 million by 2030 (Census of India, 2011). The per capita food grain production is only about 193 kg per year. There are projections that demand for food grains would increase from 234 million tonnes in 2009-10 to 345 million tonnes in 2030 (Government of India, 2009). Hence, in the next two decades the production of food grains needs to be increased @ 5.5 million tonnes annually. Simultaneously, the demand for high-value commodities *viz*., fruits, vegetables, livestock products, fish, poultry etc., are increasing faster than food grains, and is expected to increase by more than 100 per cent from 2000 to 2030.

Crop diversification is governed mostly by price fluctuation in the market and inclusion of new crops in production system, with a view to utilize unexplored and little explored resources to raise the income. Diversification should not be restricted to crop and cropping system only but also to farm enterprises like dairy, horticultural crops, vegetables, fisheries and poultry. The goal of diversification in agriculture is to stabilize the farm income particularly on small farms and to withstand the challenges of trade liberation. Therefore, crop diversification from less remunerative to more remunerative crops, need based, demand driven, location specific and national goal seeking is a continuous and dynamic concept, which involves spatial, temporal, value addition and resource complementary approaches. This diversified food basket will provide food security and improve the quality of life by adding to nutritional status of people.

Integrated farming system approach is not only a reliable way of obtaining fairly high productivity with considerable scope for resource recycling, but also a concept of ecological soundness leading to sustainable agriculture. Farming system represents an appropriate combination of farm enterprises *viz*., cropping systems, horticulture, livestock, fishery, forestry, poultry and the means available to the farmers to raise them for profitability. The goals of sustainable integrated farming systems are soil and water conservation, soil productivity restoration, improvement in air and water quality, reduction in the use of external inputs, overall increase in farm productivity and income.

Materials and Methods

The field studies on integrated farming system (IFS) were carried out at Mahatma Phule Krishi Vidyapeeth, Rahuri, District- Ahmednagar on 2.0 ha area during 2008-09 and 2009-10. The research experiment was compared with on-farm IFS model-II (Crop, dairy and poultry) at village Digraj, Tahsil-Rahuri, District-Ahmednagar and the sequence cropping (Model-III) of soybean-wheat in 2.0 ha land at Rahuri.

The experimental site is located between 19° 47' to 19° 57' N latitude and 74° 84' to 74° 19' E longitudes with altitudinal variation from 495 to 569 metres above mean sea level. The region comes under semiarid tropical zone with an average rainfall of 520 mm. The rainfall is erratic and unevenly distributed in 15 to 45 rainy days. Agro-climatically, the area comes under the drought prone area of Maharashtra. The maximum and minimum weekly temperature during the study period ranged from 26.1 to 40.8 and 7.8°C to 23.9°C, respectively. The mean weekly morning relative humidity ranged from 44 to 90 per cent and evening humidity ranged from 13 to 74 per cent. The mean pan evaporation was 4.39 mm with maximum pan evaporation of 12.4 mm in the month of May. Three farming system models on 2.0 ha area each under irrigated conditions were selected to find out the economic viability, water productivity, employment generation, energy balance and soil health improvement of each models.

The on-station integrated farming system model consisted of various components on 2.0 ha area *viz*., crop (1.50 ha), horticulture (0.40 ha pomegranate orchard), dairy (Two *Phule Triveni* milking cow), poultry (200 Rhode Ireland birds /batch), fishery (in 0.05 ha farm pond area 400 fingerlings of integrated culture of *catla, rohu and mrigal*), farm shed, cowshed and poultry house on an area of 0.05 ha while the on-farm integrated farming system model consisted of various components *viz*., crop (1.95 ha), dairy (1 Jersey cow), poultry (10 birds), cow and poultry shed on an area of 0.05 ha. The entire model was laid on an area of 2.00 ha and on-station cropping sequence model consisted of only crop component i.e soybean in *kharif* and wheat in *rabi* season and in summer season the whole area was kept as fallow. The entire model was laid on an area of 2.00 ha.

In all the three models, the seeds of cereal, pulses, oilseeds, forage and vegetable crops were obtained from Seed Cell Unit of Mahatma Phule Krishi Vidyapeeth, Rahuri while in on-station IFS model, the seedlings of banana were purchased from Jain Irrigation, Jalgaon. In case of horticultural component, the pomegranate seedlings were obtained from Central Nursery of Mahatma Phule Krishi Vidyapeeth, Rahuri. In dairy component, two *Phule Triveni* cows were purchased from Cattle Unit of this University. In poultry component, the poultry birds were purchased from, Don Bosco Poultry, Ahmednagar. In fishery component, the fish fingerlings of *Catla, Rohu* and *Mrigal* were purchased from the office of fishery, Mula dam, Rahuri. For plant protection measures the insecticides and fungicides were purchased from private agri-clinic centres while the medicines required for dairy and poultry component were purchased from medical stores.

The source of irrigation water in on-station integrated farming system model was from two tube wells with a 7 HP and 3 HP submersible pumps and also Mula canal water while in on-farm integrated farming system model was only one well with a 5 HP electric pump and in on-station cropping sequence model, canal water was the source of irrigation.

The cropping programme followed in on-station integrated farming system model during the year 2008-09 and 2009-10 is given in Table 2.

Sugarcane, banana, lucerne and hybrid napier are perennial crops. Hence, these crops were grown during 2008-09 and 2009-10. The additional crops like sorghum and pigeon pea, onion and sweet corn were grown during *kharif* followed by wheat in *rabi* in the year 2008-09. During the year 2009-10, in *kharif* season soybean and okra crops were taken followed by wheat and leafy vegetables fenugreek and spinach in *rabi* season.

Table 1: Components of integrated farming system models

Model-I : (Research Farm IFS model)

S. No.	Component	Area (ha)	Area allotted (%)
1.	Crop production	1.50	75.00
2.	Horticulture (Pomegranate-*Bhagwa*)	0.40	20.00
3.	Dairy (Two P*hule Triveni* cow)	0.05	2.50
4.	Poultry (200 *RIR* birds/batch)		
5.	Fishery (400 fingerlings of integrated culture of *Catla, Rohu and Mrigal* fish)	0.05	2.50
	Total	**2.00**	**100.00**

Model-II : (On-Farm IFS model)

S. No.	Component	Area (ha)	Area allotted (%)
1.	Crop production	1.95	97.50
2.	Dairy (one Jersey cow)	0.05	2.50
3.	Poultry (Local birds)		
	Total	**2.00**	**100.0**

Model-III : (Sequence Cropping model)

S. No.	Component	Area (ha)	Area allotted (%)
1.	Soybean-wheat-fallow	2.00	100.0
	Total	**2.00**	**100.0**

Table 2 : Cropping programme followed in on-station IFS model during the year 2008-09 and 2009-10

S. No.	2008-09					
	Summer 2008		*Kharif* 2008		*Rabi* 2008	
	Crop	Area (ha)	Crop	Area (ha)	Crop	Area (ha)
1.	Lucerne	0.10	Lucerne	0.10	Lucerne	0.10
2.	Hybrid Napier	0.05	Hybrid Napier	0.05	Hybrid Napier	0.05
3.	Sugarcane	0.30	Sugarcane	0.30	Sugarcane	0.30
4.	Banana	0.40	Banana	0.40	Banana	0.40
5.	-	-	Sorghum	0.20	Wheat	0.55
6.	-	-	Pigeon pea	0.35	-	-
7.	-	-	Onion	0.10	Sweet corn	0.10
Cropped area		0.85		1.50		1.50
Fallow area		0.65		--		--
Total area		**1.50**		**1.50**		**1.50**
S.No.	**2009-10**					
	Summer 2009		***Kharif* 2009**		***Rabi* 2009**	
	Crop	**Area (ha)**	**Crop**	**Area (ha)**	**Crop**	**Area (ha)**
1.	Lucerne	0.10	Lucerne	0.10	Lucerne	0.10
2.	Hybrid Napier	0.05	Hybrid Napier	0.05	Hybrid Napier	0.05
3.	Sugarcane (R)	0.30	Sugarcane (R)	0.30	Sugarcane (R)	0.30
4.	Banana	0.40	Banana	0.40	Banana	0.40
5.	-	-	Soybean	0.55	Wheat	0.55
6.	-	-	Okra	0.10	Leafy vegetables	0.10
Cropped area		0.85		1.50		1.50
Fallow area		0.65		--		--
Total area		**1.50**		**1.50**		**1.50**

The cropping programmes followed in on-farm integrated farming system model during the year 2008-09 and 2009-10 is given in Table 3. The farmer had grown sugarcane as a perennial crop during both the years as a fresh crop as well as a *ratoon* crop while, lucerne was grown as a perennial crop during both the years as a forage crop for animal component. The lucerne crop was grown on 0.20 ha area but the animal component was only one jersey cow hence, surplus lucerne green fodder was sold in the market. During the year 2008-09, pigeon pea, soybean and groundnut were taken during *kharif* followed by wheat in *rabi* season. During the year 2009-10, in addition to sugarcane, lucerne and soybean were grown in *kharif* on 0.80 ha area followed by wheat on 0.20 ha and chickpea on 0.40 ha area in *rabi* season.

The cropping programme followed in on-station cropping model during the year 2008-09 and 2009-10 is given in Table 4. During the year 2008-09 and 2009-10 in soybean-wheat sequence cropping model, the soybean was grown on 2.0 ha area in *kharif* season followed by wheat in *rabi* season. During summer season whole area was kept as a fallow.

In on-station integrated farming system model, the recommended packages of practices were adopted for getting higher yield from all the crops grown under crop and horticulture component are given in Table 5. Land preparation was carried out with the help of tractor drawn implements. Most of the intercultural operations in case of sugarcane, banana and pomegranate were carried manually as well as by using power tiller. All plant protection measures whenever necessary were carried out as per recommended schedule. Sowing of agronomical crops was done with the help of tractor drawn ferti-seed drill. Transplanting was done in vegetable crops, i.e. chilli and brinjal and dibbling was done in okra and sweet corn. Planting operation was carried out for sugarcane, banana and pomegranate. All the crops were sown as per the recommended plant

Table 3 : Cropping programme followed in on-farm IFS model during the year 2008-2009 and 2009-2010

S. No.	2008-09					
	Summer 2008		*Kharif* 2008		*Rabi* 2008	
	Crop	Area (ha)	Crop	Area (ha)	Crop	Area (ha)
1.	Sugarcane	0.75	Sugarcane	0.75	Sugarcane	0.75
2.	Lucerne	0.20	Lucerne	0.20	Lucerne	0.20
3.	Fallow	1.00	Pigeon pea	0.20	Wheat	0.60
4.			Soybean	0.60	Fallow	0.40
5.			Groundnut	0.20		
Cropped area		0.95		1.95		1.55
Fallow area		1.00		--		0.40
Total area		**1.95**		**1.95**		**1.95**
S.No.	**2009-10**					
	Summer 2009		***Kharif* 2009**		***Rabi* 2009**	
	Crop	**Area (ha)**	**Crop**	**Area (ha)**	**Crop**	**Area (ha)**
1.	Sugarcane	0.75	Sugarcane	0.75	Sugarcane	0.75
2.	Lucerne	0.20	Lucerne	0.20	Lucerne	0.20
3.	Fallow	1.00	Soybean	0.80	Wheat	0.20
4.			Fallow	0.20	Chickpea	0.40
5.					Fallow	0.40
Cropped area		0.95		1.75		1.55
Fallow area		1.00		0.20		0.40
Total area		**1.95**		**1.95**		**1.95**

Table 4 : Cropping programme followed in on-station sequence cropping model during year 2008-09 and 2009-10

S. No.	2008-09					
	Summer 2008		*Kharif* 2008		*Rabi* 2008	
	Crop	Area (ha)	Crop	Area (ha)	Crop	Area (ha)
1.	Fallow	2.00	Soybean	2.0	Wheat	2.00
Cropped area		-		2.00		2.00
Fallow area		2.00		-		-
Total area		**2.00**		**2.00**		**2.00**
S.No.	**2009-10**					
	Summer 2009		***Kharif* 2009**		***Rabi* 2009**	
	Crop	**Area (ha)**	**Crop**	**Area (ha)**	**Crop**	**Area (ha)**
1.	Fallow	2.00	Soybean	2.0	Wheat	2.00
Cropped area				2.00		2.00
Fallow area		2.00		-		-
Total area		**2.00**		**2.00**		**2.00**

spacing. In on-farm integrated farming system model, the land preparation as well as sowing of different crops was done by hiring the bullocks. In research farm cropping sequence model, the land preparation, sowing of soybean in *kharif* and wheat in *rabi* season was done with the help of tractor drawn implements.

The crops grown in on-station integrated farming system model were manured with farm yard manure received from dairy component. For crops like sugarcane, banana and pomegranate, the green manuring of sunhemp was done before planting of these crops to enrich the soil with organic matter. In addition, droppings received from poultry unit were also applied to high remunerative vegetable crops. In on-farm integrated farming system model, the farm yard manure obtained from one jersey cow was used for crop component while in research farm cropping sequence model, the general recommended dose of fertilizer was applied.

The fertilizer management in on-station integrated farming system model of crop component was fulfilled through urea, single super phosphate and muriate of potash and other mixed fertilizers. Whenever necessary, micronutrient application was carried out as per the recommended schedule. Most of the crops were grown under pressurized irrigation systems. The fertigation was done with the help of water soluble fertilizers viz. 19:19:19, 0:52:34, 13:0:45, 12:61:0, 13:40:13, 17:44:0 and 0:0:50 of N:P:K respectively. In on-farm integrated farming system model, the nutrient need of crops was fulfilled through urea, single super phosphate and muriate of potash and other mixed fertilizers. In on-station cropping model, the nutrient need of crops was fulfilled through urea, single super phosphate and muriate of potash and other mixed fertilizers. Whenever necessary, micronutrient application was carried out as per the recommended schedule.

The water requirement of all the components in different farming system models were worked out. In on-station integrated farming system model, irrigation was scheduled at alternate day for the crops irrigated by drip irrigation and in micro sprinkler irrigations was scheduled at every three days interval. The irrigation water requirement of crops taken under drip and sprinkler were calculated as per following formulae.

1. Net irrigation requirement (NIR)

$NIR = CPE \times Kp \times Kc \times Wa \times Es \times Ls$ … for drip

$NIR = CPE \times Kp \times Kc$ … for sprinkler

2. Gross irrigation requirement (GIR)

The total quantity of irrigation water was applied during each irrigation and it was calculated by using following formula:

$$GIR = \frac{NIR}{Uc}$$

Irrigation was done on the basis of cumulative pan evaporation. The quantity of water applied per plot per irrigation was calculated and measured in the field with the help of replogal flume. During *kharif* season, irrigation was done by considering the amount of precipitation received between two irrigations. In on-farm integrated farming system model and sequence cropping model the irrigation was applied to crops as per the critical growth stages of the crop.

The daily water requirement for dairy and poultry were measured considering the water requirement for drinking, washing, cleaning and other domestic use. The water requirement of fishery unit was calculated by considering the daily pan evaporation and quantity of water added to maintain maximum depth of water for fish development.

Water budgeting was calculated in the way of how much water was available from the different water sources viz., canal, lift irrigation, well, tube-well and precipitation. Water budgeting is very important while deciding the cropping pattern as well as selection of different components in farming system.

The water productivity of each component in different farming system models was worked out by using the following formula

$$\text{Water Productivity (Rs./ha.cm.)} = \frac{\text{Net income of component (Rs.)}}{\text{Quantity of water utilized for each component (ha.cm.)}}$$

The component wise as well as model wise energy balance was worked out by subtracting the energy input from energy output. The energy balance (input and output) of different components was worked out by the procedure given by Verma *et al.* (1994).

The labour required for various activities in crop production given as man-days/ha/year. A man working for 8 hours in a day is considered as one man day. A woman working for the same period is treated as 2/3 man days and computed to man days.

Three farming system models under irrigated conditions were evaluated to find out the economic viability, water productivity, employment generation, energy balance and soil health improvement of each model.

Results and discussion

Economics : The average cost of cultivation in research farm IFS model-I was Rs. 3,61,731/- while in on-farm IFS model-II was Rs. 95,773/- and in research farm sequence cropping model (soybean-wheat) was Rs.53, 550/- .

The average gross income from in research farm IFS model-I was Rs. 5,61,578/- while in on farm IFS model-II was Rs. 1,44,250/- however it was only Rs. 86,163/- in research farm sequence cropping model-III (soybean-wheat). The average net income realized in research farm IFS model-I was more (Rs.1,99,848/-) as compared to on-farm IFS model-II (Rs.48,477/-) and research farm sequence cropping (soybean-wheat) model-III (Rs.32,613/-). The economics indicated the research farm integrated farming system model is economically viable.

Annual water availability : Among the three farming system models the average annual water availability was higher in research farm IFS model-I (203 ha.cm.) followed by on-farm IFS model-II (122 ha.cm) and research farm sequence cropping (soybean-wheat) model-III (87 ha.cm.)

Annual water utilized : Among the three farming system models the average annual quantity of water utilized was more in research farm IFS model-I was 199 ha cm. Whereas in on-farm IFS model-II was 121 ha.cm and research farm sequence cropping model-III (soybean-wheat) was 87 ha.cm.

Water productivity : Among the three farming system models, the average water productivity was highest in research farm IFS model-I followed by on-farm IFS model-II and sequence cropping model-III. The average water productivity was highest in research farm IFS model-I (Rs. 991 ha.cm.) followed by on-farm IFS model (Rs.406 ha.cm) and research farm sequence cropping model-III (Rs.374 ha cm) The higher water productivity under in research farm integrated farming system model-I was mainly attributed to higher biological productivity of field crops and horticultural components and adoption of micro irrigation system (drip and micro-sprinkler) for efficient water utilization and inclusion of different components viz., dairy, poultry and fishery for diversified use of water. Thus, IFS model was more suitable for efficient water use for augmenting the water use productivity.

Employment generation : The average employment generated in farming system models were 1275, 657 and 227 man days, respectively in research farm IFS model, on farm IFS model and sequence cropping model (soybean-wheat). This suggested that in research farm integrated farming system model (Model-I) was more efficient for employment generation. This might be because of its diversified nature *viz*, inclusion of field crop, horticultural crops, dairy, poultry and fishery components as which are competent enough for generating employment throughout the year. These results are inconformity with the findings of Ramrao *et al.* (2005), Esther Sheikinah and Sankaran N. (2007), Ravisankar *et al.* (2007), Solaiappan *et al.* (2007) and Korikanthimath and Manjunath (2009).

Energy balance : The average energy balance was more in research farm integrated farming system model (4,11,949 MJ) followed by on farm IFS model (3,25,528 MJ). The lowest energy balance was recorded in research farm sequence cropping (soybean-wheat) model (1,53,379 MJ).The highest energy balance under IFS was mainly attributed to higher productivity of crop and dairy. Similar results were reported by Rangaswamy *et al.* (1996), Ramrao *et al.* (2005) and Esther Shekinah and Sankaran (2007).

Soil health : The soil pH and electrical conductivity of experimental site was 7.97 and 0.45 dSm^{-1}. It decreased to 7.67 and 0.37 dSm^{-1} at the end of the experiments. The organic carbon content in soil increased over the years in farming system. It was 0.60 per cent at initiation of farming system and raised to 0.70 per cent at the end of farming system experimentation. The soil available nitrogen increased from 150.2 to 175.2 $kgha^{-1}$, phosphorus 14.1 to 16.9 kg ha^{-1} and potassium 616 to 672 kg ha^{-1} respectively in research farm integrated farming system model.

In on farm IFS model the soil pH and electrical conductivity of experimental site was 8.79 and 0.51

dSm^{-1}. It increased to 8.90 and 0.53 dSm^{-1} at the end of the experiments this might be due to less quantity of water availability in summer season, accumulation of salts and less quantity of organic matter from dairy and poultry unit. The soil available nitrogen decreased from 130.50 to 120 kg ha^{-1}, phosphorus 16.18 to 15.90 kg ha^{-1} and potassium 480 to 455 kg ha^{-1} respectively in farming system model on farmer field.

In research farm cropping sequence model, there was improvement in the physical as well as the chemical properties of soil. This might be due to shedding of soybean leaves at the time of physiological maturity of plant which raised the organic carbon, population of soil microorganisms and their activity, aeration, water holding capacity and soil enzyme activity etc.

Among the three farming system models, there was better improvement in fertility status of soil in research farm integrated farming system model as compared with on-farm integrated farming system model and research farm sequence cropping model.

Conclusion : The research farm integrated farming system Model-I on 2.0 ha area under irrigated condition was more remunerative in average net returns (Rs.1,99,848/-), water productivity (991.61 Rs/ha-cm), employment generation (1275 man days), energy balance (4,11,949 MJ) and improvement in physical and chemical properties of soil.

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Table 5 : Agronomic practices followed in on-station integrated farming system model (Model-I)

S. No.	Name of crop	Season	Planting method	Seed rate/ha	Spacing	Fertilizer dose/ha	Variety
A.	**Cash crops**						
1	Sugarcane	*Suru*	Paired planting	20000 two eye budded sets	90-180 x 30cm^2	250:115:115	Co-86032
2	Banana	*Kande Bahar*	Row planting	3265 plants	1.75 x 1.75 m^2	200:40:200/pl.	Grand naine
B.	**Cereal crops**						
1	Wheat	*Rabi*	Drilling	100 kg	22.5cm	120:60:40	HD2189,Trimbak
2	Sorghum	*Kharif, Rabi*	Drilling	40 kg	--	100:50:50	Phule Mauli
3	Sweet corn	*Kharif*	Dibbling	10 kg	60 x 30 cm	100:50:50	Sugar 75
C.	**Pulse crops**						
1	Soybean	*Kharif*	Drilling	75 kg	45 x 10 cm	50:75:00	JS - 335
2	Pigeonpea	*Kharif*	Drilling	15 kg	45 x 10 cm	25:50:00	ICPL-87
D.	**Vegetable crops**						
1	Onion	*Kharif*	Transplanting	8-10 kg	15 x 10 cm	100:50:50	Phule Samartha
2	Okra	Summer	Dibbling	12-15 kg	30 x 15 cm	100:50:50	Phule Utkarsha
E.	**Forage crops**						
1	Lucerne	Perennial	Drilling	25 kg	30 cm	15:150:40 at the time of sowing	RL-88
2	Maize fodder	*Kharif, Rabi,* Summer	Drilling	75 kg	30 cm	100:50:50	African tall
3	Hybrid Napier	Perennial	Transplanting	40000 setts	90 x 60 cm	50:40:20 at sowing and 25 kg N after every cutting	Phule Jaiwant
F.	**Horticulture crops**						
1	Pomegranate	--	Row planting	750 plants	4.50 x 3.00 m^2	625:250:250/plant	Bhagwa

Table 6 : Comparative performance of different farming system models

Treatment	Cost of cultivation (x10^3 Rs./ha)	Gross returns (x10^3 Rs./ha)	Net returns (x10^3 Rs./ha)	Annual water availability (ha.cm)	Quantity of water utilized (ha.cm)	Water productivity (Rs.ha^{-1}cm.)	Energy Balance (x10^3 MJ/ha)	Total employment generation (Man days/ha/yr)
Research farm IFS model-I	361.7	561.5	199.8	203	199	991	411.9	1275
On-farm IFS model-II	95.7	144.2	48.4	122	121	406	325.5	657
Research farm sequence cropping model-III	53.5	86.1	32.6	87	87	374	153.3	227

Table 7 : Physio-chemical properties of soil of different farming system models at initiation and after completion of research work

S. No.	Soil Properties	Research farm integrated farming system model (Model-I)		On-farm integrated farming system model (Model-II)		Research farm cropping sequence model (Model-III)	
		Initial	Final	Initial	Final	Initial	Final
A.	**Physical properties**						
1.	Texture class	Clay loam	-	Sandy clay loam	-	Clay loam	-
2.	Field capacity (%) by weight basis	32.18	34.70	30.10	29.65	34.15	34.90
3.	Permanent wilting point (%) by weight	19.16	18.16	17.19	17.95	20.10	20.30
4.	Available soil moisture (%)	13.02	16.54	12.91	11.70	14.05	14.60
5.	Bulk density (Mg m^{-3})	1.34	1.24	1.40	1.37	1.30	1.25
C.	**Chemical properties**						
1	Soil pH (1:2.5)	7.97	7.67	8.79	8.90	7.90	7.60
2	EC (dSm^{-1})	0.45	0.37	0.51	0.53	0.40	0.35
3	Organic Carbon (%)	0.60	0.70	0.40	0.41	0.40	0.45
4	Available N (kgha^{-1})	150.52	175.16	130.5	120.0	160.5	178.2
5	Available P (kgha^{-1})	14.11	16.94	16.18	15.90	16.80	15.11
6	Available K (kgha^{-1})	616	672	480.0	455.0	490.0	478.0

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Effect of weed management on weeds, growth, yield and economics of rajmash (*Phaseolus vulgaris* L.)

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Abstract

A field experiment was conducted during *rabi* season of 2010-11, 2011-12 and 2012-13 at Research cum Instructional Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh to study the most effective herbicide, their appropriate dose and time of application for weed control in rajmash. Hand weeding twice at 20 and 40 DAS closely followed by pre emergence application of pendimethalin 30 EC+imazethapyr 2 EC @ 1.0 kg/ha exhibited the lowest weed dry matter production at 60 DAS, maximum weed control efficiency, tallest plant, maximum branches, highest pods/plant, longest pod, maximum grain and stover yield, maximum net return and B:C ratio over all the treatments.

Key words: Quizalofop-p-ethyl, imazethapyr, chlorimuron ethyl, pendimethalin, seed yield, weed control efficiency, weed index.

Introduction

Among the pulses, rajmash is one of the high potential crop with a yielding potential of 18 to 20 q/ha. Unlike other pulses, rajmash is inefficient in symbiotic nitrogen fixation (Ali and Lal, 1992) as it lacks nodulation due to the absence of NOD gene regulator (Kushwaha, 1994) even with native *Rhizobia* and commercially produced cultures. Hence, the nitrogen requirement of rajmash is different from other pulse crops and application of nitrogen along with sufficient quantity of P and K for its better growth and realization of yield potential. Plant has fibrous roots which draw moisture and nutrients mostly from upper layer of soil surface. It is an important winter vegetable grown both for tender pods and dry seeds, which form a rich source of crude protein (21.25%), fat (1.7%) and carbohydrates (70%). Besides, it contains 0.16 mg iron, 1.76 mg calcium and 3.43 mg zinc per 100 g of edible part (Jasvinder Kaur and Mehta, 1994). Rajmash is more sensitive to weed competition during early stages of its growth. Moreover, this crop is grown with frequent irrigations which provide congenial conditions for growth and development of crop as well as weeds. Due to high moisture and nutrients in rajmash field during its early growth stage, weeds become a problem and compete with it as weeds emerges simultaneously with the crop, leading to severe competition between them (Kandasamy, 2000). Since the initial growth of rajmash is very slow, the initial period of crop growth (30 – 45 DAS) is most crucial for crop – weed competition. In addition to slow growth, wider crop spacing also facilitates crop – weed competition which poses a serious limitation in rajmash production and thus, estimated seed yield loss may likely to go to the extent of 45 – 65 % under unweeded condition (Mishra 2006). During winter season, broad leaved weeds may become dominant in the early stages of crop growth because of their fast growth and deep root system. To control weeds, generally hand weeding is in practice that is now costly as well as difficult because of non-availability of labour at peak period. With the advancement of agro techniques, chemical weed control has become an effective and cheap alternative to control weeds.

Materials and Methods

A field experiment was conducted at Research cum Instructional Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur ($21^0$4 N, $81^0$39 E and 298 m above mean sea level), Chhattisgarh during *rabi* season of 2010-11, 2011-12 and 2012-13 to find out the most effective herbicide, their appropriate dose and time of application for rajmash. The soil of the experimental plot was sandy loam in texture (*Inceptiso*l) with pH 7.69 (neutral), low in organic carbon (0.48 %), low in available N (181 kg/ha) and P (7.74 kg/ha) and high exchangeable K (311 kg/ha) with normal electrical conductivity (0.23 d/sm at 25^{0}C). The experiment was laid out in randomized complete block design (RCBD) comprising of 10 treatments *viz.*, quizalofop-p-ethyl @ 50 and 60 g/ha and imazethapyr @ 50 and 75 g/ha (PPI) (both herbicides) applied at 30 DAS, chlorimuron ethyl @ 4 g/ha as pre-plant incorporation, pendimethalin @ 1.0 kg/ha as pre-emergence (PE), pendimethalin 30 EC + imazethapyr 2 EC @ 0.75 and 1.0 kg/ha as PE, hand weeding twice at 20 and 40 DAS and a weedy check in three replications. High yielding with semi dwarf erect type and tolerant to bean common mosaic virus 'Gujrat Rajmash-1' (100-110 days) was sown at a seed rate of 120 kg/ha with a row spacing of 30 cm in line during last week of November in 2010, 2011 and 2012. Half of recommended dose of N (60 kg/ha), full of P (60 kg/ha P_2O_5/ha) and K (40 kg K_2O/ha) through urea, diammonium phosphate and murate of potash were drilled at sowing time and the remaining N (30 kg/ha) was top dressed in two equal splits at first irrigation (25-30 DAS) and pod formation (65-70 DAS). The crop was raised under irrigated condition with recommended package of practices for the zone.

All the herbicides were sprayed as per their time of application mentioned above by knapsack sprayer using a flat fan nozzle at 500 l/ha volume by diluting with water. The economics of treatments was computed on the basis of prevailing market prices of inputs and outputs under each treatment. Pooling was made on the basis of three years data as similar trend was noticed during all the years.

Results and Discussion

Floristic composition : The predominant weeds observed in the experimental field were *Cynodon dactylon* L. (*doob* grass) among grasses, *Chenopodium album* (bathua), Cirsium arvense (*kateli*), *Melilotus alba* (*safed senji*), *Euphorbia hirta (doodhi)*, *Anagalis arvensis*, *Xanthium strumarium (gokharu),* *Convolvulus arvensis* (*hirankhuri*) among broad leaves and *Cyperus rotundus* (motha) among sedges during all the three years. Similar weed flora have also been reported by Chandrakar (2011) in lentil crop. Thus, broad leaved weeds were dominant compared to grasses and sedges during all the three years.

Effect on weeds : All the weed control treatments significantly curtailed weed dry matter production compared to weedy check (Table 1). However, hand weeding twice at 20 and 40 DAS allowed the lowest weeds dry matter production compared to other treatments. Amongst the herbicides, lowest weed dry matter production was observed in pre emergence application of pendimethalin 30 EC + imazethapyr 2 EC @ 1.0 kg/ha (10.1 and 39.1 g/m^2, respectively) at 30 and 60 DAS and was closely followed by pendimethalin 30 EC + imazethapyr 2 EC @ 0.75 kg/ha (10.6 and 45.6) over rest of the treatments and weedy check. Post emergence application of imazethapyr @ 75 g/ha at 30 DAS was also found significantly superior in the reduction of weed dry matter at 60 DAS (53.9 g/m^2) over weedy check. Combination of pendimethalin + imazethapyr and imazethapyr alone effectively controlled germinating broad leaved as well as grassy weeds which might be due to inhibition of weed seedling emergence, resulting in least weed biomass and higher crop growth. Similar findings were reported by Godara and Deshmukh (2002) in soybean and Ram *et al.* (2011) in field pea and Ram *et al.* (2012) in rajmash. Nevertheless, hand weeding twice at 20 and 40 DAS showed the lowest weed biomass (7.6 g/m^2 at 30 DAS and 23.7 g/m^2 at 60 DAS) over all the herbicide treatments including weedy check by controlling weed population to the extent of 81.1 % (Table 1). On efficiency factor, pre emergence application of pendimethalin 30 EC + imazethapyr 2 EC @ 1.0 kg/ha had maximum weed control efficiency (81.1 %) at 60 DAS and was closely followed by pre emergence application of pendimethalin 30 EC + imazethapyr 2 EC @ 0.75 kg/ha whereas, it was the least under quizalofop ethyl @ 50 g/ha applied at 30 DAS (32.5 %) and chlorimuron rthyl @ 4 g/ha as PPI (33.2 %). This might be due to the lower weed biomass and higher efficiency of weed control under combination of pendimethalin + Imazethapyr against both broad leaved and grassy weeds (Table 1). Post emergence application of imazethapyr 75 g/ha was also superior over the graded dose of quizalofop ethyl and weedy check. Ram *et al.* (2012) reported higher weed control efficiency with imazethapyr @ 50 g/ha at 20 DAS in rajmash. Use of post emergence herbicide was also found to be superior over pre emergence and pre plant incorporation applied herbicide as weeds were killed in their active growth stage bearing 2-3 leaves (Chen *et al.* 1998). Similarly, minimum weed index (15.5 %) was recorded with pre emergence application of pendimethalin 30 EC + imazethapyr 2 EC @ 1.0 kg/ha over rest of the herbicide treatments and weedy check (Table 1) as the treatment effectively controlled both broad leaved and grassy weeds.

Effect on crop : All the pre and post emergence herbicide treatments had significantly higher values of crop growth and yield contributing characters over the weedy check. Among the herbicide treatments, tallest plants (28.3 cm) and the highest branches/plant (5.2), pods/plant (13.9) and pod length (11.5 cm) were recorded with application of pendimethalin 30 EC + imazethapyr 2 EC @ 1.0 kg/ha as pre-emergence and was closely followed by pendimethalin 30 EC + imazethapyr 2 EC @ 0.75 kg/ha as pre-emergence. Because of poor weed control efficiency, chlorimuron ethyl @ 4 g/ha as pre-plant incorporation was least effective for raising crop growth and yield contributing characters of rajmash (Table 2). On the contrary, hand weeding twice at 20 and 40 DAS produced significantly

Table 1: Influence of different herbicides on weed dry matter production and weed control efficiency at 60 DAS (Pooled data of three years)

Treatments	Weed dry matter production (g/m^2)		Weed dry matter production (kg/ha)		Weed control efficiency at 60 DAS
	30 DAS	60 DAS	(%)	(%)	
Quizalofop ethyl @ 50 g/ha at 30 DAS	23.7	84.6	32.5	32.2	32.5
Quizalofop ethyl @ 60 g/ha at 30 DAS	24.4	82.0	34.6	32.0	34.6
Imazethapyr @ 50 g/ha at 30 DAS	24.5	62.2	50.4	24.1	50.4
Imazethapyr @ 75 g/ha at 30 DAS	23.8	53.9	57.0	20.9	57.0
Chlorimuron ethyl @ 4 g/ha as PPI	13.3	83.7	33.2	51.8	33.2
Pendimethalin @ 1.0 kg/ha as PE	11.3	71.3	43.1	28.9	43.1
Pendimethalin 30 EC+imazethapyr 2 EC 0.75 kg/ha PE	10.6	45.6	63.6	17.9	63.6
Pendimethalin 30 EC+imazethapyr 2 EC 1.0 kg/ha PE	10.1	39.1	68.8	15.5	68.8
Hand weeding twice at 20 and 40 DAS	7.6	23.7	81.1	-	81.1
Weedy Check	24.5	125.3	-	64.1	-
SEm(±)	0.98	4.8		48	
CD (P=0.05)	2.9	14.3	29	143	

Table 2: Influence of different herbicides on growth and yield attributes of rajmash (Pooled data of three years)

Treatments	Plant height at harvest (cm)	Branches/plant (No)	Pods/plant (No)	Pod length (cm)	Seed index (g)
Quizalofop ethyl @ 50 g/ha at 30 DAS	22.0	3.6	10.2	10.0	27.4
Quizalofop ethyl @ 60 g/ha at 30 DAS	22.1	3.8	10.8	10.4	27.5
Imazethapyr @ 50 g/ha at 30 DAS	23.9	4.1	12.5	10.9	28.1
Imazethapyr @ 75 g/ha at 30 DAS	24.9	4.2	13.2	11.0	28.2
Chlorimuron ethyl @ 4 g/ha as PPI	20.3	3.1	8.4	9.2	27.2
Pendimethalin @ 1.0 kg/ha as PE	22.9	4	11.9	10.7	27.8
Pendimethalin 30 EC+imazethapyr 2 EC 0.75 kg/ha PE	27.6	4.8	13.8	11.4	28.3
Pendimethalin 30 EC+imazethapyr 2 EC 1.0 kg/ha PE	28.3	5.2	13.9	11.5	28.3
Hand weeding twice at 20 and 40 DAS	33.3	5.8	15.9	12.3	28.9
Weedy Check	19.0	2.9	7.2	8.1	26.4
SEm(±)	1.6	0.15	0.7	0.5	0.23
CD (P=0.05)	4.8	0.47	2.1	1.5	0.65

higher plant height (33.3 cm), branches/plant (5.8), pods/plant (15.9), pod length (12.3 cm) and seed index (28.9 g) over weedy check and most of the herbicidal treatments.

Seed and stover yield of rajmash varied significantly due to weed control treatments. Significantly maximum seed and stover yield (1636 and 2639 kg/ha, respectively) was obtained with hand weeding twice at 20 and 40 DAS over rest of the treatments. Among the herbicides, application of pendimethalin 30 EC + imazethapyr 2 EC @ 1.0 kg/ha as pre-emergence recorded maximum seed and stover yield (1383 and 2277 kg/ha, respectively) which was obvious due to its higher values of yield attributes, weed control efficiency (68.8 %) and lower weed index (15.5 %) compared to the rest of the herbicide treatments. However, this treatment was at par with treatment pendimethalin 30 EC + imazethapyr 2 EC @ 0.75 kg/ha as pre-emergence. In addition, pendimethalin 30 EC + imazethapyr 2 EC @ 1.0 kg/ha also increased the seed yield to the tune of 135.60 % while pendimethalin at 1.0 kg/ha as pre-emergence alone raised seed yield by 98.13 % over weedy check. Effectiveness of these treatments could be attributed to better control of weeds during critical period of crop – weed competition and thus, provided a weed free environment for a better growth and development of rajmash. These findings are in close proximity with that of Billore *et al*. (1999) and Ram *et al*. (2011) with imazethapyr on field pea. Lower seed yield under chlorimuron ethyl could be attributed to its poor weed control efficiency and higher weed index against grassy weeds.

Economic analysis : The highest net return (Rs. 58,970/ha) and benefit: cost ratio (2.32) was fetched with hand weeding twice at 20 and 40 DAS owing to effective control of weeds (Table 3) over rest of treatments. Among the herbicide treatments, highest net return (Rs. 48,475/ha) and benefit:cost ratio (2.11) was recorded with pendimethalin 30 EC+imazethapyr 2 EC @ 1.0 kg/ha-PE and was followed by pendimethalin 30 EC+imazethapyr 2 EC @ 0.75 kg/ha-PE and imazethapyr @ 75 g/ha applied at 30 DAS. Excellent control of weeds without any adverse effect on crop growth resulting in higher seed yield might have caused superior economic indices in these treatments. Least net return (Rs. 9660/ha) and B:C ratio (0.47) was recorded with weedy check due to both poor weed control and low crop yield.

Thus, it may be inferred from the above that hand weeding twice at 20 and 40 DAS could be recommended for effective control of mixed weed flora in rajmash for getting higher productivity and

Table 3: Influence of different herbicides on seed yield, stover yield, harvest index, economics and per cent reduction in yield due to presence of weeds of rajmash (Pooled data of three years)

Treatments	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	*Gross return (Rs/ha)	*Net return (Rs/ha)	B:C ratio	Weed index (%)
Quizalofop ethyl @ 50 g/ha at 30 DAS	1109	1648	40.3	57098	34896	1.57	32.2
Quizalofop ethyl @ 60 g/ha at 30 DAS	1111	1670	40.9	57220	34813	1.55	32.0
Imazethapyr @ 50 g/ha at 30 DAS	1241	2036	37.7	64086	42273	1.94	24.1
Imazethapyr @ 75 g/ha at 30 DAS	1296	2084	38.4	66884	44695	2.01	20.9
Chlorimuron ethyl @ 4 g/ha as PPI	789	1344	37.4	40794	19473	0.91	51.8
Pendimethalin @ 1.0 kg/ha as PE	1163	1870	38.4	60029	37127	1.62	28.9
Pendimethalin 30 EC+imazethapyr 2 EC 0.75 kg/ha PE	1343	2227	37.6	69373	46911	2.09	17.9
Pendimethalin 30 EC+imazethapyr 2 EC 1.0 kg/ha PE	1383	2277	37.8	71432	48475	2.11	15.5
Hand weeding twice at 20 and 40 DAS	1636	2639	38.3	84438	58970	2.32	-
Weedy Check	587	989	37.6	30328	9660	0.47	64.1
SEm(±)	68.3	100	2.4	3390	3393	0.15	
CD (P=0.05)	203	297	NS	10071	10081	0.45	

***The price of Quizalofop ethyl Rs. 1200/-lit, Imazethapyr Rs. 1600/-lit, Pendimethalin Rs. 580/- lit, Chlorimuron ethyl Rs. 350/- lit, Pendimethalin 30 EC+Imazethapyr 2 EC)- Rs. 630/-lit, The cost of two hand weeding (20 and 40 DAS) were Rs. 4800/- for 30 mandays, Sale price Rajmash grain Rs 50/kg & Stover Rs 1/kg.**

profitability. However, in case of unavailability of agricultural labour at appropriate time for manual weeding in rajmash, pre emergence application of pendimethalin 30 EC+imazethapyr 2 EC @ 1.0 kg/ha could be a good alternative to control the weeds effectively and economically.

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An economics of sugarcane cultivation in Surguja district of Chhattisgarh

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Abstract

The findings of the study envisaged that growth in production of sugarcane of the Chhattisgarh state and Surguja district was significant that was registered to be 13.02 and 10.16 per cent growth in production over the period 2001-02 to 2010-11. It was due to attribution of significant increase in area. However, productivity of sugarcane was decline non-significantly during the same period of the state and district. Sugarcane occupied 78.65 per cent area at marginal farms of the total operated area followed by small (50.61%), medium (46.69%) and large (35.64%) farms, respectively. The most prominent cropping pattern among sample farms was paddy-sugarcane, paddy-wheat-vegetables and maize-wheat-vegetables. The cropping intensity at sample farms varied from 123 to 125 per cent for marginal to large farms. The inputs/material use for cultivation of sugarcane at sample farms was upto the approximation even though yield of sugarcane was low because of farmers didn't know the optimum time of operational practices and timely non-availability of labour. Overall, cost of cultivation of sugarcane was Rs/ha 68036/- and it varied from Rs/ha 55059.65 at marginal farms to Rs/ha 79951.40 at large farms. The share of inputs/material cost was the maximum (53.80%) followed by human labour (33.20%), fixed cost (6.53%) and cost on power use (6.47%), respectively. The obtained net return of sugarcane cultivation was Rs/ha75465 and varied from Rs/ha 56090.35 to Rs/ha 97888.60 from marginal to large farms. The return to scale is operating in sugarcane cultivation among the sample farms of study area. The cost of production of sugarcane was Rs/q 89.17, Rs/q 89.96, Rs/q 84.57 and Rs/q 80.92 for marginal, small, medium and large farms, respectively. Overall, B:C ratio in sugarcane cultivation was 1.11. The major production and marketing constraints were non-availability of human labour, reported by 92 per cent farmers and their elicitation was the main problem at the peak time of sowing, earth work and harvesting of crop that was reported by 82, 45, and 77 per cent farmers, respectively. The opinion of farmers on problems in marketing of sugarcane was more on non-availability of market news resulted not getting the better price of their produce reported by 95 per cent farmers. Transportation was another major problem that was reported by 63 per cent farmers.

Key wards: Costs and return of sugarcane, constraints in production and marketing of sugarcane, growth in area, production and yield of sugarcane

Introduction

India is one of the principal centres of origin of sugarcane (*Sacchrarum barberi*) and grown in diverse climatic conditions of the country. Out of the 121 countries of the world, India is only of the country where sugarcane cultivated in both climates i.e., tropical and sub-tropical. Worldwide sugarcane occupied 25.76 m. ha area and produced 1773.82 m. tons sugarcane with average productivity of 68.85 t/ha (Anonymous, 2010). Twelve countries namely Brazil, India, China, Thailand, Mexico, Indonesia, Austria, South Africa, Argentina, USA, Cuba, and Sri Lanka contributed 86 and 87 per cent area and production of sugarcane to the world respectively.

India occupied 5.09 m. ha area of sugarcane and total production of sugarcane was 347.87 m. tons with average productivity of 68.34 t/ha (Anonymous, 2010). The share of sugarcane area is 3.08 per cent to total cropped area of Chhattisgarh. The area of sugarcane in northern parts of Chhattisgarh is 3.44 thousand ha and production is 132.40 thousand tons with average productivity of 38.50 t/ha. The average productivity of sugarcane is quite low in northern parts of Chhattisgarh than that of other parts of the country. The importance of sugarcane cultivation is gradually increasing in the northern parts of Chhattisgarh with the start of sugar mill in Pratappur block of Surguja district. The cane is procured by sugar mill at minimum support price (MSP) and provide bonus to the farmers. For not augmenting the desire yield of sugarcane in the northern parts of the state might be poor capital base and lack of technological diffusion at fields of sugarcane. It is therefore, necessary to answers the questions what is the present status of sugarcane cultivation in study area? which types of cultivation practices adopted by the farmers in the study area? how much costs and return they obtaine? and what are the constraints in production and marketing of sugarcane. In view of this a present study has been carried out with following specific objectives:

- To estimate the growth in area, production and productivity of sugarcane in Surguja district and Chhattisgarh state.
- To find out the cropping pattern and cropping intensity of sample farmers in the study area.
- To work out the costs and return of sugarcane cultivation in sample farms
- To identify the constraints in production and marketing of sugarcane among the sugarcane growers

Material and Methods

Out of the 18 undivided districts of Chhattisgarh state, Surguja district was selected purposively for the study because the district was second largest in production and area of sugarcane cultivation than that of other districts of Chhattisgarh and good prospects with open of sugar mill in the district by the Government of Chhattisgarh State on 15th October, 2006. Among the 19 blocks of Surguja district, Pratappur, Lundra, Surajpur and Ambikapur blocks were considered for the study on the basis of more area coverage for sugarcane crop. One village for each selected block was undertaken randomly *viz.,* Kerta village for Pratappur, Kalayanpur village for Surajpur, Lamgaon village for Lundra and Surguja village for Ambikapur blocks. The list of sugarcane growers was obtained from the office of Deputy Director of Agriculture, Surguja, 15 sugarcane growers (farmers) were chosen randomly from each sample village. Totally, 60 sugarcane growers were considered for the study.

The study required both primary and secondary data. The primary data collected by field level survey method. The information were recorded from individual selected farmer on schedule designed for the study with regards to demographical features of the sample farmers, cropped area, cropping pattern, costs & return of sugarcane and constraints in production and marketing of sugarcane. The primary data was pertaining for the year 2010-11.

The time series secondary data of area, production and productivity of sugarcane by district and state was collected from the office of Directorate of Agriculture, Chhattisgarh State and Agriculture Statistics published by the Commissioner of Land Records and Settlement, Government of Chhattisgarh State for the year 2001-02 to 2010-11.

To compute the growth rate of area, production and productivity of sugarcane, the exponential function was used, which is as follows:

$Y = AB^t$

The computational form of function is, $\log Y = \log A + t \log B$

Where,

$\log Y = y$ i.e., area, production and productivity of sugarcane

$\log A = a$ is constant

$\log B = b$ is co-efficient

t = time

Then, $y = a + bt$

as $b = 1 + r$

So, $r = b - 1$

Compound Growth Rate (r) = [(Anti-log of b – 1)* 100]

The primary data were analyzed by using simple average and percentage statistical methods.

Results and Discussion

This study yielded many useful results and presented on the following heads:

Status of sugarcane : The detail insight picture of sugarcane status was understand through estimation of compound growth rate (CGR) of area, production and productivity over the period 2001-02 to 2010-11, which is given in Table 1. It indicates that significant growth in area of sugarcane was observed for the Chhattisgarh state and sample district Surguja that was found to be 15.84 and 14.64 per cent growth in area of sugarcane, respectively. However, growth in production of sugarcane was registered to be 13.02 and 10.16 per cent for the state and district that was found to be significant. While the productivity of sugarcane of the state and sample district was decline non-significantly, which was registered to be -2.47 and -3.72 per cent growth in productivity of sugarcane during the periods of study. It is important to note that production of sugarcane was significantly increased due to only attribution of sugarcane area (Kishor, *et al.,* 1997 and Singh, *et al.,* 2003). The productivity of sugarcane was decline non-significantly of the state and district during the study period was the major reason to non-adoption of full package of practices by the farmers of tribal dominated district for cultivation of sugarcane and poor resource base of farmers.

Table 1 : Compound growth rate of area, production and productivity of sugarcane

Particular	Compound Growth Rate (%)		
	Area	Production	Productivity
Chhattisgarh	15.84*	13.02*	-2.47
Surguja	14.64*	10.16*	-3.72

Note: * denotes the level of significance at 5% probability level.

Demographical features of sample households: Demographic feature provides the general characteristics of sample households, which is presented in Table 2. It reveals that average family size of sample households was approximately 7, which varied from 6 to 7 family members for marginal to large farmers. Majority of households belong to other backward caste (OBC) and it was noticed to be 50 per cent. The most of family members 18 years old age group and notice to be 33.25 per cent. The literacy among the family members was quite high and registered to be 91 per cent.

The average farm size of sample households was 0.55, 1.55, 2.49 and 4.77 ha for marginal, small, medium and large farms, respectively. The operated area is owned land plus lease in land and subtracted the lease out area that was registered to be 0.95, 1.62, 2.72 and 4.77 ha, respectively. The average irrigated area was 65.08 per cent and ranging from 60 per cent irrigation in large farms to 86.32 per cent irrigation in marginal farms.

Cropping pattern and cropping intensity: The cropping pattern and cropping intensity indicates the

Table 2 : Demographical features, average farm size and operated area of sample households.

Particulars	Farm Size of Holdings				
	Marginal	Small	Medium	Large	Total
No. of households	07	27	19	07	60
No. of family members	44	170	140	52	406
Male	25 (56.81)	89 (52.35)	71 (50.71)	27 (51.92)	212 (52.22)
Female	19 (43.19)	81 (47.65)	69 (49.29)	25 (48.08)	194 (47.78)
No. of household by caste					
Schedule tribe	-	13 (48.15)	07 (36.85)	02 (28.60)	22 (36.67)
Schedule caste	01 (14.29)	03 (11.11)	02 (10.52)	01 (14.28)	07 (11.67)
Other backward caste (OBC)	06 (85.71)	10 (37.04)	10 (52.63)	04 (57.14)	30 (50.00)
General caste	-	1 (3.70)	-	-	1 (1.66)
Total	**7**	**27**	**19**	**7**	**60**
Age of family members					
Up to 18 years	16 (36.36)	62 (36.47)	43 (30.71)	16 (30.77)	135 (33.25)
18 – 40 years	15 (34.09)	55 (32.35)	44 (31.43)	18 (34.62)	132 (32.51)
40 – 60 years	09 (20.45)	42 (24.71)	41 (29.29)	11 (21.15)	103 (25.37)
Above 60 years	04 (9.10)	11 (6.47)	12 (8.57)	07 (13.46)	36 (8.87)
Total	**44**	**170**	**140**	**52**	**406**
Level of education					
Illiterate	7 (15.90)	15 (8.82)	10 (7.14)	4 (7.69)	34 (8.87)
Primary	16 (36.36)	78 (45.88)	41 (29.29)	10 (19.23)	145 (35.71)
Middle	12 (27.28)	42 (24.71)	56 (40.00)	18 (34.62)	128 (31.53)
HSSC	05 (11.37)	25 (14.70)	24 (17.14)	14 (26.92)	68 (16.75)
Graduate	04 (9.09)	10 (5.89)	09 (6.43)	06 (11.54)	29 (7.14)
Literacy	**84.10**	**91.18**	**92.86**	**92.31**	**91.13**
Av. Farm size (ha)	0.55	1.55	2.49	4.77	2.31
Av. Operated area (ha)	0.95	1.62	2.72	4.77	2.52
Lease-in land	0.40	0.07	0.23	-	0.21
Lease-out land	-	-	-	-	-
Area irrigated (ha)	0.82 (86.32)	1.00 (61.73)	1.86 (68.38)	2.86 (60.00)	1.64 (65.08)

Note: Figures in the parentheses indicates the percentage to total.

sensitivity of climatic aberration, resource availability and socio-economic factors at farms, which is estimated on per farm area basis (Table 3). It reveals that farmers were allocating their land during *kharif* in paddy, maize and vegetables. However, sugarcane was the major crop during *rabi*, which was registered to be 31.07 per cent area irrespective to the farm size of holdings followed by wheat (13.39%) and vegetables (1.59%), respectively. The sample farms having irrigation sources, allocating their land for sugarcane cultivation during summer but proportionately the area was less. Overall, area under rabi crops was comparatively more than kharif crops and it was found to be 46.49 per cent. Sugarcane was the major crop during *rabi*. The area under kharif crops was 38.54 per cent and paddy was the major crop. The summer crops were also cultivate by famers that was noticed to be in 14.97 per cent area and vegetables cultivation was the major one and found to be 10.19 per cent area. The proportionate area of sugarcane during *rabi* was decreasing with respective to farm size of holdings and it registered 64.10, 39.11, 28.82 and 25.67 per cent area of sugarcane for marginal, small, medium and large farms, respectively. Overall, cropping intensity was nearly 124 per cent and varied from 123 to 125 per cent at farm levels.

Inputs/material use for cultivation of sugarcane: Inputs/material use for cultivation of sugarcane is important to understand how much inputs/material use is deviated from the standard package of practices in cultivation of sugarcane (Table 4). The empirical findings indicates that farmers of the study area did not follow the recommended package of practices of sugarcane cultivation resulted 25 percent less yield than that of obtainable attainable yield of sugarcane. The seed rate of sugarcane was ranging from 6.18 to 7.41 t/ha and the application of manure/ FYM was varied from 9.89 to 13.59 t/ha, which was close to the recommendation. The application of urea, single super phosphate (SSP) and murate of potash (MoP) was also nearer to the recommendation. The sever incidence of termite, early shoot borer, pyrilla and white fly to sugarcane crop was observed, hence the application of insecticides was found to 19.15 kg/ha irrespective to the farm size of holdings. Weeds are very common in Surguja district and fields of sugarcane were not away from weed infestation so that farmers were applying 1.98 kg/ha of weedicides (Atrazine and 2-4D). The application of fungicides was notice to be 1.92 kg/ha of corendazim and vitavax applying to control the red rot of sugarcane, smut and grassy shoot diseases.

Table 3 : Cropping pattern and cropping intensity of sample farms (in ha/farm)

Crops	Farm Size of Holdings				
	Marginal	Small	Medium	Large	Overall
Kharif					
Sugarcane	-	-	-	-	-
Paddy	0.15 (12.82)	0.70 (34.65)	1.02 (30.00)	1.74 (29.19)	0.86 (27.39)
Maize	0.05 (4.27)	0.03 (1.48)	0.11 (3.23)	0.95 (15.94)	0.29 (9.24)
Vegetables	-	0.05 (2.48)	0.06 (1.76)	-	0.06 (1.91)
Sub-total	**0.20 (17.09)**	**0.78 (38.61)**	**1.19 (34.99)**	**2.69 (45.13)**	**1.21 (38.54)**
Rabi					
Sugarcane	0.75 (64.10)	0.79 (39.11)	0.98 (28.82)	1.53 (25.67)	.98 (31.21)
Wheat	0.08 (6.84)	0.18 (8.91)	0.57 (16.76)	0.87 (14.60)	0.43 (13.69)
Vegetables	0.02 (1.71)	0.02 (0.99)	0.05 (1.47)	0.12 (2.01)	0.05 (1.59)
Sub-total	**0.85 (72.65)**	**0.99 (49.01)**	**1.60 (47.05)**	**2.52 (42.28)**	**1.46 (46.49)**
Summer					
Sugarcane	-	0.03 (1.49)	0.26 (7.65)	0.17 (2.86)	0.15 (4.78)
Vegetables	0.12 (10.26)	0.22 (10.89)	0.35 (10.29)	0.58 (9.73)	0.32 (10.19)
Sub-total	**0.12 (10.26)**	**0.25 (12.38)**	**0.61 (17.94)**	**0.75 (12.59)**	**0.47 (14.97)**
Gross Cropped Area	1.17 (100)	2.02 (100)	3.40 (100)	5.96 (100)	3.14 (100)
Net Cropped Area	0.95	1.62	2.72	4.77	2.52
Cropping Intensity (%)	**123.16**	**124.70**	**125.00**	**124.95**	**124.45**

Note: Figures in the parentheses indicates the percentage to total.

The total number of irrigation was recommended from 12 to 15 at different crop growth stages of sugarcane and farmers were applying 11 irrigations to the crop. The human labour requirement for sugarcane cultivation was raging form 250 to 300 days/ha that was registered to be 225.80 days/ha at the sample farms. Nearly, 3-4 pairs of bullock labour days/ha and 8 to 12 machine hours/ha were used for preparation of land (Kishor, *et al.,* 1999). It is important to note that farmers were obtaining the poor yield of sugarcane although applying inputs/material for its cultivation up to the approximation as per the recommendations. It is because of farmers were not knowing the optimum time of operational practices for sugarcane cultivation and labour availability in time was the major problem.

Costs and return of sugarcane cultivation: The costs and return of sugarcane cultivation was estimated in Rs/ha, which is given in Table 5. It reveals that total cost of cultivation of sugarcane was in Rs/ha 68036/- irrespective to the farm size of holdings and

Table 4 : Inputs/material and labour use in sugarcane cultivation.

Particular	Farm Size of Holdings				
	Marginal	Small	Medium	Large	Overall
Yield (q/ha)	61.75	71.65	86.69	98.80	79.72
Inputs/material					
Seed (t/ha)	6.18	6.17	7.41	7.41	6.79
Manure & FYM (t/ha)	9.89	11.11	12.35	13.59	11.74
Fertilizers (kg/ha)					
Urea	420	494	543	618	519
SSP	210	298	275	310	275
MOP	49	75	99	124	87
Plant Protection Chemicals (kg or lit/ha)					
Insecticides	14.83	17.29	19.76	24.71	19.15
Fungicides	1.24	1.73	2.22	2.47	1.92
Weedicides	1.24	1.98	2.22	2.47	1.98
No. of Irrigation (per ha)	8	10	12	14	11
Human labour days (in ha)					
Family labour days	135.36	141.50	103.56	93.30	118.43
Hired labour days	41.06	66.69	141.09	180.99	107.46
Total human labour days	176.42	208.39	244.09	274.29	225.80
Power use					
Bullock labour days (in ha)	3.00	3.00	-	-	1.50
Machine hours (in ha)	6.08	6.63	9.88	9.88	8.12

Note: Recommended package of practices: Seed (sets) @ 5–10 t/ha, Manure & FYM @ 10 t/ha, Fertilizers: Urea @ 445– 650 kg/ha, SSP @ 500-625 kg/ha, MoP @ 100-135 kg/ha and No. of Irrigations @ 12–15 per ha

the share of inputs/material cost was the maximum that was found to be 53.80 per cent followed by human labour cost (33.20%), fixed cost (6.53%) and cost on power use (6.47%), respectively. Among the inputs/material cost, seed and fertilizers costs were noticed to be major one. However, imputed value of family labour cost was shared comparatively more than that of hired labour cost. The share of cost on machine power was more than that of bullock power cost in sugarcane cultivation. The interest on working capital was more as compared to land rent.

The empirical findings indicates that total cost of cultivation was increasing with increase in the farm size of holdings that was the maximum and found to be Rs/ha 79951.40 under large farms and minimum in marginal farms (Rs/ha 55059.65). The cost on inputs/material and human labour use was also increasing as per increasing the farm size of holdings. While fixed and power use cost was constant with respect to the farm size. It can be concluded that total cost of cultivation was increasing with regards to increase in farm size of holdings. It is because of large farmers incurred more expenditure on inputs/material use.

Economics of sugarcane cultivation : The economics of sugarcane cultivation is to understand the estimation of economic parameters *viz;* cost of cultivation & production, input-out ratio, gross & net returns and B:C ratio and same is presented in Table 6. It is observed from the findings that net return of sugarcane was Rs/ha 75465/- irrespective to the farm size of holdings and varied from Rs/ha 56090.35/- to Rs/ha 97888.60/- for marginal to large farms. It indicates that return to scale is operate in sugarcane cultivation (Maheshwarappa, *et al.,* 1998) The cost of production of sugarcane was registered to be Rs/q 89.17, Rs/q 86.96, Rs/q 84.57 and Rs/q 81.58 for marginal, small, medium and large farms, respectively. While input-output and B:C ratios were showing increasing trend with regards to increase in farm size. Overall, input-output ratio and B:C ratio noticed to be 1:2.11 and 1.11, respectively.

Constraints in production and marketing of sugarcane: The opinion of farmers with regards to constraints in production and marketing of sugarcane have been undertaken and their elicitations are presented in Table 7. It reveals that availability of human labour was the most burning problem as reported by 92 per cent farmers. Their elicitation on labour non-availability was more during the peak time of sowing, earth work and harvesting of crop that was reported by 82, 45 and 77 per cent farmers, respectively. Nearly, 85 per cent farmers reported that non-availability of owned irrigation sources was next important problem and mostly depends on rainfall and purchase water. The opinion of farmers with regards to resources availability have taken, nearly, 73 per cent farmers reported that poor resource base had the main cause and mostly loan taken from banks, traders and relatives. The perception of farmers on follow up the recommended package of practices for sugarcane cultivation as 57 per cent farmers elicit that no recommendation available to them because extension personnel not visited frequently to their fields. The management committee of sugar mill, Ambikapur had taken the initiative for providing the

Table 5 : Costs and return of sugarcane cultivation

Particular	Farm Size of Holdings				
	Marginal	Small	Medium	Large	Overall
Cost on inputs/material use					
Seed (t/ha)	14828.90	14817.49	17783.48	17788.94	16304.70
Manure & Fertilizers	10322.15	12063.91	13532.73	15287.37	12801.54
Plant Protection Chemicals	2199.62	3086.97	3838.27	4570.78	3423.91
Irrigation charges	2965.78	3704.37	4445.87	5188.44	4076.12
Sub-total	**30316.45**	**33672.74**	**39600.35**	**42835.53**	**36606.27**
	(55.06)	**(54.04)**	**(54.02)**	**(53.58)**	**(53.80)**
Cost on human labour					
Imputed value of Family labour	13536.12	14150.58	10356.85	9330.00	11843.39
Hired labour cost	4106.47	6669.67	14109.87	18098.82	10746.21
Sub-total	**17642.59**	**20820.25**	**24466.72**	**27428.82**	**22589.60**
	(32.04)	**(33.41)**	**(33.37)**	**(34.41)**	**(33.20)**
Cost on power use					
Bullock labour cost	751.59	750.58	-	-	751.09
Cost on machine hours	2737.64	2981.41	4445.87	4447.24	3653.04
Sub-total	**3489.23**	**3731.99**	**4445.87**	**4447.24**	**4404.13**
	(6.34)	**(5.99)**	**(6.06)**	**(5.56)**	**(6.47)**
Fixed Cost					
Land revenue	10	10	10	10	10
Interest on working capital	3601.38	4075.75	4795.91	5229.81	4425.71
Sub-total	**3611.38**	**4085.75**	**4805.91**	**5239.81**	**4435.71**
	(6.56)	**(6.56)**	**(6.55)**	**(6.55)**	**(6.53)**
Total Cost	**55059.65**	**62310.73**	**73318.85**	**79951.40**	**68035.71**

Note: Figures in parentheses indicates the percentages of total Seed (sets) @ Rs/q 240, Manure & FYM @ 50 per qtl, Fertilizers: Urea @ Rs/q 600, SSP @ Rs/q 545, MOP @ Rs/q 1150 No. of Irrigations @ 12–15 per ha Imputed value of Family labour @ Rs/day 100, Hired labour @ Rs/day 100, Bullock pair @ Rs/day 250, Machine hour @ Rs/hour 450 and Irrigation charges @ Rs/no. 150 Interest on working capital @ 7% .

Table 6 : Economics of sugarcane cultivation

Particular	Farm Size of Holdings				
	Marginal	Small	Medium	Large	Overall
Yield (t/ha)	61.75	71.65	86.69	98.80	79.72
Cost of Cultivation (Rs/ha)	**55059.65**	**62310.73**	**73318.85**	**79951.40**	**68035.71**
Gross Return (Rs/ha)	111150	128970	156047	177840	143501
Net Return (Rs/ha)	56090.35	66659.27	82728.15	97888.60	75465.29
Cost of Production (Rs/q)	89.17	86.97	84.57	81.58	84.87
Input-Output Ratio	1:2.02	1:2.07	1:2.13	1:2.22	1:2.12
Benefit Cost Ratio (B:C Ratio)	1.02	1.07	1.13	1.22	1.11

Note: Procurement price of sugarcane was Rs/q 145 plus Bonus Rs/q 35.

seeds of improved varieties of sugarcane and the State Agriculture Department facilitates to disseminate the seeds of improved seeds, which was reported by 63 per cent farmers.

The opinion of farmers with regards to constraints in marketing of sugarcane have taken and their elicitation was more on marketing news having importance to get higher price of their produce and reported by 95 per cent farmers. In context to the market news, farmers reported that more demand of sugarcane promote for more remunerative price of sugarcane. Despite marketing constraints, transport-tation was also the major problem that was reported by 63 per cent farmers.

Conclusion : Sugarcane is the most important cash crop in Surguja district of Chhattisgarh state for generating more income and employment at farm level. So, the present study seeks to examine by estimating (i) the growth in area, production and productivity of sugarcane of the state and sampled district Surguja, (ii) cropping pattern and cropping intensity of sample farms, (iii) costs and return of sugarcane at sample farms and (iv) to identify the constraints in production & marketing of sugarcane. This study was conducted in 4 blocks of Surguja district of Chhattisgarh state. One village for each sampled block was taken randomly and totally, 60 farmers were selected randomly from the sample villages comprised of marginal (7), small (27), medium (19) and large (7) farmers, respectively. Both primary and time series secondary data required to accomplish the study. The findings of study envisaged that average farm size of sample farms was 2.31 ha and the literacy percentage was 91.13 per cent. The cropping intensity was 124.45 among the sample farms. The major crops grown by the farmers were rice and maize in kharif and sugarcane & wheat in rabi and summer. The major source of irrigation was tube-well and shared 80.48% irrigation. The growth in area and production of the state was found to be 15.84 and 13.02 per cent during the study period 2001 to 2011. Growth in area and production of sugarcane of Surguja district was 14.64 and 10.16 per cent for the same period. The growth in productivity of sugarcane of the state and sampled district Surguja was negative and non-significant during the study period. Growth in production of sugarcane

Table 7: Farmers' perception on constraints in production and marketing of sugarcane.

Particular	No. of farmers	
	Yes	No
Production constraints		
Non availability of improved seeds	22 (36.67)	38 (63.33)
Non-adoption of recommended package of practices	34 (56.67)	26 (43.33)
If yes then, No such recommendation	13 (21.67)	
No frequent visit of extension worker	27 (45.00)	
No interest of farmers	21 (35.00)	
Lack of resources	44 (73.33)	16 (26.67)
If yes then, loan not available from banks	29 (48.33)	
Loan not available from traders	22 (36.67)	
Loan not available from relatives & others	15 (25.00)	
Lack of irrigation facilities	51 (85.00)	9 (15.00)
If yes then, Lack of own irrigation source	35 (58.33)	
Dependency on rainfall	34 (56.67)	
Dependency on purchase water	18 (30.00)	
Lack of availability of labour	55 (91.67)	5 (8.33)
If yes then, at the time of sowing	49 (81.67)	
At the time of earthing working	27 (45.00)	
At the time harvesting of crop	46 (76.67)	
Marketing		
Lack of demand of the produce	8 (13.33)	52 (86.67)
Low price of the produce	16 ()26.67	44 (73.33)
Lack of transportation facilities	38 (63.33)	22 (36.67)
Problem in marketing due to small quantity of produce	11 (18.33)	49 (81.67)
Lack of awareness of marketing news & intelligence	30 (50.00)	30 (50.00)
Is the market news help to get the higher price of produce	57 (95)	3 (5)

Note: Figures in the parentheses indicates the percentage to total.

was attributed by significant increase in area not by productivity. The average cost of cultivation of sugarcane was found to be Rs/ha 68036/- and cost on per quintal was Rs 84.87. Overall yield of sugarcane was 79.72 t/ha among the sample farms. The benefit over Re 1 investment was 1.11. The major constraints in production was lack of availability of human labour at peak time of sowing earth work and harvesting of crop, lack irrigation facilities. Major constraint in marketing of sugarcane was reported by farmers on non-availability of facilities should be incurred, market news were marketing new and transportation facilities.

The study suggested that to improve the status of sugarcane by increasing the irrigation facilities, developing the linkages for procurement of sugarcane on assured price, to protect the farmers against natural disasters, crop insurance scheme should compulsory impose to sugarcane growers. Malpractices with regards to weighing grading of sugarcane should discourage and avoid the discrimination among farmer to farmers at the time of procurement. Statutory Minimum Price (SMP) of sugarcane should be increased looking the cost of production. The payment to the farmers against the purchase of sugarcane should not be delayed.

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Calibration and validation of ArcSWAT model for estimation of surface runoff and sediment yield from Dhangaon watershed

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Abstract

Soil and Water Assessment Tool (SWAT) is a distributed parameter continuous time model and was tested on daily and fortnightly basis for a small agricultural watershed (Dhangaon). The SWAT model recently interfaced with ArcGIS and called as ArcSWAT. The watershed and sub-watershed boundaries, drainage networks, slope and texture maps were generated in the environment of ArcGIS of ArcSWAT. Supervised classification method was used for land use/cover classification from satellite imageries of the years 2009 and 2012.

Manning's roughness coefficient 'n' for overland flow and channel flow and Fraction of Field Capacity (FFC) were calibrated for monsoon season of the years 2009 and 2010. The model was validated on daily basis for the years 2011 and 2012 by using the observed daily rainfall and temperature data. Calibration and validation results revealed that the model was predicting the daily surface runoff and sediment yield satisfactorily. Sensitivity analysis showed that the annual sediment yield was inversely proportional to the overland and channel 'n' values whereas; annual runoff and sediment yields were directly proportional to the FFC.

Model was also tested (calibrated and validated) for the fortnightly runoff and sediment yield for the year 2009-10 and 2011-12, respectively. Simulated values of fortnightly runoff and sediment yield for the calibration and validation years compared well with their observed counterparts. The calibration and validation results revealed that the ArcSWAT model could be used for identification of critical sub-watershed and for developing management scenarios for the Dhangaon watershed. Further, model should be tested for simulating the surface runoff and sediment yield using generated rainfall and temperature before applying it for developing the management scenario for the critical or priority sub-watersheds.

Key words: Watershed, hydrologic and water quality, ArcSWAT model, remote sensing, GIS, runoff and sediment yield.

Introduction

Surface hydrologic modelling for watershed includes processes like generation and transport of runoff, sediment, and pollutants from watersheds. Effective control of soil erosion and sediment yield requires implementation of best management practices in critical erosion prone areas. This effort can be enhanced by the use of physically based computer simulation models. Among these models ArcSWAT is one of the most recently developed distributed parameter continuous time model. It has been developed as a result of the United States of America-Agricultural Research Service's (USDA-ARS) continuing efforts in non point source pollution modelling and evaluation (Arnold *et al.* 1996). It has been used most widely for simulating the runoff, sediment yield and water quality of small watersheds. It has also capability to simulate the long-term effect of Best Management Practices.

The compilation and input of hydrologic data that are required by the ArcSWAT model are often cumbersome. Remote Sensing Technology (RST) is suitable to study the most recent pattern of land use/land cover and Geographic Information System (GIS) is computer-based tools that analyses and manage spatial data. The tediousness and time-consuming nature of extraction of watershed parameters can be eliminated by means of RST and GIS in addition to obtaining high accuracy. Also they can assist management agencies in identifying most vulnerable erosion prone areas and selecting appropriate management practices. The Digital Elevation Models (DEMs) can be used successfully to extract several watershed parameters. These techniques can provide more precise and reproducible measurements than the traditional manual techniques applied to topographic maps, so that the input data for the ArcSWAT model can be extracted with the use of RST and GIS mainly from the map layers including land use/land cover, DEM, soil, slope, drainage and watershed and sub-watershed boundaries.

Several applications of SWAT in various parts of the United States and India have shown promising results (Srinivasan *et al.*, 1993; Srinivasan and Arnold, 1994; Rosenthal *et al.*, 1995; Cho *et al.*, 1995; Bingner, 1996; Srinivasan *et al.* 1998; Peterson and Hamlett, 1998; Gassman *et al.* 2007; Agrawal *et al.* 2009; Tripathi 2012). In these studies, the model was tested mainly on daily, monthly and annual basis for predicting runoff. However, the model has not been tested widely for prediction of sediment yield. Also very little work on assessment of the impact of management practices on runoff, sediment yield and nutrient losses has been reported. Although the model operates on a daily time step and is efficient enough to run for many years, it is intended as a long term yield model and is not capable of detailed, single-event, flood routing (Arnold *et al.*, 1998).

This study discusses the approach of using physically based model and GIS to estimate the surface runoff and sediment yield of the Dhangaon watershed. The major objective of the study is to estimate the daily and fortnightly runoff and sediment yield at the outlet of the Dhangaon watershed using remote sensing data, GIS technique and ArcSWAT model.

Theoretical Consideration : A brief description of sub-basin components and the mathematical relationships used to simulate the processes and their interactions in the model as described by Arnold *et al.* (1996) are considered in this study. The mathematical relationships used in the model for simulating runoff volume and sediment yield are described in this paper.

Runoff Volume : ArcSWAT predicts surface runoff for daily rainfall by using the Soil Conservation Service (SCS) Curve Number (CN) method (USDA-SCS, 1972). The model adjusts curve numbers based on Antecedent Moisture Condition (AMC). The basic equations used in SCS curve number method are as follows:

$$Q = \frac{(R-0.2s)^2}{R+0.8s}, \quad R > 0.2s \qquad \text{....(1)}$$

Q=0.0, *Rs*=≤0002... ....(2)

Where, Q is the daily runoff, R is the daily rainfall, and s is the retention parameter. The retention parameter varies in space because of varying soil, land use, management, and slope; and in time because of changes in soil water content. The parameter s is related to CN as follows;

$$s = 254\left(\frac{100}{CN} - 1\right) \qquad \text{....(3)}$$

The constant, 254, in equation 3 gives *s* in mm. Thus, R and Q are also expressed in mm. The curve number for average moisture condition II (CN_2) is appropriate for a slope of 5% and can be adjusted for other slopes using the following formula;

$$CN_{2s} = \frac{1}{3}(CN_3 - CN_2)\left[1 - 2\exp(-13.86S)\right] + CN_2 \qquad \text{....(4)}$$

Where CN_{2s} is the handbook CN_2 value adjusted for slope, CN_3 is the curve number for moisture condition III (wet), and S is the average slope of the watershed. Curve numbers for moisture conditions I (CN_1) and III (CN_3) can be estimated using CN_2 as follows;

$$CN_1 = CN_2 - \frac{20(100 - CN_2)}{100 - CN_2 + \exp\left[2.533 - 0.0636(100 - CN_2)\right]} \qquad \text{....(5)}$$

$$CN_3 = CN_2 \exp\left[0.00673(100 - CN_2)\right] \qquad \text{....(6)}$$

Eq. (7) describes change in retention parameter based on fluctuations in soil water content:

$$s = s_1\left(1 - \frac{FFC}{FFC + \exp\left[w_1 - w_2(FFC)\right]}\right) \qquad \text{....(7)}$$

Where, s_1 is the value of s associated with CN_1, w_1 and w_2 are the shape parameters and FFC is the fraction of field capacity and can be computed using Eq. (8):

$$FFC = \frac{SW - WP}{FC - WP} \qquad \text{....(8)}$$

Where, SW is the soil water content in the root zone, WP is the wilting point water content and FC is the field capacity water content.

Values for w_1 and w_2 can be obtained from a simultaneous solution of Eq. (7) and Eq. (8) according to the assumptions that $s = s_2$ when FFC = 0.6 and $s = s_3$, when (SW-FC)/(PO-FC) = 0.5;

$$w_1 = \ln\left(\frac{60}{1 - s_2/s_1} - 60\right) + 60\,w_2 \qquad \text{....(9)}$$

$$w_2 = \frac{\ln\left(\frac{60}{1 - s_2/s_1}\right) - 1\ln\left(\frac{POFC}{1 - s_3/s_1} - POFC\right)}{POFC - 60} \qquad \text{....(10)}$$

Where, s_3 is the CN_3 retention parameter and POFC is the porosity-field capacity ratio and can be computed with the following equation;

$$POFC = 100 + 50\left(\frac{\sum_{l-1}^{M}(PO_l - FC_l)}{\sum_{l-1}^{M}(FC_l - WP_l)}\right) \qquad \text{....(11)}$$

Where, PO is the porosity of soil layer l. Eqs. (9) and (10) assure that CN_1 corresponds with the wilting point and that the curve number can not exceed 100.

The FFC value obtained in Eq. (8) represents soil water uniformly distributed through the top 1.0 m of soil. Runoff estimates can be improved if the depth distribution of soil water is known. The model estimates daily water content of each soil layer and thus the depth distribution is available. The effect of depth distribution on runoff is expressed in the depth weighting function:

$$FFC^* = \frac{\sum_{l=1}^{M} FCC_l \frac{Z_l - Z_{l-1}}{Z_l}}{\sum_{i=1}^{M} \frac{Z_i - Z_{l-1}}{Z_i}}, \qquad Z_i \le 1.0\, m \qquad \text{....(12)}$$

Where, FFC^* is the depth weighted FFC value for use in Eq. (7), Z is the depth in m to the bottom of soil layer l, and M is the number of soil layers.

Sediment yield : Sediment yield is computed for each sub-basin with the Modified Universal Soil Loss Equation (MUSLE) (Williams and Berndt, 1977);

$$Y = 11.8\left(V\, q_p\right)^{0.56}(K)(C)(PE)(LS) \qquad \text{.... (13)}$$

Where, Y is the sediment yield from the sub-basin in tonnes, V is the surface runoff volume for the sub-basin in m^3, q_p is the peak flow rate for the sub-basin in $m^3 s^{-1}$, K is the soil erodibility factor, C is the crop management factor, PE is the erosion control practice factor and LS is the slope length and steepness factor.

The LS factor is computed with the equation (Wischmeier and Smith, 1978);

$$LS = \left(\frac{\lambda}{22.1}\right)^{\xi}\left(65.41 S^2 + 4.465\, S + 0.065\right) \qquad \text{....(14)}$$

Where, λ is the average slope length and S is the average slope of the sub-basin.

The exponent varies with slope and is computed with the equation; $\xi = 0.6\left[1 - \exp(-35.835\, S)\right]$ ....(15)

The crop management factor, C, is evaluated for all days when runoff occurs using the equation;

$$C = \exp\left[(-0.2231 - CVM)\exp(-0.00115 CV) + CVM\right] \qquad \text{....(16)}$$

Where, CV is the soil cover (above ground biomass + residue) in $kg\,ha^{-1}$ and CVM is the minimum value of C. The value of CVM is estimated from the average annual C factor using the equation;

$$CVM = 1.463 \ln(CVA) + 0.1034 \qquad \text{....(17)}$$

The value of average annual C factor CVA for each crop and PE factor for each sub-basin can be determined from tables and information prepared by Wischmeier and Smith (1978).

Materials and Methods

The Dhangaon watershed was selected for the present study. This watershed is located in upper Hump River of Shivnath subbasin, Bemetra district of Chhattisgarh, India (Fig. 1). The watershed has 65.38 km^2 area, lies between 81° 27' 30" E to 81° 35' 0" E longitude and 21° 46' 15" N to 21° 51' 15" N latitude with elevation ranging from 270 m to 290 m above MSL. The slope of the watershed ranges from 1 to 3.5%. Watershed comprises 15 villages including Dhanali, Dhangaon, Lawatara, Chamari, Khandsara, Ataria, Ghanadih Kalan, Karchua, Kewanchhi, Banaspur, Rampur, Khursbod, Sameria and Martara. Dhangaon watershed is a 5th order watershed. The predominant soil of watershed is clay (*kanhar)* and soil depth ranges from 0 to 155 cm. The watershed receives an average annual rainfall of 1000 mm (1998 to 2012). The daily mean temperature ranges from 40.0°C to 43.0°C. The daily mean relative humidity varies from a minimum of 40% in the month of April to a maximum of 85% in the month of July. The overall climate of the area can be classified as sub-tropical. Major crops grown in the area are paddy, maize and minor millet in *kharif* season.

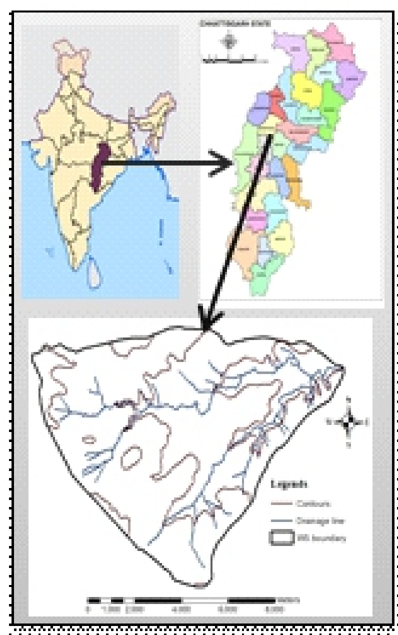

Fig. 1: Location map of Dhangaon watershed

Data Acquisition and Analysis : The cloud free geocoded digital data of the study area was obtained from NRSA, Hyderabad, India. The path 102, row 057, scenes of IRS-P6 (LISS III) satellite with date of pass 8th October, 2012 was used for the study. Survey of

India topographic map with 1:50,000 scale was used. Meteorological data such as rainfall and temperature (25 years) and hydrological data such as runoff and sediment yield (5 years) of the watershed were collected, respectively from Centre Water Commission, Mahanadi Bhawan, Bhubaneswar and Office of Assistant Soil Conservation Officer (ASCO), Bemetara, Department of Agriculture, Govt. of Chhattisgarh. Groundwater data were collected from CGWB, NCR, Raipur. The cadastral/ revenue map of Dhangaon village was acquired from the Office of the Tehsildar, Govt. of C.G. Most of the thematic maps like watershed, sub-watersheds, drainage, DEM, soil and land use have been prepared using GIS technique. The maps were traced, scanned and exported to the ArcSWAT for registration, digitization and further processing. Digitizing the contour map of Dhangaon watershed using topographic map of Survey of India having 10 m contour intervals. Digitized contour map was then used for preparing the DEM. The DEM of the watershed was prepared in 24 m by 24 m resolution. Other researchers have used DEM of 30 m by 30 m resolution and found satisfactory results (Bingner, 1996; Sharma *et al.*, 1996; Tiwari *et al.*, 1997; Wang and Hjelmfelt, 1998).

Watershed can be subdivided on the basis of natural topographic boundaries, smaller relatively homogenous areas and grids or cells (Arnold *et al.* 1998). The ArcSWAT model can work on sub-watershed basis, so the watershed was divided into 10 sub-watersheds on the basis of drainage and elevation information of corresponding watershed. Area corresponding to different sub-watersheds of Dhangaon watershed was determined. The sub-watersheds were given different colours for easy identification. The watershed and sub-watersheds boundary, drainage networks and slope map were generated using the procedure described by Jenson and Domingue (1988).

Land use/cover classification was done using satellite image of *kharif* 2009 and 2012 by adopting supervised method of classification in the environment of ERDAS imagine. The grid size 24 x 24 m was considered for image classification. Area occupied by different land use during the *kharif* season of the years 2009 and 2012 are given in Table 1. Accuracy of image classification was judged after performing the land use/cover classification. A high value of overall accuracy 87.7 and 86.2%, respectively for the year 2009 and 2012; and Kappa coefficient (*KHAT*) of 0.85 and 0.84 respectively for the year 2009 and 2012 of Dhangaon watershed indicated that the land use/cover classification was appropriate for the study watershed. Land use/cover classification was matched well with the land use/cover actually mentioned in the field. In many previous studies similar range of classification accuracy and Kappa coefficient were observed and accepted for further use (Yifang *et al.*, 1995; Pratt *et al.*, 1997; Tiwari *et al.,* 1997; Tripathi *et al.*, 2003).

Table 1: Area covered under different land use classes during *kharif* 2009 and 2012

Land use class	2009			2012		
	No. of pixel	Area (km^2)	% area of image	No. of pixel	Area (km^2)	% area of image
Shallow water	107	0.062	0.08	1583	0.912	1.18
Shrubs/ bushes	75	0.043	0.06	80	0.046	0.06
Deep water	218	0.126	0.16	105	0.060	0.08
Waste land	145	0.084	0.11	404	0.233	0.30
Orchards	76	0.044	0.06	52	0.030	0.04
Lowland paddy	36212	20.858	27.00	24591	14.164	18.33
Barren land	21122	12.166	15.75	47436	27.323	35.36
Settlement	7935	4.571	5.92	15959	9.192	11.90
Pasture	38487	22.1685	28.70	28371	16.341	21.15
Upland paddy	29761	17.142	22.19	15557	8.961	11.60
Total	134138	77.263	100.00	134138	77.263	100.00

Soil texture land use information was used by the ArcSWAT for determining the runoff Curve Number (CN) for each sub-watershed (Dhruva Narayana, 1993). Therefore model overlaid sub-watershed map was with the soil map, land use/cover map and slope of the watershed to get the resultant statistics. Other input parameters of the delineated sub-watersheds, such as overland and channel slope, channel length and average slope length were extracted by the model using the various maps including DEM, sub-watershed map, slope map and drainage map. Sub-watershed wise input parameters were analyzed using the standard procedure and are given in Table 2.

Soil texture map was prepared using soil resources data which was collected personally using PRA technique. In the study watershed, there is mainly one series of soil known as Boda series. There are four types of soil texture existing in the watershed. They are locally known as Bhata (sandy loam), Matasi (sandy clay loam), Dorsa (loam) and the Kanhar (clay), which occupied 198, 2542, 49 and 4955 ha area, respectively. The predominant soil of watershed is clay. Sandy clay loam, sandy loam and loam are also found in this watershed.

Table 2: Sub watershed wise input data for the SWAT model

Sub-watershed	**Area (km^2)**	**Slope (%)**	**CN**		**Channel length (m)**	**Channel slope (%)**	**K value**	**P value**
			2009	**2012**				
SW1	13.75	3.8	89.41	87,08	13.21	0.002	0.16	0.60
SW2	00.70	1.2	79.89	81.05	02.67	0.001	0.11	0.60
SW3	09.04	5.6	88.72	83.83	05.69	0.004	0.18	0.60
SW4	02.15	6. 4	89.53	85.93	02.99	0.005	0.18	0.60
SW5	11.28	4.5	89.70	91.26	05.88	0.002	0.20	0.50
SW6	02.84	1.1	77.98	85.83	03.84	0.001	0.18	0.60
SW7	07.94	4.2	89.20	83.42	04.93	0.002	0.22	0.50
SW8	03.90	6.8	90.20	89.00	04.43	0.003	0.18	0.60
SW9	13.78	3.8	85.85	86.57	05.74	0.002	0.17	0.60
WS*	65.38	4.3	86.72	85.99	05.49	0.002	0.18	0.60

* Whole Dhangaon watershed

The observed surface runoff and sediment yield for monsoon season (June to October) were collected, analyzed and used for evaluation of model calibration and validation performance. The input parameters in the calibration run were given for the each sub-watershed. Most of the parameters showed negligible variation in fortnightly surface runoff and sediment yield therefore those were not calibrated and taken as suggested in the User's Manual (Arnold *et al.*, 1996). The weighted average values for the parameters such as curve number, surface slope, channel length, average slope length, channel width, channel depth, soil erodibility factor and other soil layer data were taken for each sub-watersheds. Initial soil water storage and Manning's 'n' value for overland flow and channel flow were calibrated and sensitivity analysis was also performed to observe the effect of these parameters on runoff and sediment yield.

ArcSWAT being a physically based and distributed parameter model, its calibration is possible only for gauged watersheds (Arnold *et al.*, 1996 and 1998). The model was calibrated using the observed daily rainfall and temperature data for the years 2009-2010. Daily and fortnightly values of surface runoff and sediment yield recorded at the outlet of Dhangaon watershed during monsoon season (June to October) of years 2009 and 2010 were also used for calibration of the model. ArcSWAT automatically extracts data from thematic maps and writes all the input files except weather data. Some of the input data for each sub-watershed were entered manually into the respective files and the model was run to get the daily output. Different values of input parameters were tried and several simulations were performed to get the adequately calibrated model.

The model performance was evaluated on the basis of test criterion recommended by ASCE Task Committee (1993). Various other methods such as graphical and linear regression method, statistical tests of significance and Nash-Sutcliffe simulation efficiency (Nash and Sutcliffe, 1970) were also used. The validation of a calibrated model is an essential part of the model testing. Therefore, the model was validated using the observed daily rainfall and temperature data for the years 2010-2011. Similarly for fortnightly validation, the observed runoff and sediment yield for the years 2011 and 2012 of monsoon season from June to October were analyzed and compared with the simulated results for the evaluation of model validation performance in respect of surface runoff and sediment yield. All the calibrated and known parameters were considered for model validation. Land use/cover data of year 2012 was used for model validation.

Results and Discussion

Model Calibration : Daily and fortnightly values of observed surface runoff and sediment yield of monsoon season (June to October) of years 2009 and 2010 were used for calibration of the model. Surface runoff and sediment yields simulated by the ArcSWAT model were compared with their observed counterparts using various methods such as mathematical, graphical, linear regression and statistical tests of significance. The calibrated values for hydraulic conductivity of alluvial soil for surface and channel were found to be 6.4 and 1.0 mm/hr, respectively, and roughness coefficient for channel and over land flow were found to be 0.065 and 0.025, respectively. Calibrated values of different parameters and prescribed range for various conditions are given in Table 3.

Table 3: Parameters used for the model calibration

Calibrated parameters	Values chosen	Prescribed range
Base flow factor	0.00	0.0-1.0
Effective hydraulic conductivity	6.4	6.4-25.0
Channel 'n' value	0.025	0.025-0.065
Overland flow 'n' value	0.065	0.06-0.12
Fraction of field capacity	0.0	0.0-1.0
Alpha factor for ground water	0.8	0.0-0.1
Specific yield	0.30	0.0-0.5

Surface Runoff

Daily distribution: The statistical results showing comparison between the observed and simulated daily runoff are given in Table 4. The time series of observed and simulated daily runoff is shown in Fig. 2. For the calibration period, the total of simulated daily runoff was higher than the total of observed daily runoff because of over prediction of peak runoff rates by the model. This over prediction of the peak runoff rates resulted in higher standard deviation and mean for simulated runoff. Student's t-test showed that the means of observed and simulated runoff were significantly different at 95 % confidence level. The Nash-Sutcliffe simulation efficiency (Nash and Sutcliffe, 1970) of 0.960 indicated that there was good agreement between the observed and simulated runoff. The overall deviation indicated that the model was over predicting the daily runoff during calibration about 10.80 %. Over prediction of high values of runoff by the model might be because of existing tillage practices (country plough) that were included during calibration run. The existing conventional tillage practices may not loosen the soil properly that is why rainfall could not infiltrate in the soil easily and resulted in higher runoff during the beginning of monsoon.

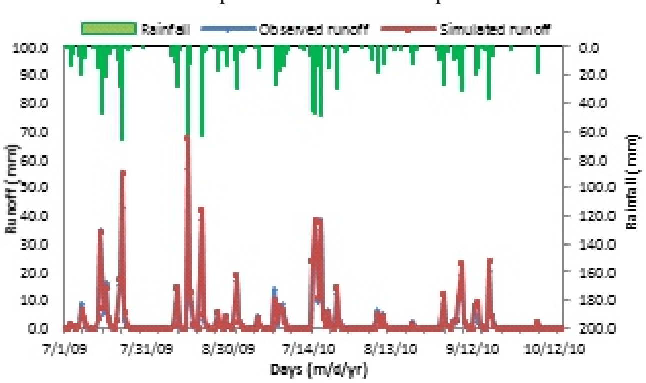

Fig. 2: Comparison between observed and simulated daily runoff for model calibration

The scattergram of observed and simulated daily runoff for the calibration period along with the 1:1 line is shown in Fig. 3. The simulated runoff volumes were distributed uniformly about the 1:1 line for lower values of observed runoff. For high values of observed runoff, the simulated values were slightly above 1:1 line, indicating that the model over predicted high flow volumes. Regression analysis was performed between the observed and simulated runoff values and the best-fit line is shown in Fig. 3.

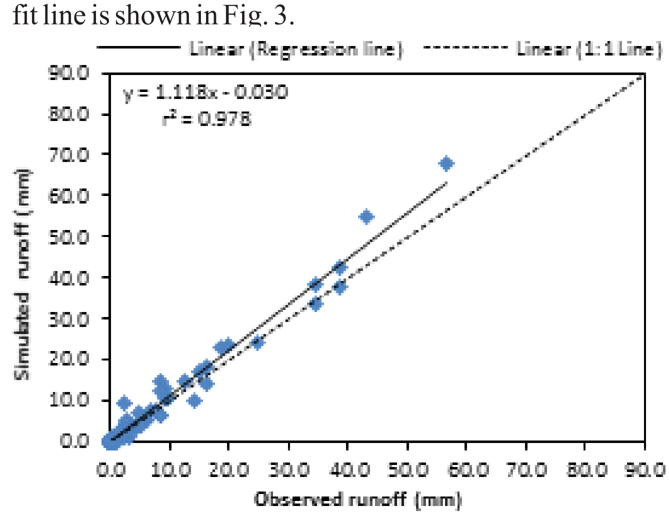

Fig. 3: Scattergram of observed and simulated daily runoff for model calibration

The model predicted runoff was close to observed values for well distributed daily rainfall events. It implies that the weighted average CN values for average condition (AMC-II) assigned to each sub-watershed by the model are reasonable. A high value (0.978) of the coefficient of determination (r^2) indicated a close relationship between measured and simulated runoff.

Fortnightly distribution: On fortnightly basis, the model simulated surface runoff was in close agreement with the measured surface runoff (Table 5). The student's t-test was used for testing the difference between fortnightly means of observed and simulated runoff. The difference between observed (47.25 mm) and simulated (52.37 mm) means was not significant at 95 per cent confidence level. Overall percent deviation (10.83 %) indicated that model was predicting fortnightly runoff quite accurate. The scattergram of observed and simulated fortnightly runoff for the calibration period (2009-2010) along with the 1:1 line is shown in Fig. 4.

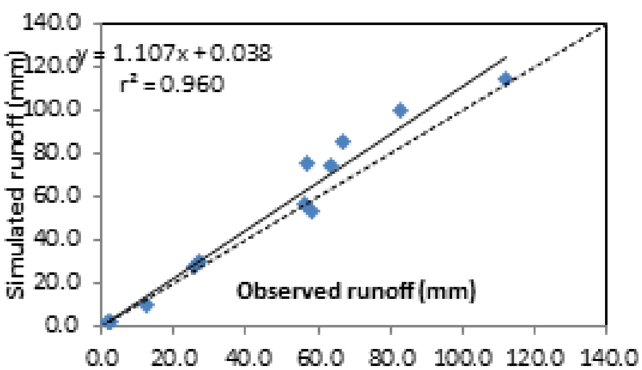

Fig. 4: Scattergram of observed and simulated fortnightly runoff for model calibration

A high value (0.960) of the coefficient of determination (r^2) indicated a close relationship between measured and simulated runoff. In addition, the model simulated both the high and low fortnightly runoff values similar to the observed values during calibration period. For high magnitude events the model generally over predicted the runoff where as for other events it predicted runoff volume quite accurately. During the commencement of the monsoon, model was over predicting the peak events and after advancement of monsoon, model was continuously predicting runoff very close to the observed runoff values till the end of monsoon.

Developer of the SWAT model and it's users also reported similar results (Srinivasan *et al.*, 1993; Srinivasan and Arnold, 1994; Rosenthal *et al.*, 1995; Bingner, 1996; Peterson and Hamlett, 1998; Srinivasan *et al.*, 1998). Overall prediction of daily and fortnightly surface runoff by the ArcSWAT model during the calibration period was satisfactory and was accepted for further analysis.

Sediment Yield

Daily distribution: Similar to runoff, the model was also calibrated for the sediment yield by estimating sediment loading at the outlet of the Dhangaon watershed for the monsoon season of the years 2009 and 2010. The descriptive statistics for both measured and simulated daily sediment yields are given in Table 4.

Table 4: Statistical analysis for daily observed and simulated runoff and sediment yield during calibration period (monsoon season of the years 2009-2010)

Statistics	Runoff (mm)		Sediment yield (t/ha)	
	Observed	Simulated	Observed	Simulated
Mean	3.08	3.41	0.067	0.056
Standard deviation	8.16	9.22	0.234	0.206
Maximum peak	56.74	67.78	2.15	2.07
Total	567.04	628.47	12.34	10.39
Count	184	184	184	184
t-calculated	-2.731		2.619	
t-critical (two tailed)	1.973		1.973	
r^2	0.978		0.954%	
deviation	-10.834		15.808	
COE	0.959		0.943	

A close agreement between mean and standard deviation indicated that the frequency distributions of observed and simulated sediment yields were similar. Though, the comparison of means using student's t-test (t-cal = -1.160 and t-critical = 1.975) revealed that the mean values of observed and simulated sediment yields were significantly different at 95 per cent confidence level. However, the maximum sediment yield simulated by the model was slightly lower than that of the observed maximum sediment yield. A Nash-Sutcliffe simulation efficiency of 0.943 indicated that there was

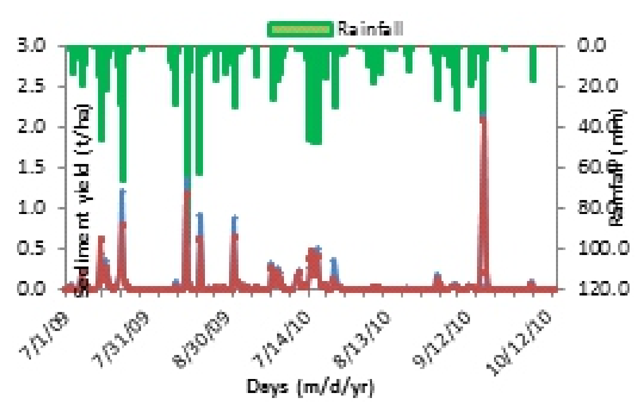

Fig. 5: Comparison between observed and simulated daily sediment yield for model calibration

good agreement between the observed and simulated sediment yields during the calibration period. Overall percent deviation of simulated sediment yield from observed sediment yield indicated that model under predicted by about 15.8 per cent.

The compression between observed and simulated daily sediment yield is shown in Fig. 5. Daily-predicted sediment yield values were plotted against the measured values and their distribution about the 1:1 line is shown in Fig. 6. The simulated sediment yields were distributed uniformly along the 1:1 line for both lower and higher values of observed sediment yield. A high value (0.954) of the coefficient of determination (r^2) indicated a close relationship between measured and simulated sediment yield.

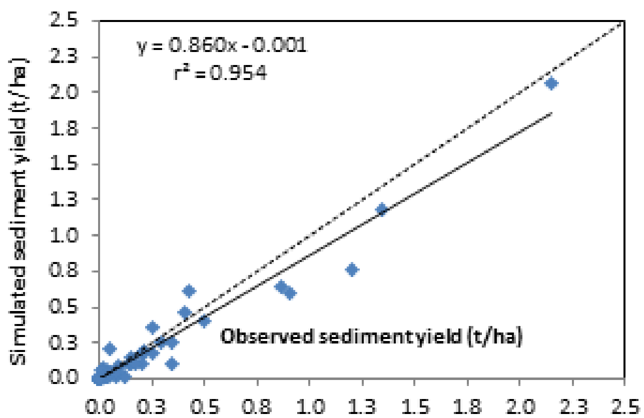

Fig. 6: Scattergram of observed and simulated daily sediment yield for model calibration

Fortnightly distribution: The measured and simulated fortnightly sediment yield for the monsoon season was compared and the results are given in Table 5. Fortnightly means of observed (1.028 t/ha/yr) and simulated (0.866 t/ha/yr) sediment yields were not similar at 95 % level of confidence. However, overall deviation (15.81 %) indicated that the simulated fortnightly sediment yield compared marginally well with observed sediment yield. The scattergram of observed and simulated fortnightly sediment yield for the calibration period 2003-2004 along with the 1:1 line is shown in Fig. 7. A high value (0.913) of the coefficient of determination (r^2) indicated a close relationship between measured and simulated sediment yield.

Overall prediction of lower values of sediment yield by the model might be because of existing tillage practices (country plough) that were included during

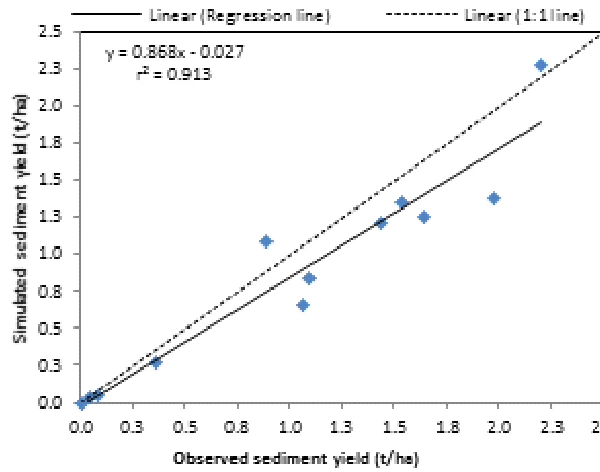

Fig. 7: Scattergram of observed and simulated fortnightly sediment yield for model calibration

calibration run. The lower sediment yield results might be due low concentration of sediment in runoff even though runoff volume was also decreased at the beginning of season. Also, since the SWAT operates on a daily time step, it could not simulate sediment rate for an event of smaller duration. A shorter and more flexible time increment may improve the sedimentation rate. Further, the sediment routing equations are relatively simplistic and assume that the channel dimensions are static throughout the simulation.

Based on the above results, it can be inferred that the model was reasonably calibrated for predicting daily and fortnightly sediment yields from the Dhangaon watershed.

Table 5: Statistical analysis for fortnightly observed and simulated runoff and sediment yield during calibration period (monsoon season of the years 2009-2010)

Statistics	Runoff (mm)		Sediment yield (t/ha/yr)	
	Observed	Simulated	Observed	Simulated
Mean	47.25	52.37	1.028	0.866
Standard deviation	33.78	38.17	0.764	0.695
Maximum peak	112.27	113.89	2.202	2.272
Total	567.04	628.47	12.339	12.388
Count	12	12	12	12
t-critical (two tailed)	1.973		1.973	
t-calculated	-2.106		2.475	
t-critical (two tailed)	2.201		2.201	
r^2	0.960		0.913%	
deviation	10.83		15.81	

Sensitivity Analysis : Sensitivity analysis revealed that the sediment yield was more sensitive as compared to the surface runoff to overland flow and channel 'n' values. Calibrated values of Manning's 'n' for overland flow and channel flow were found to be 0.065 and 0.025, respectively for the Dhangaon watershed. The annual sediment yield increased with decrease in the channel 'n' value. There is no effect of FFC value on annual runoff but sediment yield increased by increasing Fraction of Field Capacity (FFC) value.

Model Validation : The calibrated ArcSWAT model was validated using the observed daily rainfall and temperature data for the years 2011 and 2012. Similarly for fortnightly validation, the observed runoff and sediment yield for the year 2011 and 2012 of monsoon season from June to October for the Dhangaon watershed were analyzed and compared with the simulated results for the evaluation of model validation performance in respect of surface runoff and sediment yield. Thereafter, the observed and simulated daily and fortnightly runoff and sediment yield were compared graphically.

Surface Runoff

Daily distribution: The descriptive statistics for both the measured and simulated daily runoff are given in Table 6.

Table 6: Statistical analysis for daily observed and simulated runoff and sediment yield during validation period (monsoon season 2011-2012)

Statistics	Runoff (mm)		Sediment yield (t/ha/yr)	
	Observed	Simulated	Observed	Simulated
Mean	3.360	3.267	0.053	0.043
Standard deviation	6.855	6.403	0.161	0.146
Maximum peak	45.03	42.54	1.20	1.21
Total	567.88	552.17	9.01	7.39
Count	169	169	169	169
t-calculated	1.484		4.472	
t-critical (two tailed)	1.974		1.974	
r^2	0.989		0.976	
% deviation	2.766		17.979	
COE	0.987		0.966	

A close agreement between means and standard deviation of measured and simulated runoff indicated that the frequency distributions were similar. Student's t-test was performed to test the similarity between the means of observed and simulated runoff. The t-calculated 1.484) being lower than t-critical (1.974), it was inferred that the means were not significantly different at 95 per cent confidence level. However, the maximum runoff simulated by the model was slightly lower than the observed maximum runoff. A high value (0.987) of the Nash-Sutcliffe simulation efficiency and low Dv value (2.766 %) indicated that the model was accurately validated for predicting runoff for the monsoon season of the years 2011 and 2012 from the Dhangaon watershed.

The graphical representation of validation results for the daily runoff from Dhangaon watershed is shown in Fig. 8.

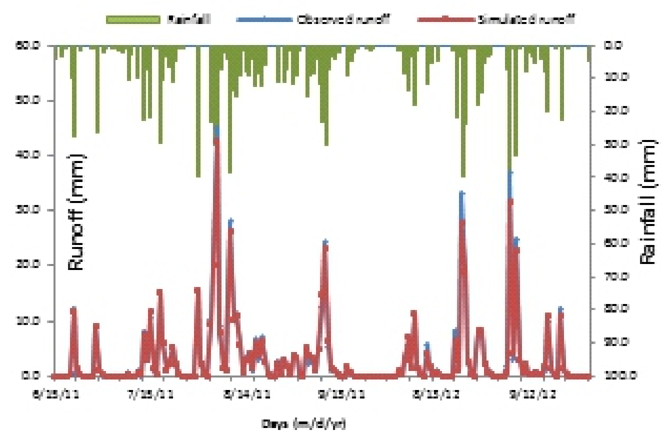

Fig. 8: Comparison between observed and simulated daily runoff for model validation

The graph shows that the magnitude and temporal variation of simulated runoff matched closely with the observed runoff values. Daily predicted runoff values for monsoon season of the years 2011 and 2012 were plotted against the measured values and their distribution along with the 1:1 line is shown in Fig. 9. As seen from Fig. 9 the points are somewhat evenly distributed about the 1:1 line, except for the events corresponding to higher magnitude of runoff. The results showed that the distribution of observed and simulated runoff was uniform throughout the season and best-fit line was obtained. Regression analysis between the observed and simulated runoff values resulted in a high value (0.989) of the coefficient of determination (r^2) indicating a close relationship between measured and simulated runoff. Based on the above results, it could be said that the model was accurately validated for predicting the daily runoff from the Dhangaon watershed for the monsoon season of the years 2011 and 2012.

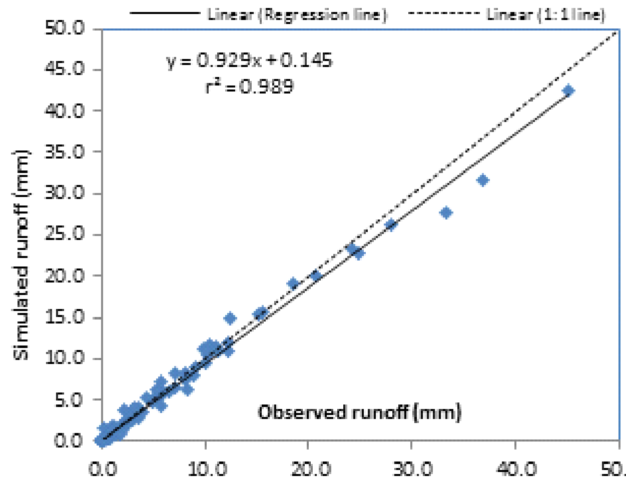

Fig. 9: Scattergram of observed and simulated daily runoff for model validation

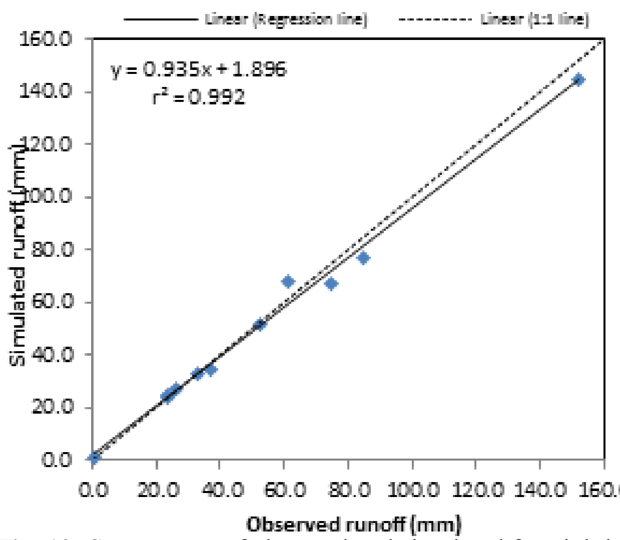

Fig. 10: Scattergram of observed and simulated fortnightly runoff for model validation

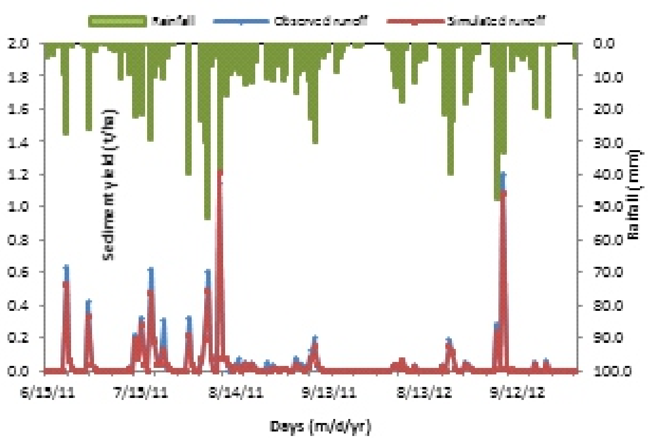

Fig. 11: Comparison between observed and simulated daily sediment yield for model validation

Fortnightly distribution: The measured and simulated fortnightly surface runoff was compared for evaluating

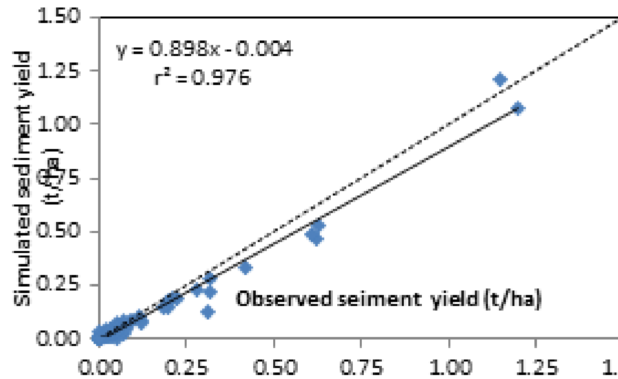

Fig. 12: Scattergram of observed and simulated daily sediment yield for model validation

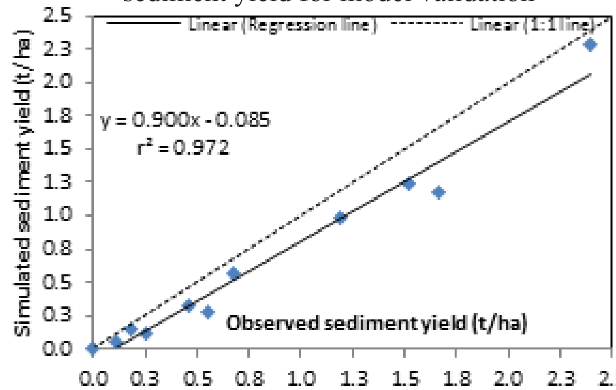

Fig. 13: Scattergram of observed and simulated fortnightly sediment yield for model validation

the model performance on fortnightly basis (Table 7). A low value of per cent deviation (2.77%) indicated the close agreement between simulated and observed fortnightly runoff. Statistical test of significance indicated good agreement between mean fortnightly observed and simulated runoff at 95 per cent confidence level since t-calculated (1.484) was lower than t-critical (1.974) for Dhangaon watershed of the years 2011-2012.

Fortnight wise graphical representation and comparisons of observed and simulated runoff were performed. The fortnight wise validation was performed for the year 2011-2012 of monsoon season from June to October. Fortnightly observed runoff values were plotted against the measured values and their distribution about the 1:1 line is shown in Fig. 10. The coefficient of determination (r^2) of 0.992 indicated a close relationship between measured and predicted runoff. On the basis of above results it can be inferred that the ArcSWAT could predict daily and fortnightly surface runoff reasonably well and can be applied for watershed evaluation and management.

Sediment Yield

Daily distribution: The descriptive statistics for both measured and predicted daily sediment yields are given in Table 6. The means and standard deviation of measured and simulated sediment yields indicates that the frequency distributions for the occurrence of sediment yields were not similar. Comparison of means using student's t-test (t-calculated = 4.472 and t-critical = 1.974) revealed that the mean values of observed and simulated sediment yields were significantly different at 95 % confidence level. However, the maximum sediment yield predicted by the model was slightly lower than the observed maximum sediment yield. The Nash-Sutcliffe simulation efficiency (0.966) and r^2 (0.976) indicated that there was very good agreement between observed and simulated sediment yield. The overall deviation indicated that the model was under predicting the sediment yield by about 17.97 %.

The time series of observed and simulated daily sediment yield of the Dhangaon watershed for the validation period was compared graphically as shown in Fig. 11 The time to peak sediment yield in case of predicted graph matched consistently well with the measured sediment graph throughout the season. However, the model predicted values were sometimes higher and sometimes lower than the observed values during the validation period. For high rainfall events, model generally under predicted the sediment yield where as for other events it predicted sediment yield quite well. The under prediction of sediment yield for high magnitude of rainfall events may be because of the existing conventional tillage practice.

The scattergram of observed and simulated daily sediment yield for the validation period of 2011-2012 along with the 1:1 line is shown in Fig. 12. The simulated sediment yield values were distributed evenly about the 1:1 line for lower as well as higher values of observed sediment yield. A high value (0.976) of the coefficient of determination (r^2) indicates a close relationship between measured and simulated sediment yields.

Fortnightly distribution: The results of measured and simulated fortnightly sediment yield for the monsoon season of the year 2011-2012 was also compared and are shown in Table 7. Results showed that most of the time the model predicted sediment yield was close to the observed sediment yield during each fortnight of monsoon seasons. Statistical test of significance indicated that there was not good agreement between mean fortnightly observed and simulated sediment yield at 95 per cent confidence level since, the t-calculated was higher than t-critical. The per cent deviation was indicated that model was under predicting sediment yield buy 2.04 per cent.

Table 7: Statistical analysis for fortnightly observed and simulated runoff and sediment yield during validation period (monsoon season 2011-2012)

Statistics	Runoff (mm)		Sediment yield (t/ha/yr)	
	Observed	Simulated	Observed	Simulated
Mean	51.625	50.197	0.819	0.652
Standard deviation	41.504	38.983	0.771	0.703
Maximum peak	152.15	145.00	2.391	2.280
Total	567.88	552.17	9.005	7.168
Count	11	11	11	11
t-calculated	1.484		4.472	
t-critical (two tailed)	1.974		1.974	
r^2	0.992		0.972	
% deviation	2.77		2.04	

Fortnightly observed sediment yield was plotted against the simulated values and their distribution along with the 1:1 line as shown in Fig. 13. The simulated sediment yields were distributed uniformly about the 1:1 line for both lower and higher values of observed sediment yield. Regression analysis was also performed between the observed and simulated sediment yield values and the best-fit line was obtained. A value of r^2 0.972 indicates a close relationship between the measured and simulated sediment yields. On the basis of above results it can be said that the ArcSWAT model can accurately simulate daily and fortnightly sediment yield from the Dhangaon watershed.

Conclusions : On the basis of results of this study, it can be concluded that the ArcSWAT model accurately predicting both surface runoff and sediment yield on daily and fortnightly basis from the Dhangaon watershed. On the basis of calibration and validation results, it is inferred that the ArcSWAT model can successfully be used for planning and management of the study watershed.

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Taguchi optimization methods for production of cutting blades for gender-friendly paddy weeder

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Abstract

Taguchi method is an optimization technique used to find the optimal process parameters for a process. Paddy weeder is an equipment, used to control weeds. The paddy weeder consists of several parts, and most important part is the cutting blade. The cutting blades are joined on a rotor for delivering the rotary motion and are helpful in removing weeds from field and incorporating with soil. Through this study, one can determine the optimal process parameters for cutting blades manufacturing, and the main process parameters that affect its quality. The settings of the process parameters were determined by using Taguchi's experimental design method. The paper presents a detailed study of all the processes involved in the production of blades and hence selection of several control factors, constructing orthogonal arrays, the signal-to-noise (S/N) ratio, and regression analyses are employed to find the optimal process parameter levels, were employed to investigate the quality characteristics of cutting blades manufactured, and time involved in it. The improved die proved to be 88.6% efficient than the traditional methods and 71.4% efficient than the production by normal dies.

Key words : Taguchi method, cutting blades, design of experiments, paddy weeder.

Introduction

Taguchi method of experimental design has been widely used in manufacturing industry for the purpose of finding factors that are most important in achieving goals in a manufacturing process. Factors that are related to the goals and are under the user's control were selected. These factors varied over three levels in a systematic manner. Experiments were then designed according to an orthogonal array to show the effects of each potential primary factors. The Taguchi method involves an analysis that reveals which of the factors are most effective in achieving the goals and the directions in which these factors should be adjusted to improve the results. The control over achieving the goals will be best obtained by changes in these primary factors in the direction indicated by the analysis (Liu, 2005).Taguchi method has been extensively adopted in manufacturing for nearly three decades to robustly design a product or process with a single quality characteristic (QC)(Pan, 2007). In this study the quality control (QC) was to minimize the time involved in the production of cutting blades. The calculation in Taguchi method algorithm converts the quantitative assessment of specific QC into signal to noise ratio (SNR). The SNR quantifies the ability to achieve the target value for a QC while minimizing the variation from the target for a specific experimental condition or machine operating scenario.

The applications of Taguchi method in either machining or manufacturing field have been extremely successful. The efforts laid by the workers in removing the weeds especially in a paddy field is a time taking process and involves several man-hours to complete the job. The paddy weeder developed at Indira Gandhi Agricultural University, Raipur, helps in reducing the amount of efforts laid on field to a considerable low of 40% (Verma, 2007), and hence facilitates the timely work in fields. In recent years, the demand for paddy weeder has been on a rise in an exponential manner. To meet the demand without compromising quality and hence facilitating a timely production, there was a need to study all the processes used in the manufacturing the blades analytically. The processes involved in production are all capable of producing satisfactory results, but the emphasis is more in reducing the time elapsed in the production so as to facilitate mass production.

Design of Experiments (DOE) was found to be an effective tool that leads to the setting up of parameters at different levels and that too of different combinations. Levels were set at low and high so as to determine the optimum method for production, orthogonal arrays

(OA) were constructed which certainly depend upon the number of parameters taken and number of levels chosen. In Taguchi method, process parameters which influence the products are separated into two main groups control factors and noise factors. The control factors are used to select the best conditions for stability in design of manufacturing process, whereas the noise factors denote all factors that cause variation. Taguchi proposed to acquire the characteristic data by using orthogonal arrays, and to analyze the performance measure from the data to decide the optimal process parameters (Lee, 2003). This method uses a special design of orthogonal arrays to study the entire parameter space with small number of experiments only. In this study, four machining parameters were used as control factors and each parameter was designed to have three levels, denoted 1, 2 and 3. According to the Taguchi quality design concept, a *L9* orthogonal arrays table with 9 rows (corresponding to the number of experiments) was chosen for the experiments.

Materials and Methods

Paddy weeder is employed with five cutting blades, Fig. 1 shows a cross sectional view of paddy weeder. Table 1 shows the dimensions of sheet metal before performing the cutting operation on it.

Table.1 Specifications of cutting blades

S. No.	Particulars	Specifications
1	Length	83 mm
2	Width	76 mm
3	Thickness	3 mm

The methods involved in manufacturing of cutting blades were thoroughly studied and examined analytically. Three methods were found to be efficient enough to deliver a complete product. All the methods are discussed here:

(a) Production by traditional methods.

(b) Production using dies.

© Production using improved die.

Production by traditional methods : The production of cutting blades by traditional

(I) Methods involved series of operations namely, sheet marking, followed by sheet cutting and manual markings done on the sheet obtained with the help of a specimen (Fig. 2).

Fig.1. Cross sectional view of paddy weeder

Fig.2. Cutting blades with respect to markings

Since the cut obtained with the help of cutter is not clean, the operator performs the job of taking out the portion of sheet on which, the cutting operation was performed (Fig. 3).

Fig. 3. Fabrication of blade

(i) **Production using dies :** The production of cutting blades for paddy weeder can be performed by another method that involves the use if die (Fig. 4) to perform the blanking operation, to produce teeth for blades.

Fig. 4. Die used for blanking

The production process starts with markings on sheet metal, cutting of sheet metal into plates of desired dimensions, followed by installation of die on the work bench of a power press, and obtaining the semi-finished blades (Fig. 5).

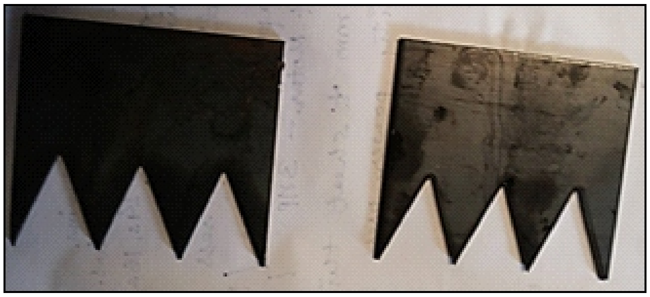

Fig.5. Blades after blanking operation

The blades are then subjected to notching operation (Fig. 6), and hence the desired shape and dimensions of a blade are achieved (Fig. 7).

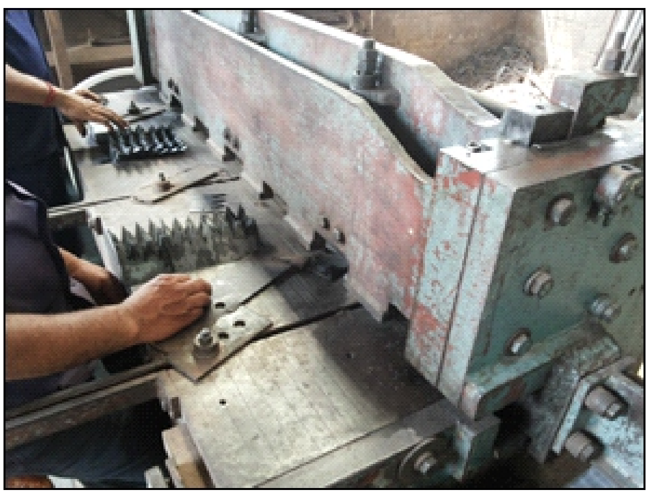

Fig.6. Notching operation for blades

The cutting blades obtained in this method, proved time saving with desirable quality standards (Fig. 7).

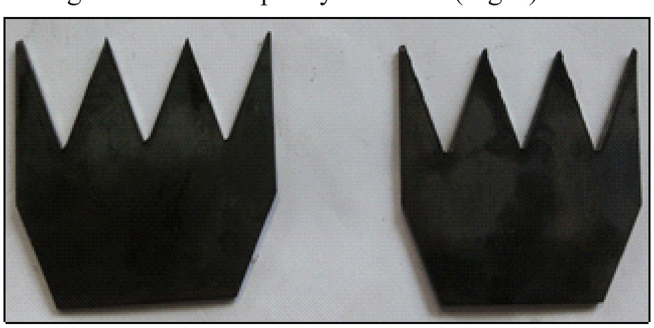

Fig.7. Blades produced after blanking & notching operation

(I) **Production by improved dies :** The processes involved in production of blades with the help of improved dies proved to be most economical and time saving. The production process involves operations such as markings on the sheet metal, cutting of sheet metal, followed by installation of improved die (Fig. 8) on work bench of hydraulic press.

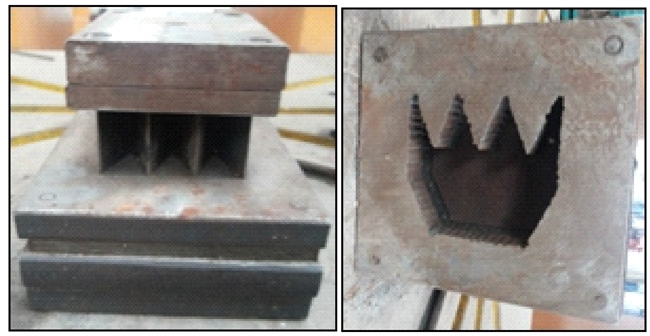

Fig.8. Improved die for blanking of blades

After the installation of improved die, the cutting operation of sheet metal is performed. The blades produced by this method depict high quality standards with minimum time elapsed in production.

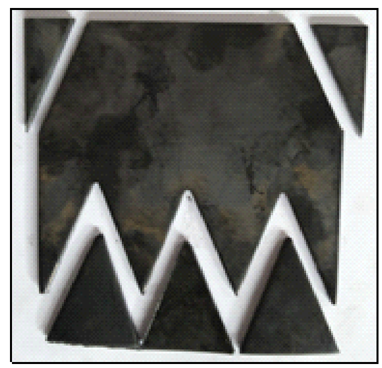

Fig.9. Blade produced after blanking operation

Taguchi method : Taguchi method is based on statistical design of experiments. For the optimization process several parameters of control factors were found to be effective, and the most relevant ones were set as control factors for production process. The objective of the study was to minimize the production time for cutting blades. The input characteristics chosen for experiments and their settings are shown in table 2.

Table 2 Control factors and their range settings

Labels	Control Factors	Level 1	Level 2	Level 3
A	Sheet Marking	2	1	0
B	Sheet Cutting	2	1	0
C	Die Installation	0	2	1
D	Cutting Teeth	8	5	1

Results and Discussion

Design of experiments : Choice of orthogonal array is an important step in, the process and allows the examiner to compute the effects by minimum number of experimental trials. Here, L9 orthogonal array with nine rows and four columns was used. Hence, nine experimental trial runs were conducted for production process (table 3).

Table 3 Experimental layout

Factors/ Interactions	A	B	C	D	Time Elapsed (s)
1	1	1	1	1	140, 145
2	1	2	2	2	60, 56
3	1	3	3	3	18, 16
4	2	1	2	3	30, 32
5	2	2	3	1	125, 115
6	2	3	1	2	50, 47
7	3	1	3	2	55, 52
8	3	2	1	3	25, 24
9	3	3	2	1	120, 112

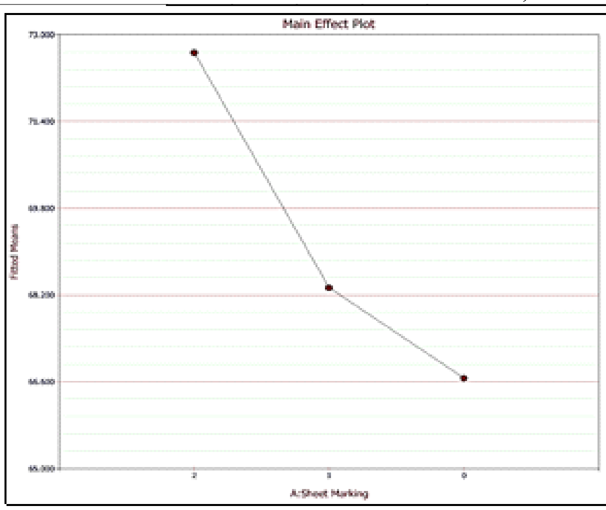

Fig. 10 (a) Main-effect plot for control factor

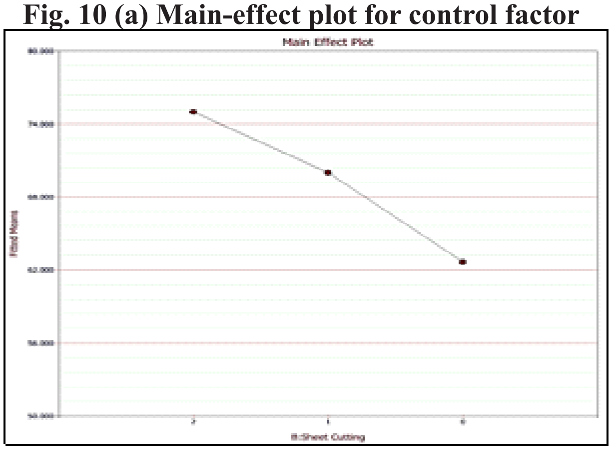

Fig. 10 (b) Main-effect plot for control factor

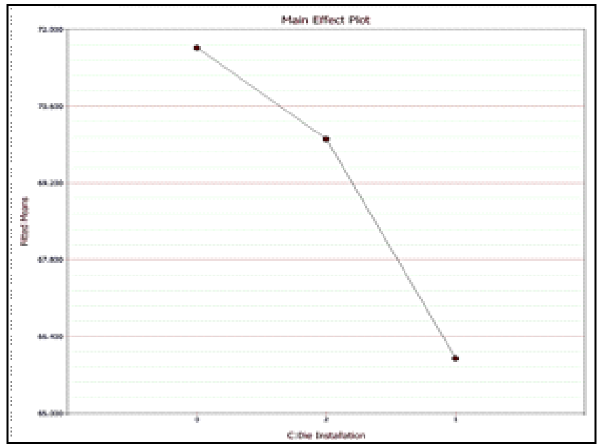

Fig. 10 (c) Main-effect plot for control factor

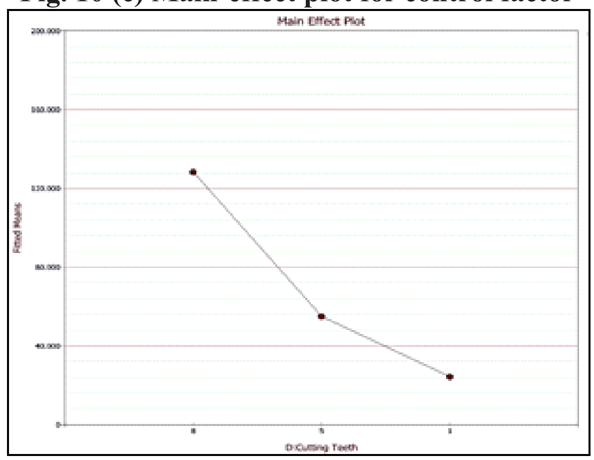

Fig. 10 (d) Main-effect plot for control factor

The sound to noise ratio related to smaller-the-better (STB) was used. Fig. 10 shows the range settings of main plot for control factors in the process of cutting blades. For STB quality characteristics, the SNR is given by the following equation

$$SNR = -10 * \log(\Sigma\,(Y^2)/n)$$

Where, n = number of values at each trial condition

Y = each observed value.

In situations where there is a feasibility to perform multiple runs for each of the experimental runs provided by design matrix. Experimental run with different settings proved to be helpful in reducing the amount of time consumed. Two runs were performed for each of the experiments, so as to get a brighter idea about the process. Table 4 illustrates the SNR values (based on Equation 1) corresponding to each trial condition. The values obtained from each trial were substituted in the Equation 1 and the values thus obtained were termed as the SNR value of that respective operation. The interaction of all the factors for each parameter (Fig. 11) shows the effects of the all the factors with each other with the help of line graph. The SNR values thus obtained were established categorically and were analyzed for Settings of the control factors (table 3).

The average SNR values at each levels were taken,

Average SNR at level 1 for factor "A" =

Table 4 SNR Values obtained

S. No.	Experimental Run	SNR
1	1	-41.3167
2	2	-33.5128
3	3	-22.8630
4	4	-28.0708
5	5	-39.8302
6	6	-31.9580
7	7	-32.8095
8	8	-26.0242
9	9	-39.5334

$$SNR\,A_1 = \frac{1}{3} * \{(-41.3167) + (-33.5128) + (-22.8630)\}$$

$$= -32.5641$$

SNR at level 2 for factor "A" was calculated,

$$SNRA_2 = \frac{1}{3} * \{(-28.0708) + (-39.8302) + (-31.9580)\}$$

$$= -33.2863$$

Similarly, SNR at level 3 for factor "A" was calculated,

$$SNRA_3 = \frac{1}{3} * \{(-32.8095) + (-26.0242) + (-39.5334)\}$$

$$= -32.7890$$

Effect Estimate = Maximum - Minimum

$$SNRA_1 - SNR\,A_2$$

$$= -32.5641 - (-33.2863) = 0.7222$$

Similarly, the values for all the control factors were calculated, and were tabulated, the values of SNR at both the levels are as shown in table 5.

Table 5 Average SNR Values

Factors	A	B	C	D
SNR-1	-32.5641	-34.0656	-33.0996	-40.2267
SNR-2	-33.2863	-33.1224	-33.7056	-32.7601
SNR-3	-32.7890	-31.4514	-31.8342	-25.6526
Effect (Max. – Min.)	0.7222	2.6142	1.8714	14.5741

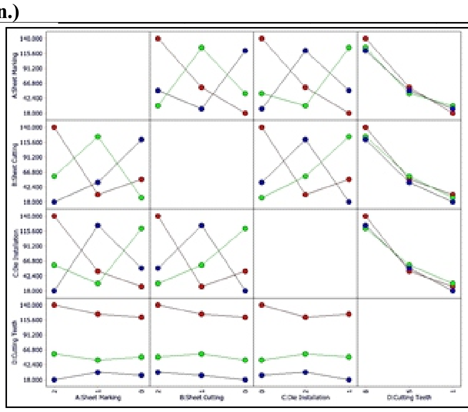

Fig. 11 Interaction matrix

Taguchi analysis is performed based on "average-of-results" methodology. Table 5 represents the average SNR values at all the three levels and the effects of each parameters on SNR. Namely, SNR-1 for level 1 settings, SNR-2 for level 2 settings, and SNR-3 for level 3 settings.

The Fig. 12 shows the line graph of main effects with their parameters and their variation between the high and low levels (SNR values from Table 5). The Fig. shows that the most dominant characteristic is teeth cutting operation, followed by sheet cutting, sheet marking, and die installation. In order to study the effect of variables and the possible interactions between them in a minimum number of trials, the Taguchi method to experimental design was adopted. The optimum control levels were found to be (i) Sheet marking = Level 1 (2 times), Sheet cutting = Level 3 (2 times), Die installation = Level 3 (1 time), Cutting teeth = Level 3 (1 time). Table. 6 represents the optimal control settings.

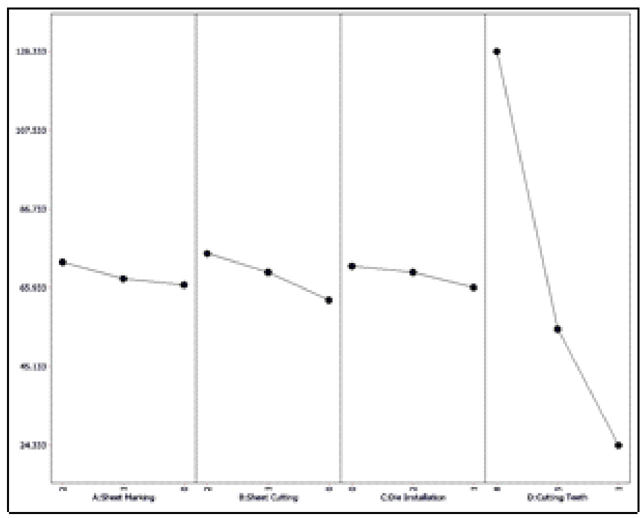

Fig. 12 Interaction of parameters

Determination of optimal control factor settings : A total of five equipment were manufactured with the obtained settings, and the average production time was recorded as 18 seconds. Which certainly shows an improvement of around 88.6 percent on the average production time.

Table. 6 Optimal control factors

Control Factors	Optimum level
Sheet Marking	Level 1
Sheet Cutting	Level 3
Die Installation	Level 3
Cutting Teeth	Level 3

Conclusion : The process parameters that affect the production of cutting blades, were listed and tested with level values for the operation, a complete design of experiments was constructed and all the possible combinations of parameters, to the production of a complete product were executed. The sound to noise ratio (SNR) was calculated and since the objective was to minimize the time elapsed in the process, hence in the experiment for lowering the time consumed in production, both high and low SNR values are compared and lowest SNR values were taken. The Taguchi method is a powerful approach to address process variability and optimization problems. All control parameters were studied at two levels, principal benefits include considerable time and resource savings; determination of important factors affecting operation, performance and cost; and quantitative recommendations for design parameters which help in achieving lowest cost with high quality solutions.

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Rainwater surplus/deficit based rce crop planning for Durg district of Chhattisgarh

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Abstract

Estimation of mean rainfall, expected rainwater availability and ET demands at a given probability level is useful for crop and water resources planning. Mean annual rainfalls for the three study blocks *viz.* Durg, Dhamdha and Patan were found as 1067.9 mm, 908.7 mm and 1088.8 mm, respectively. About 98 %, 97% and 98%, respectively of annual rainfall are received during monsoon season. Out of 20 years analyzed, 20%, 11% and 22% of the years were excess rainfall years, 55% 66% and 50% were rainfall deficit years and 25%, 23% and 28% were normal rainfall years, indicating larger rainfall deficiency at Dhamdha compared to other two blocks. Probability analysis of weekly and seasonal rainfall showed that weekly rainfall for 23-28 SMWs and for37-43 SMWs follows exponential distribution and rainfall for 29-36 SMWs follows normal distribution. The seasonal and annual rainfall follows only normal distribution at all the three study blocks, as per Chi-square test of goodness of fit. The seasonal rainfall amounts of 743 mm, 730 mm, and 881 mm are likely to occur in Durg, Dhamdha and Patan block respectively, at 75% probability level. The expected ET demand of rice crop at the three blocks is 738 mm for medium duration rice variety. Considering the whole crop duration, seasonal rainfall meets the ET demands. However, the distribution of probable weekly rainfall is found to be erratic. The nursery stage of rice crop is well short of rainwater in comparison to ET demand. The expected weekly rainfall amounts for seedling and vegetative stages are reasonably in surplus compared to ET demand and excess rainwater needs to be harvested. The last two weeks (39-40 SMW) of reproductive stage is likely to face drought situation at the study blocks and need supplemental irrigation from harvested rainwater for good rice yield.

Key words: Probability analysis; evapotranspiration; surplus; deficit; ET rice

Introduction

The state of Chhattisgarh is predominantly a rice producing area, mainly grown in *kharif* season. About 70 per cent of net sown area of the state is under rainfed farming. Irrigation is limited to about 32% only that too is of protective nature. Under rainfed condition, the rice yield is very low. Large irrigation projects are unlikely to be built due to huge capital requirement and added environmental problems. So in future also, the major part of agriculture will have to depend on rainfall.

In order to exploit the available rainfall effectively, crop planning and management practices must be followed based on the rainfall amount and distribution at a place. On an average, Chhattisgarh receives about 1200 mm annually which seems to be enough for successful rice crop. Though, the average rainfall is good enough, its distribution is not uniform during entire crop growth period. Particularly, during critical growth stages (flowering and reproductive phases), terminal droughts often occur. The success or failure of rainfed rice is intimately related to the rainfall conditions, which are not in one's control. It is nevertheless possible to get crop production to a certain optimum level by adjusting crop plans, agronomic practices and land-water management options according to probable rainfall availability and crop-water demands. The quantity of rainfall received over a period of time provides a general picture of its sufficiency or inadequacy to meet crop demands. Analysis of daily or monthly rainfall data is not usually considered appropriate from point of view of crop planning. Thus, it was decided to consider the week as the unit of time as the rainfall is showery and highly freakish in intensity, amount and distribution.

The concept of estimating probabilities with respect to a given amount of rainfall is regarded as extremely useful strategy for effective planning of crop and water resources management. Probability analysis provides us a critical tool for forecasting the occurrence of future rainfalls based on historical rainfall record (Kumar and Kumar, 1989). Probability analysis of rainfall for crop and water resources planning has been attempted at different places in India (Jeevathnam and Jaykumar, 1979; Sharda and Bhushan, 1985; Praksh and Rao, 1986; Agrawal *et al*, 1988; Bhatt *et al.*, 1996; Mohanty *et al.*, 1999; Rizvi *et al.*, 2001; Singh, 2001; Bhakhar *et al.*, 2006). In the growing crop season, decisions have to be taken many times based on the probability of receiving certain amount of rainfall and evapotranspiration demands of the crop during the season. Therefore, the assessment of expected rainwater surpluses and deficits during the entire crop season might be a great idea for making appropriate water management interventions for sustainable crop production. In view of this, the present analysis was taken up and expected weekly and seasonal rainwater surpluses/deficits were assessed for three blocks of Durg district in Chhattisgarh. Based on the this information of rainwater surplus/deficit, planning strategies for good rice yield have been suggested in this paper.

Materials and Methods

The Study Area : Three blocks of Durg district in Chhattisgarh, namely Durg, Dhamdha and Patan were included in the present study. These blocks represent Chhattisgarh agro-climatic zone of the state as per NARP classification. District Durg is geographically located at 81^0 24' E longitudes and 21^0 19' N latitudes with an altitude of 317 m above mean sea level (Fig.1). The study blocks together have a total geographical area of about 2238 sq.km. Rainy season begins from middle of June and starts terminating by the end of September. Summer season is hot reaching a peak temperature of 45^0C in second fortnight of May. The month of December in winter usually experiences a minimum temperature of 7-8^0C. The RH is very low (19%) in summer and goes up to 80% during monsoon period. The winds blow with moderate speed of about 5-6 km h^{-1}. The mean monthly values of meteorological parameters are given in Table 1. The characteristic toposequence is has *kanhar* (vertisols) found in the lowest land portion, d*orsa* (alfisols) situated just upstream of *kanhar soils, matasi* (inceptisols) found just upstream side of *dorsa* soils and *bhata* (entisols) encountered at the top of the toposequence. The largest cultivated area in Durg district is occupied by *matasi* soils. Rice is the main *kharif* crop that covers 80-90% of total cultivated area in monsoon season. Farmers of the area, generally grow long and medium duration photosensitive tall rice varieties, which flower by mid to late September and mature by mid to late November depending upon the duration of the rice varieties grown.

Data Collection and Analysis : Daily rainfall data of 20

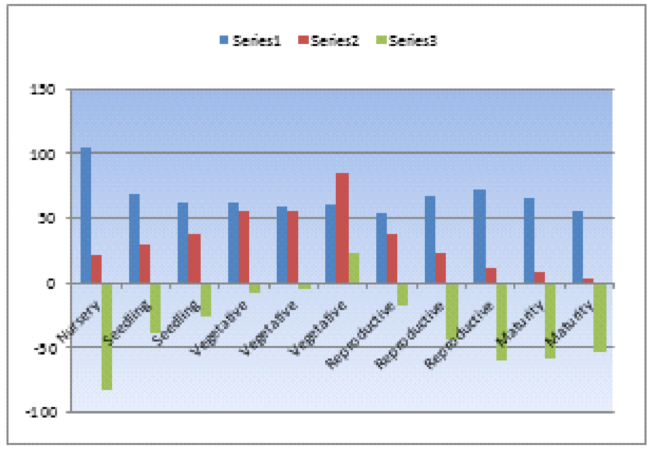

Fig. 1 Comparison of ET demand, rainwater availability and rain surplus/deficit at Durg block

Table 1 : Mean annual, seasonal and weekly rainfall availability at study blocks

Period/SMW	Rainfall availability		
	Durg	**Dhamdha**	**Patan**
Annual	1067.9	908.7	1088.8
Seasonal (monsoon)	1045.0	844.0	1054.0
23	11.8	9.4	17.6
24	66.2	48.6	53.3
25	60.9	44.8	48.3
26	41.0	62.1	40.8
27	76.7	58.2	76.1
28	53.3	66.7	66.9
29	74.6	50.6	90.7
30	91.2	82.0	81.5
31	57.3	56.1	109.6
32	71.1	60.2	63.7
33	88.9	56.7	84.2
34	85.4	57.2	79.7
35	59.5	55.6	69.3
36	43.5	36.1	47.3
37	34.7	32.3	41.3
38	46.9	24.5	27.3
39	19.9	12.7	11.4
40	23.7	16.6	8.2
41	9.6	3.8	6.9
42	18.6	12.7	22.4
43	10.4	6.6	7.3

years (1991-2010) were collected from Chhattisgarh State Data Centre, Raipur for all the three blocks- Durg, Dhamdha and Patan of Durg district. The daily data were then transformed into weekly and seasonal rainfall. Weekly and seasonal average rainfalls were also computed based on 20 years of rainfall record. The weekly and seasonal total rainfall values were also subjected to probability analysis by fitting the best-fit distribution models and expected rainwater availability at different probabilities of exceedence was worked out. The details of the bet-fit probability distribution models are described below.

Probabilistic Rainfall : Expected rainfall amounts were estimated by fitting

Normal Distribution : Normal distribution returns normal cumulative distribution function and the probability distribution is expressed by the following function:

$$f(x,\mu,\sigma) = \frac{1}{\sqrt[\sigma]{2\pi}} \exp\left[\frac{(x-\mu)^2}{2\sigma^2}\right] \quad \text{-----------} (1)$$

Where, x is a variable for which the distribution is required; $\mu$is arithmetic mean of the distribution, and $\sigma$is standard deviation of the distribution.

Exponential Distribution : It returns exponential cumulative distribution and the distribution is expressed by the following probability density function:

$$f(x;\lambda) = \lambda e^{-\lambda X} \quad \text{---------} (2)$$

Where λ is parameter of distribution.

Computation of Crop Evapotranspiration : Weekly potential or reference evapotranspiration (ET_o) values were estimated using 26 years of climatic data of Durg district by Modified Panman method using CropWat software. Probability analysis of weekly ET_o values was carried out by fitting Gamma distribution and the Expected ET_o values at different probability levels were computed. The crop coefficient (K_c) approach was used for calculating the crop evapotranspiration (ET_c) of rice for the monsoon weeks. The expected weekly ET_o values at 50% probability level were used for estimating actual ET_c values for corresponding weeks as suggested by Sahu, (2000). The reason for using ET_o values of 50% probability level was then Senapati *et.al.* (1996) used ET_o at 20% probability level and found that if this ET_o value is used for computing actual ET_c, the ET_{rice} would be overestimated compared to long term measured values by lysimeter and drum culture technique. However, ET_c corresponding to ET_o at 50% probability level was found very close to the measured values. Therefore, $ET_c = K_c \times Et_o$

The values of ET_c for two consecutive weeks during monsoon period have been computed based on daily ET_o at 50% probability level computed from climatic parameters of Durg block only. Since, all the climatic parameters for Dhamdha and Patan blocks were not available; the estimated ET_o values of Durg block were assumed to be applicable for Dhamdha and Patan blocks

Table 2: Expected rainfall at different probability levels during monsoon at Durg block

SMW/ Period	Distribution	Probability levels					
		25%	40%	50%	60%	75%	80%
23	Exponential	16.3	10.8	8.1	6.0	3.4	2.6
24	Exponential	91.7	60.6	45.9	33.8	19.0	14.8
25	Exponential	84.4	55.8	42.2	31.1	17.5	13.6
26	Exponential	56.8	37.6	28.4	21.0	11.8	9.2
27	Exponential	106.3	70.3	53.2	39.2	22.1	17.1
28	Exponential	73.9	48.8	36.9	27.2	15.3	11.9
29	Normal	116.1	90.1	74.5	59.0	33.0	22.8
30	Normal	160.1	117.1	91.2	65.2	22.2	5.1
31	Normal	93.1	70.8	57.4	43.9	21.6	12.7
32	Normal	108.1	85.0	71.1	57.1	34.0	24.8
33	Normal	137.0	107.0	88.9	70.8	40.7	28.7
34	Normal	126.6	101.0	85.4	69.9	44.2	30.0
35	Normal	98.8	74.3	59.5	44.7	20.2	10.4
36	Normal	69.8	53.3	43.5	33.6	17.1	10.6
37	Exponential	48.1	31.8	24.1	17.7	10.0	7.7
38	Exponential	65.0	43.0	32.5	24.0	13.5	10.5
39	Exponential	27.5	18.2	13.8	10.1	5.7	4.4
40	Exponential	32.9	21.7	16.4	12.1	6.8	5.3
41	Exponential	13.3	8.8	6.7	4.9	2.8	2.1
42	Exponential	25.7	17.0	12.9	9.5	5.3	4.1
43	Exponential	14.4	9.5	7.2	5.3	3.0	2.3
Monsoon	Normal	1346.7	1158.1	1044.7	931.3	742.7	667.9

Table 3: Expected rainfall at different probability levels during monsoon at Dhamda block

SMW/ Period	Distribution	Probability levels					
		25%	40%	50%	60%	75%	80%
23	Exponential	67.4	44.5	37.7	24.8	14.0	10.9
24	Exponential	62.1	41.1	31.1	22.9	12.9	10.0
25	Exponential	86.1	56.9	43.1	31.7	18.9	13.9
26	Exponential	80.6	53.3	40.3	29.7	16.7	13.0
27	Exponential	92.5	61.6	46.2	34.1	19.2	14.9
28	Exponential	111.7	73.8	55.9	41.2	23.2	18.0
29	Normal	110.5	91.8	80.6	69.3	50.7	43.3
30	Normal	122.8	97.0	82.0	66.9	41.9	31.9
31	Normal	87.6	68.0	56.1	44.3	24.7	16.9
32	Normal	85.3	69.7	60.2	50.8	35.8	29.0
33	Normal	95.1	71.1	56.7	42.3	18.1	8.9
34	Normal	88.8	69.0	57.2	45.3	25.6	17.8
35	Normal	86.1	67.1	55.6	44.2	25.1	17.6
36	Normal	57.3	44.1	36.1	28.2	14.9	9.7
37	Exponential	34.0	22.5	17.0	12.9	7.1	4.5
38	Exponential	17.7	11.7	8.8	6.5	3.7	2.8
39	Exponential	23.0	15.2	11.5	8.5	4.8	3.7
40	Exponential	5.2	3.5	2.6	1.9	1.1	0.8
41	Exponential	17.6	11.7	8.8	6.5	3.7	2.8
42	Exponential	9.2	6.1	4.6	3.4	1.9	1.4
43	Exponential	8.7	5.7	4.3	3.2	1.8	1.4
Monsoon	Normal	1037.1	941.2	883.7	825.9	730.0	692.0

Table 4 : Expected rainfall at different probability levels during monsoon at Patan block

SMW/ Period	Distribution	Probability levels					
		25%	40%	50%	60%	75%	80%
23	Exponential	24.4	16.2	12.2	9.0	5.1	3.9
24	Exponential	74.0	49.0	37.0	27.3	15.4	11.9
25	Exponential	66.9	44.3	33.5	24.7	13.9	10.8
26	Exponential	56.6	37.5	28.4	20.9	11.8	9.1
27	Exponential	105.5	69.8	52.8	39.0	21.9	17.0
28	Exponential	92.8	61.4	46.5	34.2	19.3	15.0
29	Normal	135.2	107.4	90.7	74.0	46.2	35.2
30	Normal	119.3	95.7	81.6	67.4	43.8	34.4
31	Normal	173.5	133.6	109.6	85.6	45.7	29.9
32	Normal	100.3	77.4	63.7	50.0	27.1	17.0
33	Normal	146.7	107.4	84.2	31.0	22.5	7.1
34	Normal	124.7	96.6	79.7	62.8	34.8	23.6
35	Normal	127.2	91.1	69.4	47.7	11.6	6.9
36	Normal	66.7	54.6	47.3	40.1	28.0	23.2
37	Exponential	50.0	38.4	29.0	21.3	12.0	9.3
38	Exponential	37.8	25.0	18.9	13.9	7.8	6.1
39	Exponential	15.8	10.4	7.9	5.8	3.3	2.5
40	Exponential	11.3	7.5	5.7	4.2	2.3	1.8
41	Exponential	9.5	6.3	4.7	3.5	2.0	1.5
42	Exponential	31.1	20.5	15.5	11.5	6.5	5.0
43	Exponential	10.0	6.6	5.0	3.7	2.1	1.6
Monsoon	Normal	1227.7	1119.5	1054.3	989.3	881.1	838.2

also as the climatic conditions of all the three blocks are almost similar. The K_c values for the corresponding periods were adopted from previous research work carried out by Gul, 2007. The computation of ET_c values that were common for all three study blocks has been worked out in Table 4.

Computaion of Rainwater Surplus/Deficit : The surplus/deficit of rainfalls for different weeks at 75% and 80% probability of rainfall in comparison to ET_c demands of rice crop for the corresponding weeks were worked out. The surplus/deficit values were worked out to know whether supplemental irrigation is needed in particular weeks of rice crop growth stages. The

Table 5 : ET_{rice} demand and rainfall at different growth stages at study blocks

Growth stage	SMW	Daily ET_o at 50% Prob. (mm)	K_c	Daily ET_{rice} (mm)	Total ET_{rice} demand (mm)
(1)	(2)	(3)	(4)	(5)	(6) = (5) x 14 days
Nursery	23+24	8.8	0.85	7.48	104.72
Seedling	25+26	5.5	0.89	4.895	68.53
Seedling	27+28	5.0	0.9	4.5	63
Vegetative	29+30	4.5	1.0	4.5	63
Vegetative	31+32	4.2	1.01	4.242	59.388
Vegetative	33+34	4.3	1.02	4.386	61.404
Reproductive	35+36	3.8	1.03	3.914	54.796
Reproductive	37+38	4.6	1.05	4.83	67.62
Reproductive	39+40	4.9	1.06	5.194	72.716
Maturity	41+42	4.7	1.0	4.7	65.8
Maturity	43	4.5	0.9	4.05	56.7
				Total	**737.674**

quantities of surplus/deficit rainfall are worked out in Table 5.

Results and Discussion

Mean Rainwater Availability : The mean weekly, seasonal and annual rainfall received at Durg, Dhamdha and Patan blocks have been given in Table 2. It is obvious from the table that the mean annual rainfalls of the three blocks were found to be 1067.9 mm, 908.7 mm and 1088.8 mm, respectively having standard deviation from the mean as 441.9mm, 234.1 mm and 279.4 mm, and coefficient of variation as 0.41, 0.26 and 0.26 respectively. The lower coefficient of variation at Dhamdha and Patan blocks in comparison to that of Durg block is indicative of less annual rainfall variability with more stability in the rainwater availability. About 98 %, 97% and 98%, respectively of annual rainfall are received at Durg, Dhamdha and Patan block during monsoon season itself leaving negligible amounts to occur as winter rains. Therefore, under rainfed conditions, only less moisture intensive crops like gram, moong, safflower etc can be grown in comparatively heavy soils of the study areas.

The analysis of the recorded 20 years annual rainfall data revealed that about 20%, 11% and 22% of the years were found to be excess rainfall years at Durg, Dhamdha and Patan block, respectively. About 55% years at Durg, 66% at Dhamdha and 50% at Patan block were rainfall deficit years and the rest 25%, 23% and 28% years at these blocks were observed as normal rainfall years. This indicates that Dhmadha block is relatively more prone to yearly rainfall deficiency in comparison to Durg and Patan blocks.

Mean weekly rainfall data showed that the highest mean weekly rainfalls of about 91 mm, 82 mm were recorded at Durg and Dhamdha blocks, respectively in 30^{the} SMW, while the highest mean weekly rainfall as 109.6 mm was obtained at Patan block in 31st SMW. Both 30th and 31st SMWs fall during vegetative growth period of rice crop indicating sufficient rainfall period. During early reproductive period (35 – 38 SMW) of rice crop, total availability of rainfall is about 184.6 mm at Durg block, where as ET requirement is about 122.5 mm. At Dhamdha block, total rainfall availability during this period (35 – 38 SMW) is about 148.5 mm in comparison to ET requirement of 122.5 mm and at Patan block, the rainfall availability during the same period is about 185.2 mm compared to ET demand of 122.5 mm. This shows that during the period from 35 to 38 SMW coinciding with early reproductive phase, the rainwater availability is higher enough to meet the ET demand of rice crop and thus the rice crop will not face drought condition during early reproductive phase. On the other hand, the late reproductive phase (39-40 SMW) during which grain formation and milking take place is likely to receive less amount of rainfall in comparison to ET demands of rice crop. It is evident from Table 2 that the rainwater availability during late reproductive phase (39-40 SMW) about 43.6 mm at Durg block, 29.3 mm at Dhamdha block, and 19.6 mm at Patan block, whereas ET demand is about 72.3 mm. This is indicative of rainwater shortage to meet the ET demands during grain formation and milking stages and any water shortage during this period may adversely affect the quality and weight of the rice grain resulting in reduced yield.

Probabilistic Rainfall and Surplus/Deficit : The expected amounts of rainfall at different probability levels, has been given in Tables 2, 3 and 4 for Durg, Dhamdha and Patan blocks, respectively. It is observed from these tables that during early (23-28 SMW) and recession (37-43 SMW) periods of monsoon season with erratic rainfall, the exponential distribution was found good fit to available rainfall amounts. On the other hand, during stable rainfall period (29-36 SMW) and monsoon season as a whole, the normal distribution fits well, based on Chi-square test. It is also found that expected seasonal (monsoon) rainfall amount at 75% probability level, is 743 mm, 730 mm, and 881 mm at Durg, Dhamdha and Patan block respectively. However, at 50% probability level of potential evapotranspiration (ET_o), the ET_c demand of rice in whole crop duration is estimated to be 738 mm for medium duration variety. This means that if the whole crop duration is taken into consideration, the seasonal availability of rainwater seems to be sufficient for growing rice crop at all the three places. Comparing amongst the study blocks, Patan block gets about 16-17% more seasonal rainfall than Durg and Dhmdha blocks. This indicates that more water can be harvested at Patan block as compared to the other two blocks.

Though, the expected amount of seasonal (monsoon) rainfall as 742.7 mm in Durg block, 730.0 mm in Dhamdha block, and 881.1 mm in Patan block at 75% exceedence probability are either very close or more than the seasonal ET demand of 737.67 mm of the rice crop. However, it is seen that ET demands are not fulfilled by rainwater availability at 75% exceedence probability for all the growth stages of the rice crop. Comparing Tables 2, 3, and 4 with Table 5, It is observed that the expected rainfall amounts received at 75% exceedence probability at nursery stage (23+24 SMW) of the rice crop are 22.4 mm in Durg block, 26.9 mm in Dhamdha block, and 20.5 mm in Patan block but the ET demand at this stage is 104.72 mm , which clearly indicates that the nursery stage may experience acute shortage of rainwater and without supplemental irrigation from other sources, good and healthy rice nursery may not possible at all the three blocks. At seedling stage (25-28 SMW), the total ET demand was worked out to be 131.53 mm. However, the expected amount of rainwater at 75% probability level are 66.7 mm, 78.0 mm and 66.9 mm in Durg, Dhamdha and Patan blocks, respectively. This shows that at seedling stage also, there may be considerable shortage of rainwater to fulfill the total ET demand of 131.53 mm and thus supplemental irrigation will be required at seedling stage also. It is also seen that about 23.5 mm rainfall is received in surplus to ET demand of rice crop at vegetative stage (33+34 SMW) in Durg block; 29.6 mm during seedling stage (27+28 SMW) in Dhamdha block, and about 40 mm during vegetative stage in Patan block.

Similarly, reproductive stage is likely to experience considerable shortage of rainwater availability, when compared with ET demand at stage in all the three places. Reproductive stage is considered as the most crucial rice growth stage and any shortage of water at this stage is very detrimental to crop yield. The rainwater shortage during crop maturity period is not much important but it is considered beneficial for timely maturity and harvest of rice crop. As a part of water

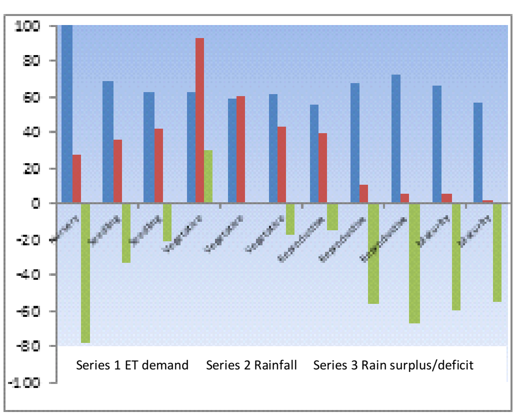

Fig. 2 Comparison of ET demand, rainwater availability and rain surplus/deficit at Dhamdha block

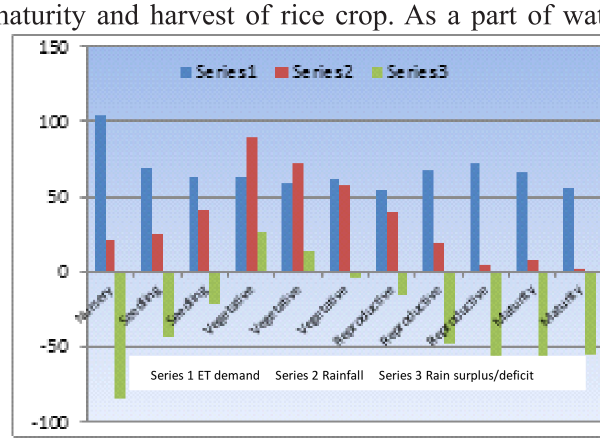

Fig. 3 Comparison of ET demand, rainwater availability and rain surplus/deficit at Patan block

resources planning, surplus rainwater periods (seedling and vegetative growth periods) at the three study places can be utilized for harvesting excess rainwater in on-farm storages structures for recycling during reproductive stage in order to realize optimum rice crop yield.

Conclusions : The mean annual and seasonal rainfall at the study blocks appear to be sufficient for rice crop but probability distribution of weekly rainfall is quite erratic. Nursery stage and later two weeks of reproductive stage are likely to suffer severely from drought situation at the study blocks. The excess rainwater during seedling and vegetative growth stages should be harvested in on-farm storage structures for recycling for supplemental irrigation during reproductive stage in order to obtain good yield of rice crop. The analysis of mean annual and seasonal rainfall also indicated that about 55 to 66 per cent years of rainfall occurrence are likely to be rainfall deficit years at the three study blocks. This is also indicative of severity of drought conditions for rice crop in the whole Durg district and emphasize upon the essential necessity for rainwater harvesting at farm levels.

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Studies on performance of some morphological recombinants of yellow sarson (*Brassica rapa* L.)

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Abstract

The experiments were conducted during two consecutive years (2008-09 and 2009-10) at Instructional Farm, Jaguli, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. The prime objective was to study the performance of different groups of morphological recombinants of *Brassica rapa* L. var. yellow sarson on the basis of seed yield and yield related traits and the relationship of different characters among the recombinants. The morphological recombinants had combination of traits like waxy/ non-waxy, petalous/ apetalous, multilocular/ bilocular, top/ mid/ basal branching and yellow/ white flower. Twenty six recombinant lines and one check having distinct features were line sown in a Randomized Block Design with three replications. Fourteen characters were studied in both the years. The recombinants were evaluated for their mean and yield attributes. Analysis of variance for fourteen characters over the years revealed presence of significant variability for all these traits among the genotypes tested. Among all the characters height upto first fruiting branch, number of siliqua on main raceme, number of siliqua on branches and seed yield per plant recorded higher value of GCV and PCV. Estimates of high heritability in broad sense coupled with high genetic advance (% mean) were observed for height upto first fruiting branch, number of siliqua on main raceme and 100 seed weight over the years. The six genotypes (4, 6, 10, 16, 20 and 21) showed higher and stable performance over the years in seed yield. These four lines were waxy, petalous and basal branching except genotype 4 but differed in flower colour and siliqua chamber. Top branching lines having waxy leaf and stem either petalous or apetalous, two chambers or four chamber recorded lowest seed yield per plant. The mean values of different groups of lines classified according to single morphological character showed that basal branching, petalous and white flower group differed significantly in seed yield per plant and basal branching recorded numerically higher seed yield per plant. The group-9 having combination waxy, petalous, basal branching, white flower and four chambered recorded highest seed yield per plant followed by group-3 and group-8 having combination of waxy, petalous, basal branching, yellow flower and two chambered and waxy, petalous, basal branching, yellow flower and four chambered respectively. It was evident that the waxy, petalous, basal branching combination was the best for seed yield per plant.

Key words: *Brassica rapa*, waxy, petalous, basal branching

Introduction

In trade, sarson, toria and taramira are known as rapeseed and rai as mustard. Rai and yellow sarson is self fertile and rest of the cruciferous oilseeds, viz. brown sarson, toria, taramira, banarasi rai and white mustard are self incompatible. The acreage under yellow sarson is scanty (mainly in Bihar, Central Uttar Pradesh and West Bengal) and constantly on the decrease. In oilseed *Brassicas*, the yield of the seed is the most, if not the only, important character. Seed yield, however, is a very complex entity, influenced by several components. For a rational approach to the improvement of yield, therefore, it is essential to have some information on the nature of inheritance and association between different yield components and their relative contributions to yield. The most important components are: the number of branches, siliqua per plant and 1000 seed weight. Siliqua locule number has been taken as a morpho-physiological character to find out the effect of bilocular and tetralocular siliqua on yield and its components of *B. rapa* var. yellow sarson. It is well established that multilocular types bear greater number of seeds per siliqua than the bilocular types (Sinhamahapatra *et al*., 2010). Siliqua locule number is a monogenic trait, where, bilocular type is dominant over multilocular type. Isolation of three distinct types for the angle of inclination of siliqua (pedicel) with respect to its bearing branch in tetralocular yellow sarson also prompted scientists to study the effect of siliqua orientation on seed yield and yield attributing traits. It was reported that 'upright' or 'erect' siliqua types recorded high values for all yield attributes in comparison to 'pendant' or 'horizontal' types (Shikari and Sinhamahapatra, 2004). Augmentation of yield by changing the plant architecture especially basal branching or otherwise is a widely debated topic. Branching habit can be visualized into three different types (i) basal branching (ii) top branching and (iii) non-branching except the normally existing mid branching type. Basal branching ideotype showed positive association and positive direct effect on seed yield per plant, while the primary branches arising on the upper half of the plant had the opposite effect (Satyavathi *et al*., 2001). In rapeseed, apetalous flower morphology is also very interesting, as rapeseed plant has a mass of brightly coloured flowers at the top layer for an extended period. In the present study true breeding petalous and apetalous lines of *Brassica rapa* L. var. yellow sarson accompanying other morphological characters (waxy/non-waxy, yellow/white flower, bilocular and multilocular, top/mid/basal branching) were tested for their performance for seed yield and yield attributes and their relationship in the seasons 2008-2009 and 2009-2010.

Materials and Methods

The materials represented the seeds of true breeding recombinant lines ($F_4/F_5/F_6$) having features waxy, non-waxy, apetalous, petalous, bilocular (two chambered), tetralocular (four chambered), top, mid and basal branching, white flower, yellow flower, erect, horizontal siliqua arrangement were developed and maintained at Department of Plant Breeding, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia. The morphological types comprising of 26 strains with Binoy (B-9) as a check were line sown in a Randomized Block Design with three replications at Instructional Farm, Bidhan Chandra Krishi Viswavidyalaya, Jaguli, Nadia, West Bengal during rabi seasons of two consecutive years (2008-09 and 2009-10). Data was taken on to fourteen characters viz. plant height (cm), height upto first branching (cm), main raceme length (cm), number of primary branches per plant, number of siliquae on main raceme, number of siliquae on branches, number of seeds per siliqua, days to 50% flowering, leaf fall at 88 days after sowing, days to physiological maturity, days to siliqua maturity, proportion of ten plant husk (%), 100 seed weight (g) and seed yield per plant (g). Analysis of variance was done by the method suggested by Panse and Sukhatme (1978).

Results and Discussion

Analysis of variance (table 1) for fourteen characters pooled over two years showed that differences due to genotypes, environments and genotype × environment interactions were highly significant for all the characters except days to siliqua maturity in case of genotype × environment interaction.

The mean values of different groups of genotypes when classified according to a single morphological character over the two years were presented in tables 2. As the numbers of lines in each group varied considerably, the comparison of means should not be done. Still the trend of the mean values may give some ideas about the groups. Basal branching group recorded significant difference in seed yield per plant with non-waxy, apetalous, top branching, mid branching and yellow flower group and also recorded highest seed yield per plant (5.85 g) and number of siliqua on branches (102.65). White flower group recorded significant difference in seed yield per plant with non-waxy, apetalous, top branching and mid branching group and also recorded highest plant height (122.35 cm). Petalous group recorded significant difference in seed yield per plant with top branching and mid branching group and showed highest main raceme length (41.95 cm). Non-waxy group recorded lowest height upto first fruiting branch (12.65 cm), leaf fall at 88 DAS (11.35), days to siliqua maturity (35.40) and proportion of ten plant husk (37.85%) and highest number of branches per plant (10.20). Four chambered group recorded highest main raceme length (41.95 cm), number of siliqua on main raceme (29.50) and number of seeds per siliqua (32.80).

The estimates of GCV and PCV (Table 3) were comparatively high for height upto first fruiting branch, number of siliqua on main raceme, number of siliqua on branches and seed yield per plant, which indicated the presence of high amount of both the genotypic as well as phenotypic variability for these traits in the genetic material. Earlier, high estimates of GCV (%) as well as PCV (%) were reported by Singh *et al*., (2001) for primary branches per plant, siliqua per plant seed yield per plant. The value of genotypic and phenotypic coefficients of variation were moderate for main raceme length, number of branches per plant, number of seeds per siliqua, leaf fall at 88 DAS, proportion of ten plant husk and 100 seed weight. The estimates of GCV (%) and PCV (%) were in low magnitude for plant height, days to 50% flowering, days to physiological maturity and days to siliqua maturity.

Table 1: Analysis of variance for different characters of 27 lines over two years (2008-09 and 2009-10).

Sources of variation	d.f	Mean sum of squares (MS)													
		Plant height (cm)	Height upto first fruiting branch (cm)	Main raceme length (cm)	No. of siliqua on main raceme	No. of siliqua on branches	No. of branches per plant	No. of seeds per siliqua	Days to 50% flowering	Leaf fall at 88 DAS	Days to physiological maturity	Days to siliqua maturity	Proportion of 10 plant husk (%)	100 seed wt. (g)	Seed yield per plant (g)
Environments	1	2526.82**	634.04*	1747.72**	4004.63**	8829.73**	1.91	233.28**	526.32**	325.69**	8220.47**	189.04**	1041.91*	0.659**	162.02**
Genotypes	26	519.55**	1699.62**	107.08**	75.57**	3852.93**	12.78**	200.25**	13.12**	3.38**	8.55**	13.42**	195.47**	0.001*	10.93**
E × G	26	220.74**	102.91**	34.84**	41.56**	2120.80**	7.86**	17.21**	5.65**	4.07**	4.35**	0.73	179.90**	0.002**	2.97**
Error	104	18.14	8.70	10.68	4.89	40.52	0.93	1.92	0.65	0.66	0.94	0.73	7.71	0.001	0.46

*, **= Significant at 5% and 1% levels respectively.

Table 2: Mean values of different yield attributing traits of different groups of morphological characters over two years (2008-09 and 2009-10).

Characters	No. of lines	Plant height (cm)	Height upto first fruiting branch (cm)	Main raceme length (cm)	No. of siliqua on main raceme	No. of siliqua on branches	No. of branches per plant	No. of seeds per siliqua	Days to 50% flowering	Leaf fall at 88 DAS	Days to physiological maturity	Days to siliqua maturity	Proportion of 10 plant husk (%)	100 seed wt. (g)	Seed yield per plant (g)
Waxy	23	118.25	34.60	41.30	27.80	80.50	8.95	26.95	48.10	11.70	99.15	36.50	42.80	0.35	5.20
Non-waxy	4	106.70	12.65	36.20	24.80	97.85	10.20	22.30	48.50	11.35	98.90	35.40	37.85	0.35	4.80
Apetalous	8	109.45	20.35	37.05	24.55	92.75	10.10	21.90	48.80	11.70	98.75	35.60	40.95	0.35	4.75
Petalous	19	119.50	36.00	41.95	28.55	79.00	8.65	28.60	47.90	11.70	99.30	36.60	42.55	0.35	5.35
Two chambered	15	113.30	23.60	39.40	25.70	92.35	9.55	21.70	48.10	11.70	98.80	35.75	41.40	0.35	5.10
Four chambered	12	120.65	41.05	41.95	29.50	68.05	8.55	32.80	48.35	11.60	99.55	37.05	42.70	0.35	5.20
Top branching	10	119.35	50.25	41.70	28.20	62.25	8.10	29.50	47.85	11.85	99.35	37.00	42.40	0.35	4.45
Mid branching	4	117.75	36.45	39.55	26.80	71.45	8.95	27.05	49.40	11.80	99.45	36.50	37.85	0.34	4.45
Basal branching	13	114.00	15.20	39.95	26.95	102.65	9.95	23.85	48.05	11.50	98.80	35.75	43.10	0.35	5.85
Yellow flower	21	114.85	29.40	40.80	26.90	87.00	9.35	24.50	48.30	11.75	99.25	36.35	42.75	0.35	5.00
White flower	6	122.35	38.25	39.65	29.20	69.15	8.30	32.40	48.00	11.55	99.00	36.65	40.85	0.35	5.65
CD at 5%		**4.88**	**3.38**	**3.74**	**2.53**	**7.29**	**1.11**	**1.59**	**0.92**	**0.93**	**1.11**	**0.98**	**3.18**	**0.03**	**0.78**

A comparison of estimates of GCV (%) with their corresponding PCV (%) for different traits revealed that in general, the estimates of GCV (%) were close to the estimates of PCV (%) for days to 50% flowering, days to physiological maturity and days to siliqua maturity. This indicated that majority of the traits studied were more influenced by the environment except days to 50% flowering, days to physiological maturity and days to siliqua maturity.

The estimates of heritability in broad sense for different traits (Table 3) revealed that, the high values of heritability were observed for height upto first branching (63.60%), number of siliquae on main raceme (74.40%), days to 50% flowering (73.50%), leaf fall at 88 days after sowing (62.60%), days to Physiological maturity (91.80%) and 100 seed weight (77.00%). The higher estimates of heritability for these traits indicated that simple selection on the basis phenotypic performance of genotypes would also be more efficient in further improvement of these traits. This result was in accordance with the findings of Singh *et al.*, (2003). Moderate values of heritability were registered by plant height (55.70%), number of siliquae on branches (54.20%), number of branches per plant (44.90%), days to siliqua maturity (55.30%), seed yield per plant (45.60%). This suggested that it was moderately

Table 3: Variability parameters of different characters of 27 lines over two years (2008-09 and 2009-10)

Parameters	Mean	Range	PCV	GCV	h^2 in broad sense (%)	Genetic Advance as % of mean
Plant height (cm)	116.54	93.27-135.88	10.34	7.72	55.70	11.86
Height upto first fruiting branch (cm)	31.34	10.00-57.07	56.21	44.82	63.60	73.62
Main raceme length (cm)	40.54	33.08-49.02	15.89	9.57	36.20	11.86
No. of siliqua on main raceme	27.39	20.48-35.17	25.42	21.93	74.40	38.97
No. of siliqua on branches	83.07	45.03-132.68	39.53	29.10	54.20	44.14
No. of branches per plant	9.12	6.57-11.57	22.13	14.83	44.90	20.47
No. of seeds per siliqua	26.61	20.00-35.65	23.47	14.29	37.10	17.92
Days to 50% flowering	48.17	45.50-51.00	5.46	4.68	73.50	8.26
Leaf fall at 88 DAS	11.67	10.27-13.27	16.57	13.11	62.60	21.37
Days to physiological maturity	99.11	96.83-100.83	7.51	7.20	91.80	14.20
Days to siliqua maturity	36.33	34.33-39.67	5.52	4.11	55.30	6.29
Proportion of 10 plant husk (%)	42.07	34.11-57.92	20.52	11.83	33.20	14.04
100 seed wt. (g)	0.35	0.32-0.38	20.42	17.92	77.00	32.39
Seed yield per plant (g)	5.14	3.35-8.75	37.31	25.21	45.60	35.09

Table 4: Comparison of means of different characters of 27 lines over two years (2008-09 and 2009-10).

Characters	Means													
Lines	Plant height (cm)	Height upto first fruiting branch (cm)	Main raceme length (cm)	No. of siliqua on main raceme	No. of siliqua on branches	No. of branches per plant	No. of seeds per siliqua	Days to 50% flowering	Leaf fall at 88 DAS	Days to physiological maturity	Days to siliqua maturity	Proportion of 10 plant husk (%)	100 seed wt. (g)	Seed yield per plant (g)
1. W/APET/Y.F/B.B/2ch	102.05	15.98	36.68	23.21	85.93	8.98	22.38	47.00	10.83	98.17	36.00	45.28	0.35	5.40
2. NW/APET/Y.F/B.B/2ch	93.27	10.00	35.78	20.48	84.87	8.52	23.78	46.67	10.97	98.50	35.00	39.84	0.34	4.08
3. W/PET/Y.F/B.B/4ch	111.50	17.24	44.05	30.94	84.35	9.90	32.20	48.50	11.77	98.50	36.67	57.92	0.35	5.30
4. NW/APET/G.B.B/Y.F/2ch	113.93	12.83	41.40	27.35	127.68	11.57	22.20	51.00	11.92	100.00	36.00	36.65	0.33	6.60
5. NW/APET/B.B/Y.F/2ch	105.67	14.20	33.08	23.63	79.68	10.77	23.08	47.83	11.37	97.67	36.33	40.92	0.38	4.38
6. W/PET/Y.F/B.B/2ch	121.87	19.52	44.85	29.69	128.17	10.78	21.60	48.33	12.27	98.17	35.50	40.58	0.34	6.82
7. W/PET/Y.F/B.B/2ch	124.50	17.17	45.40	23.87	132.68	9.87	20.00	47.17	12.60	100.17	34.67	50.53	0.37	4.82
8. W/APET/Y.F/M.B/2ch	123.13	37.08	40.43	24.70	71.05	11.57	21.33	51.00	12.50	100.50	36.50	38.33	0.36	4.66
9. W/PET/Y.F/T.B/2ch	115.30	47.75	42.97	25.87	58.27	6.57	22.10	48.33	13.27	99.83	38.17	42.23	0.35	4.58
10.W/PET/Y.F/B.B/2ch	111.25	10.05	42.35	22.15	107.77	10.03	21.68	46.17	10.50	98.50	35.17	47.66	0.35	5.64
11. W/PET/Y.F/T.B/4ch	135.88	53.27	49.02	31.03	53.38	7.83	32.47	49.83	12.57	100.17	36.67	42.91	0.37	4.59
12. NW/APET/Y.F/B.B/2ch	113.82	13.40	34.57	27.73	99.02	10.02	20.10	48.33	11.17	99.50	34.33	34.11	0.37	4.15
13. W/PET/Y.F/M.B/4ch	111.75	34.67	40.85	26.92	77.78	8.65	33.90	48.83	12.17	100.00	36.67	36.61	0.35	3.90
14. W/PET/Y.F/T.B/4ch	110.42	52.40	44.53	26.23	92.45	11.42	33.48	49.33	11.80	100.83	38.33	51.81	0.33	5.40
15. W/APET/Y.F/T.B/2ch	111.37	46.57	36.08	24.53	70.65	8.25	20.40	48.00	12.37	97.83	34.83	43.64	0.35	3.84
16. W/PET/W.F/B.B/4ch	119.57	17.38	37.75	29.97	79.93	9.45	33.87	46.83	11.67	98.17	34.67	42.88	0.35	8.08
17. W/APET/Y.F/B.B/2ch	112.45	12.82	38.05	24.93	122.82	11.12	21.80	50.50	12.43	97.83	36.00	48.87	0.35	4.64
18. W/PET/W.F/M.B/4ch	123.22	39.93	42.63	27.63	69.63	7.50	30.98	50.83	11.33	100.50	38.00	40.04	0.34	4.53
19. W/PET/W.F/T.B/4ch	132.75	49.75	42.65	27.73	55.85	8.52	30.30	48.50	10.67	100.50	39.67	45.40	0.35	4.46
20. W/PET/W.F/B.B/4ch	129.23	22.65	42.10	35.17	91.28	8.80	31.70	48.00	11.37	99.17	36.00	36.29	0.33	7.84
21. W/PET/Y.F/B.B/2ch	122.93	14.72	43.62	31.22	110.25	9.80	20.95	48.17	10.80	100.17	38.50	39.24	0.37	8.75
22. W/PET/Y.F/T.B/4ch	127.72	48.78	47.63	33.70	45.03	7.38	32.17	47.33	11.40	100.67	38.83	39.61	0.36	4.51
23. W/PET/Y.F/T.B/4ch	116.22	57.07	39.43	30.32	48.63	7.73	34.83	48.00	10.27	100.17	37.83	38.73	0.35	4.49
24. W/PET/W.F/T.B/4ch	118.57	45.32	37.35	30.50	53.70	7.18	31.90	47.00	11.73	98.33	35.33	46.15	0.37	4.84
25. W/PET/W.F/T.B/4ch	110.72	54.17	35.37	24.07	64.57	8.37	35.65	46.67	12.40	97.50	36.00	34.27	0.35	4.21
26. W/PET/Y.F/T.B/2ch	114.62	47.48	41.60	28.05	79.98	7.60	21.38	45.50	11.97	97.83	34.50	38.87	0.36	3.35
27. Binoy (check)	112.82	34.10	34.32	27.88	67.38	8.07	22.15	47.00	11.00	96.83	34.67	36.51	0.32	4.85
Grand Mean	**116.54**	**31.34**	**40.54**	**27.39**	**83.07**	**9.12**	**26.61**	**48.17**	**11.67**	**99.11**	**36.33**	**42.07**	**0.35**	**5.14**
CD at 5%	**4.88**	**3.38**	**3.74**	**2.53**	**7.29**	**1.11**	**1.59**	**0.92**	**0.93**	**1.11**	**0.98**	**3.18**	**0.03**	**0.78**

W=Waxy, NW=Non-waxy, APET=Apetalous, PET=Petalous, Y.F. =Yellow Flower, W.F. = White Flower, T.B=Top branching, B.B=Basal branching, M.B=Mid branching, 2ch= Two chambered, 4ch=Four chambered.

influenced by environment and genetic enhancement through selection might be difficult due to masking effects of the environment on the genotypic effect. Genetic advance expressed as percentage of mean revealed that high estimates of genetic advance (% mean) were observed for height upto first fruiting branch (73.62), number of siliqua on main raceme (38.97), number of siliqua on branches (44.14), 100 seed weight (32.39) and seed yield per plant (35.09). This indicated that inheritances of these characters were under the control of additive genes and selection would be rewarding for further improvement of these traits. The moderate estimates of genetic advance (% mean) were observed for plant height (11.86), main raceme length (11.86), number of branches per plant (20.47), number of seeds per siliqua (17.92), leaf fall at 88 DAS (21.37), days to physiological maturity (14.20) and proportion of ten plant husk (14.04) indicating that these characters were under the influence of both additive as well as non-additive gene effect thereby suggesting that reciprocal recurrent selection would be effective for further improving these traits. Genetic advance (% mean) was low in magnitude for characters like days to 50% flowering (8.26) and days to siliqua maturity (6.29) suggesting that these characters were under the influence of non-additive genes, thus emphasizing the importance of heterosis breeding for exploitation of these non-additive genes. High heritability coupled with high genetic advance (% mean) were observed for height upto first fruiting branch, number of siliqua on main raceme and 100 seed weight revealing that these characters can be improved by simple phenotypic selection as they are more likely to be controlled by additive gene action. Similar result reported by Mandal and Khajuria (2000) for 1000 seed weight. In the present investigation the estimates of high heritability and moderate genetic advance (% mean) were observed for leaf fall 88 DAS and days to physiological maturity emphasizing the role of both additive and non-additive gene action for these traits.

Hence, recurrent selection or reciprocal recurrent selections are the best suited method for exploitation of both additive and non-additive genetic components. Further, high heritability coupled with low genetic advance (% mean) was exhibited by days to 50% flowering indicating that there is little scope for further improvement through selection for this trait due to the involvement of non-additive effect in the inheritance of this trait. Days to siliqua maturity exhibited moderate heritability and low genetic advance (% mean) indicating that this trait was under the influence of non-additive gene action. In the present investigation, considering the importance of genetic parameters like GCV, heritability and genetic advance (% mean) together, it is evident that height upto first fruiting branch, number of siliqua on main raceme and number of siliqua on branches are the most important traits for improving seed yield of *Brassica rapa* L. var. yellow sarson.

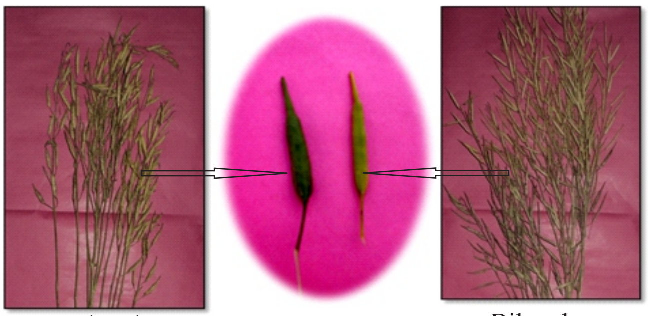
The mean values of seed yield per plant and different yield attributing characters of the twenty seven lines over two years (Table 4) were evident that seed yield per plant of six lines i.e. (4, 6, 10, 16, 20 and 21) were significantly higher than that of check (4.85 g) as well as than the grand mean (5.14 g). The most important yield attributing characters are plant height (cm), height upto first fruiting branch (cm), main raceme length (cm), number of siliqua on main raceme, number of siliqua on branches, number of branches per plant, number of seeds per siliqua and 100 seed weight were recorded highest score in lines 11, 23, 11, 20, 7, 4 and 8, 25 and 5 and were recorded lowest score in lines 2, 2, 5, 2, 22, 9, 7 and 27 (check) respectively. The six lines recorded higher seed yield per plant which were basal branching while the lowest yielding lines were top branching.

Thus, the six lines i.e. (4, 6, 10, 16, 20, and 21) showed higher and stable performance over the years in seed yield. Therefore these lines should be considered as promising for future testing. All these lines shared same common morphological characters. These lines were waxy, petalous and basal branching except line 4 but differed in flower colour and siliqua chamber. Therefore, it can be assumed that high yielding type should have these characters. As number of apetalous lines was smaller than petalous lines, the promises of apetalous lines were not established although many authors have reported (Zhao and Wang, 2004 and Zhang *et al.,* 2002). Top branching lines having waxy, petalous or apetalous, two chambered or four chambered recorded lowest seed yield per plant. Therefore, it can be assumed that under the present spacing and fertilizer dose, the top branching lines are not promising so far

PHOTOGRAPHS OF DIFFERENT MORPHOLOGICAL RECOMBINANTS

Top Branching   Midium Branching   Basal Branching

Fig. 1. Representative branching types in *Brassica rapa* var. yellow sarson



Tetralocular   Bilocular

Fig. 2. Representative plants of bilocular and multilocular siliquae

White Flower   Yellow Flower

Fig. 3. Representative inflorescence of white and yellow flower plants

Petalous   Apetalous

Fig. 4. Representative inflorescence of petalous and apetalous flower plants.

Waxy   Non waxy

Fig. 5. Representative lines of waxy and non-waxy plants

seed yield per plant is concerned.

It was evident that the group-9 having waxy, petalous, basal branching, white flower and four chambered recorded highest seed yield per plant followed by the group-3 and group-8 having combination of waxy, petalous, basal branching, yellow flower and two chambered and waxy, petalous, basal branching, yellow flower and four chambered. It appears that the common features of these two groups are that both are waxy, petalous and basal branching. Recently Sinhamahapatra *et al*., (2010) suggested an ideotype for yellow sarson where the importance of waxy, basal branching, multilocular (four chamber) and apetalous traits were emphasized as most promising recombinants for enhancing seed yield in yellow sarson.

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Short Communication

Combining ability analysis for seed yield and its attributing traits in soybean (*Glycine max* L. *Merrill*)

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Soybean is an important oilseed crop of the world. There is a strong global demand for soybean for its oil and meal. Demand of this crop is increasing since it is an important commodity for food manufacturers, animal feed companies, pharma industries and biodiesel producers. The estimates of world soybean area, production and productivity for 2013-14 are 113.01 million ha, 283.79 million tonnes and 2.51t/ha, respectively thus exhibiting an increase in area (3.5%), production (5.6%) and productivity 2.0% over the corresponding year 2011-12. The increase in world soybean production is on account of increased area in Brazil, Argentina, India and substantial increase in productivity in the USA and Argentina. Among the major soybean growing countries, India ranked fourth in terms of both area and production (Anonymous, 2013-14).

The development of high yielding varieties with proper plant architecture and duration is of paramount importance. For this purpose, the genotypes with suitable plant types are to be selected from a diverse pool for their future use as parents in hybridization programme. Success of any plant breeding programme depends on the choice of appropriate genotypes as parents in the hybridization programme.

The present investigation was conducted in a Randomized Complete Block Design (RBD) with three replications at Research cum Instructional Farm, Department of Genetics and Plant Breeding, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during *Kharif* 2012 and *Kharif* 2013 to estimate combining ability among yield traits .

The experimental material used in the present study was obtained from All India Coordinated Research Project on Soybean (AICRP on Soybean), Department of Genetics and Plant Breeding, IGKV, Raipur (C.G.) which consisted of 5 diverse genotypes *viz.*, JS 97-52, MACS 1336, MAUS 504, MACS 1140 and MACS 1340. All the parents were crossed in all possible combination in a half diallel fashion. The crosses were attempted during *Kharif*- 2012. The parents and 10 F_1's were grown in a Randomized Complete Block Design (RBD) in three replications during *Kharif* 2013. Each entry was grown in a single row of 2 m length spaced at 30 cm and 20 cm between plants. All the recommended package of practices were adopted to raise the normal crop. The crop was sown on 3rd July, 2013. Combining ability analysis was carried out by the procedure giving by Griffing (1956) as per the method II (model II). This applied for the set of data involving parents and F_1's excluding reciprocals.

The analysis of variance for general combining ability and specific combining ability (Table -1) were found highly significant for most of the characters, evaluated like number of primary branches per plant and number of pods per plant. The mean sum of squares due to general combining ability (gca) and specific combining ability (sca) were highly significant for most of the characters.

The estimates of gca and sca effects for all the characters have been presented in the Table 2 and 3, respectively. The gca effects of parents ranged from -0.67 (JS-97-52) to 0.54 (MAUS-504) for protein content. Out of five, two parents showed significant gca effects. Among two significant parents, one parent exhibited significant positive gca effect and another one parent showed significant negative gca effect. The highest significant positive gca effects of parent was MAUS-504. The sca effects of the hybrids ranged from -1.89 (JS-97-52 × MACS-1140) to 0.94 (MACS-1340 × MACS-1336). The four hybrids showed significant sca effects of which one hybrid showed significant positive sca effect and remaining three hybrids showed significant negative sca effects. The highest and significant positive sca effect was exhibited byof hybrid MACS-1340 × MACS-1336. Similar findings have also been reported by Ramana and Satyanarayana (2006).

The gca effects of parents for oil content ranged from -0.31 (MACS-1340) to 0.33 (MACS-1140). Out of five, two parents showed significant gca effects. Among two significant parents, one parent (MACS-1140) exhibited significant positive gca effect and another one parent (MACS-1340) showed significant negative gca effect.

Table 01 : Analysis for variances for combining ability analysis in soybean

Characters	Mean Sum of Squares			Additive variance	Dominance variance	A/D
Source of variance	GCA	SCA	Error			
Degree of freedom	4	10	28			
Days to 50% flowering	15.57	10.88	0.144	-26.64	96.69	-0.28
Days to maturity	10.53	2.95	0.229	3.60	10.24	0.35
Plant height (cm)	48.6	94.71	7.005	-215.07	358.7	-0.60
Number of primary branches per plant	0.024	0.103	0.0148	2.48	-0.22	-11.29
Pod bearing length (cm)	48.6	94.71	7.005	-215.07	358.71	-0.60
Number of pod bearing nodes	2.94	1.334	0.071	-0.45	7.32	-0.06
Number of pods per plant	14.91	12.79	5.902	-19.52	-367.8	0.05
Number of seeds per pod	0.0053	0.029	0.0044	0.52	-0.08	-6.54
100 seed weight (g)	1.82	1.918	0.044	-0.03	6.35	0.00
Protein content (%)	1.67	1.477	0.788	-2.31	-51.43	0.04
Oil content (%)	0.36	0.988	0.185	-2.40	-5.66	0.42
Seed yield per plant (g)	1.047	3.064	0.379	-7.56	-1.2	6.30

Table 02: Estimates of general combing ability effect (gca) for seed yield and its components in half diallel in soybean

Characters	Parents					SE(gi)±	SE(gi-gj)±
	JS-97-52	MAUS-504	MACS-1140	MACS-1340	MACS-1336		
Days to 50% flowering	1.19**	-0.95	1.76**	-0.14	-1.86**	0.016	0.041
Days to maturity	2.16**	-0.41	-0.27**	-0.79**	-0.70**	0.026	0.065
Plant height (cm)	3.09**	-0.03	-4.12**	-0.06	1.21*	0.800	2.001
Number of primary branches per plant	-0.05*	-0.02	0.00	0.10**	-0.02	0.001	0.004
Pod bearing length (cm)	**3.06****	**-0.03**	**-4.12****	**-0.06**	**1.12***	**0.800**	**2.001**
Number of pod bearing nodes	0.97**	-0.75	-0.28**	-0.19**	0.26**	0.008	0.020
Number of pods per plant	2.38**	-0.41	0.28	-0.99*	-1.27*	0.674	1.686
Number of seeds per pod	0.00	0.00	0.01	-0.04**	0.04**	0.0005	0.0012
100 seed weight (g)	-0.80**	0.22	0.35**	-0.20**	0.43**	0.005	0.012
Protein content (%)	-0.67**	0.54	-0.11	-0.17	0.41*	0.090	0.225
Oil content (%)	-0.07	0.03	0.33**	-0.31**	0.03	0.021	0.052
Seed yield per plant (g)	-0.12	0.15	0.39**	-0.61**	0.19	0.043	0.108

***, ** significant at 5% and 1% levels, respectively**

The gca effects of parents ranged from -0.31 (MACS-1340) to 0.33 (MACS-1140). Out of five, two parents showed significant gca effects. Among two significant parents, one parent (MACS-1140) exhibited significant positive gca effect and another one parent (MACS-1340) showed significant negative gca effect. The sca effects of the hybrids ranged from -1.31 (JS-97-52 × MACS-1340) to 1.41 (MACS-1140 × MACS-1340) and indicated the nine hybrids showed significant sca effects and of which two hybrids showed significant positive sca effects and seven hybrids showed significant negative sca effects. The highest and significant positive sca effects of hybrids were of MACS-1140 × MACS-1340 and MAUS-504 × MACS-1336. Similar findings have also been revealed by authors Ramana and Satyanarayana (2006).

The gca effects of parents ranged from -0.61 (MACS-1340) to 0.39 (MACS-1140) for seed yield per plant (g). The two parents showed significant gca effects among five parents and of which parents (MACS-1140) exhibited significant positive gca effect and another parent (MACS-1340) showed significant negative gca effect. Similarly the sca effects of the hybrids ranged from -2.59 (MAUS-504 × MACS-1140) to 1.25 (MAUS-504 × MACS-1336) and out of ten hybrids, seven hybrids showed significant sca effects and of which two hybrids showed significant positive sca effects and five hybrids showed significant negative sca effects. The highest and significant positive sca effect was shown by hybrid MAUS-504 × MACS-1336. Similar findings were also reported by authors Ramana and Satyanarayana (2006). Combining ability analysis indicated the predominance of additive gene action in the expression of the combining ability and gene effects revealed contribution of both additive and non-additive gene effects playing an important role for all the characters. Parents JS-97-52 were found to be the good general combiners for plant height (cm), pod bearing length, number of pod bearing nodes, number of pods per plant and MACS-1336 for day to 50% flowering, days to maturity ,number of seed per pod and 100 seed

Table 03: Estimates of specific combing ability effect (sca) for seed yield and its components in half diallel in soybean

F_1's	Characters											
	01	02	03	04	05	06	07	08	09	10	11	12
JS-97-52 × MAUS-504	-1.57**	0.83**	7.60**	-0.07	7.50**	-0.21	-5.86**	0.00	0.72**	-1.52**	-0.56**	-0.98**
JS-97-52 × MACS-1140	-1.29**	2.35**	1.13	-0.37**	1.12	-1.99**	3.05**	-0.12**	-1.58**	-1.89**	-0.45*	-1.29**
JS-97-52 × MACS-1340	-1.71**	-1.46**	4.46**	-0.33**	4.43**	-0.47**	4.38**	-0.13**	-0.67**	0.36	-1.13**	-0.19
JS-97-52 × MACS-1336	1.33**	-2.89**	-2.45*	-0.34*	-2.41*	0.14	-3.86**	-0.28**	0.14	-0.89*	-0.70**	-1.85**
MAUS-504 × MACS-1140	4.52**	0.92**	0.65	0.00	0.64	1.89**	0.64	-0.12**	-2.60**	-0.26	0.22	-2.59**
MAUS-504 × MACS-1340	-3.24**	-0.89**	10.17**	-0.09	10.16**	0.86**	-3.56**	-0.13**	-0.53**	-0.11	-0.49**	-1.75**
MAUS-504 × MACS-1336	-2.86**	0.35	0.61	0.23**	0.60	-0.14	4.53**	-0.01	0.20*	-0.35	1.31**	1.25**
MACS-1140 × MACS-1340	2.05**	-0.37	-5.13**	0.35**	-5.10**	0.80**	-1.18	-0.08**	1.45**	0.65	1.41**	0.60*
MACS-1140 × MACS-1336	-1.57**	-1.79**	-17.70**	0.34**	-17.50**	-0.21	1.71	0.04	-1.05**	0.12	-1.07**	-0.26
MACS-1340 × MACS-1336	-4.33**	2.40**	-5.40**	0.11**	-5.50**	-0.83**	-1.03	0.02	-0.10	0.94*	-0.37*	-0.22

***Significant at 5 %, ** Significant at 1% respectively**

1. Days to 50% flowering 2. Days to maturity 3. Plant height (cm) 4. Number of primary branches per plant 5. Pod bearing length (cm) 6. Number of pod bearing nodes 7. Number of pods per plant 8.Number of seeds per pod 9. 100 seed weight (g) 10. Protein content (%) 11. Oil content (%) 12. Seed yield per plant (g)

weight(g). The present finding are in conformity with the results of Krishnawat and Milo (2004). The hybrid MAUS-504 × MACS-1336 was found good specific combiners for oil content (%), days to 50% flowering, 100 seed weight (g) and seed yield per plant (g). The ratio of additive variance to dominant variance ranged from -11.29 (number of primary branches per plant) to 6.30 (seed yield /plant). Out of twelve characters nine showed less than unity and three showed more than unity ratio of additive variance to dominant variance. Highest ratio recorded was for the character number of primary branches per plant (-11.29) which was followed by number of seeds per pod (-6.54) and seed yield per plant (6.30). The present finding are in conformity with the results of previous worker Eren, *et al*., (2012).

Non-additive gene action played an important role in the expression of all the characters except pod length and harvest index which shows additive gene effect. The parent JS-97-52 and MACS-1336 appeared to be good general combiners and can be involved in the further crossing programme for crop improvement. The crosses MAUS-504 × MACS-1336 proved the best specific combination for seed yield per plant. The crosses MACS-1340 × MACS-1336 proved the best specific combination for protein content. The crosses MACS-1140 × MACS-1340 and MAUS-504 ×MACS-1336 proved the best specific combination for oil content (%).

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Short Communication

Effect of nitrogen level and its scheduling on aerobic rice in inceptisols of Chhattisgarh plains

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Aerobic rice production system is gaining importance for increased productivity and reduced water requirement. Further, it is expected to occupy 10-15 per cent of total area in India. Nitrogen plays a vital role for improving the photosynthetic activity and productivity of rice. Therefore, optimum quantity and its time of application are important for harnessing the potential yield of rice under aerobic condition (Sathiya *et al*., 2008). Keeping all above facts in view, an experiment was conducted to find out the nitrogen level and its scheduling for aerobic rice.

A field experiment was conducted on sandy loam soil at Instructional cum Research Farm, IGKV, Raipur during *kharif* season of 2013. The soil was neutral in pH with low in nitrogen and medium in phosphorus and potassium**.** The experiment was laid out in factorial randomized block design with three replications involving two nitrogen levels *viz***.** 120 and 150 kg ha^{-1} and six nitrogen scheduling *viz.* two splits (1/2 as B + 1/2 at PI), two splits (1/2 at 10-12 DAE + 1/2 at PI), three splits (1/3 as B + 1/3 at AT + 1/3 at PI), three splits (1/3 at 10-12 DAE + 1/3 at AT + 1/3 at PI), four splits (1/4 as B + 1/4 at AT + 1/4 at PI + 1/4 at F) and four splits (1/4 at 10-12 DAE + 1/4 at AT + 1/4 at PI + 1/4 at F). The entire dose of 60 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1} was applied as basal in the form of single super phosphate and muriate of potash, respectively. Rice cultivar Indira Rajeshwari was used as test crop.

Panicle length, panicle weight and test weight were statistically similar in two levels of nitrogen (Table 1). Higher effective tillers m^{-2} and number of filled grains panicle^{-1} contributed higher grain yield of rice under 150 kg N ha^{-1} as compared to 120 kg N ha^{-1}. The similar findings have been reported by Devi *et al.* (2012). Sterility percentage was significantly higher under 120 kg N ha^{-1} as compared to 150 kg N ha^{-1}. These results are in agreement with the findings of Sarkar *et al.* (2002). The maximum net return (Rs. 42,455 ha^{-1}) and B: C ratio (1.94) was recorded in 150 kg ha^{-1}.

Among the nitrogen scheduling, application of nitrogen in four splits as 1/4 at 10-12 DAE + 1/4 at AT+1/4 at PI stage +1/4 at F produced significantly higher effective tillers as compared to other split application of nitrogen but remained on par with 1/4 at B + 1/4 at AT + 1/4 at PI stage +1/4 at F and 1/3 at 10-12 DAE + 1/3 at AT + 1/3 at PI. The highest number of filled grains panicle^{-1}, panicle weight, test weight and grain yield was recorded under the application of nitrogen in three splits (1/3 at 10-12 DAE + 1/3 at AT + 1/3 at PI). However, panicle weight and test weight of this treatment also found to be comparable with the application of nitrogen in four splits as 1/4 at 10-12 DAE + 1/4 at AT + 1/4 at PI stage +1/4 at F . More number of tillers and translocation of photosynthates towards reproductive parts might have increased the economic yield. Similar results were also reported by Sharma and Agrawal (2006). Nitrogen applied in three splits as (1/3 at 10-12 DAE + 1/3 at AT + 1/3 at PI) save higher net return (Rs. 52597 ha^{-1}) and B:C ratio (2.43). It is due to more productivity in comparison to less cost. This is in accordance with the findings of Singh *et al.* (2005). The interaction effect of nitrogen level and nitrogen scheduling was not found significant.

It can be concluded that application of nitrogen @150 kg ha^{-1} gave higher effective tillers, filled grains panicle^{-1}, grain yield, net return and B:C ratio of aerobic rice than that of 120 kg N ha^{-1}. Among the split application of nitrogen, nitrogen applied in three splits as 1/3 at 10-12 days after emergence (DAE) + 1/3 at active tillering (AT) + 1/3 at panicle initiation (PI) stage was superior with respect to grain yield, net return and B: C ratio as compared to other split application of nitrogen.

Table 1: Effect of nitrogen level and scheduling on yield attributes, yield, harvest index and economics of Aerobic rice

Treatment	Effective tillers (No. m^{-2})	Filled grains Panicle[1] (No.)	Sterility (%)	Panicle length (cm)	Panicle weight (g)	Test weight (g)	Grain yield (q ha^{-1})	Harvest index (%)	Net return (Rs. ha^{-1})	B:C ratio
Nitrogen levels (kg ha^{-1})										
120	257	110.52	21.25	22.37	4.09	24.22	40.16	36.14	38240	1.78
150	268	112.25	20.63	22.58	4.26	24.46	43.36	36.66	42456	1.94
CD (P = 0.05)	10.2	0.7	0.5	NS	NS	NS	1.0	0.5	-	-
N scheduling										
2 splits (1/2 as B + 1/2 at PI)	226	93.45	29.11	21.61	3.56	23.50	30.60	34.88	24546	1.15
2 splits (1/2 at 10-12 DAE + 1/2 at PI)	253	102.23	23.92	22.03	3.75	23.83	37.07	35.47	34047	1.60
3 splits (1/3 as B + 1/3 at AT+1/3 at PI)	261	113.60	19.83	22.56	4.26	24.03	43.96	36.67	43572	2.01
3 splits (1/3 at 10-12 DAE + 1/3 at AT + 1/3 at PI)	272	131.20	14.08	23.36	4.74	25.00	50.25	37.46	52597	2.43
4 splits (1/4 as B + 1/4 at AT + 1/4 at PI + 1/4 at F)	279	108.03	22.11	22.26	4.20	24.48	42.22	36.45	40676	1.85
4 splits (1/4 at 10-12 DAE + 1/4 at AT +1/4 at PI+1/4 at F)	285	119.82	18.57	23.02	4.52	25.18	46.47	37.45	46649	2.12
CD (P = 0.05)	17.7	1.2	0.9	0.9	0.4	0.7	1.8	0.9	-	-

*DAE- Days after emergence, B- Basal, PI- Panicle Initiation, AT- Active tillering, F- Flowering

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Short Communication

Reactions of traditional aromatic rice varieties against major diseases of rice under natural conditions

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Key words : Traditional rice, brown spot, bacterial leaf blight, sheath rot, sheath blight, blast.

Chhattisgarh is famous for its diversity of rice. In every district of CG specific traditional rice is famous, which is locally grown by the farmers and very much popular among the local peoples for consumption in daily diet. These varieties are locally adapted by farmers and grown as traditional rice by the farmers and they are maintaining them without any scientific method since ancestry. Some of these lines are collected by the scientists from different places, their progenies are evaluted, purified and the promising one is multiplied. The traditional rice is supposed to be the less yielder than the improved higher yielding varieties. There are number of reasons for low yielding, such as low test weight, lodging losses, unawarness regarding fertilizer use, spacing and susceptibility to diseases and pests. Diseases and insects infestation is one of the major factors of yield loss in traditional rice. Raipur is a traditional rice growing area and supposed to be the hot spot for many rice diseases. These prominent aromatic rice lines collected from different locations were screened under natural conditions against major diseases of rice.

Twenty seven aromatic rice varieties named Badshahbhog, Bisni, Chatri, Chinoor, Dubraj, Dujai, Elaychi, Ganga Baru, Gopalbhog, Jaigundi, Jeeradhan, Jeeraphool, Kalikamod, Kapoorsar, Karigilas, Katarnibhog, Kerghul, Kubrimohar, Lohandi, Samudrafen, Shuklphool, Shyamjeera, Srikamal, Tilkasturi, Tulsimanjari, Tulasiprasad, and Vishnubhog were collected from their respective localized areas purified and screened in field condition for major diseases of rice prominent at Chhattisgarh during *kharif* 2012. 21 days old seedlings of the test variety 'swarna' were transplanted in 1.60 x 2.10 m^2 plots with a spacing of 1m plot to plot and replication to replication. The spacing between plants to plant was 15cm and row to row was 20cm. The experiment was laid in Randomized Block Design (RBD) with three replications. Recommended dose of fertilizer was applied @ $N_{120}P_{50}K_0$/ha. Total P was given as first basal dose. All standard agronomical practices were applied during the crop season for its normal development. The Incidence of diseases, their intensities are to be recorded from the frist diseases symptoms till the physiological maturity at 7 days intervals .In case of foliar diseases i.e. Observations on severity of sheath blight (*Rhizoctonia solani*), brown spot (*Dreheslera oryzae*) and bacterial leaf blight (*Xanthomonas oryzae* pv. *oryzae*) is recorded based on percentage of leaf /sheath area covered by particular disease. At any crop stage ,the physiologically active leaves in each tiller of a hill as been taken for assessing the severity to arrive at the average for each hill, and there after for all the hills in each sampling unit. In case of sheath rot (*Soracladium oryzae*) disease record the no. of percent panicle/sq.m affected. Score for the diseases in the particular varieties adopting SES scale.

Lot of diversity in cultivated as well as its wild relative's prominant in the state. Different regions have traditional rice varieties famous in that area for their good test and aroma, and in much demand by the consumers. Since in some parts of the state the rice crop is grown twice or even thrice, the pressure of diseases and pests in irrigated rice is very much almost every year. Meteriological factors are the most important elements in the epidemiology of rice disease. Normal regular distribution of rains combine with cloudy weather make suitable moisture and temperature conditions favourable for natural infection of diseases and which is better for natural screening purpose., Blast, bacterial leaf blight, sheath blight, sheath rot, and brown spot are the major diseases of the state. Some of the traditional rice varieties were collected from the farmer's field, purified on the basis of DUS descriptors and progeny eveluation and the best promising progeny is multiplied for seed. These varieties are also evaluated against mentioned diseases in the *kharif* 2012. Observations were recorded under natural conditions.

Among the traditional aromatic rice varieties Badshahbhog, Dubraj, Kergul, Shuklphool, Srikamal,Tulsi Manjari and Bisnubhog were free from brown spot disease(score-0) whereas in varieties Bisni, Chhatri, Chinoor, Dujai, Elaychi, Gangabaru, Gopalbhog, Jaigundi, Jeeradhan, Jeeraphool, Kali kamod, Kapoorsar, Lohandi, Smudrafen, Shyamjeera, Tilkasturi and Tulsiprasad showed less disease severity (score -2). Ganguly and Padmanabhan (1959) and Padmanabhan *et al*., (1966) had tested large numbers of rice varieties and reported CH 13, CH 45, T 141, T 298-2A, CO 20, BAM 10, T 998, T 211 and T 960 resistant to brown spot.

Jeeradhan and Kapoorsar had exhibited moderately resistant reaction (score -5) against BLB whereas rest of the varieties showed susceptible to highly susceptible reactions for the disease. Kotasthane and Agrawal (1991) revealed that out of 278 entries, 33 entries were highly resistant score 1;66 entries were resistant with score 3;82 entries were moderately resistant with score5 and remaining 97 entries were in susceptible group with score 7 and above during their study at Raipur .

Table 1: Reactions of traditional aromatic varieties against major diseases of rice under natural conditions.

Variety	Brown Spot	Bacterial Leaf Blight	Sheath Rot	Sheath Blight
Badshahbhog	0	9	0	0
Bisni	2	7	0	0
Chhatri	2	7	5	0
Chinoor	2	9	0	0
Dubraj	0	9	0	0
Dujai	2	7	5	0
Elaychi	2	9	3	0
Gangabaru	2	9	0	0
Gopalbhog	2	7	3	0
Jaigundi	2	9	3	3
Jeeradhan	2	5	0	0
Jeeraphool	2	9	0	0
Kalikamod	2	9	3	0
Kapoorsar	2	5	3	0
Karigilas	3	9	3	3
Katarnibhog	3	7	5	0
Kergul	0	7	5	0
Kubarimohar	3	9	3	0
Lohandi	2	7	3	0
Samudrafen	2	7	3	0
Shuklphool	0	9	0	0
Shyamjeera	2	7	0	0
Srikamal	0	9	5	3
Til Kasturi	2	7	5	3
Tulsi Manjari	0	7	0	0
Tulsi prasad	2	7	0	0
Vishnubhog	0	7	3	0
Swarna	5	7	9	7
TN1	3	9	7	9
HR12	5	9	7	9

Under natural conditions, Badshahbhog, Bisni, Chinoor, Dubraj, Gangabaru, Jeeradhan, Jeeraphool, Shuklphool, Shyamjeera, Tulsimanjari and Tulsiprasad were observed free from infection of sheath rot. Whereas, varieties Elaychi, Gopalbhog, Jaigundi, Kalikamod, Kapoorsar, Karigilas, Kubrimohar, Lohandi, Samudrafen and Vishnubhog were found for resistant reactions (score -3) for sheath rot disease, Chhtri, Dujai and Katarnibhog, Kergul, Shrikaml and Tilkasturi were showed moderately resistant reactions for the disease (table-1). These results confirms the findings of Mukerjee et al., (1980) and Anonymous (2010) who also reported resistance in aromatic entries against sheath rot disease in rice.

Jaigundi, Karigilas, Srikamal and Tilkasturi were showed resistant reaction for sheath blight whereas rest of the entries were free from Sheath blight infection (Table-1). Silva *et al*., (2012) also reported resistance against sheath blight in traditional rice varieties.

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Short Communication

An assessment for yield estimation in upland rainfed ecosystem of Raigarh, Chhattisgarh

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The important yield attributes for yield estimation in rice are number of panicles m^{-2}, number of spikelets per panicle, percentage of fertility of spikelets and test weight. The relation between grain yield and given yield components were established (De Datta 1981, Vergara (1979), Arraudeau and Vergara, 1988) can be expressed as Grain yield (g m^{-2}) = No. panicles m^{-2} x no. spikelets $panicle^{-1}$ x % fertile spikelets $panicle^{-1}$ x weight of single spikelet (g) x 10^{-5}. This formula does not work well for rainfed upland rice when the paired 't' test is applied. But modified formula given by Rao (1997) hold well for this estimation.

The experimental material comprised of diversified 21 rice genotypes tested in Randomized Compete block design with 2 replications during *kharif* 2013. They were direct seeded (10g m^{-2}) at upland ecosystem of Research Farm of College of Agriculture and Research Station, Raigarh. The soil is low in available Nitrogen and P_2O_5 and medium in K_2O at pH 5.8. A dose of 40-8.8-8.3 Kg NPK ha^{-1} was applied. The given observations have been collected as usual based on five randomly selected plant and on plot basis. Grain yield was estimated by substituting the yield attributes in the conventional and a modified formula for all the genotypes. Paired 't' test for observed grain yield were calculated.

Table 1: Yield attributes and estimated yield of extra early and early rice genotypes under upland rainfed ecosystem, Raigarh, Chhattisgarh during *Kharif*, 2013

S. No.	Panicle m^{-2}	No. of Filled Spikelet/ panicle	Spikelet fertility (%)	1000- grain weight (g)	Grain yield (g/m^{-2})	Estimated Grain yield (g/m^{-2})	
						Conventional	Modified
1	294.5	81.8	73.87	26.13	275.33	464.87	232.44
2	313.0	77.9	80.93	31.08	303.33	613.18	306.59
3	333.0	83.6	75.51	24.73	242.00	519.77	259.88
4	324.5	84.9	75.98	28.15	291.00	589.28	294.64
5	321.5	90.8	77.06	27.58	246.33	620.30	310.15
6	407.0	97.1	84.33	27.50	286.67	916.51	458.25
7	396.0	77.6	79.62	26.05	283.67	637.34	318.67
8	324.0	89.1	78.33	20.95	300.33	473.74	236.87
9	288.5	93.2	81.11	28.40	235.67	619.41	309.71
10	351.5	88.5	75.27	26.60	265.00	622.80	311.40
11	372.5	116.9	84.70	21.33	235.67	786.52	393.26
12	350.0	117.6	78.88	24.53	346.00	796.30	398.15
13	290.5	82.3	71.57	26.43	275.33	452.19	226.09
14	351.0	82.7	81.10	23.95	287.67	563.82	281.91
15	234.5	89.2	80.06	25.88	278.00	433.31	216.66
16	301.0	88.0	75.30	25.70	280.67	512.57	256.29
17	273.0	111.6	77.23	24.90	234.67	585.91	292.96
18	261.5	69.7	70.05	31.33	176.00	399.94	199.97
19	280.5	108.8	85.66	21.50	268.33	562.06	281.03
20	283.0	85.3	72.33	27.63	256.33	482.34	241.17
21	295.5	78.7	62.61	26.75	278.33	389.50	194.75
Mean	316.5	92.6	77.21	26.05	268.8		
CD 5%	92.56	39.33	14.19	5.93	85.56		
‘t’ value Goodness of fit						13.87 **	1.23 NS

** Significant at 1% level; NS : non-significant

The test assumes that both values were at par and results showed that goodness of fit was significant for the convention formula and non significant for the modified formula. The low fertility and typically poor yield of the upland ecosystem may be attributed to the low average of sunshine hours per day, cloudy weather prevailing during crop stages in the wet season in Raigarh, Chhattisgarh conditions. Hence, use of the modified formulae seems to be accurate for assessing yield of extra-early and early rice genotypes grown in the upland ecosystem of Raigarh.

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Short Communication

Effect of herbicide combinations on productivity of direct seeded rice (*Oryza sativa* L.)

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In Chhattisgarh rice is an important crop grown nearly 3.67 m ha with the production of 5.56 m t and productivity of 2.04 t ha^{-1} (Anonymous, 2014). Direct seeding of rice refers to the process of establishing the crop from seeds sown in the field rather than by transplanting seedlings from the nursery (Farooq *et al*., 2011). Direct seeding avoids three basic operations, namely, puddling, transplanting and maintaining standing water. Weeds are one of the most important biotic barrier. Weeds compete severely for space, nutrient, air, water and light for their nourishment through rapid development and manifestation by quick root and shoot development than crop. Weeds under adverse condition affects plant height, leaf architecture, tillering habit, growth pattern and life duration of rice cultivars. Herbicides offer most effective, economical and practical way of weed management. Herbicides are considered to be an alternative supplement to hand weeding.

A field experiment was carried out with eleven weed control treatments (Table 1) followed in a randomized block design with three replication at Instructional cum Research Farm, I.G.K.V., Raipur (C.G.) during *kharif* 2013.The experimental soil was *Inceptisol* which was low in organic carbon (0.58%), available nitrogen (225.4 kg ha^{-1}), medium in phosphorus (21.5 kg ha^{-1}) and high in potassium (310.24 kg ha^{-1}) with neutral soil reaction. Medium duration rice cultivar MTU-1010 was taken as test crop with seed rate of 60 kg ha^{-1}. The rice was sown in second fortnight of June at a spacing of 20 cm row to row with recommended dose of fertilizer i.e. 100:60:40 kg ha^{-1} N:P:K. Full dose of phosphorus and potash along with one third of nitrogen was applied as basal. Rest of the nitrogen was applied in two splits at tillering and panicle initiation. Harvesting was done in the third week of October. The observation on yield attributing characters, grain and straw yield were recorded at harvest.

The results revealed that grain yield varied significantly due to different weed management practices (Table 1). All the weed management practices were found equally effective and were significantly superior over unweeded control. However, highest grain yield (5.16 t ha^{-1}) was recorded under pendimethalin @ 1000 g ha^{-1} at 2 DAS fb bispyribac sodium @ 25 g ha^{-1} at 21 DAS fb hand weeding at 45 DAS (T_5), this was followed by pendimethalin @ 1000 g ha^{-1} at 2 DAS fb bispyribac sodium @ 25 g ha^{-1} at 25 DAS (T_2), oxadiargyl 100 g ha^{-1} at 2 DAS fb bispyribac sodium @ 25 g ha^{-1} at 25 DAS (T_3) and hand weeding at 20, 40 and 60 DAS (T_{10}), in descending order. Walia *et al.,* (2008) timely and effective control of weeds with integrated use of pre-and post-emergence herbicides resulted in increased yield components, which ultimately reflect on grain yield.

Straw yield was the highest (6.28 t ha^{-1}) under pendimethalin @ 1000 g ha^{-1} at 2 DAS fb bispyribac sodium @ 25 g ha^{-1} at 21 DAS fb hand weeding at 45 DAS (T_5), followed by pendimethalin @ 1000 g ha^{-1} at 2 DAS fb bispyribac sodium @ 25 g ha^{-1} at 25 DAS (T_2). Rest of the treatments followed the trend as that of grain yield.

In respect of effective tillers, all the weed management practices of herbicide, proved significant superior to unweeded control. Highest number of ear bearing tillers was found under pendimethalin @ 1000 g ha^{-1} 2 DAS fb bispyribac sodium 21 DAS @ 25 g ha^{-1} at fb hand weeding at 45 DAS (71.11). This is quite possible because these combinations of herbicides might have been very effective to reduce the mixed weeds density and their growth resulting better and congenial environment favoured the rice plant to utilize nutrients, light, space luxuriantly and grew well to produce more number of fertile tillers.

Panicle length was significantly influenced by all the weed management practices of pre and post emergence herbicides, mechanical weeding and hand weeding as compared to unweeded control. All the treatments produced significantly higher length of panicle than unweeded control. Panicle length was longest (24.59 cm) in pendimethalin @ 1000 g ha^{-1} at 2 DAS fb bispyribac sodium @ 25 g ha^{-1} at 21 DAS fb hand weeding at 45 DAS (T_5), followed by pendimethalin @

Table 1: Effect of herbicide combinations on yield and yield attributes in direct seeded rice

Treatment	Dose (a.i. g ha^{-1})	Time of application (DAS)	Effective tillers m^{-1} row length	Panicle length (cm)	Number of filled grains panicle^{-1}	Test weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1 Bispyribac sodium	25	21	61.78	21.60	106.60	25.61	4.27	5.45
T_2 Pendimethalin* fb bispyribac sodium	1000/25	2 fb 25	75.00	23.70	117.83	25.90	5.03	6.09
T_3 Oxadiargyl fb bispyribac sodium	100/25	2 fb 25	67.22	23.24	116.60	25.43	4.98	6.07
T_4 Pyrazosulfuron fb bispyribac sodium	20/25	2 fb 25	65.78	22.63	115.07	25.86	4.63	5.73
T_5 Pendimethalin* fb bispyribac sodium fb HW	1000/25	2 fb 21 fb 45	71.11	24.59	119.57	26.63	5.16	6.28
T_6 Pendimethalin* fb HW	1000	2 fb 26	64.00	22.49	114.83	25.26	4.58	5.71
T_7 Bispyribac sodium +(CME+MSM)	20+4	21	63.89	21.88	107.57	25.40	4.30	3.34
T_8 Azimsulfuron	35	21	67.89	22.48	110.07	25.35	4.55	5.89
T_9 Mechanical weeding		20,40,60	61.89	22.42	106.60	25.70	4.33	5.40
T_{10} Hand weeding		20,40,60	68.44	23.14	116.27	26.30	4.86	5.89
T_{11} Unweeded control			34.44	19.25	71.43	25.23	0.89	1.73
SEm±			**4.12**	**0.76**	**5.31**	**0.37**	**0.36**	**0.28**
CD (P=0.05)			**12.1**	**2.26**	**15.67**	**NS**	**1.07**	**0.81**

CME+MSM = Chlorimuron ethyl + Metsulfuron methyl; DAS = Days after sowing; fb = followed by; HW = Hand weeding; * Pendimethalin (stomp xtra 38.7% CS).

Table 2: Effect of herbicide combinations on weed density, weed dry matter and weed control efficiency direct seeded rice

Treatment	Dose (a.i. g ha^{-1})	Time of application (DAS)	Weed density (No. m^{-2}) 60 DAS	Weed dry matter (g m^{-2}) 60 DAS	Weed control efficiency (%) 60 DAS
T_1 Bispyribac sodium	25	21	11.09 (122.64)	8.27 (75.7)	37.00
T_2 Pendimethalin* fb bispyribac sodium	1000/25	2 fb 25	7.24 (52.00)	5.83 (33.5)	72.00
T_3 Oxadiargyl fb bispyribac sodium	100/25	2 fb 25	6.46 (41.33)	5.27 (27.3)	77.00
T_4 Pyrazosulfuron fb bispyribac sodium	20/25	2 fb 25	6.15 (37.33)	5.26 (27.18)	77.00
T_5 Pendimethalin* fb bispyribac sodium fb HW	1000/25	2 fb 21 fb 45	4.06 (16.00)	3.32 (10.56)	91.00
T_6 Pendimethalin* fb HW	1000	2 fb 26	6.86 (46.67)	5.79 (33.1)	72.00
T_7 Bispyribac sodium +(CME+MSM)	20+4	21	6.15 (37.33)	5.81 (31.3)	74.00
T_8 Azimsulfuron	35	21	8.99 (80.34)	8.14 (65.8)	45.00
T_9 Mechanical weeding		20,40,60	8.51 (71.99)	7.4 (54.3)	55.00
T_{10} Hand weeding		20,40,60	5.08 (25.33)	4.43 (19.2)	84.00
T_{11} Unweeded control			10.82 (116.66)	10.98 (120.2)	---
SEm±			**0.67**	**0.29**	
CD (P=0.05)			**1.99**	**0.87**	

CME+MSM = Chlorimuron ethyl + Metsulfuron methyl; DAS = Days after sowing; fb = followed by; HW = Hand weeding; * Pendimethalin (stomp xtra 38.7% CS); Original data are given in parenthesis.

1000 g ha^{-1} at 2 DAS fb bispyribac sodium @ 25 g ha^{-1} at 25 DAS (T_2), oxadiargyl 100 g ha^{-1} at 2 DAS fb bispyribac sodium @ 25 g ha^{-1} at 25 DAS (T_3) and hand weeding at 20,40 and 60 DAS (T_{10}) in desending order.

Number of grains panicle^{-1} of all the treatments proved significantly superior over unweeded control in increasing number of filled grains panicle^{-1}. Among various treatments, highest (119.57) filled grains panicle^{-1} were recorded under pendimethalin @ 1000 g ha^{-1} at 2 DAS fb bispyribac sodium @ 25 g ha^{-1} at 21 DAS fb hand weeding at 45 DAS (T_5), followed by pendimethalin @ 1000 g ha^{-1} at 2 DAS fb bispyribac sodium @ 25 g ha^{-1} at 25 DAS (T_2). Lowest grains panicle^{-1} was recorded under unweeded control.

Variation in test weight due to various weed management practices of pre and post emergence herbicide, mechanical weeding and hand weeding were not significant. However, maximum test weight (26.63 g) was observed under pendimethalin @ 1000 g ha $^{-1}$ at 2 DAS fb bispyribac sodium @ 25 g ha $^{-1}$ at 21 DAS fb hand weeding at 45 DAS (T_5), The test weight of unweeded control was recorded the minimum (25.23 g) than rest of treatment.

Result presented in Table 2 indicated that application of pendimethalin @ 1000 g ha $^{-1}$ at 2 DAS fb bispyribac sodium @ 25 g ha $^{-1}$ at 21 DAS fb hand weeding at 45 DAS (T_5) was significantly lowest in respect of weed dry matter and weed density at 60 DAS and maximum weed density and dry matter was observed in unweeded control plot because no control measure was adopted in this plot.

Weed control efficiency at 60 DAS, the maximum weed control efficiency was observed with pendimethalin @ 1000 g ha $^{-1}$ at 2 DAS fb bispyribac sodium @ 25 g ha $^{-1}$ at 21 DAS fb hand weeding at 45 DAS (T_5) and it was followed by hand weeding at 20,40 and 60 DAS(T_{10}). It was noted that application of herbicides enhanced weed control efficiency due to restricted weed growth, resulted lower production of dry matter of weeds lead to high weed control efficiency. Singh and Namdeo (2004) found that hand weeding (20 and 40 days after sowing) showed 72 per cent weed control efficiency.

Thus, it can be stated that application of pendimethalin @ 1000 g ha $^{-1}$ at 2 DAS fb bispyribac sodium @ 25 g ha $^{-1}$ at 21 DAS fb hand weeding at 45 DAS (T_5) favoured significant enhancement in number of effective tillers, panicle length, number of filled grains panicle $^{-1}$,straw and grain yield. This was owing to high growth and yield attributes as well as low crop-weed competition and longer weed free period under this treatment.

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Short Communication

Effect of FYM and weed management on weed dynamics, growth, yield attributes and yield of direct seeded rice (*Oryza sativa* L.) under minimum tillage.

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Rice is the most important cereal food crop of India, which occupies about 24 per cent of gross cropped area of the country. It contributes 42 per cent of total food grain production and 45 per cent of total cereal production of the country. Rice accounts for 35 to 75 per cent of the calories consumed by more than 3 billions Asians and is planted to about 154 millions hectare annually or on about 11 per cent of the total world's cultivated land (Kumar *et al*., 2006). Incorporation of organic sources viz., FYM along with chemical fertilizers is effective in alleviating the nutrient deficiency in soil and enhance the yield potential as well. Line sowing coupled with application of herbicide may prove to be very promising on farmer's field. Most of the field experiments and on farm researches have established that direct seeded rice, if properly managed, can yield as high as transplanted rice. Change in the method of crop establishment from traditional *biasi* or manual transplanting of seedlings to direct line seeding has occurred in many Asian countries in the last two decades in response to rising production costs, especially for labour and water. Keeping these points in view the present experiment was carried out.

The experimental site was located at Instructional cum-Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during *kharif*, 2012. It receives 1388.8 mm rainfall. The soil of the experimental field was clay loam in texture *(Alfisols)* locally known as *"Dorsa"* soil. The soil was neutral in reaction (pH 7.41). It had low available nitrogen (220.00 kg ha^{-1}), medium available phosphorus (18.10 00 kg ha^{-1}) and high potassium contents (313.00 kg ha^{-1}). The experiment was laid out in Factorial randomized block design (F-RBD) and treatments were replicated thrice. The treatments comprised of two fertility (FYM) levels and eight weed management practices. Fertility level consists of no FYM and 5 t FYM ha^{-1}. The FYM was incorporated in the soil with minimum tillage. Weed management consist of chemical weeding with bispyribac sodium @ 20 gm ha^{-1}, 25 DAS (W1), mechanical weeding 25 DAS (W2), mechanical weeding 25 DAS + hand weeding 45 DAS (W3), Hand weeding 25 DAS (W4), hand weeding intra row 25 DAS + hand weeding 45 DAS (W5), mechanical weeding inter row followed by hand weeding intra row 25 DAS (W6), hand weeding 25 & 45 DAS (W7) and unweeded check (W8). Rice variety "MTU-1010" was sown as test crop @ 80 kg ha^{-1} treated with carbendazim @ 2g kg^{-1} seeds at a depth of 4-5 cm keeping the row distance of 20 cm on 12 July, 2012. The crop was harvested on 19 November, 2012. FYM was applied manually @ 5 t ha^{-1} after layout of the field then incorporated manually. Recommended dose of N; P_2O_5 and K_2O i.e. 80:40:30 kg ha^{-1} was applied through urea, Di-ammonium phosphate and Muriate of potash, respectively. The data on pre harvest crop observations *viz.* plant height (cm), dry matter accumulation (g) were recorded at 80 DAS. Leaf area index was estimated. The data on weed density and weed dry matter production were recorded from randomly selected two places from each plot by using quadrate of 0.25 m^2 size at 50 DAS and they were subjected to square root transformation by using the formula $\sqrt{X+0.5}$ before statistical analysis. The average values of harvest index was obtained by following standard method.

Predominant weed species observed in the experimental field were *Commelina benghalensis, Cyanotis axillaris, Cyperus difformis, Echinochloa colona* and *Monocharia vaginalis.*

FYM @ 5 t ha^{-1} produced higher weed density and total weed dry matter production while weed control efficiency was higher with no FYM. Treatment with no FYM produced significantly taller plant than FYM @ 5 t ha^{-1}. While application of FYM @ 5 t ha^{-1} recorded higher plant dry matter accumulation than no FYM because organic manure provide plant nutrient for plant growth and development (Table 1). Sharma *et al* (1999) also found that the growth and vigour of rice plants were better with FYM application. Kundu *et al* (2004) also found that the growth factors like plant height, dry

Table 1: Effect of FYM and weed management practices on weeds and weed control efficiency as well as growth parameters of direct seeded rice under minimum tillage

	Treatments	Weed density (No. m^{-2})	Weed dry matter production (g m^{-2})	Weed control efficiency (%)	Plant height (cm)	Plant dry matter accumulation (g m^{-2})	Leaf area index
	Fertility (FYM) level						
F0	No FYM	4.80 (22.56)	2.60 (6.24)	60.49	89.05	395.70	9.08
F1	FYM @ 5 t ha^{-1}	6.18 (37.72)	3.22 (9.88)	52.77	86.07	463.00	8.69
	SEm±	**0.48**	**0.05**		**0.60**	**13.10**	**0.184**
	CD (P=0.05)	**0.33**	**0.16**		**1.75**	**37.85**	**NS**
	Weed management						
W1	Chemical weeding Bispyribac Sodium @ 20 g ha^{-1} 25 DAS	7.36 (53.60)	3.53 (11.96)	71.38	93.56	525.30	9.62
W2	Mechanical weeding 25 DAS	9.91 (97.80)	6.26 (38.64)	37.56	83.58	389.05	8.38
W3	Mechanical weeding 25 DAS + Hand weeding 45 DAS	0.71 (0.00)	0.71 (0.00)	80.38	88.60	416.45	9.02
W4	Hand weeding 25 DAS	8.51 (71.84)	5.09 (25.40)	27.90	83.89	391.40	8.58
W5	Hand weeding intra row 25 DAS + Hand weeding 45 DAS	0.71 (0.00)	0.71 (0.00)	80.38	87.00	404.15	8.87
W6	Mechanical weeding inter row followed by Hand weeding intra row 25 DAS	7.12 (50.24)	4.77 (22.28)	32.04	86.21	395.70	8.70
W7	Hand weeding 25 & 45 DAS	0.71 (0.00)	0.71 (0.00)	80.38	94.54	535.85	9.69
W8	Unweeded check	14.30 (204.00	7.43 (54.64)	-	83.07	376.85	8.21
	SEm±	**0.23**	**0.11**		**1.21**	**26.20**	**0.368**
	CD (P=0.05)	**0.67**	**0.32**		**3.50**	**75.75**	**1.063**

*Original data are given in parenthesis

matter accumulation and yield respond positively when the crop was provided with inorganic nitrogen fertilizers along with FYM @ 5 t ha^{-1}.

Among different weed management practices, the lower weed density and weed dry matter production was observed under hand weeding 25 and 45 DAS (W7), mechanical weeding 25 DAS + hand weeding 45 DAS (W3) and hand weeding intra row 25 DAS + Hand weeding 45 DAS(W5) than others. However, the highest were observed under unweeded check (W8). Hand weeding twice was effective in reducing weed dry matter production. Mechanical weeding 25 DAS+ hand weeding 45 DAS(W3) and hand weeding intra row 25 DAS+ hand weeding 45 DAS(W3) and hand weeding intra row 25 DAS+ hand weeding 45 DAS(W5) were also effective in reducing weed dry matter production because of complete removal of weeds. The highest weed control efficiency was observed under hand weeding 25 and 45 DAS (W7). The tallest plants were recorded under hand weeding twice 25 and 45 DAS (W7) whereas it was at par with chemical weeding with bispyribac sodium @ 20 gha^{-1} 25 DAS (W1). All the treatments of weed management were significantly superior over unweeded check (W8). The highest plant dry matter accumulation was obtained at 80 DAS under hand weeding twice at 25 and 45 DAS (W7) but it was at par with chemical weeding with bispyribac sodium @ 20 g ha^{-1} 25 DAS (W1) at 80 DAS. The lowest plant dry matter accumulation was recorded under unweeded check (W8). The highest leaf area index was observed under hand weeding 25 and 45 DAS (W7) and lowest was recorded under unweeded check (W8).

Fertility level of FYM @5t ha^{-1} gave significantly higher, panicle length, test weight, than no FYM. Among different weed management practices, hand weeding twice 25 and 45 DAS (W7) gave highest effective tillers, panicle length, filled grains $panicle^{-1}$ and harvest index. Chemical weeding with bispyribac sodium @ 20 g ha^{-1} 25 DAS (W1), mechanical weeding 25 DAS + hand weeding 45 DAS (W3), hand weeding 25 DAS (W4), hand weeding intra row 25 DAS + hand weeding 45 DAS (W5) and mechanical weeding inter

Table 2: Effect of FYM and weed management practices on yield attributes, yield and harvest index) of direct seeded rice under minimum tillage.

	Treatments	Effective tillers (no m^{-2})	Panicle length (cm)	Filled grains $panicle^{-1}$ (no.)	Test weight (g)	Grain yield (t ha^{-1})	Harvest index (%)
	Fertility (FYM)level						
F0	No FYM	235.10	22.62	97.83	24.3	3.47	43.69
F1	FYM @ 5 t ha^{-1}	236.45	23.21	105.64	23.5	3.63	44.02
	SEm±	**6.77**	**0.19**	**3.043**	**0.1**	**0.10**	**1.13**
	CD (P=0.05)	**NS**	**0.55**	**NS**	**0.2**	**NS**	**NS**
	Weed management						
W1	Chemical weeding (Bispyribac sodium @ 20 g ha^{-1} 25 DAS)	259.15	23.30	102.7	25.3	4.03	51.37
W2	Mechanical weeding (25 DAS)	226.65	22.69	97.46	23.5	3.31	37.96
W3	Mechanical weeding (25 DAS) + hand weeding (45 DAS)	249.60	23.18	102.53	24.8	4.01	47.37
W4	Hand weeding (25 DAS)	200.40	22.77	99.9	23.6	3.39	41.46
W5	Hand weeding intra row (25 DAS) + hand weeding (45 DAS)	243.75	22.79	101.9	23.8	3.69	46.48
W6	Mechanical weeding (inter row) followed by hand weeding (intra row) (25 DAS)	245.40	22.77	100.07	23.6	3.59	45.50
W7	Hand weeding (25 & 45 DAS)	266.65	23.86	115.93	25.6	4.21	51.54
W8	Unweeded check	194.60	21.98	93.4	23.1	2.16	29.16
	SEm±	**13.54**	**0.38**	**6.09**	**0.1**	**0.20**	**2.26**
	CD(P=0.05)	**39.10**	**1.10**	**17.58**	**0.3**	**0.59**	**6.54**

row followed by hand weeding intra row 25 DAS (W6) were at par with the hand weeding twice 25 and 45 DAS (W7).While hand weeding 25 DAS (W4) was also at par with W1 in increasing panicle length. The smallest panicles, effective tillers, filled grains $panicle^{-1}$ and were observed under unweeded check (W8). Hand weeding twice 25 and 45 DAS (W7) proved significantly superior over rest of the weed management practices in producing higher test weight, but it was found at par to chemical weeding with bispyribac sodium @ 20 g ha^{-1} 25 DAS (W1). Hand weeding twice 25 and 45 DAS (W7) proved significantly superior over rest of the weed management practices in producing higher grain yield but it was found at par to chemical weeding with bispyribac sodium @ 20 g ha^{-1} 25 DAS (W1), mechanical weeding 25 DAS + hand weeding 45 DAS (W3), and hand weeding intra row 25 DAS + hand weeding 45 DAS (W5) (Table 2). Higher grain yield under these treatments was due to the weed managed at critical period of weed-crop competition and early crop growth, higher dry matter accumulation, high growth in terms of tiller numbers, which resulted in higher production of photosynthesis, and acts as a source and greater translocation of food materials to the reproductive parts resulted in superiority of yield attributing characters (tillers, filled grains $panicle^{-1}$, test weight) and ultimately high yield. Lower weed density and higher weed control efficiency also resulted in higher grain yield. The lowest grain yield was observed under unweeded check (W8). Nagappa and Biradar (2002) and Saha *et al* (2005) have also reported the higher grain yield under two hand weedings.

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Short Communication

Effect of optimal, sub-optimal and integrated nutrient management on soil properties and nutrient uptake of rice (*Oryza sativa* L).

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Although, due to favourable monsoon during last few years, Chhattisgarh state delighted with good production of rice, the long-term productivity of rice is always remained (around 13-15 q ha^{-1}) below the national average. The main reasons for low productivity even in irrigated area are application of inadequate and unbalanced quantity of fertilizers to this nutrient exhaustive crop of rice. This not only resulted in low yield but also consequently declined the soil organic carbon and nutrient status. Application of organic manures improves the soil organic carbon for sustaining the soil physical properties and also increases the soil N. crop residue also have potential for improving the soil and water conservations, sustaining the soil productivity and enhancing crop yield (Das *et al*., 2003). The use of *in-situ* green manuring in combination with chemical fertilizer tends to increase the fertility of rice field. However, at present the use of the green manures is become limited.

The present investigation was carried out at the Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during *kharif* season of 2010. The soil of experimental field was inceptisols locally known as *Matasi*. It was neutral in reaction, low in nitrogen, medium in available phosphorus and potassium. The experiment was laid out in randomized block design with three replications. The twelve treatments consisted of different nutrient levels having optimal, sub-optimal and integrated nutrient management *viz*. T_1:No fertilizer, no organic manure (control), T_2:50% recommended NPK dose (RDF) through fertilizers(40:30:20), T_3: 50% RDF through fertilizers, T_4: 75% RDF through fertilizers, T_5: 100% RDF through fertilizers (80:60:40), T_6:50% RDF+50%N through farmyard manure (FYM), T_7: 75% RDF through fertilizers +25%N through FYM, T_8: 50% RDF through fertilizers +50% N through composted rice residue (RR), T_9: 75% RDF through fertilizers +25% N through (RR), T_{10}: 50% RDF through fertilizers +50% N through green manure (GM), T_{11}: 75% RDF through fertilizers +25% N through GM and T_{12}: farmer's practice (50:30:20). Soil organic carbon and available N, P and K in soil were determined through rapid titration method, alkaline permanganate method, Olsen's method and flame photometer method respectively.

Grain yield : Grain yield of rice increased with increasing the levels of nitrogen from 50 to 100 % of RDF (Table 1). Treatment T_{10} consisting of 50% RDF + 50% N as received from green manuring registered significantly highest grain yield of rice (56.19 q ha^{-1}) which was significantly superior to the sub optimal doses of 50 % of RDF (T_2 and T_3), farmers' practice (T_{12}) and the control treatment (T_1). The rice grain yield of other integrated nutrient treatments using GM or FYM or RR was also similar amongst them and was found to be significantly higher over farmer's practice with respect to rice yield. Integration of organic manure with inorganic fertilizer either with FYM at 50% N level (T_6) or with GM at 25% N level (T_{11}) or with rice residues of 50% N under T_8 and 25% N under T_9 respectively produced grain yield comparable to that of 100% chemical fertilizer treatment (T_5). Even, the inorganic fertilizers treatment (50% dose of fertilizer under T_3) performed significantly to that of farmer's practice might be due to the residual effects of 100% NPK dose in wheat in same treatment during previous *rabi* season. While, the lowest yield of rice (13.63 q ha^{-1}) was recorded with no manures and fertilizers i.e. control. These findings indicated that integrated use of chemical fertilizers with FYM or GM or RR facilitates to curtail the use of expensive chemical fertilizers upto 50% and is a better alternative to use of full dose of recommended fertilizers (Gill *et al*., 2008).

Soil properties

Organic carbon: Exclusion/omission of inorganic fertilizers from system (control plot) lowered the organic carbon (0.48%) even it was remained lesser than the initial values (0.51%) as compared to all the other treatments (Table 1). Incorporation of FYM, RR or GM in conjunction with fertilizers increased significantly organic carbon (OC) content of surface soil. While, among the organic fertilizer treatments; only 100% RDF was found comparable to those which have received integrated nutrient management practices and improved the OC content (0.69%) even more than 50% or 75% N through RR. Application of FYM to supplement the 50% N and 25 % N + 50%RDF or 25% RDF respectively in T_6 and T_7 and GM (50% RDF + 50% N through GM and 75% RDF + 25 % N through GM) in T_{10} and T_{11} respectively increased significantly the OC over initial values. Improvement in OC status in FYM/RR/GM treated plots after a continuous 31 cycles was also reported by Sharma *et al*. (2007).

Available N : The highest available N in surface soil (272 kg ha^{-1}) was recorded with *in-situ* application of GM for 50% N + 50% RDF (T_{10}) followed by 75% RDF through fertilizers +25% N through GM (T_{11}). Adding *Sesbania aculeata* as green manure favoured the soil conditions and might have helped in the mineralization of soil N leading to build-up of increased available N (Bajpai *et al*., 2006). On the otherhand, increase in supply of available N from 50% to 75% FYM (T_7) and RR (T_9) failed to adding of N to the available pool of the soil and did not showed the comparable values to that of GM. Among the inorganic fertilizer treatments, 100% RDF in T5 has maintained the N status in soil. It has significantly improved the N status (263 kg ha^{-1}) over sub-optimal doses as well as to those of T^7 and T_9 and over the initial values of 234 kg ha^{-1}. This also indicates that if balanced fertilizer is used or integrated with manures rationally, the substantial improvement in soil health could be expected.

Available P : Incorporation of 50% N through GM + 50% RDF (T_{10}) and 100% RDF (T_5) both recorded the significantly higher available P (29.47 and 27.87 kg ha^{-1} respectively) than the farmer' practice, T_2, T_3, T_4, T_6, T_8, T_9 and control T_1 (Table 1). Available P content of the soil was also increased with incorporation of varying level of FYM (both 25 and 50% N) comparable to those of T5 and T10. Incorporation of RR at 25 and 50% N substitution of chemical fertilizer not succeeded to improve P status markedly as compared to sub-optimal and farmer's practice might be due to lesser P content of RR which failed to add more P in the soil. Increase in available P with FYM application might also be due to solubilization of the native P in the soil through release of various organic acids. This is more pronounced at the higher moisture level as under irrigated conditions. Organic manures enhanced the labile P in soil through complexing of cations like.

Ca^{2+} and Mg^{2+} which are mainly responsible for fixation of P when it is applied in combination with inorganic fertilizer. Tolanur and Badanur (2003) also reported that organic matter like FYM and GM in conjunction with inorganic fertilizers had the beneficial effect on increasing the phosphate availability.

Available K : Green manure in combination with fertilizer (50% N through GM + 50% RDF) could only increase the available K(297kgha^{-1}) significantly over the other treatments and to that of initial status (Table 1). It is noteworthy that like N and P status, 100% RDF level (T_5) could not maintain comparable K level as much to that of T_{10}. Even, incorporation of FYM to meet 25% N + 75% RDF exhibited the significantly higher available K over sub-optimal doses of fertilizers, RR integration and slightly over 100% RDF. Increase in available K due to GM application might have attributed to the direct addition of K to the available pool of the soil. Kharub and Chander (2010) also reported less negative K balance where organic sources of nutrients applied in parts or full. The beneficial effect of GM and FYM on available K may be ascribed due to interaction of organic matter with clay, besides the direct K addition to the K pool of the soil. But, the available K content in the soil could not rise in RR incorporation over control and graded inorganic fertilizer treatments as in rose under GM/FYM. This could be due to more K removal than small addition in rice in rice – wheat cropping system (Kumar *et al*., 2008).

Uptake of nitrogen : Uptake of nitrogen: total uptake of N in rice increased significantly by applying different levels of fertilizers and/or supplemented with different organic manures such as FYM (T_6 and T_7), composted rice residue (T_8 and T_9) and GM (T_{10} and T_{11}). The total N uptake was maximum (97.21 kg ha^{-1}) with T_{10}: 50% RDF through fertilizers +50% N through GM closely followed by T_5: 100% RDF through fertilizers (96.9 kg ha^{-1}) and T_6:50% RDF+50%N through FYM (Table 2). Application of nutrients as per farmer's practice also showed significantly more N uptake than the control.

Table 1: Grain yield of rice and available nutrient status in soil as affected by different nutrient management options

Treatment	Grain yield (q ha^{-1})	OC (%)	Available nutrient status (kg ha^{-1})		
			N	P	K
T_1:No fertilizer, no organic manure (control)	13.63	0.48	172	11.60	172
T_2:50% recommended NPK dose (RDF) through fertilizers (40:30:20)	34.79	0.52	208	18.33	220
T_3: 50% RDF through fertilizers	39.63	0.60	232	20.13	230
T_4: 75% RDF through fertilizers,	42.58	0.61	246	20.60	241
T_5: 100% RDF through fertilizers (80:60:40)	55.19	0.69	263	27.87	276
T_6:50% RDF+50% N through farmyard manure (FYM)	55.10	0.66	260	24.73	280
T_7: 75% RDF through fertilizers +25% N through FYM	53.42	0.66	256	26.33	285
T_8: 50% RDF through fertilizers +50% N through composted rice residue (RR)	54.29	0.59	253	23.07	263
T_9: 75% RDF through fertilizers +25% N through (RR)	53.54	0.57	247	20.13	260
T_{10}: 50% RDF through fertilizers +50% N through green manure (GM)	56.19	0.70	272	29.47	297
T_{11}: 75% RDF through fertilizers +25% N through GM	54.50	0.69	265	25.27	280
T_{12}: farmer's practice (50:30:20)	30.27	0.59	228	21.00	241
Initial status	-	0.51	234	11.5	232
SEm±	2.24	0.01	5	1.01	5
CD (P =0.05)	6.58	0.04	15	2.95	16

Table 2: N, P and K content and uptake by rice as affected by different nutrient management options

Treatment	Nutrient content (%)						Nutrient uptake (kg ha^{-1})								
	N		P		K		N			P			K		
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T1	0.90	0.31	0.17	0.037	0.160	1.72	12.22	7.06	19.34	2.27	0.83	3.10	2.18	39.09	41.27
T2	0.95	0.35	0.18	0.040	0.187	1.71	32.85	17.66	50.51	6.25	2.00	8.25	6.48	85.62	92.10
T3	0.99	0.35	0.18	0.047	0.193	1.78	39.10	18.30	57.28	7.00	2.42	9.42	7.66	92.29	99.95
T4	0.97	0.37	0.19	0.043	0.197	1.75	41.45	22.81	64.28	8.23	2.65	10.88	8.37	106.84	115.21
T5	1.20	0.40	0.23	0.060	0.233	1.94	66.04	30.87	96.90	12.69	4.59	17.28	12.88	148.40	161.28
T6	1.16	0.35	0.24	0.040	0.200	1.89	63.92	26.87	90.78	13.22	3.07	16.29	11.02	145.05	156.07
T7	1.13	0.32	0.22	0.040	0.200	1.83	60.54	23.71	84.24	11.75	2.96	14.71	10.68	135.29	145.97
T8	1.10	0.31	0.21	0.040	0.190	1.79	59.54	22.68	82.21	11.22	2.89	14.11	10.32	129.29	139.60
T9	1.06	0.33	0.20	0.047	0.187	1.76	56.58	23.61	80.15	10.71	3.33	14.04	9.99	125.98	135.97
T10	1.13	0.44	0.23	0.040	0.227	1.91	63.49	33.65	97.21	12.74	3.07	15.80	12.74	146.61	159.35
T11	1.10	0.38	0.21	0.040	0.190	1.85	60.13	29.29	89.43	11.63	3.08	14.71	10.36	142.65	153.00
T12	0.97	0.32	0.19	0.037	0.173	1.78	29.26	15.65	44.87	5.75	1.80	7.55	5.25	87.46	92.71
SEm±	0.05	0.06	0.009	0.006	0.008	0.04	3.30	1.52	3.32	0.66	0.42	0.66	0.65	3.68	3.62
CD P=0.05	0.14	0.22	0.029	0.017	0.028	0.11	9.68	4.47	9.73	1.94	1.24	1.94	1.91	10.80	10.62

Higher uptake of N with 100% RDF was also reported by Kumari *et al*. (2010) and with integrated nutrient management by Gupta *et al*. (2006).

Uptake of phosphorus: P uptake in rice grain was significantly highest under 50% RDF through fertilizers +50% N through GM over control (T1), sub optimal doses of nutrients (T2, T3 and T4) and over T8 and T9 where N was supplemented through composted rice residues due to lesser amount of soil applied P and lower yields. While, uptake of P by rice straw and total uptake (grain + straw) was recorded significantly higher under 100% RDF through fertilizers with optimum dose of nutrients (Table 2).

Uptake of potassium: Like P, the total uptake of K by rice was significantly increase with the use of 100% RDF through fertilizers (T_5) and addition of GM (T_{10} and T_{11}) over sub-optimal doses, control and farmer's practice (T_{11}). The total uptake was the maximum with the treatment T_5 (161.28 kg ha^{-1} of total uptake) followed by 50% N substitution through GM + 50 % RDF

(159.35 kg ha^{-1}). The results are in conformity with the findings of Gupta *et al*. (2006).

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Short Communication

Effect of seedling age and planting geometry on yield of short grain aromatic rice (*Oryza sativa* L.)

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Rice is the most important food grain crop of Asian countries, especially for India. Though sufficient food is produced on global basis to feed everyone, the pains of hunger continue to be a common experience of many people in the world today, especially in the developing countries and under developed countries because of the rapid population growth. The major portion of this rice area is devoted to the course and medium slender rice varieties. Chhattisgarh is very well known for its traditional short grain aromatic rice. However, very less area has been given to the production of fine and scented rice. In general, fine and scented rice are tall in height, low responsive to inputs, long duration and low yielder. Scented rice, a unique class, is a very popular and highly priced due to this inherent aroma and cooking characteristics. Aromatic rice is also used for the export. Rice quality is considered from the viewpoint of milling quality, grain size, shape, appearance and cooking characteristics. Consumer judges the quality of rice mostly on its appearance, particularly the colour, size and shape and on its elongation during cooking. On the other hand, millers and traders prefer a variety capable of giving high head rice recovery (Sharma, 2002). High yield potential ability of short grain aromatic rice can be only exploited under appropriate agronomical management practices. Among various agronomical management practices, the optimum age and number of seedlings for planting, geometry, nutrients, weeds and water management play significant role in increasing the productivity of rice. One of the major constraints for low yield is the low plant population per unit area and lack of optimum crop geometry. Uniform distribution of crop plants over an area results in efficient use of nutrients, moisture and suppression of weeds leading to high yield. Transplanting aged seedling is considered as a negative factor in tapping the production potential. Spacing and number of seedlings hill^{-1} are the two cultural practices, which exercise considerable influence on the stand geometry of rice. Transplanting of young seedlings 8-15 days before plant enter their fourth phyllochron of growth might have preserved the plants potential for massive tillering. So it is required to use optimum age of seedling and planting geometry to produce more yield with quality rice.

A field experiment was conducted at the Research cum Instructional Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur, (C.G.) during *kharif* season of 2013. The soil of the experiment was clayey in texture (*Vertisols*) and was low, medium and high in available N, P and K, respectively. Climate of this region is sub- humid with an average annual rainfall of about 1200-1400 mm and the crop received 1326.2 mm of rainfall during its crop growth. A uniform dose of 60 kg N, 40 kg P_2O_5, 30 kg K_2O ha^{-1} were applied in all plots. The experiment was laid out in split plot design with three replications. The treatment comprised of four age of seedlings like (AS_1) 12-14 days, (AS_2) 18-20 days, (AS_3) 24-26 days and (AS_4) 30-32 days in main plot and four planting geometries *i.e.* (PG_1) 20 cm x 20 cm, (PG_2) 20 cm x 10 cm, (PG_3) 15 cm x 10 cm and (PG_4) 10 cm x 10 cm in sub plots. In experiment, short grain aromatic rice variety 'Bisni' was used as test crop.

Results of the experiment revealed that age of seedling and the planting geometry showed significant variations on yield attributes and yield of short grain aromatic rice like panicle length, number of grains panicle^{-1}, number of filled grains panicle^{-1}, sterility per cent, grain yield, straw yield and harvest index. Significantly highest number of effective tillers hill^{-1} was recorded in transplanting of 12-14 days old seedlings, however it was statistically at par with 18-20 days and 24-26 days of seedling. The data further revealed that younger seedlings produced more effective tillers hill^{-1} than older seedlings. The reduction in effective tillers with old seedlings was attributed to the lower productive tillers hill^{-1} in rice. The similar finding was also reported by Krishna and Biradarpatil (2009). On the other hand, panicle length, number of grains panicle^{-1}, number of filled grains panicle^{-1}, grain yield, straw yield and harvest index were found significantly higher under 12-14 days old seedlings as compared to older seedlings of 18-20 days to 30-32 days, however, in case of harvest

Table1: Effect of age of seedling and planting geometry on yield attributes and yield of short grain aromatic rice

Treatments	No. of effective tillers hill^{-1}	Panicle length(cm)	No. of grains panicle $^{-1}$	No. of filled grains panicle $^{-1}$	Sterility (%)	Grain yield (qha^{1})	Straw yield (q ha^{-1})	Harvest index (%)
Age of seedling								
12-14 days	5.68	26.72	228.00	211.55	7.23	35.57	70.90	33.41
18-20 days	5.61	25.50	220.17	203.32	7.67	33.14	68.33	32.62
24-26 days	5.57	25.35	218.65	200.94	8.10	30.68	64.97	32.12
30-32 days	5.13	24.91	213.32	194.80	8.68	29.54	62.57	32.05
SEm±	0.10	0.30	2.01	1.89	0.12	0.70	1.50	0.27
CD (P=0.05)	0.36	1.02	6.94	6.53	0.42	2.41	5.20	0.95
Planting Geometry								
20cm x 20cm	5.98	26.63	226.67	209.17	7.13	32.84	67.54	32.73
20cm x 10cm	5.55	26.01	220.67	204.96	7.75	34.43	68.80	33.32
15cm x 10cm	5.46	25.44	219.18	201.37	8.14	32.12	66.71	32.50
10cm x 10cm	5.00	24.40	213.62	195.10	8.68	29.55	63.71	31.65
SEm±	0.12	0.38	2.27	2.13	0.12	0.38	1.06	0.33
CD (P=0.05)	0.36	1.12	6.62	6.22	0.36	1.12	3.11	0.97

Table2: Grain yield and harvest index of short grain aromatic rice as influenced by interaction between planting geometry and age of seedling.

Treatments	**Grain yield (q ha^{-1})**				**Harvest index (%)**			
	Age of seedling							
Planting geometry	12-14 days	18-20 days	24-26 days	30-32 days	12-14 days	18-20 days	24-26 days	30-32 days
20cm x 20cm	36.26	31.84	32.58	30.67	33.37	32.11	32.08	33.34
20cm x 10cm	38.50	37.45	30.59	31.17	34.24	34.83	33.01	31.20
15cm x 10cm	35.56	30.54	31.26	31.13	34.04	31.47	31.51	32.99
10cm x 10cm	31.96	32.75	28.31	25.19	32.00	32.06	31.88	30.68
Two planting geometry mean at same level of age of seedling			**SEm±**	0.77			**SEm±**	0.67
			CD(P=0.05)	2.25			**CD(P=0.05)**	1.95
Two age of seedling mean at same / different level of planting geometry			**SEm±**	0.96			**SEm±**	0.64
			CD(P=0.05)	2.85			**CD(P=0.05)**	1.89

index it was at par to 18-20 days old seedlings. Lowest sterility was recorded under 12-14 days seedlings which was significantly lower than rest of the age of seedlings. All yield contributing characters were recorded lowest in 30-32 days of seedling. Similar finding was also observed by Singh *et al*., (2004) in which seedling age is known to influence the grain yield.

In case of planting geometry, number of effective tillers hill^{-1}, panicle length, number of grains panicle^{-1} and number of filled grains panicle^{-1} were found significantly superior under 20cm x 20cm as compared to others, however except number of effective tillers above parameters were comparable with 20cm x 10cm . This might be due to higher and balanced availability of nutrients to the plants and wider spacing might have also facilitated better utilization of resources by the plants converting majority of the tillers into productive tillers (Gani *et al.,* 2002, Sarath and Thilak, 2004). Significantly highest grain yield was recorded under 20cm x 10cm due to higher number of hills per unit area (50 hills m^{-2}) and comparable yield attributes with 20 cm x 20 cm spacing might have compensated the grain yield. Thiyagarajan (2006), Shrirame *et al.* (2000), and Reddy *et. al.* (2008) also found similar results. Lowest sterility was recorded under 20 cm x 20 cm which was significantly lower than rest of the planting geometry.

The interaction between age of seedling and planting geometry on grain yield and harvest index was found significant (Table 2). The interaction between 12-14 days seedling and 20 cm x 10 cm planting geometry recorded significantly higher grain yield (38.50 q ha^{-1}) as compare to other interactions, however it was at par to interaction of 18-20 days seedling planted with 20 cm x 10 cm (37.45 q ha^{-1}) and 12-14 days seedlings planted with 20 cm x 20 cm (36.26 q ha^{-1}). On the other hand, 18-20 days seedling transplanted at 20 cm x 10 cm recorded highest harvest index (34.83%) followed by 12-14 days seedling planted at 20 cm x 10 cm spacing (34.24%).

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Short Communication

Effect of combination of herbicides on productivity and economics of transplanted rice (*Oryza sativa* L.)

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Rice is the vital food for more than two billion people in Asia and four hundred million people in Africa and Latin America (IRRI, 2006). Chhattisgarh is known as "**Rice bowl**" because rice is an important crop grown in nearly 3.67 m ha with the production of 7.49 m t and productivity of 2.04 t ha^{-1} (Anonymous, 2014). One of the major reason of low productivity of rice is weed infestation. Extent of yield reduction in rice due to weeds alone is about 15 to 20 percent for transplanted rice, 30-35 percent for direct seeded puddle rice and 5-95 percent and even more in direct seeded rice under severe weed infestation (Choubey *et al*., 2001). Transplanted rice faces diverse types of weed flora, consisting of grasses, broadleaf weeds and sedges. Competition of these weeds bring reduction in yield of transplanted rice by about 50 percent (Mukherjee and Singh, 2005). Manual weeding is very effective but it is tedious, time consuming and expensive in large scale cultivation. Continuous rains in rainy season and unavailability of man power make manual weeding difficult. In such a situation, herbicides hold great promise as they can arrest weed growth from the beginning of the crop growth. Many times due to various constraints at farm level, the application of herbicides within 3-4 days after transplanting is not possible and continuous use of same herbicide might cause resistance in weeds. Therefore, the present study was undertaken to evaluate effective combination of herbicides for control of weeds.

A field experiment was carried out with twelve weed control treatments followed in a randomized block design with three replications at Instructional cum Research Farm, I.G.K.V., Raipur (C.G.) during *kharif* 2013.The experimental soil was *Inceptisol* low in organic carbon (0.44%), low in available nitrogen (211.4 kg ha^{-1}), and medium in phosphorus (18.4 kg ha^{-1}) and high in potassium (282 kg ha^{-1}) with neutral soil reaction. The treatment combinations were Bispyribac-Na @ 25gha^{-1} at 25 DAT(T_1), Pretilachlor @ 1000gha^{-1} at 3 DAT (T_2), Pyrazosulfuron- ethyl @ 20gha^{-1} at 3 DAT (T_3), Bispyribac-Na + ethoxysulfuron @ 25 + 18.75 g ha^{-1} at 25 DAT (T_4), Bispyribac-Na + (chlorimuron-ethyl + metsulfuron-methyl) @ 20 + 4 g ha^{-1} at 25 DAT (T_5), Azimsulfuron @ 35 g ha^{-1} at 23 DAT (T_6), Pretilachlor fb ethoxysulfuron @ 750/18.75 g ha^{-1} at 25 DAT (T_7), Pretilachlor fb (chlorimuron-ethyl + metsulfuron-methyl) @ 750/4 g ha^{-1} at 25 DAT (T_8), Pyrazosulfuron-ethyl fb manual weeding @ 20 g ha^{-1} at 3 fb 25 DAT (T_9), Pretilachlor (6%) + bensulfuron (0.6%) 6.6% GR @ 660 g ha^{-1} at 4 DAT (T_{10}), Hand weeding at 25 and 45 DAT (T_{11}), Weedy check (T_{12}). Medium duration rice cultivar MTU-1010 was taken as test crop. The transplanting of rice was done on 16th July, 2013 at a spacing of 20 cm row to row and 10 cm plant to plant with recommended dose of fertilizer i.e. 100:60:40 kg ha^{-1} N:P_2O_5:K_2O. Full dose of phosphorus and potash along with one third of nitrogen was applied as basal. Rest of the nitrogen was applied in two splits at tillering and panicle initiation. Harvesting was done in the 5th November. The observation on yield attributing characters, grain and straw yield were recorded.

The results of effect of combination of herbicides on yield attributes, yield and economics are presented in Table 1. Yield attributes i.e. effective tillers $hill^{-1}$ were significantly highest under hand weeding at 25 and 45 DAT (T_{11}) but it was statistically similar to bispyribac-Na @ 25gha^{-1} at 25 DAT (T_1), bispyribac-Na + ethoxysulfuron @ 25 + 18.75g ha^{-1} at 25 DAT (T_4), bispyribac-Na + (chlorimuron-ethyl + metsulfuron-methyl) @ 20 + 4 g ha^{-1} at 25 DAT (T_5), azimsulfuron @ 35g ha^{-1} at 23 DAT (T_6), pretilachlor fb ethoxysulfuron @ 750 fb 18.75g ha^{-1} at 25 DAT(T_7), pretilachlor fb (chlorimuron-ethyl + metsulfuron-methyl) @ 750 fb 4 g ha^{-1} at 25 DAT) (T_8), pyrazosulfuron-ethyl fb manual weeding (T_9) @20 g/ha at 3 fb 25 DAT and pretilachlor (6%) + bensulfuron (0.6%) 6.6% GR @ 660 g ha^{-1} at 4 DAT (T_{10}).

Produced hand weeding at 25 and 45 DAT (T_{11}) recorded the maximum panicle weight which was significantly superior over others but was found at par to treatment bispyribac-Na + ethoxysulfuron @ 25 + 18.75 g ha^{-1} at 25 DAT (T_4), bispyribac-Na + (chlorimuron-ethyl + metsulfuron-methyl) @ 20 + 4 g ha^{-1} at 25 DAT (T_5) and pyrazosulfuron-ethyl fb manual weeding @ 20 g/ha at 3 fb 25 DAT (T_9) treatments. Total number of grains panicle^{-1} behaved similarly as noted under panicle weight however, treatment bispyribac-Na @ 25 g ha^{-1} at 25 DAT (T_1) was also found comparable. Significantly higher grain yield (52.00 q ha^{-1}) was recorded under hand weeding at 25 and 45 DAT (T_{11}) than weedy check (21.87 q ha^{-1}) (T_{12}) but it was statistically at par with bispyribac-Na @ 25 g ha^{-1} at 25 DAT (T_1), bispyribac-Na + ethoxysulfuron @ 25 + 18.75 g ha^{-1} at 25 DAT (T_4), bispyribac-Na + (chlorimuron-ethyl + metsulfuron-methyl) @ 20 + 4 g ha^{-1} at 25 DAT (T_5) and pyrazosulfuron-ethyl fb manual weeding @ 20 g/ha at 3 fb 25 DAT (T_9). In case of straw yield significantly highest value was noted under hand weeding at 25 and 45 DAT (T_{11}) and it remarked significantly superior over others but was found at par with bispyribac-Na @ 25 g ha^{-1} at 25 DAT (T_1), bispyribac-Na + ethoxysulfuron @ 25 + 18.75 g ha^{-1} at 25 DAT (T_4), bispyribac-Na + (chlorimuron-ethyl + metsulfuron-methyl) @ 20 + 4 g ha^{-1} at 25 DAT (T_5), azimsulfuron @ 35 g ha^{-1} at 23 DAT (T_6), pretilachlor fb (chlorimuron-ethyl + metsulfuron-methyl) @ 750 fb 4 g ha^{-1} at 25 DAT, (T_8), pyrazosulfuron-ethyl fb manual weeding @ 20 g/ha at 3 fb 25 DAT (T_9). Straw yield followed almost similar trend as that of grain yield (Rao and Singh, 1997). The yield levels are achieved in a line with the contributing attributes. The highest yielding treatment as stated above has the highest values for all the yield attributing characters. Similarly weedy check has the lowest yield and lower values of all the yield attributing characters. Halder and Patra (2007) reported that minimum yield and yield attributes in unweeded check were the result of severe weed competition by uncontrolled weed growth.

With regards to economics, the maximum net return (45155.8 Rs ha^{-1}) and B:C ratio (1.65) was noted under bispyribac-Na + (chlorimuron-ethyl + metsulfuron-methyl) @ 20 + 4 g ha^{-1} at 25 DAT (T_5) followed by bispyribac-Na + ethoxysulfuron @ 25 + 18.75 g ha^{-1} at 25 DAT (T_4). Similar results were also reported by Yadav *et al.* (2009) and Saha and Rao (2012).

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Table 1: Effect of combination of herbicides on yield attributes, yield and economics of transplanted rice

	Treatment	Effective tillers hill^{-1} (No.)	Panicle weight (g)	Total Number of grains panicle^{-1}	Test weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Gross returns (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
T_1	Bispyribac-Na @ 25 g ha^{-1} at 25 DAT	8.20	2.82	119.46	26.63	48.60	60.51	69717.0	42693.8	1.58
T_2	Pretilachlor @ 1000 g ha^{-1} at 3 DAT	6.80	2.08	105.35	26.03	41.90	52.62	60151.0	34182.8	1.32
T_3	Pyrazosulfuron-ethyl @ 20 g ha^{-1} at 3 DAT	7.33	2.36	112.38	26.26	42.50	54.25	61100.0	35188.8	1.36
T_4	Bispyribac-Na + Ethoxysulfuron @ 25 +18.75 g ha^{-1} at 25 DAT	9.07	3.06	125.70	26.73	50.00	61.47	71647.0	44023.8	1.59
T_5	Bispyribac + (CME + MSM) @ 20+4 g ha^{-1} at 25 DAT	9.13	3.16	129.26	26.76	50.60	62.18	72504.0	45155.8	1.65
T_6	Azimsulfuron @ 35 g ha^{-1} at 23 DAT	8.07	2.82	117.26	26.60	45.20	57.57	64969.0	37145.8	1.34
T_7	Pretilachlor fb Ethoxysulfuron @ 750 fb 18.75 g ha^{-1} at 3 fb 25 DAT	7.80	2.76	113.49	26.42	44.60	56.00	64026.0	37091.8	1.38
T_8	Pretilachlor fb (CME + MSM) @ 750 fb 4 g ha^{-1} at 3 fb 25 DAT	7.80	2.81	116.94	26.53	45.00	56.99	64649.0	37989.8	1.43
T_9	Pyrazosulfuron-ethyl fb manual weeding @ 20 g ha^{-1} at 3 fb 25 DAT	8.40	3.01	121.99	26.63	49.80	61.31	71369.0	42712.8	1.49
T_{10}	Pretilachlor (6%) + Bensulfuron (0.6%) 6.6% GR @ 660 g ha^{-1} at 4 DAT	7.73	2.69	112.91	26.36	43.20	55.98	62190.0	35166.8	1.30
T_{11}	Hand weeding at 25 and 45 DAT	9.20	3.31	135.26	26.83	52.00	63.06	74426.0	42938.8	1.36
T_{12}	Weedy check	3.60	1.80	95.33	25.41	21.87	40.76	32725.7	7643.5	0.30
	SEm±	**0.52**	**0.16**	**5.71**	**1.44**	**2.17**	**2.37**	-	-	-

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Short Communication

Yield, yield attributes and varietal resistance of rice entries under rainfed ecology

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Rice is a staple food and being grown in a vast ecological situation i.e upland, low land, deep water and rain fed in the world and about 50% of the area is under intensive irrigated situation which accounts 75% of global rice production and other half area is rain fed (Pandey *et al*, 2010)**.** Total rainfed area under rice cultivation in Chhattisgarh is 81.92 per cent which accounts 25% of India under rainfed (Pandey *et al*., 2012). Rice yield in all rainfed ecosystems is very low and deviate year to year according to distribution of rains. Bacterial leaf blight is a major disease of rice and occupy important place in Chhattisgarh (Trimurthy *et al;* 1993). Rice blast (P*yricularia grisea*) also account for serious yield loss (5-70 %) where rain fed crop is being mostly grown in Jharkhand (Dubey 2004). Looking to the rain fed situation, water scarcity and global warming ahead development of rice variety for rain fed ecological situation will increase the productivity of rain fed area Therefore, evaluation of rice variety/ line against the diseases which is prevailing in the area to a part of crop improvement programme. A experiment was conducted to see the performance of rice entries under rain fed ecological situation their yield , yield attributes reaction for against bacterial leaf blight and blast under natural field condition. Six varieties(R-RF 70, R-RF -36, R-RF 23, R-RF -69 and ABR-6) including check (MTU1010) (Table 1) were provided by Deptt. of Genetics and Plant Breeding, Indira Gandhi Agricultural University, Raipur, Chhattisgarh for evaluation at Regional Agricultural Research Stataion , Boirdadar, Raigarh (CG) under IRRI CURE BMGF Project. The trial was conducted in the year 2009 in *Kharif*. The experiment was carried out in 10^2 plot size in two replications followed by Randomized block design(RBD). The crop direct sown in 20cm row distance. Fertilizers was applied as per recommended dose i.e. 60 N : 40 P : 20 K/ha. Total amount of phosphorous and potash and half amount of nitrogen were applied at the time of sowing. Remaining half amount of nitrogen was given at panicle initiation stage.

One hand weeding was done at the crop stage of 25 -30 DAS and no plant protection i.e. fungicides and insecticide was applied to see the actual occurrence of the disease. Data of yield attributes and disease was taken on the basis of 20 randomly selected plants and for the scoring of the disease 0-9 scale was adopted (SES 2002). Yield data was taken at the time of harvesting per plot basis and converted in to yield q/ha. Data regarding weather i.e temp ^{0} C (% Max & Min) and rainfall (cm), rainy days and dry spell collected from Central Silk board, silk multiplication unit, Raigarh . During the crop season 54.61 cm rains were received, temp range (max

Table1: Yield and yield Attributes of rice genotypes under rainfed ecological situation.

Entries name	Cross Combination	Plant height (cm.)	Root Length	No. of tillers/plant	Panicle length (cm)	Grains/ panicle	Days of 50 percent Flowering	Yield q/ha	Disease Reaction Blast	Disease Reaction Bacter leaf blight
R-RF- 70	Swarna /IR42253	100.9	13.43	5.2	13.25	71.5	64	35.5	S	MR
R-RF- 36	IR12979-24-1-IUPLR15	118.8	13.44	4.6	13.9	73.00	63	33.7	S	MR
R-RF- 23	Mahamaya /ICT993	93.3	11.69	4.6	15.00	65.5	60	33.7	S	S
R-RF- 69	Mahamaya IR62266	98.05	13.79	5.4	16.05	74.00	60	28.2	S	S
ABR-6	IR-64 / Budda	90.6	16.62	7.9	19.1	86.4	63	40.0	MR	MR
MTU1010	Released variety	102.9	14.47	7.2	20.1	85	61	36.0	MR	MR
CD at 5%		17.76	2.19	1.92	2.90	5.02	3.26	1.57		

27-33 ^{0}C, min.13-29^{0}C) and humidity (Max.83-92% and min humidity 36-85%) .

The result showed in the Table 1 that maximum yield (q/ha) was obtained from variety ABR-6 (40 q/ha) and showed moderately resistant reaction against both the disease. Next best entry was check variety MTU 1010 which is popular early duration variety of Chhattisgarh gave 36.0 q/ha yield and sowing moderate resistance against the disease. Both the entries are statistically different to each other regarding yield q/ha. Similar worke has been done by Tiwari and Kumar (2000) with different entries against *Xanthomnas oryzae* and *Rhizoctonia solani* in Chhattisgarh condition.

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Short Communication

Performance of bottle gourd genotypes for earlinees and yield under Chhattisgarh plains

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Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] belongs to the family cucurbitaceae having chromosome number 2n=22. Bottle gourd is one of the most important cucurbits cultivated in India. It is grown in rainy season and as well as summer season vegetable. Tender fruits are used as cooked vegetable and also for making sweets. There is a vast scope for cultivation of bottle gourd in Chhattisgarh as there is a regular demand of crop for vegetable as well as for medicinal uses. It is highly renumerative crop which fetches sizeable income to the farmer within two or three months. However, the yield of bottle gourd in Chhattisgarh is not satisfactory enough in comparison with other cucurbit growing states due to less use of improved varieties. Thus, studies were conducted to evaluate the performance of some genotypes of the crop during summer season to identify promising and stable variety for production.

The study was carried out during summer season (2012-2013) at Horticulture Research cum Instructional farm at Department of Horticulture, IGKV, Raipur. The experiment comprised of twenty two genotypes of bottle gourd *viz.,* 2012 BOG VAR 1, 2012 BOG VAR 2, 2012 BOG VAR 3, 2012 BOG VAR 4, 2012 BOG VAR 5, 2012 BOG VAR 6, 2012 BOG VAR 7, 2012 BOG VAR 8, 2011 BOG VAR 1, 2011 BOG VAR 2, 2011 BOG VAR 3, 2011 BOG VAR 4, 2011 BOG VAR 5, 2011 BOG VAR 6, 2011 BOG VAR 7, 2010 BOG VAR 1, 2010 BOG VAR 2, 2010 BOG VAR 3, 2010 BOG VAR 4, 2010 BOG VAR 5 along with two checks NDBG 104 and Pusa Naveen. The experiment was laid out in a Randomized Block Design with three replications at 3.0 × 0.5 m row to row and plant to plant spacing. All the recommended cultural practices were adopted to raise a healthy crop. Data were recorded on five randomly selected plants with respect to characters *viz.,* days to first male and female flower appear, node number at which first male and female flower appear, days to 50% flowering, days to fruit set, number of branches per plant, days to first fruit harvest, fruit length (cm), average fruit weight (g), fruit girth (cm), number of fruits per plant, fruit yield (q/ha) and crop duration. The data were subjected to statistical and biometrical analysis (Singh and Chaudhary, 1985).

The mean values of different growth and yield parameters with respect to genotypes are presented in Table 1. The genotypes significantly differed for days to first male and female flower appear, days to 50% flowering, node number at which first male and female flower appear, days to fruit set, days to first fruit harvest, fruit length (cm), fruit girth (cm), number of branches per plant, fruit weight (g), number of fruits per plant, fruit yield (q/ha), crop duration. Significant early flowering for days to 50% flowering was noticed in 2012 BOG VAR 4 (25 DAT) while 2011 BOG VAR 7 (40.67 DAT) was found to be late in this respect. The genotype 2012/BOG VAR 4 produced early male and female flowering *i.e.* 16.26 and 25.66 DAT respectively. Male flower was produced at lower nodes (2.33) in Pusa Naveen whereas, 2011 BOG VAR 3 produced female flower on the lower node (4.80). The genotype 2010/BOG VAR 3 exhibited early fruit setting (31.93 DAT) followed by 2011/BOG VAR 1 (33.20 DAT) and the same genotype also recorded early harvesting (41.33 DAT). The results are in agreement with that of Pandey and Singh (2007) in sponge gourd, Kumar *et al.* (1999) and Sirohi *et al.* (1988) in bottle gourd.

Higher number of branches was recorded in 2010/BOG VAR 2 (6.26). The length of fruit ranged from 10.19 cm in 2011/BOG VAR 4 to 35.36 cm in 2012/BOG VAR 3. The fruit of 2011 BOG VAR 3 was marked for the maximum fruit girth (12.20 cm) while fruit of 2011/BOG VAR 6 recorded the least girth (3.85 cm). The genotype 2011/BOG VAR 3 recorded highest fruit weight (1135 g) and the fruit weight was lowest in 2012/BOG VAR 1 (713 g). Number of fruits per plant was highest in NDBG 104 (14.83) and lowest in 2011/BOG VAR 7 (7.37). The results obtained are in

Table 1: Mean performance of various genotypes of bottle gourd for earliness, yield and its different components.

Characters	Node no at which 1st male flower appear	Node no at which 1st female flower appear	Days to 1st male flower appear (DAT)	Days to 1st female flower appear (DAT)	Days to 50% Flowering (DAT)	Days to fruit set (DAT)	Days to 1st fruit harvest (DAT)	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	No. of fruits per plant	No. of branches per plant	Fruit yield (q/ha)	Crop duration (sowing to last harvest)
2012 BOG VAR 1	3.53	5.40	16.66	26.93	26.67	35.33	49.20	30.33	7.27	713.00	8.40	4.56	264.22	126.67
2012 BOG VAR 2	3.46	7.66	27.33	34.00	35.33	42.26	47.47	26.67	10.29	926.67	10.33	4.70	327.33	124.00
2012 BOG VAR 3	3.20	8.66	20.20	27.86	33.27	38.40	48.87	35.54	6.70	870.00	12.53	5.43	370.40	122.33
2012 BOG VAR 4	2.50	6.44	16.26	25.66	25.40	34.00	42.87	29.33	7.62	971.67	12.33	5.13	398.53	125.33
2012 BOG VAR 5	4.86	7.66	22.60	32.20	32.33	38.53	45.03	23.54	7.88	863.33	11.73	6.06	336.20	125.67
2012 BOG VAR 6	4.66	9.23	20.80	29.73	32.00	41.40	48.17	19.63	10.05	1070.00	11.68	4.13	415.29	124.00
2012 BOG VAR 7	5.46	8.23	22.53	32.66	33.20	38.26	50.43	35.36	6.94	921.67	10.47	4.00	323.18	118.67
2012 BOG VAR 8	2.60	9.26	28.26	35.33	38.53	40.46	61.67	20.53	6.75	774.00	8.50	4.33	219.05	119.00
2011 BOG VAR 1	3.13	6.13	21.10	29.33	28.13	33.20	42.73	31.00	7.07	930.00	9.27	3.90	289.29	112.67
2011 BOG VAR 2	4.40	10.00	32.26	37.66	38.33	37.26	50.35	25.33	7.99	1014.00	9.10	3.53	316.33	118.00
2011 BOG VAR 3	2.93	4.80	19.20	26.40	27.60	34.80	42.67	17.67	12.20	1135.00	8.60	3.66	395.33	100.33
2011 BOG VAR 4	2.90	6.40	18.66	26.00	25.73	35.06	44.93	10.19	3.88	941.67	8.73	4.06	328.67	105.33
2011 BOG VAR 5	3.66	7.13	22.33	30.33	29.47	34.13	46.33	27.90	7.54	805.00	7.87	4.02	213.00	103.67
2011 BOG VAR 6	2.66	7.60	19.20	27.73	27.00	36.40	46.87	10.33	3.85	1053.33	8.64	4.03	302.33	107.67
2011 BOG VAR 7	3.33	11.40	31.00	39.26	40.67	44.33	48.33	10.60	4.05	886.67	7.37	2.43	215.60	110.67
2010 BOG VAR 1	2.66	7.40	22.66	32.00	33.33	35.53	43.40	23.00	7.29	660.00	9.93	6.13	217.38	112.33
2010 BOG VAR 2	2.80	7.66	20.93	30.33	30.57	34.13	48.67	27.00	6.62	775.00	11.33	6.26	294.87	104.33
2010 BOG VAR 3	2.86	7.33	23.33	31.33	33.00	31.93	41.33	27.23	7.47	828.33	12.67	5.33	349.00	112.33
2010 BOG VAR 4	2.80	8.00	20.66	29.33	31.33	35.93	44.33	29.87	7.82	866.67	10.87	3.33	322.67	107.67
2010 BOG VAR 5	2.81	8.60	22.00	31.60	32.13	34.02	44.47	26.47	7.97	810.00	11.67	4.06	313.33	110.00
NDBG 104	4.40	8.86	22.66	32.46	33.87	34.66	47.33	34.33	7.17	838.33	14.83	3.93	376.27	122.00
PUSA NAVEEN	2.33	6.66	21.00	29.00	30.33	34.13	45.60	26.05	6.63	745.00	11.20	6.00	280.56	107.67
Mean (x)	**3.36**	**7.75**	**22.35**	**30.78**	**31.73**	**36.56**	**46.86**	**24.90**	**7.32**	**881.78**	**10.36**	**4.58**	**312.22**	**114.56**
SEm±	**0.32**	**0.61**	**1.08**	**1.03**	**1.24**	**0.97**	**2.33**	**1.74**	**0.31**	**29.39**	**0.64**	**0.12**	**25.84**	**3.79**
CD (p=0.05)	**0.93**	**1.75**	**3.08**	**2.96**	**3.56**	**2.77**	**6.65**	**4.98**	**0.88**	**83.88**	**1.82**	**0.37**	**74.08**	**10.82**
CV (%)	**16.93**	**13.71**	**8.38**	**5.84**	**6.80**	**4.59**	**8.61**	**12.19**	**7.33**	**5.77**	**10.07**	**4.81**	**14.42**	**5.74**

accordance with those of Mahto *et al.* (2010) for fruit length and Sharma and Sengupta (2013) for fruit length, fruit girth and fruit weight.

Significantly higher fruit yield per hectare was recorded in 2011/BOG 6 (415.29 q/ha) followed by 2012/BOG VAR 4 (398.53 q/ha). Minimum crop duration (100.33 days) was recorded in 2011/BOG VAR 3 and the maximum crop duration (126.67 DAT) was observed in 2012/BOG VAR 1. Similar results obtained are in lines with those of Mahto *et al.* (2010), Husna *et al* (2011), Yadav and Kumar (2012), Harika *et al.* (2012) and Sharma and Sengupta (2013) for fruit yield.

Performance studies revealed that the genotypes 2012 BOG VAR 6, 2012 BOG VAR 4, 2011 BOG VAR 3, 2010 BOG VAR 3 and NDBG 104 were found promising for earliness and fruit yield. In order to improve the fruit yield per plant and other important attributes genotypes falling in distant characters may be utilized in future breeding programme.

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Short Communication

Performance of foliar application of different agrochemicals on productivity and nutrient uptake of aromatic short grain rice under organic and inorganic nutrient supply system

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Aromatic short grain rice is gaining importance now a day due to consumers' preference. The nutrients macro or micronutrients plays crucial role in plant nutrition and to achieve higher yields from aromatic short grain rice. Nitrogen, phosphorous and potassium are the major nutrients required by plants in large quantity. Besides, many micro nutrients are also required by rice plants to complete its life cycle and to produce grain yield. The various studies suggested that use of organic materials for supplying nutrients is better option to meet the nutritional demand of crop and maintaining soil health. However, application of balance use of nutrients through inorganic sources does not hamper the physical properties of the soil and meet the demand at crucial periods, help to boost the productivity of rice. The supply of nutrients through foliar spray on plant canopy increases it's utilization by plant and enhance the plant components which directly affects the grain yield of rice. Keeping these in view, present investigation was carried out at the Instructional-cum-Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, (CG) During *Kharif*, 2013.

The soil of experimental field was clay-loam (*Vertisols*) in texture, locally known as "*Kanhar*" which was low in available N (219.52 kg ha^{-1}) and P (10.20 kg ha^{-1}) and high in available K (467.50 kg ha^{-1}). The soil was neutral in reaction (pH 7.6). Rice variety "Dubraj" was planted on 22^{nd} July, 2013 at a spacing 20 x 10 cm. The crop was fertilized with 60:50:50 kg of N, P_2O_5 and K_2O ha^{-1} for inorganic treatments, respectively. For organic treatments, 4 tonnes ha^{-1} vermicompost (containing 1.5:1.0:1.25 per cent of NPK) and 33.3 kg ha^{-1} of rock phosphate (P_2O_5-30%) was applied. The treatment consisted of T_1- Application of Nutrients through inorganic (I) source (60:50:50 kg NPK ha^{-1}); T_2- Application of Nutrients through organic(O) source (4 t ha^{-1} vermicompost); T_3- T_1 + Foliar spray (FS) of Potassium Chloride (KCl @ 1% L^{-1}); T_4- T_1 +FS of Silicic acid (SA @ 16 g ha^{-1}); T_5- T_1 + FS of Di-ammonium phosphate (DAP @ 1% L^{-1}); T_6- T_1 + FS of Boron (B @ 0.3% L^{-1}), T_7- T_1 +FS of Chlormequat chloride (CCC @ 1500 ppm); T_8- T_2+FS of KCl; T_9- T_2+ FS of Silicon; T_{10}- T_2+ FS of DAP; T_{11}- T_2+ FS of Boron; T_{12}- T_2 + FS of CCC. All these agrochemicals were sprayed at 25, 45 and 65 days after transplanting (DAT).

The application of T_1 + FS of DAP (T_5) gave the highest dry matter accumulation (DMA) at all the growth stages (Table 1), which was comparable to T_1 + Foliar spray of CCC (T_7) or KCl (T_3) or Boron (T_6). The increase in leaf area index (LAI) and SPAD value maintained sufficient food supply under these treatments enhanced the dry matter accumulation at all the growth stages as also reported by Lavanya and Ganpathy (2011). The treatment of application of nutrients through inorganic source supplemented with foliar spray of KCl (T_3) or DAP (T_5) or Boron (T_6) or CCC (T_7) found to be equally effective for number of panicles, panicle length, filled grains $panicle^{-1}$ and finally the yields of grain and straw (Table 2). All these treatments produced significantly higher yields of grain and straw over treatment of application of nutrients through either source. {*i.e.* inorganic (T_1) or organic (T_2)}. Almost similar effects were obtained for the uptake of nitrogen, phosphorus and potash. The increased concentration of nutrient in grain and straw and bio-mass production under above treatments enhanced the uptake of N, P and K. Similar results have been reported by Agrawal (1980) and Doss *et al*. (2013).

The comparison of organic and inorganic source revealed that application of nutrients through inorganic source (T_1) was found better as compared to application of nutrients supplied through organic source (T_2) for

Table 1: Dry matter accumulation (DMA), SPAD value and leaf area index (LAI) of aromatic short grain rice as influenced by organic and inorganic nutrient source and foliar application of different agrochemicals

	Treatments	Dry matter accumulation ($g\ hill^{-1}$)				SPAD value			LAI		
		50 DAT	75 DAT	100 DAT	At harvest	50 DAT	75 DAT	100 DAT	50 DAT	75 DAT	100 DAT
T_1	Nutrients applied through inorganic source	8.69	19.16	28.03	34.70	33.50	34.19	31.30	3.02	3.90	1.70
T_2	Nutrients applied through inorganic source	7.52	16.54	24.05	29.52	32.03	32.72	29.83	2.12	3.41	1.23
T_3	$T_1 + FS_{KCl}$	9.95	21.88	32.14	37.71	36.96	37.65	34.86	3.26	4.24	1.67
T_4	$T_1 + FS_{SA}$	9.37	20.60	28.30	36.55	34.33	35.02	32.13	3.15	4.09	1.67
T_5	$T_1 + FS_{DAP}$	10.15	21.54	31.01	37.82	37.24	37.93	35.04	3.30	4.31	1.81
T_6	$T_1 + FS_B$	9.37	20.96	29.31	36.91	35.00	35.68	32.79	3.18	4.13	1.75
T_7	$T_1 + FS_{CCC}$	9.93	21.83	30.59	37.76	36.93	36.92	34.83	3.21	4.17	1.77
T_8	$T_2 + FS_{KCl}$	9.02	18.47	26.54	32.36	34.91	35.94	32.69	2.28	3.15	1.26
T_9	$T_2 + FS_{SA}$	8.81	18.45	26.37	32.00	35.64	36.33	33.44	2.34	3.17	1.25
T_{10}	$T_2 + FS_{DAP}$	8.67	18.41	26.38	31.91	35.53	36.22	33.33	2.28	3.14	1.31
T_{11}	$T_2 + FS_B$	9.03	18.52	26.42	32.63	35.86	36.57	33.68	2.34	3.20	1.32
T_{12}	$T_2 + FS_{CCC}$	8.39	17.80	24.30	31.01	34.87	35.75	32.46	2.24	3.09	1.20
SEm±		**0.29**	**0.62**	**0.78**	**0.80**	**1.15**	**1.17**	**1.16**	**0.05**	**0.07**	**0.05**
CD (P=0.05)		**0.90**	**1.82**	**2.28**	**2.29**	**3.37**	**3.42**	**3.39**	**0.15**	**0.20**	**0.16**

Table 2: Yield attributes, grain yield and nutrient uptake of aromatic short grain rice as influenced by organic and inorganic nutrient source and foliar application of different agrochemicals

	Treatments	No. of panicles m^{-2} (No.)	Panicle length (cm)	Filled grains $panicle^{-1}$ (No.)	Grain yield ($q\ ha^{-1}$)	Straw yield ($q\ ha^{-1}$)	Total N uptake ($kg\ ha^{-1}$)	Total P uptake ($kg\ ha^{-1}$)	Total K uptake ($kg\ ha^{-1}$)
T_1	Nutrients applied through inorganic source	171	21.78	119	30.32	57.15	47.45	13.16	102.15
T_2	Nutrients applied through inorganic source	157	20.26	107	25.42	49.14	38.1	10.21	83.93
T_3	$T_1 + FS_{KCl}$	202	24.27	129	34.58	66.53	60.92	16.76	134.35
T_4	$T_1 + FS_{SA}$	192	23.44	122	32.23	61.82	53.94	15.74	123.29
T_5	$T_1 + FS_{DAP}$	202	24.52	131	35.01	67.39	61.63	17.38	139.22
T_6	$T_1 + FS_B$	188	23.58	123	33.10	62.31	56.86	15.21	119.77
T_7	$T_1 + FS_{CCC}$	207	24.17	127	34.26	65.75	58.00	16.78	131.67
T_8	$T_2 + FS_{KCl}$	177	21.78	113	28.17	55.92	46.75	12.54	99.31
T_9	$T_2 + FS_{SA}$	189	22.56	116	29.17	59.38	50.18	13.26	112.81
T_{10}	$T_2 + FS_{DAP}$	185	22.55	115	28.60	58.69	48.29	13.03	108.6
T_{11}	$T_2 + FS_B$	190	22.61	116	29.39	60.27	51.29	13.94	116.61
T_{12}	$T_2 + FS_{CCC}$	179	21.28	113	27.93	54.69	46.5	12.49	100.41
SEm±		**8.48**	**0.76**	**2.29**	**1.02**	**2.62**	**1.43**	**0.28**	**6.57**
CD (P=0.05)		**24.86**	**2.24**	**6.70**	**3.00**	**7.71**	**4.21**	**0.83**	**19.27**

increasing yield attributes, grain yield and uptake of nitrogen, phosphorus and potash. The increase in grain yield was obtained up to the extent of 12.16%. Similar findings were also reported by Nair and Gupta (1999). The increase in grain yield was found mainly associated with the significant increase in LAI, dry matter accumulation, SPAD value and yield attributes.

From the above results it can be inferred that treatment of nutrients supplied through inorganic source supplemented with foliar spray of DAP (T_5) registered maximum grain yield (35.01 q ha^{-1}), which was followed by application of 100% RDN supplied through inorganic supplemented with foliar spray of KCl (T_3) or CCC (T_7).

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