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DESIGN AND DEVELOPMENT OF INTEGRATED FARMING SYSTEM MODELS FOR LIVELIHOOD IMPROVEMENT OF SMALL FARM HOLDERS OF WESTERN PLAIN ZONE OF UTTAR PRADESH

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Abstract

Studies conducted in India and abroad has recognized the utility and importance of IFS approach in livelihood improvement of small farm holders representing more than 86 percent of the total farm families of the country. Six years long IFS study conducted at PDFSR, Modipuram confirmed (Singh and Gill 2010 ; Gill et al 2009) the findings and envisaged that from 1.5 hectare irrigated land besides fulfilling all the household food and fodder demand inclusive cost of production, created an additional average annual savings of Rs. 47000/- in first three years of its establishment and more than Rs.50, 000 in subsequent years. Singh 2004 also reported the similar results . Recycling of all the crop residues, animal and farm wastes and use of leguminous crops as green manure or dual purpose crops and biofertilizers could save more than 36% of plant nutrients. The analysis made on on-farm production and inter-relationship of different enterprises within the system envisage that more than 57 percent of the total cost on farm production Rs.1,97,883 per annum is met from the inputs (out- put of another enterprise/enterprises) generated within the system itself. This shows the significance of IFS approach and advocate that farming can be made more sustainable and economic by adopting it under small farm conditions. The approach was found enhanced and regular income and employment generative and environment friendly too. The paper includes the concept, methodology and format of development a representative IFS model for the farmers of western plain zone of U.P. in particular and similar agro climatic conditions of Uttar Pradesh , Haryana, Punjab and other northern states of the country.

Major concern

Indian economy depends primarily from rural & agricultural sectors. Contribution of Agriculture to GDP has gone down to 17.1% from 65% five decades ago. Two third of our population still depends on Agriculture for their livelihood. Small and marginal farmers constitute more than 86% of farming population and will reach to 95% in coming 30 years or so at present population growth rate. The major concern of coming era include unchecked population growth, shrinking land holding size, continuous fall in water table, decreasing factor productivity, stability in production and decreasing profit margins of small farm holder farmers. Agriculture to these categories of farmers is a subsistence type of farming and force to live farmers in poverty and constraints. These situations lead to large scale migration from villages to nearby towns and cities.

Rout of enhanced and sustained livelihood of smallholder farmers

Looking in to the present agriculture scenario at small-holders, the single commodity / discipline based research efforts made in past are not sufficient to meet the future demands of small holders representing more than $4/5^{th}$ of total farm families in India. Though, in isolation but concerted efforts made by several researchers in different parts of the country confirmed that Integrated Farming System Approach is the only way through which the livelihood of smallholders can be ensured and the production base soil and water can be sustained for a long

Farming System Approach

"Farming system" is a complex inter-related matrix of soil, plants, animals, implements, power, labour,capital and other inputs controlled in parts by farming families and influenced in varying degrees by political, economic, institutional and social forces that operate at many levels (Mahapatra, 1987). Farming system aims for increased productivity, profitability along with sustainability, balanced food, clean environment, exploring synergy among interacting enterprises through recycling farm wastes and by-products, generating family income & employment round the year, solving energy, fuel and fodder crises, increased input efficiency, enhanced opportunity for agriculture oriented industries and ultimately , improved standard of living of the farmers. In other words farming system management is the sound management of farm resources to enhance the farm productivity, reduce the environmental degradation, improve quality of life of resource poor farmers and to maintain sustainability.

Aims of Integrated Farming System

- Livelihood improvement
- Nutritional security
- Income growth
- Poverty alleviation
- Employment generation
- Judicious use of land and water resources
- Sustainable agricultural development
- Environmental improvement

Possible output of Integrated Farming System

To meet growing demand of human and animals and to provide gainful employment, IFS has several advantages over arable farming such as;

a) **Increased food supply:** Horticultural and vegetable crops can provide 2-3 times more calories than cereal crops on the same piece of land and will provide food and nutritional security. Similarly inclusion of Bee keeping, fisheries, sericulture, mushroom, cultivation under two or three tier system of integrated farming can give substantial additional high energy food without affecting production of food grains.

b) **Recycling of farm residues:** Proper collection & utilization of cowdung & urine of animals in the form of FYM and vermicompost alone can save about 50% of NPK requirements of the crops. Vermicompost containing 3 to 4 % more N content than FYM can be produced from crop residue mixed with cowdung for restoring soil fertility. Further, if we utilize even 1% of annually available 200 metric ton crop residue for mushroom cultivation then we can produce 2 lakh tons mushroom against only 40 tons of present day production.

c) **Use of marginal and wastelands:** Combination of forestry, fishery, poultry, dairying, mushroom and bee keeping can be combined with crop raising and all these activities can be undertaken on marginal to wastelands too.

d) **Increased employment:** Studies conducted in India and elsewhere, indicated 200 to 400 percent increase in gainful employment and additional income to farm families to increase their standard of living.

e) **Restoration of soil fertility and conserving environment:** With efficient recycling of crop and animal residue in crop-live stock- poultry-fishery system, at least half of the nutrient (if not more) can be saved along with restoration of soil fertility and cleaner environment be maintained. Preparation and large scale use of wormy compost will further help in decreasing dependence on chemical fertilizers and will also help in keeping clean and healthy environment.

Farming System Research Methodology

Major steps in integrated farming system approach

- Characterization of prevailing On-Farm Farming Systems of the region/ area.
- Bridging yield gaps by minimizing production constraints through adoption of latest viable production technologies
- Maximization of farm production & profits by diversification of prevailing On-Farm Farming Systems through integration of economically viable but socially accepted low cost/ cost effective farm- enterprises

Way and means to achieve desired goal

- To understand the farmer and his resources
- Estimation of family annual food and fodder demands
- Allocation of farm land and other resources for livelihood improvement
- Formulation of cost effective viable technological module/modules for different component enterprises to bridge the yield gaps
- Diversification of prevailing farming systems through integration of some additional need based socially accepted low cost enterprises which suits to his farm conditions

PROJECT AREA AND PRESENT STATUS OF AGRICULTURE IN WESTERN PLAIN ZONE OF UTTAR PRADESH

Location:

The Project Directorate for Farming Systems Research Modipuram fall in Upper Gangetic Plain Region and is located on Delhi – Hardwar Highway No. 58, at a distance of about 10 K.M. from zero mile of Meerut city in the state of Uttar Pradesh. Modipuram is situated at an elevation of 237 meters above mean sea level, $29^0 4^/$ N latitude and $77^0 46^/$ E longitude.

Soils and climate:

The project area falls under Agro-ecological Region No.4, i.e., "Northern Plain and Central Highlands, Hot Semi-Arid Eco-region" with alluvium derived soils. Soils of PDFSR, Modipuram research farm are representative of the region and are neutral to slightly alkaline in nature and belong to Typic Ustochrept group. Present fertility status of the soils in U.P. revealed that about 98% developmental blocks of the state are in low to very low in N & P and 57% blocks are medium in K content. Topography of the soil more or less is flat/leveled except few sand dunes and moderate slops near riverbanks. The climate of the region is broadly classified as semi-arid sub-tropical, characterized by very hot summers and cold winters. The hottest months are May-June, when maximum temperatures may shoot up as high as 45^{0}C to 49^{0}C, whereas during coldest months December- January, minimum temperature often goes below 5^{0}C. The average annual rainfall is 862.7 mm, 75-80% of which is received through southwest monsoons during July to September.

Irrigation facilities:

More than 90% of the crops are grown under assured irrigation conditions propagated by the network of river canals (about 1/4th of the total irrigated area) and rest with diesel engine or electric operated deep bore wells.

Farmers and farm conditions:

The marginal (76%) and small (14%) farmers constituting major part of the total farm families are owing only 58% of cultivated land with holding size ranging from 0.70 ha with marginal and 1.2 hectare land with small farmers. More than 31% of the farmers fall under below poverty line. Most of them are resource poor, illiterate, live in diverse, risk prone conditions. The problems faced by most of the farmers included high rates of agricultural loans, farming not secured by any financial /insurance institutions, no price support, poor marketing facilities and lack of technological know how and all these bother mainly to the poor of the poorest. The fields are yet scattered and divided in very small plots not suited for mechanization.

SWOT analysis of small farm holders.

Before planning and start of any programme or project, SWOT analysis is must to get success. Our client in IFS are marginal and small farm holders and it is desirable to know the strength, weaknesses, opportunities and threats coming in the way of running the programme with these categories of farmers.

Table 1: General Status of Small land holders in the zone

FARMER	FARM LAND	INSTITUTIONS
MARGINAL -76% (Owing 34% land)	SMALL LAND HOLDINGS (0. 7 to 1.21 ha)	LACK OF TECHNICAL KNOW HOW
AND SMALL- 14% (Owing 24% land)	Not ideal for mechanized farming)	HIGH RATE OF AGRICULTURAL LOANSLACK OF MARKET FACILITIESNO PRICE SUPPORT
FINANCIALLY WEAK(31% below poverty line)	LOW SOIL FERTILITY (In U.P. 98% blocks are L to VL in N&P and 57% blocks are Medium in K level)	
RESOURCE POOR(Depend on others)		
MOST OF THEM ARE ILLITERATE	SCATTERED UNDULATED FIELDS	

Table 2. SWOT analysis of small farm holders.

Strengths	Weaknesses	Opportunities	Threats
Sufficient Man power	1. Small & fragmented land holdings 2. Wide spread Poverty 3. Lack of resources 4. Illiteracy 5. Laggardness 6.Low risk bearing capacity 7.Poor technological know-how	1. Loans on low interests 2. Subsidies on implements, milch animals and new enterprises like fish production, horticulture and a number of small scale industries. 3. Free trainings for agriculture related enterprises. 4. Research oriented technologies to increase the productivity and profitability of existing On-Farm farming Systems.	1. Any type of technological and/ or methodological failures can affect the economic condition of the family. 2. Small farmers' works in risk prone diverse conditions. 3. Environmental factors such as climate and weather adversities are beyond the control of small farm holders who are economically handicapped. 3. High risk to introduce any new technology.

Present Farming Systems Scenario

- **Prevailing Farming System of the area-** Crops +Dairy.
- **Major crops -** Sugarcane, wheat, rice, mustard and fodder crops sorghum (Kh.) & berseem /oats.
- **Dominate cropping systems:** Sugarcane –wheat and Rice-wheat-summer sorghum.
- **Major dairy animals –** Buffaloes and cows (Buffaloes have an over edge on cows).
- **Other options/enterprises**

a) Leading:- Horticulture

b) Found Economical but not common:- Bee keeping, Fishery, Piggery, Poultry & Mushroom.

The dominant on-farm farming system practiced by most of the farmers in western plain zone of Uttar Pradesh is **crops + dairy**. Some of the farmers owing large land holdings also integrate horticulture and or apiary with existing farming system as above. Under horticulture, fruit orchards of mango & guava mainly with large farmers and seasonal vegetables & marigold flowers mainly near vicinity of the towns and cities are becoming popular because of high income but with market risks. There are some other very promising but socially less accepted enterprises, including poultry, fishery, piggery, mushroom and vermiculture adopted by few farmers having zeal to get higher incomes

Demand and supply

The brief account of the present status of demand and supply under different components of various farming practices adopted by the farmers is described below;

Crops: - The farmers grow selected crops (Rice, wheat, sugarcane and sorghum) and are dependent on local market mainly for pulses oilseeds and some times green fodder too. – ***The annual minimum need of family for food, fodder and fuel are not met out.***

Dairy:-Rearing of indigenous & low yielding (4-6kg milk/day) breeds of buffaloes and cows. Fodders having very low nutrition value including wheat straw and sugarcane tops are fed as fodder for more than six months. Lack of leguminous and green fodders – ***Raring of un- economical animals and poor nutrition are among the major constraints identified***.

Fruit cultivation:-Mango, guava, peach and pear are major fruit trees. The fruit orchards however are dominated by mango mixed in different ratios of peach/pear or guava. Farmers grow any of the field crops even sugarcane or rice or wheat or sorghum in newly planted orchards. ***Alternate bearing & blackheart disease in mango orchards are serious concern to the fruit grower – Lack of technological know-how.***

Bee keeping:-Bee keeping is practiced mainly by the orchard owners or the farmers residing near vicinity of the orchard owners , as this particular enterprise need constant flowering crops/trees. ***Small holdings do not give room for fruit tree plantations and also inclusion of flowering crops like mustard and sunflower etc.***

Fishery, piggery and poultry:- Few farmers go for these three socially not accepted enterprises. Pounding and maintaining a certain depth of water in fishpond through out the year is the major constraint of fish farming***. Heavy loss due to diseases in piggery & poultry and social status& religion is the major hindrances in popularizing these areas of great potentialities.***

Yield gaps

The survey of existing farming system of western plain zone of Uttar Pradesh revealed that there is wide gap between farmer yield and achievable yield of different farm commodities (Table-3).

Constraints responsible for yield gaps:

The constraints analysis is most important exercise in order to find out or suggest specific solutions to specific problems. With the help of survey following problems/constraints were analyzed which will help to identify researchable issues/interventions to make the different enterprises more profitable:

Table 3. Farmer yield, achievable yield and yield gap of some of the farm commodities

Farm commodities	Farm yield (Av.) q/ha	Achievable yield (Av.) q/ha	Gap (%)
Sugarcane (Plant crop)	540	1100	103.0
Sugarcane (Ratoon crop)	740	1300	75.7
Wheat	46	65	41.3
Rice	42	65	54.8
Buffaloes	5.22kg/Animal/day	12.0kg/Animal/day	129.9
Improved cows	7.36kg/Animal/day	18.0kg/Animal/day	161.7

A. Crop production

- Late planting of crops, especially of sugarcane and wheat.
- Use of higher seed rates
- Poor seed management
- No seed treatment
- Improper sowing methods mainly broadcasting in wheat
- Excess use of N, imbalanced use of nutrients and improper application methods
- Use of poor quality FYM
- Lack of knowledge about disease and pests management in respect of application methods, time of application, rates of pesticides and use of right pesticides.

B. Animal husbandry

- Rearing of Non-descript of animal
- Feeding of animals with poor quality feed and fodder
- Animals are not feed with balanced ration
- Incidence of diseases and other problems
- Fertility problem, anoestrus, repeat breeding, low conception rate, improper time of service, service by local and non-descriptive bull
- Little use of minerals, salts and vitamins

C. Horticultural crops

- Mango: The main problems of mango include alternate bearing, malformation, disease like bacterial blight and powdery mildew and pests like hopper and mealy bug, taking orchard by non-traditional farmers, grow unsuitable crops in orchards and lack of processing units.
- Vegetables: In vegetable main problems were non-availability of good quality seed, sowing of seed without proper treatment, lack of suitable variety and suitable techniques and pests and disease problems.
- Floriculture: In floriculture, there is no suitable variety of marigold, particularly for rainy season crop and disease and pest.

D. Bee- keeping

- Lack of technical know- how, adoption at small scale, non-availability of desired flower plants round the year for honey bees for feeding, lack of improved honeybees colonies and incidence of pests and diseases.

E. Poultry

- Lack of technical know-how, poor housing facility, non-availability of electricity, not taking regular batches of poultry are some of the problems of poultry.

F. Fishery

- Social factor, use of small size ponds, theft, poisoning, lack of technical no-how and un- awareness among farmers.

By solving above constraints/ problems we may improve inputs use efficiency, resulting in improved out put per unit area and time, the ultimate aim of farming system approach.

ANNUAL FOOD AND FODDER DEMANDS OF AN INDIAN 7 MEMBERS' HOUSEHOLD

To reduce market dependency and allocation of farm resources, estimation of annual household food and fodder

Table 4. Diet standards for different categories of farm workers (Average balanced diets for adult male and female- g/person/day)

Food Stuff	Male		Female	
	Moderate work	Heavywork	Moderatework	Heavy work
Cereals	450(450)	630 (630)	310 (310)	440 (440)
Pulses	80 (65)	80 (65)	60 (50)	60 (50)
Green leaf vegetables	125 (125)	125 (125)	100 (100)	100 (100)
Other vegetables	75 (75)	100 (100)	75 (75)	75 (100)
Root and tubers	100 (100)	100 (100)	75 (75)	100 (100)
Fruits	60 (60)	60 (60)	60 (60)	60 (60)
Milk	400 (250)	400 (250)	400 (250)	400 (250)
Fats and oils	40 (40)	50 (50)	35 (40)	40 (45)
Sugar and Jaggery	40 (40)	55 (55)	30 (30)	40 (40)
Meat and fish	0 (60)	0 (60)	0 (60)	0 (60)
Eggs	0 (30)	0 (30)	0 (30)	0 (30)
Nuts	50 (50)	50 (50)	40 (40)	40 (40)

(Figures given in parenthesis are for non vegetarian man/woman)
Source: Dr. M.S.Swaminathan,1998

Table5: Total annual requirement of different farm commodities of 7 members' household

Farm commodities	Quantity (Kg/ton)
Cereals	1550 Kg
Oilseeds	130 Kg
Pulses	200 Kg
Sugarcane	1600 Kg
Green fodders	40 Ton
Fruits	200 Kg
Vegetables	900 Kg
Milk	1120 Kg
Honey	20 Kg
Meat/Fish etc.	160 Kg **

**** Only for non-veg. families**

demand of the family is a pre – requisite. Several standards have been fixed for the purpose. However, in this project standard set by Dr. M.S.Swaminathan (1998) have been used and family annual requirements have been estimated (Table-4).

Based on the calculations as per standard given in above table the total annual requirement of different farm commodities is summarized in the table-5.

DEVELOPMENT OF INTEGRATED FARMING SYSTEM MODEL

Characterization of On- Farm Farming Systems of an area if properly done give sufficient information on the prevailing farming systems, farm resources, yield gaps in different enterprises , constraints responsible for yield gaps and farmers' choices and priorities. Keeping all these aspects in mind, an Integrated Farming System Model and technological modules for each and every enterprise is prepared in consultation with the farmer and multi disciplinary team of scientists. Based on the information collected during diagnostic surveys conducted in the region and results of a six years (2004-05 to 2009-10) study on IFS at PDFSR, Modipuram, an ideal IFS model for one hectare cultivated irrigated land for small farm holders of western plain zone of Uttar Pradesh is hereby suggested for further dissemination of the technology.

Components of IFS Model

Prevailing Farming System **(Crops + Dairy animals)** +

Most accepted and profitable enterprise **(Horticulture)** +

Supplementary and most enterprising component **(Fresh water fish production)** + Value adding enterprise **(Vermicompost)** +

Safeguarding field crops and producing long term income **(Boundary plantations)**

Allocation of farm land and other resources for livelihood improvement

To meet at least the minimum essential annual requirements of food and fodder etc. of a household and reduced dependence on market for these commodities, it is must to allocate farm land and other resources including money in family purse, judiciously and accordingly. The remaining farm

Table 6. Allocation of one hectare irrigated farm land for livelihood improvement

Farm commodities	Quantity (kg/ton)	Land allocation for basic commodities (ha)	Distribution of left out land area under suggested additional enterprises (ha)
Cereals	1550 Kg	0.35	-
Oilseeds	130 Kg	0.11	-
Pulses	200 Kg	0.17	-
Sugarcane	1600 Kg	0.03	0.14 **(Main cash crop of the region)**
Green fodders	40 Ton	0.67	A part of cropping systems followed
Fruits	200 Kg	*	0.22 **(mango and guava)**
Vegetables	900 Kg	**	** Will be met out from intercropping in fruit orchards and kitchen gardening
Milk	1120 Kg	***	*** Will be met out from dairy animals
Meat/Fish etc.	160 Kg	****	**** 0.10 **(Under fish pond)**

NOTE: To meet minimum basic food and fodder requirements of the family a farmer need 1.33 ha gross cultivated area. Under irrigated conditions , more than two crops per year are taken from the same piece of land. Considering an average 250% cropping intensity the net cultivated area required comes to 5320 sq.m. or say 0.54 ha only. Now the remaining land area (0.46 ha) out of 10000 sq.m. (1.0 ha) is available for diversification of the prevailing on – farm farming systems either with high value crops or by integrating some additional more paying enterprises to make the system holistic and also more profitable and sustainable.

resources then should be/or may be allotted to some additional but few new enterprises already tested/proven beneficial and economical for further upliftment of the family. Based on the IFS study conducted at PDFSR, Modipuram, resource allocation for 1.0 ha irrigated land area representing marginal and small farmers both is given in table – 6 below.

Formulation of enterprise modules

As it is not possible to solve all the problems and constraints thereof, it is always advisable to prioritize the problems and related constraints causing much difference in yields if not solved. Then identify most viable and cost effective technologies which are feasible in operation and environment friendly too.

A) Crops:

Selection of crops and cropping systems

Select crops and cropping systems which satisfy household food and fodder requirements and are comparatively

Table 7. Productivity and profitability of different crop sequences (2004-2010)

S. N.	Crop sequences and technological interventions	Yield (SEY) t/ha/ year)	Net returns (Rs./ha/ year)	B:C	Option/ Suitability
1	Sugarcane (Feb) + **onion/ tomato** * –Ratoon (***Two year rotation)***	95.94	63887	1.53	More productivity/ profitability from existing sugarcane based cropping systems
2	Sugarcane (May) +**Cowpea (GM)** * -ratoon-wheat ***(Two year rotation)***	86.98	53818	1.28	More productivity / profitability from existing sugarcane based cropping systems
3	Rice – **potato *-** wheat – ***Sesbania aculeate*** * (GM)***(One year rotation)***	131.01	67312	1.56	Diversification of existing Rice-wheat cropping systems
4	Rice-berseem **+ mustad** *-pearlmillet ***(One year rotation)***	100.62	70162	1.73	Better choice for animal based systems
5	Sorghum (SF) – rice **(hybrid)** *-berseem (One year rotation)	146.42	166637	3.14	Better choice for animal based systems
6	Rice (basmati) – **potato *– marigold** *(One year rotation)	164.54	150812	1.57	Most profitable cropping system for the farmers living in near vicinity of cities and towns
7	Maize **(Dual purpose) *+ red gram** * – wheat (One year rotation)	82.23	123343	1.94	A better cropping system with considerably higher net returns and B:C ratio.
8	Sorghum (SF) - rice **(Hyb.)** * - mustard ***(One year rotation)***	88.00	88380	2.40	For the farmers living at far distances of cities

* Technological interventions for increased efficiency of prevailing systems. However, all the crops included in different cropping systems were grown with improved practices recommended for respective crops.

A. Crop module for household food and feed security

Major Farm commodities	Household Needs, Farm production and market value of produces (kg/q)	Crop sequences proposed and expenditure involved (Rs./seqence)	Net area alloted (Sq.m.)	Farm Commodities Produced	Expected Production (kg/q)
Cereals (Rice, Maize, wheat)	1550 Kg* **(3340 kg)** **Rs.40,080**	Rice (Hyb.) – potato - wheat – Sesbania aculeate (GM) (Rs.16500)**	1200	Rice, Wheat GM (Fresh wt.) Dry fodders (Rice husk + Wheat straw)	720 kg 660 kg 42.00 q 325.00 q 15.45 q
Oilseeds (Mustard)	130 Kg **(216 kg)** **Rs.6,480***	Sorghum-mustard- Maize+ cowpea (Rs.7320)**	1200	Mustard Sorghum (GF) Maize+cowpea	216kg 84.0 q 66.00 q
Pulses (Red gram, black gram)	200 Kg **(268 kg)** **Rs.8,040***	Maize + red gram– wheat Sorghum-blackgram-wheat (Rs.10880)**	800 800	Maize Red gram Black gram Wheat Sorghum (GF) Dry fodders (Wheat straw + Maize curvi)	360 kg 148 kg 120 kg 880 kg 56.00 q 16.0 q
Sugar crops (Sugarcane)	16.00 q **(128.0 q)** **Rs.23,040***	Sugarcane (Feb) + onion – Ratoon (Rs.20000)**	1600	Sugarcane Onion Green fodder (Sugarcane tops)	128.0 q 10.0 q 51.0 q
Green fodders Sorghum Berseem Oats Sugarcane tops	400.00 q **455.0 q** **(Rs.34,125***	Sorghum (GF) – rice (hybrid) - berseem/oats (Rs.8520)**	1200	Rice Sorghum (GF) Berseem (GF) Oats (GF) Dry fodder (Rice husk)	720 kg 84.0 q 66.0 q 48.0 q 7.20 q
Dry fodders (Wheat straw, Rice husk, maize curvi etc.)	38.0 q **(38.6 q)** **Rs.11,580***	-	-	-	-
Vegetables Potato Onion	5.60 q **(42.0q)** **Rs.42,000** **(10.0q)** **Rs.10,000**	-	-	-	-
Net area 6800 sq.m.	**Gross return** Rs. 1,65,345	**Cost of cultivation** Rs.63,220	6800	**Net profit** Rs.1,02,125/ 6800Sq.m. area	-

* Market value of the produce ** Cost of production

Yield levels

Rice; 60q/ha, Wheat;55q/ha, Maize ; 45q/ha, Mustard; 18 q/ha, Potato;350q/ha, Red gram;18.6q/ha, Onion;250q/ha

Green fodders: Sorghum; 700 q/ha, Maize + cowpea ; 550q/ha, Berseem;1100q/ha, Oats; 800q/ha

Prevailing market rates

Cereals; Rs.12/kg, Pulses and oilseeds ; Rs.30/kg, Potato;Rs10/kg, Onion more paying. During last six years of studies on crops and cropping systems under IFS project at PDFSR, Modipuram, following cropping plan was found highly profitable as well helping in livelihood improvement. Farmers can choose and incorporate suitable crops in different crop rotations as per need of the family and farm resources .

Technological package (Crops):

- Selection of season specific HYVs
- Use of RCTs (Zero tillage, BBF and residue recycling)
- SSNM
- INM –Increased use of organic sources of nutrients along with chemical fertilizers
- In situ and ex situ green manuring
- Use of Vermicompost in place of cow dung/FYM

B. Dairy (Milk production):

Size of the animal unit –

2 milch animals (1 buffaloes + 1 cow **or** 2 buffaloes as per choice of the family) & their young ones

Economics of milk production:

1. Production costs (Fixed + Recurring)

a) Fixed cost :

i) Purchase cost of the animals:

One buffalo @ 55,000/buffalo = Rs.60,000/-

One H F crossbred cow = Rs.45,000/-

Total cost of animals = Rs.1, 05,000/-

ii) Miscellaneous expenditures including milking utensils and other petty items during initial establishing phase = Rs.5,000/-

Total (a) = Rs. 1,10,000/-

b) Recurring expenditure:

1) Concentrate mixtures = Rs.36,160

@ 4kg/day/animal x two animals x265 days @ Rs 18/kg

2) Dry period ration = Rs.7,200

@2kg/day/animal x two animal x 100 days x Rs.18/kg

3) Dry fodder/straw = 38.0q x Rs.300/q = Rs.11,400

@ 5kg/day/animal x two animal x365 days

4) Green fodder =Rs.19,875

@25kg/day/animal x two animals x365days x Rs.0.75/kg

5) Mineral mixture = Rs.2375

@50 gm/day/animal x two animals x 365 days x Rs.65/kg

6) Medicines and other miscellaneous = Rs.5, 000

7) Cost of vermicompost preparation = Rs.10,800

8) Labour - 4 hours daily @ Rs .150/ day = Rs.27375

Total b) = Rs.1,20,185

Total cost of production = Rs.1,35,685

(Depreciation value of animals@10% of purchase value Rs.10,500+ Miscellaneous expenditure Rs.5000 + Recurring cost Rs.92,810)

2. Production from dairy animals:

i) Milk production

Buffalo – At an average milk production of 8.0 liter per day = 2120 liter

X 265 days milk period

Market value @ Rs.28.0 per liter = Rs.59, 360

H.F.Cow - At an average milk production of 12.0 liter per day = 3600 liter

X 300 days milk period

Market value @ Rs.25.0 per liter = Rs.90,000

ii) Young ones of animals –Two @ Rs.5000/calf = Rs.10,000

iii) Vermicompost 60.0 q @ Rs.500 per quintal = Rs.30,000

Gross returns from dairy unit = Rs.1,89,360

Net Profit

Gross returns Rs.1,89,360 **- Cost of production** Rs.1,35,685 = Rs.53,675

C. Horticulture (Fruits and vegetables production)

Total area under fruits = 2200 sq.m.

Fruit species

i) Mandarin var. kinnow (Papaya and vegetables as intercrops) = 1000 sq.m.

ii) Banana var. Grain Nain(Fodder / vegetables as intercrops) = 1200 sq.m

Economic evaluation of horticultural unit

1. Cost of cultivation: *(Considering average age of the orchard as 15 years)*

a) Establishment year *(Cost of pits, plants , plantation and input costs etc.)*

Banana plantations (280 plants) = Rs.11, 250

Kinnow plantations (66 plants) = Rs.8800

Guava plantations (50 plants) = Rs.3,000

(A*s boundary plantation)*

Karonda plants (244) in between guava = Rs.3660

(A*s boundary plantation)*

Total cost = Rs.26,710

Considering the average age of fruit plant as 15 years, the fixed cost = Rs.1,536

b) Recurring expenditures during subsequent years

@ Rs.50/tree/year for 396 tree/ plants = Rs.19,800

@ Rs.9/tree/year for 244 Karonda plants = Rs.2196

(Pruning and harvesting etc)

c) Labor cost – 4 hours per day @ Rs.150/mandays of 8 hours = Rs.27,375

d) Annual expenditure (Fixed + running costs) = Rs.50,907

Interest on borrowed money @7% = Rs.3565

e) Total expenditure / year to be incurred = Rs.54472

2. Annual production/income

From banana unit (1st Year onward) Rs.35,000/year

From Kinnow (4th.year and onward) Rs.31,000/year

From guava (4^{th}. year and onward) Rs.22,000/year

From Karonda (4^{th}. year and onward) Rs.6000/year

Gross Returns/ year ***(Averaging production years of 14 for banana, 12 each for kinnow and guavaand kinnow)*** Rs.94,000/year

3. Net returns

(Gross returns Rs.94,000 **– cost of cultivation** Rs.54,472) =Rs. 39,528/year

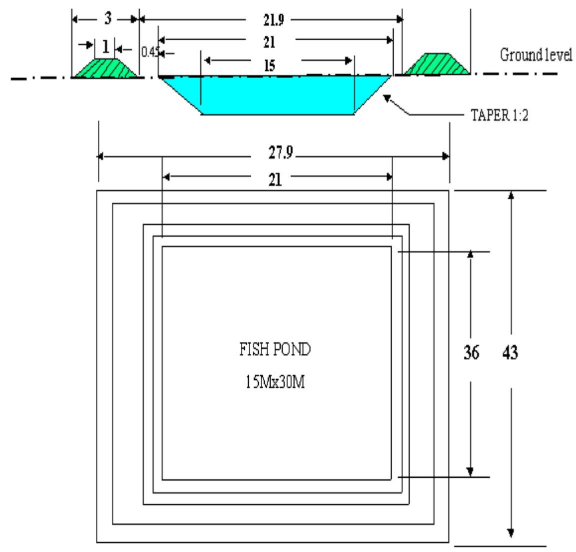
D. Fresh water fish production – Composite fish culture

Under low lying and assured water supply conditions composite fish culture is an ideal enterprise giving higher income per unit area per unit time and that too with locally available recycled farm inputs (cow dung, rice bran, animal wash, vermicompost and fresh leaves of leguminous fodders) within the system itself. A small fish pond of 0.1 ha developed at PDFSR, Modipuram produced fish yield of 148 kg in first year of it's establishment to as high as 472 kg in fourth and 518 kg in fifth year with gross and net returns of Rs.25900 and Rs.16063, respectively.

Besides fish production, nutrient rich pond silt (de-silted once in every third year) and pond water (recycled as irrigation water for crop production twice a year in ***kharif*** rice and ***rabi*** wheat) were applied for productive use in crops. A total amount of 18.56 kg N, 6.21 kg P and 74.24 kg K was added by excavation of 15 cm deep ground soil surface of 800 m^2 pond area saving an amount of about rupees nine hundred fifty. The OC% of the soil was as high as 1.20 with an average value of 0.95. Addition of pond silt and water was found to increase the yield of rice and wheat by 3.48 q/ha and 2.41 q/ha, respectively.

In addition to this bund dykes was also utilized for raising fruits like banana citrus , guava and also many other crops including short duration vegetables and green manure crops *Sesbania aculeate* , *Lucenea lucocephala.* These crops not only add in to production but save bund slops from soil and water erosion.

Design and expenditure details of fish pond:



All dimension in meter

i) Volume of the soil to be dug out = ½ (15+21) x 30x 1.5 = 810 cu.m.
ii) Volume of cut and fill soil for making embankments all around the fish pond = ½ (1+3) x 116x 0.5 = 116 cu.m.
iii) Corner Work =4(1/2(1.45+0.45)x6.5 = 12.35 cu.m.
iv) Total volume of soil for embankment = 116+12.35 = 128.35 cu.m.
v) Surface area at the bottom of the pond = 15mx30m = 450 sq.m.
vi) Surface area at the top of the pond = 21mx36m = 756 sq.m.
vii) Total land area covered under fish pond = 28mx43m =1204 sq.m.
viii) Depth of standing water to be filled and maintained = 1.5 m

In 0.10 ha land area allotted to fish pond It is proposed to develop a small fish pond of 810 cu.m. volume. The design of the pond and it's specifications are given below;

Major fish species and number & ratio to be cultivated in the pond

A composite mixed fish culture has been found ideal under fresh water fish production in small pond for optimum utilization of all the water depth layers. The farmers can choose the species as per market need and seed availability among the following fish species;

Local ***IMC*** fish species: Bhakur (Catla), Rehu (Rohu), Nain (Mrigal)

Exotic carps: Silver Carp or Grass Carp

Seed rate (Number of fingerlings): 1000

Fish ratio: Catla, Rohu, Mrigal and Grass carp (30:20:20:30)

Cost of production

Fixed cost:

Cost of pond construction for an area of 1000 sq.m. = Rs. 45,000 (Approx.)

Considering total age of fish pond as 20 year, depreciation valueof fish pond = Rs.2250/-

(About 50% subsidy on pond construction and fish cultivation is given in most of the states)

Recurring cost

Average Cost of fish production/ha/ year in a scientifically managed fish pond to get maximum production

Annual Fish Production: Av. Fish yield 400 kg/year/1000 sq. m. pond area

Expected income from 1000 sq.m. fish pond:

Total income taking fish v a l u e @ R s H Y P E R L I N K "mailto:value@Rs25/-per"50HYPERLINK "mailto:value@Rs25/-per"/-per kilogram = Rs.20,000 per year

Net Profit per year (Rs. 20,000 - (Rs.2250 + Rs.3043)=Rs.14707/1000 sq.m.

Sr. No.	Items	Quantity	Approx. cost (Rs.)
1.	Lime	250 kg	1250/-
2.	Cow dung	20 tonnes	5000/-
3.	Ammonium sulphate	450 kg	3150/-
4.	Single Super Phosphate	250 kg	1750/-
5.	Murrete of Potash	40 kg	280/-
6.	Broken rice (Kanni)	500 kg	4000/-
7.	Mustard cake	500 kg	4000/-
8.	Fish seed cost	10000 in Nos.	4000/-
9.	Water charges	Maintaining desired water level whole the year	3000/-
10.	Mahi /harvesting of fishes	-	2000/-
11.	Miscellaneous expenditures	-	2000/-
	Total per hectare cost on fish production/year	30430/-	

Total running cost on fish production/year from an area of 1000 sq.m = Rs.3043/-

Depreciation cost of fish pond = Rs.2250/-

Vermicompost:

Animal unit with two buffalos or one buffalo and one H.F. cow with two young ones produces more than 200 quintal of fresh cow dung. If 3/4th'of this cowdung is used for Vermicompost preparation and 1/4th' used for fish pond and FYM etc. than more than 60 quintal vermicompost can be prepared for fulfilling the need of field and plantation crops of the model. Vermicompost content of macro and micro nutrients N(%),P(%),K(%),Zn(ppm),Cu(ppm),Mn(ppm),Fe(ppm)is about 1.68, 0.23, 1.26, 112, 48, 397, 3323 as compared to respective values 0.70,0.19,1.37,75,34,222,3134 found in FYM.

Method of Vermicompost preparation

Component of Vermicompost:

Pit size and depth of the pit : 1.5 to 3.0 meter length, 1.0 to 1.5 meter wide and 0.9 -1.5 feet deep pit size is ideal for Vermicompost preparation. Farmers can prepare as many as required such pits.

Farm products: Cow dung, Grain straw, Crop residues and other farm wastes

Value addition: Press mud from sugar mills, Spent Mushroom Substrates and or any other nutrient rich by products

Earthworm species: *Eisina faetida, Lumbricus rubellus and Perionyx excavator*

Weight of earthworm: For one quintal mixture of cowdung etc 250g to 500 gm **Composition of different constituents of Vermicompost mixture:**

50-75% cow dung + 25-30%% Crop residues/straw etc +SMS/Pressmud alone or in combinations

Precautions:

- Proper shade on Vermicompost material is essential to save it from direct sunshine and rainy water
- The mixture should well moisten and loosen fortnightly for proper moisture (70-80%) and aeration which is a pre requisite for fat growth of the earthworms.
- Use neem cake time to time to save earthworm from ants etc.

Application Rates in different field and plantation crops:

S.N.	Crops	Quantity/ha
1	Cereals	5t/ha
2	Pulses	5t/ha
3	Oilseeds	7-12 t/ha
4	Spices	10t/ha
5	Vegetables	10-12 t/ha
6	Fruit plants	2-3 kg/plant
7	Cash crops	12.5 t/ha
8	Flowers	10 t/ha
9	Plantation crops	5 kg/plant

Boundary Plantations:

All the field borders should invariably be planted with either perennial fruit tree species or grasses having little or no shade effect on companion crops and that will be a source of permanent income in long run. The plant and grass species tried at PDFSR, Modipuram for boundary plantations were jack fruit, bel, jamun, citrus species nimboo and karonda and aonla. *Cenchrus ciliaris* (Subabul) was also planted on pond dykes and field boundaries produced huge amount of green leguminous fodders and fuel wood. In addition to this guava and banana can also be planted on boundaries of crop fields as well as fruit orchards. They will save the crops from winds and hot waves besides income to the farmers.

Livelihood security and economic viability of Integrated Farming System Model

Overall evaluation of the proposed IFS model based on averaged crop yields, prevailing market prices and estimated

Farm produces under different farm enterprises	Expected annual production (kg)	Gross value of the produce at prevailing market price (Rs.)	Estimated requirements of a Family (7 members) (kg)	Product Value of home consumption (Rs.)
A. Crop production		**1,00,305**		
i) Cereals (Paddy, maize, wheat)	3340	44080	1550	18600
ii) Pulses (Green gram, pigeon pea, black gram)	268	8040	200	6000
iii) Oilseeds (Mustard)	216	6480	130	3900
iv) Green fodders(Sorghum, berseem, oats)	45500	34125	21900	16425
v) Dry fodders(Wheat straw, paddy husk, maize &sorghum curvi and pulses straw etc.)	3860	11580	3800	11400
B. Dairy		**1,79,360**		
Milk (Liters)	5720	149360	1575	40950
Vermicompost	6000	30000	6000	30000
C. Horticulture Unit		**123300**		
Fruits production &	5720	94000	210	2100
Vegetables (intercrop)	2930	29300	560	5600
D. Fishery	400	**20,000**	155**	7750
Total (A+B+C+D)	-	**4,22,965**	-	**1,42,725** **1,34,975 for Indian Non-veg**

** **For non- veg. families**

(All the figures included in the table are achievable and/or based on the yield levels achieved in an IFS model at PDFSR, Modipuram and prevailing market prices of (2010-11)

Total cost of production (Rs.2,58,670)

Crops Rs. 63,220+ Dairy +Vermicompost Rs. 1,35,685 + Horticulture Rs. 54,472 + Fishery Rs.5,293

Gross returns (Rs.4,22,965)

Crops Rs. 1,00,305+ Dairy +Vermicompost Rs. 1,79,360 + Horticulture Rs. 1,23,300 + Fishery Rs.20,000

Net returns = Rs. 4,22,965 - Rs . 2, 58,670 = Rs.1,64,295

Family consumption = Rs. 1,34,975

Net savings = Rs.29, 320 (After meeting house hold food and fodder requirements)

Note: The project proposal submitted and production and economic values/figures (achievable) included show the soundness of the IFS approach. However, it takes two to three years to achieve the targeted goals because the project involve enterprises like fruit plantations, boundary plantations etc. which start giving returns from third or more than third year of establishment of the project.

demand of a seven member Indian (Non-veg.) family has been summarised in the table below. The figures included in the table envisage the importance of IFS approach for livelihood improvement of small farm holder farmers. The approach not only fulfil the household food and fodder needs of a family but save a sizable cash for other liabilities of the family including education and health etc. Further, diversified nature of the approach extends possibilities of nutritional security along with round the year funds availability.

Conclusion

IFS approach not only fulfils the household needs but enrich diet of human being and animals both and simultaneously keep the people away from the hazards of residual toxicity of the chemicals being used in agriculture on a large scale. Further, diversified nature of the project provides huge employment opportunity for unemployed rural youths. In addition, net saving of more than Rs.25,000/year or more than that will help to meet other liabilities of the family including education, health and social obligations and overall improvement in livelihood of small farm holders. The IFS model is a basket of options and farmers can choose appropriate combinations of enterprises as per their resources and family needs. Farmers having sufficient land and other farm resources can go for horticultural crops viz; fruits, vegetables and floriculture. Whereas, marginal farmers or land less farmers can integrate apiary and mushroom in to their existing farming systems. Farmers having sufficient irrigation water and / or living in low lying riverbed areas can choose fishery as an additional enterprise. Similarly, farmers living in near vicinity of the towns and cities can grow vegetables and green fodders as per market demand and availability.

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PRODUCTIVITY, PROFITABILITY AND NUTRIENT REMOVAL OF RICE (*ORYZA SATIVA*)- MAIZE (*ZEA MAYS*) CROPPING SYSTEM AS INFLUENCED BY SITE SPECIFIC NUTRIENT MANAGEMENT

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Abstract

A field experiment was conducted during 2006-07 to 2007-08 at Bihar Agricultural College, Farm ,Sabour, Bhagalpur to study the effect of site- specific nutrient management (SSNM) on crop productivity, profitability and nutrient removal of rice (*Oryza sativa*) – maize (*Zea mays*) cropping system. The experiment comprised 10 treatment combinations, wherein farmer's fertilizer practice and state recommendation were compared with eight SSNM options. Pooled analysis revealed that application of 150 kg N,60 kg P_2O_5 ,100 kg K_2O in rice and maize and 40 kg S/ha in rice only resulted in significantly higher values of grain yields of hybrid rice (79.1 q/ha) , maize (90.5 q/ha), rice-equivalent yields (161.7 q/ha), net returns (Rs.70,955/ ha) and B:C ratio (1.53) as well as nutrient uptake by rice and maize crops over the farmer's practice, state recommendation and the treatments in which either of the P_2O_5 ,K_2O and S were omitted from fertilizer schedule. The optimum dose of P_2O_5 ,K_2O and S for rice as per regression equation worked out to the extent of 54.7, 89.6 and 69.9 kg/ha, respectively whereas, optimum doses of P_2O_5 and K_2O for maize were 78.4 and 89.4 kg/ha , respectively. Application of balanced dose of nutrients improved the organic carbon, available N, P_2O_5 and S contents of the soil. However, marginal decline in K-status from its initial level was also observed in all the treatments.

Key words: Site Specific Nutrient Management, Productivity, Profitability, Nutrient removal Energetic, Rice-Maize system,

Rice (*Oryza sativa*)-maize (*Zea mays*) is the most dominant cropping system in irrigated ecology of alluvial plains of Bihar. Both rice and maize are the most important cereal crops of Bihar having high yield potential (50-90 q/ha). The rice - maize system is an exhaustive cropping system, requiring higher quantum of nutrients. Its continuous cultivation over a longer period leads to nutrient deficiency. One of the major reasons for this nutrient deficiency in soil is low level of replenishments through inadequate nutrient supply causing negative nutrient balances in the soil on (Yadav *et al.,* 1998). Maintenance of soil fertility at healthy levels (supply of all nutrients in proportions matching with a crop's needs) is one of the key steps towards safeguarding high productivity on a sustained basis. To meet the large nutrient needs of rice-maize system, SSNM can facilitate the desired know how in an efficient and cost effective manner. Therefore, the present investigation was carried out for achieving maximum economic yields through site- specific nutrient management in rice-maize system.

Materials and Methods

A field experiment was conducted for two consecutive years from 2006-07 to 2007-08 on a fixed site at Bihar Agricultural College Farm, Sabour, Bhagalpur. The experimental soil was clay loam having pH 8.0 with organic carbon 0.47 %, available N 175.6 kg/ha, P_2O_5 31.10 kg/ha, K_2O 220.6kg/ha, S 22.0 kg/ha and available micronutrients were B 0.7, Cu 6.5, Fe 54.0, Mn 9.8 and Zn 4.7 mg/kg. The experiment was laid out in randomized block design with 4 replications. Based over soil analysis report, the treatment comprising combinations of 150 kg N/ha along with 3 levels each of P_2O_5 (0, 30 and 60 kg/ha), K_2O (0, 50 and 100 kg/ha) in rice and maize crop and 4 levels of S (0, 20, 40 and 60 kg/ha) applied only in rice. The experiment comprised 10 treatment combinations, wherein Farmer's nutrient management practices (FP) and state recommendation (SR) were compared with eight site- specific nutrient management (SSNM) options ($SSNM_1$ to $SSNM_8$). In case of each of the nutrients applied, there had been an addition treatment in which it was not applied, so that its response could be calculated as per the missing plot techniques. The SSNM worked out to achieve a yield target of 9.0 t/ha in rice and 9.0 t/ha in maize was kept at 150 kg N, 60 kg P_2O_5 and 100 kg K_2O in rice and maize and 40 kg S only in rice. Succeeding maize received only N, P and K fertilizers, as to assess the carry over effect of secondary nutrient (Sulphur). Recommended doses of 100 kg N, 40 kg P_2O_5 and 20 kg K_2O/ha and 120 kg N, 75 kg P_2O_5 and 50 kg K_2O/ha were applied in rice and maize, respectively. A dose of 70 kg N, 30 kg P_2O_5 and 15 kg K_2O/ha and 100 kg N, 30 kg P_2O_5 and 20 kg K_2O/h was applied in rice and maize, respectively as farmer's fertilizer practice treatments. The crops in all the plots were raised under optimum conditions. Apart from differences in nutrient application rates, all other practices were the same for SSNM, SR and farmer's practice. N, P, K and S were applied in the form of urea, diammonium phosphate, muriate of potash and elemental sulphur. Hybrid rice variety PHB-71 was transplanted by 1st week of July at a spacing of 20 x 10 cm^2 and maize variety Shaktiman-3 was sown in last week of November with a spacing 60x20 cm^2. The hybrid rice was harvested in the last week of October and maize was harvested in the 2nd week of May. The prevailing market price of different commodities was used to work out the rice-equivalent yield and economics of the system. The data of 2 years were pooled and subjected to statistical analysis. Nutrient uptake of N, P,K and S by plants were computed using standard procedures. After harvesting, separate soil samples were collected from each plot for estimation of organic carbon, available N, P, K and S.

Results and Discussion

Grain yield of rice and maize

Among the three nutrients management options tried in the study, SSNM proved significantly superior to farmers practice and state recommendations. Application of 150 kg N, 60 kg P_2O_5, 100 kg K_2O in both rice and maize and 40 kg S/ha only in rice recorded the highest grain yields of hybrid rice (79.1 q/ha), maize (90.5 q/ha) system productivity (169.6 q/ha) and rice-equivalent yield (161.7 q/ha), which brought an improvement of 28.8 q/ha in rice ,22.6 q/ha in maize, 51.8 q/ha in system productivity and 49.5 q/ha in rice-equivalent yield over farmer's practice . The magnitude of such advantage over state recommendation were 16.4, 13.2, 29.6 and 29.7 q/ha, respectively (Table 1). Omission of any of the nutrient (P_2O_5 and K_2O in rice and maize and S in rice) in spite of application of 150 kg N /ha and also the rest of nutrients , grain yields of rice and maize as well as rice-equivalent yield decreased significantly than that recorded under the treatment giving the highest yield ($SSNM_6$). Significant yield advantage under SSNM treatments may

Table 1. Effect of site specific nutrient management on grain, straw, rice-equivalent yields and economics of rice and maize (mean of 2 years)

Treat-ment	Nutrients (kg/ha)				Grain yield (q/ha)		Increase over S.R.(q/ha)		Straw/Stover yield (kg/ha)		System (q/ha)	REY (q/ha.)	Cost of culti-vation (Rs./ha)	Net returns (Rs./ ha)	B:C ratio
	N	P_2O_5	K_2O	S*	Rice	Maize	Rice	Maize	Rice	Maize					
$SSNM_1$	150	30	100	40	76.23	84.21	21.6	8.9	99.81	141.20	160.44	153.14	45,193	65,490	1.45
$SSNM_2$	150	60	100	40	79.05	90.54	26.1	17.1	103.32	151.86	169.59	161.72	46,450	70,955	1.53
$SSNM_3$	150	0	100	40	65.74	72.49	4.9	-6.2	90.25	122.21	138.23	131.95	43,940	52,581	1.20
$SSNM_4$	150	30	50	40	73.51	81.31	17.3	5.2	96.92	137.00	154.82	147.78	44,423	63,034	1.42
$SSNM_5$	150	30	0	40	62.95	69.89	0.4	-9.6	86.59	118.84	132.84	126.78	43,653	49,112	1.13
$SSNM_6$	150	30	100	60	77.76	85.99	24.1	11.2	101.86	144.65	163.75	156.31	45,543	67,847	1.49
$SSNM_7$	150	30	100	20	70.97	80.60	13.2	4.3	95.58	136.72	151.57	144.59	44,593	59,935	1.34
$SSNM_8$	150	30	100	0	67.63	78.93	7.9	2.12	93.30	134.13	146.56	139.79	43,993	58,148	1.32
S.R.	100(120)	40(75)	20(50)	0	62.67	77.30	-	-	88.20	129.67	139.97	132.04	43,487	54,126	1.24
F.P.	70(100)	30(30)	15(20)	0	50.28	67.88	-	-	76.49	118.12	118.16	112.23	41,468	41,664	1.00
	SEm±				1.78	1.98	-	—	2.03	3.35	-	2.68	-	1,997	0.04
	CD(P=0.05)				**5.14**	**5.71**	**-**	**-**	**6.08**	**9.71**	**-**	**7.76**	**-**	**5,789**	**0.12**

* Sulphur was applied to rice only, F.P. - Farmer's fertilizer practice, SR – State recommendation, REY- rice-equivalent yield.

be due to the application of higher amounts of nutrients which might have increased the availability of nutrients in root zone and thus greater uptake of nutrients by plants resulted in higher grain production. Regmi and Ladha (2004) also reported significant increase in yield of rice- wheat through SSNM over local management practice

Effect of P_2O_5

Rice responded significantly only up to 30 kg P_2O_5 /ha whereas maize responded significantly up to 60 kg P_2O_5 /ha. (Table 1). Application of 60 kg P_2O_5/ ha in both the crops increased the yield of rice , maize and rice-equivalent yield by 13.3, 18.0 and 29.8 q/ha over the crop raised without P-applications . The possible reason for increase in grain yields with phosphorus fertilizers could be attributed to the fact that phosphorus plays a key role in root development. The increased root bio-mass might have improved the nutrient-uptake by exploiting greater volume of soil resulting in better physiological and metabolic functions inside the plant body which in turn laid down the foundation of higher yields in both the crops. Sharma *et al.* (1998) also reported the similar results in rice- wheat system.

Effect of K_2O

Significant response in grain and straw yields of rice and maize were recorded with the application of 50 kg K_2O/ha. Application of 50 kg K_2O/ha ($SSNM_4$) gave 10.6, 11.4 and 21.0 q/ha additional yield of rice, maize and rice-equivalent yield over no K- application. Increasing dose beyond 50 kg K_2O /ha could not bring any significant yield advantage. Higher yields under K application was ascribed to increasing photosynthetic activities , resulting higher production of photosynthates and their translocation to sink , which might have directly contributed towards the better yield. The increase in grain yield with increasing rates of K application has been reported by Tiwari (2002).

Effect of Sulphur

Application of gradient of S (0, 20, 40 and 60 kg/ha) in rice and their residual effect on maize brought a linear increase in productivity of rice and maize crop but the responses were significant only up to 40 kg/ha (Table 1). At this application rate, rice and maize crop had 8.6 and 5.3 q/ha yield gain at the rate of 12.7 and 6.6 %, respectively over no S-application. The increase in grain yield of wheat with residual effect of S-application was also reported by Singh *et al.* (2005). This could be attributed to the fact that S application improved nutritional environment of rhizosphere as well as nutrient uptake and ultimately metabolic and photosynthetic activities, resulting in better yield of both the crops

Economics

Economic analysis of data revealed that the highest net returns of Rs.70,955 /ha from the rice-maize system was realized with the application of 150 kg N + 60 kg P_2O_5 + 100 kg K_2O /ha in both the crops and 40 kg S/ha only in rice, which, however, was at par with those treatments which got 150 kg N along with 30 kg P_2O_5 and 100 Kg K_2O/ha and 40 or 60 kg S ($SSNM_6$ & $SSNM_1$). The highest economic return giving treatment ($SSNM_2$) earned an additional income of Rs.29,291 /ha and Rs.16,829 /ha over the farmers' practice and state recommendation, respectively. The treatment showing the highest net return also had the highest B: C ratio (1.53). The farmer's practice had the lowest profitability (Rs.41,664 /ha). It was also noted that skipping P_2O_5 from the fertilizer schedule caused highest reduction in profitability (Rs 21,843 /ha/ year), followed by K_2O (Rs 16,378/ha) and S (Rs 7,912/ha).Thus, balancing N, P, K with S is necessary for profit maximization.

Nutrient uptake

The application of 150kg N, 60 kg P_2O_5, 100 kg K_2O/ha in rice and maize and 40 kg S/ha only in rice resulted in significantly higher N, P,K and S uptake by rice and maize crops over farmer's practice, state recommendation and the treatment in which either of the P_2O_5,K_2O and S were skipped from fertilizer schedule (Table 2). The application of fertilizers as per crop's needs increased its uptake by rice and maize owing to fertilizer application might have improved the availability of nutrient in the soil which led to increased nutrient content in the plant and ultimately uptake.

Increasing levels of P_2O_5 and K_2O in rice and maize S in rice enhanced the P,K and S uptake by crops significantly up to 60 kg P_2O_5, 50 kg K_2O and 40 kg S /ha which increased its uptake by 30.9,19.7 & 26.1% in rice and 39.5, 19.2 and 22.7 % in maize, respectively over their control. This increase in P,K and S uptake by crops can be ascribed to the influence of applied P_2O_5 ,K_2O and S on availability of nutrients in the soil as well as in view of prolific root system developed by balanced nutrient application giving rise to better absorption of water and nutrient. Moreover, the uptake followed the pattern of yield. These results are in close conformity with the findings of Viravipour et al (1999)

Total N,P and K uptake data (Table 2) also revealed that in the process of producing 169.6 q/ha grain with the application of 150 kg N,60 kg P_2O_5 and 100 kg K_2O /ha in rice and maize and 40 kg S/ha only in rice-maize system absorbed 907.9 kg N + P_2O_5 + K_2O. This value was composed of 38.8 % N, 13.4% P_2O_5 and 47.8% K_2O in a proportion of 100:35:123. On an average to produce a tonne of grain, rice absorbed 18.7 kg N,6.9 kg P_2O_5 and 24.2 kg K_2O, the corresponding figures for maize being 22.6 kg N, 7.4 Kg P_2O_5 and 26.8kg K_2O/ ha. In addition to N,P and K the rice-maize system absorbed 88.6 kg S/ha. Out of the total NPK uptake the share of rice was 43% and that of maize was 57%. The greater share of maize was primarily due to its higher productivity. Similar results were reported by Tiwari and Sharma (2006).

Response functions

Response to P, K and S were quadratic, indicating the operation of the law of diminishing return.

Phosphorus:	Rice: $Y= 65.74 + 0.48 X-0.0043 X^2$
Maize:	$Y=72.49 + 0.48 X - 0.0030 X^2$
Potassium:	Rice: $Y = 62.95 + 0.29 X- 0.0016 X^2$
Maize:	$Y=69.89 + 0.31X – 0.0017 X^2$
Sulphur:	Rice: $Y= 67.35 + 0.25 X - 0.0011 X^2$

Where Y, Grain yield (q/ha); X , dose of specific nutrient.

As per above equations, the optimum dose of P_2O_5, K_2O and S for rice were worked out to be 54.7, 89.6 and 69.9 kg/ ha, respectively. The corresponding values of optimum yield were 79.1, 76.3 and 80.3 q/ha, respectively. The optimum dose of P_2O_5 and K_2O for maize were also calculated, which were 78.4 and 89.4 kg/ha and their corresponding yield were 91.8 and 84.3 q/ha, respectively. As compared to the state recommendation of 20 and 50 kg /ha for rice and maize developed long back, the computed value of K_2O requirement for

Table 2. Nutrient uptake (kg/ha) by rice and maize as influenced by site specific nutrient management (mean of 2 years)

Treat-ment	Nutrient (kg/ha)				Nutrient uptake (kg/ha)											
					Rice				Maize				Rice-maize system			
	N	P_2O_5	K_2O	S	N	P_2O_5	K_2O	S	N	P_2O_5	K_2O	S	N	P_2O_5	K_2O	S
$SSNM_1$	150	30	100	40	141.4	51.6	185.4	33.8	189.4	59.8	226.1	49.7	330.8	111.4	411.5	83.5
$SSNM_2$	150	60	100	40	147.9	54.6	190.7	34.9	204.4	67.4	242.9	53.7	352.3	122.0	433.6	88.6
$SSNM_3$	150	0	100	40	123.6	41.7	164.4	28.8	161.7	48.3	194.0	43.3	285.3	90.0	358.3	72.1
$SSNM_4$	150	30	50	40	140.1	49.4	171.2	32.9	183.4	56.1	208.7	48.4	323.4	105.4	379.9	81.2
$SSNM_5$	150	30	0	40	120.2	42.7	137.6	28.1	157.5	49.0	175.1	41.6	277.6	91.7	312.6	69.7
$SSNM_6$	150	30	100	60	146.7	53.9	189.5	35.9	195.3	61.6	228.6	50.5	342.0	115.4	418.0	86.3
$SSNM_7$	150	30	100	20	136.3	48.0	173.1	31.0	180.2	58.2	218.7	45.8	316.5	106.2	391.8	76.8
$SSNM_8$	150	30	100	0	129.9	46.7	166.5	26.8	177.2	56.4	212.7	40.5	307.0	103.1	379.1	67.2
S.R.	100(120)	40(75)	20(50)	0	113.7	43.8	147.8	24.4	158.8	55.9	192.3	39.4	272.4	99.7	340.0	63.8
F.P.	70(100)	30(30)	15(20)	0	90.1	34.9	120.3	19.6	136.1	45.1	167.2	33.8	226.2	80.0	287.4	53.4
		SEm±			3.2	1.2	4.0	0.8	4.7	1.4	5.9	1.1	5.8	1.9	7.1	1.4
		CD (P=0.05)			9.2	3.4	11.6	2.2	14.0	4.0	17.0	3.2	16.7	5.4	20.6	4.0

rice and maize were much higher. The P_2O_5 doses under recommendation are close to that worked out under this experiment. At present S application is not recommended and to be essential for increasing crop productivity of rice-maize system.

Energetics

The highest energy input (56,230 MJ/ha) and energy output (5, 68,259 MJ/ha) was realized with the application of 150 Kg N + 60 Kg P_2O_5 + 100 Kg K_2O to both rice and maize and 40 Kg S/ha only to rice, which showed statistical parity with the treatment receiving 150 Kg N + 30 Kg P_2O_5 + 100 Kg K_2O to both rice and maize and 60 Kg S/ha to rice only (Table 3). The Higher energy output in these treatments was mainly due to higher yield of crops. The treatment giving the highest energy output ($SSNM_2$) also showed the highest energy output: input ratio (10.1) as well as energy productivity (301.6 g/MJ) and the lowest specific energy (331.6 MJ/q).

Fertility status of soil

Application of balanced dose of nutrients in rice and maize was helpful in improving organic carbon, available N and P_2O_5 contents of the soil (Table 4). However, organic carbon, available N and P content slightly reduced in farmer's fertilizer practice when compared with initial value. Although, the variation was very marginal. A marginal decline in K-status from its initial level was also observed in all the treatments. Application of balanced dose of nutrients maintained the initial level of sulphur, of the soil. The treatments in which P or K or S were skipped showed reduction in available P, K and S content in the soils.

On the basis of results, it can be inferred that application of 150 kg N + 30

Table 3. Energetics as influenced by site specific nutrient management (mean of 2 years)

Treat-ment	Nutrients(kg/ha)				Energy Input (MJ/ha)	Energy Output (MJ/ha)	Energy output: input ratio	Specific energy (MJ/q)	Energy produc-tivity (g/MJ)
	N	P_2O_5	K_2O	S					
$SSNM_1$	150	30	100	40	55,564	5,37,096	9.7	346.3	288.7
$SSNM_2$	150	60	100	40	56,230	5,68,259	10.1	331.6	301.6
$SSNM_3$	150	0	100	40	54,898	4,68,766	8.5	397.2	251.8
$SSNM_4$	150	30	50	40	54,894	5,19,973	9.5	354.6	282.0
$SSNM_5$	150	30	0	40	54,224	4,52,056	8.3	408.2	245.0
$SSNM_6$	150	30	100	60	55,982	5,48,843	9.8	341.9	292.5
$SSNM_7$	150	30	100	20	55,146	5,13,176	9.3	363.8	274.8
$SSNM_8$	150	30	100	0	54,728	4,99,731	9.1	373.4	267.8
S.R.	100(120)	40(75)	20(50)	0	49,620	4,78,080	9.6	354.5	282.1
F.P.	70(100)	30(30)	15(20)	0	45,711	4,16,944	9.1	386.9	258.5
		SEm±			-	9,025	0.2	6.1	4.3
		CD(P=0.05)			-	**26,292**	**0.5**	**17.4**	**13.2**

Table 4. Effect of site-specific nutrient management on fertility status of soil.

Treatments	Nutrients (kg/ha)				Organic carbon (%)	Available Nutrients (Kg/ha)			
	N	P_2O_5	K_2O	S		N	P_2O_5	K_2O	S
$SSNM_1$	150	30	100	40	0.53	185.2	34.20	210.4	22.20
$SSNM_2$	150	60	100	40	0.54	183.3	39.41	208.2	22.53
$SSNM_3$	150	0	100	40	0.51	197.5	26.82	212.3	23.82
$SSNM_4$	150	30	50	40	0.52	185.7	35.23	204.5	23.65
$SSNM_5$	150	30	0	40	0.51	194.8	34.35	199.6	24.26
$SSNM_6$	150	30	100	60	0.54	186.8	35.91	207.6	26.10
$SSNM_7$	150	30	100	20	0.52	188.5	35.75	209.7	22.70
$SSNM_8$	150	30	100	0	0.51	190.2	36.82	210.6	18.65
S.R.	100(120)	40(75)	20(50)	0	0.50	173.6	38.35	205.4	18.31

kg P_2O_5 + 50 kg K_2O + 40 kg S/ha in rice and 150 kg N + 60 kg P_2O_5 + 50 kg K_2O/ha in maize were found optimum for maximization of productivity and profitability without deteriorating the fertility of soil of rice – maize cropping system.

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PERMANENT PLOT EXPERIMENT ON INTEGRATED NUTRIENT SUPPLY SYSTEM IN PEARL MILLET [*PENNISETUM GLAUCUM* (L.) R. BR. EMEND STUNTZ] – WHEAT (*TRITICUM AESTIVUM* L. EMEND. FLORI & PEOL) CROP SEQUENCE

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ABSTRACT

A field experiment was conducted during 1986-87 to 1995-96 in North Gujarat Agro-climatic region to study the integrated nutrient management through organic and inorganic sources of fertilizer in pearl millet [*Pennisetum glaucum* (L.) R. Br. emend stuntz] – wheat (*Triticum aestivum* (L.) emend. Flori & Peol) crop sequence. The maximum pearl millet grain yield was obtained from 75 per cent recommended NPK dose through chemical fertilizer (80 - 40 - 00) + 25 per cent N through green organic manure (guar). While in *rabi*, the maximum wheat yield was obtained from 50 per cent recommended NPK dose through fertilizers along with 50 per cent N through crop residue (wheat cut straw) in *kharif* followed by 100 per cent recommended dose through chemical fertilizer in *rabi*. The total productivity in pearl millet wheat crop sequence was higher when the pearl millet crop received 50 per cent N through green manuring along with 50 per cent recommended NPK nutrients and 100 per cent recommended NPK nutrient to wheat crop. The total uptake of nutrients was higher when fertilizer was applied at 100 per cent recommended level. The nutrient status was built for nitrogen, phosphorus and organic carbon whereas potash content of soil was not much affected.

Pearl millet [*Pennisetum glaucum* (L.)] – wheat [*Triticum aestivum* (L.)] is popular crop sequence in irrigated area in North Gujarat Agro-climatic Zone. The judicious and balanced fertilization through organic manures and inorganic fertilizers can maximize farm production per unit area. Organic manures and other renewable sources are helpful for the maintenance of soil fertility, but inorganic fertilizers will be one of the main instruments for increasing the pace of agricultural production. Thus, it is necessary to find out their suitable combination with organic manures to get maximum yield of crops.

The present experiment was therefore, under taken to find out the long term effect of cereal based cropping sequence and manuring for getting higher crop production without impairing the soil health.

MATERIALS AND METHODS

A field experiment was conducted during the year 1986-87 to 1995-96 of rainy (*Kharif*) and winter (*Rabi*) seasons at main Cropping Systems Research Centre, Gujarat Agricultural University, Sardarkrushinagar (Gujarat) on loamy sand soil with initial soil status of 191 kg N, 28 kg P_2O_5 and 216 kg K_2O/ha. The climate was arid. The long dry spell is common occurrence in the rainy season.

The experiment was laid out in randomized block design in fixed plots having twelve treatments. The treatments consisted of applying different levels of inorganic fertilizers, either alone or in combination with organic manures

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Table 1. Treatment details

Treatment	*Kharif*	*Rabi*
T_1	No fertilizerNo organic manure (Control)	No fertilizerNo organic manure (Control)
T_2	50% recommended NPK dose through fertilizers	50% recommended NPK dose through fertilizers
T_3	50% recommended NPK dose through fertilizers	100% recommended NPK dose through fertilizers
T_4	75% recommended NPK dose through fertilizers	75% recommended NPK dose through fertilizers
T_5	100% recommended NPK dose through fertilizers	100% recommended NPK dose through fertilizers
T_6	50% recommended NPK dose through fertilizers + 50 % N through FYM	100% recommended NPK dose through fertilizers
T_7	75% recommended NPK dose through fertilizers + 25 % N through FYM	75% recommended NPK dose through fertilizers
T_8	50% recommended NPK dose through fertilizers + 50 % N through wheat cut straw	100% recommended NPK dose fertilizers
T_9	75% recommended NPK dose through fertilizers + 25 % N through wheat cut straw	75% recommended NPK dose fertilizers
T_{10}	50% recommended NPK dose through fertilizers + 50 % N through green organic matter	100% recommended NPK dose through fertilizers
T_{11}	75% recommended NPK dose through fertilizers + 25 % N through green manure	75% recommended NPK dose through fertilizers
T_{12}	Farmer practices (40-00-00)	Farmer practices (80-00-00)

at different proportions to rainy (*Kharif*) seasons pearl millet and only in organic fertilizers at different levels to the following winter (*Rabi*) season wheat (Table 1). The fertilizers levels were 100, 75 and 50 per cent of the recommended dose. The recommended fertilizers at 100 per cent level were applied @ 80 kg N, 40 kg P_2O_5 and 0 kg K_2O for rainy season pearl millet and 120 kg N, 60 kg P_20_5 and 0 kg K_2O for winter – season wheat. The inorganic fertilizers were supplied through urea and single super phosphate fully decomposed FYM and wheat cut straw were applied to respective treatments and thoroughly mixed with soil by harrowing, whereas, green organic matter cluster bean (*Cyamopsis tetragonoloba*) was applied to respective treatments 30 days before sowing and was mixed in soil by harrowing. Full dose of P and half of N was applied at the sowing time and remaining half nitrogen was top dressed to both the crops at 30 days after sowing.

N content of grain and straw was determined by Kjeldhal's method (Jackson, 1973) and N uptake was calculated with the data of dry matter production.

Results and Discussion

The pooled data showed that grain yield of pearl millet increased significantly due to application of different organic and inorganic sources of fertilizers compared with control. The

Table 2. Pearl millet grain yield (kg/ha)

Treatment	YEAR								
	1986-87	**1987-88**	**1988-89**	**1989-90**	**1990-91**	**1993-94**	**1995-96**	**Pooled**	**Y x T**
T_1	181	455	488	263	67	—	—	206	**
T_2	654	2037	1053	726	510	191	139	758	**
T_3	506	2188	1235	869	624	196	156	825	**
T_4	722	1924	1333	1061	559	247	170	858	**
T_5	940	2131	1538	1135	597	319	580	1034	**
T_6	712	2459	1225	1050	678	260	451	977	**
T_7	828	2847	1471	1170	623	326	479	1181	**
T_8	656	2211	1182	1038	636	214	403	906	**
T_9	700	2250	1220	1010	650	280	575	955	**
T_{10}	715	3030	1878	1962	736	351	486	1308	**
T_{11}	1160	3010	2270	1998	735	333	413	1417	**
T_{12}	822	1638	1323	1047	550	33	52	781	**
S.Em.± (kg/ha)	51	154	65	37	22	11	29	98	69.0
C.D. at 5 %	147	444	186	105	63	31	84	276	191
C.V.%	13.8	14.06	9.6	6.58	7.56	9.41	18.57	14.83	

1991-92, 1992-93 and 1994-95 failed.

maximum pearl millet grain yield (1417 kg/ha) was obtained from 75 per cent recommended NPK dose through chemical fertilizer (80-40-00) plus 25 per cent N through green organic matter (Guar) but was at par with T_{10} (50% recommended NPK + 50 % N through green organic matter) and T_7 (75 % through recommended NPK chemical fertilizers + 25 % N through FYM) and superior to rest of all the treatments. This clearly indicates the beneficial role of organic matter. The same trend was also observed in most of the individual years data (Table 2).

The maximum wheat yield (1819 kg/ ha) was obtained from T_8 (50% recommended NPK dose through fertilizer along with 50 % through crop residue in *kharif* followed by 100 % recommended dose through fertilizers in *rabi* (120-60-00). However, it remained at par with T_3 (50 % recommended NPK fertilizer in *kharif* followed 100 % recommended NPK in *rabi*), T_5 (100 recommended NPK in *kharif* and *rabi*), T_6 (50 % recommended NPK through fertilizer + 50 % N through FYM in *kharif* a followed 100 % recommended dose in *rabi*), T_7 (75 % recommended NPK + 25 % N through FYM in *kharif* followed 75 % recommended NPK dose through fertilizer in *rabi*), T_{10} (50% recommended NPK + 50 % N through green manuring in *kharif* followed 100 % recommended NPK dose through fertilizer in *rabi*), T_{11} (75 %

Table 3. Wheat grain yield (kg/ha)

Treatment	YEAR										
	1986-87	1987-88	1988-89	1989-90	1990-91	1993-94	1994-95	1995-96	Pooled	YxT	Total
T_1	504	496	493	363	57	45	22	00	245	**	451
T_2	1618	1260	1568	691	658	630	695	344	933	**	1691
T_3	2684	2143	2401	757	1132	1410	1196	372	1512	**	2337
T_4	1817	1818	1929	720	872	1067	754	417	1174	**	2032
T_5	2066	2016	2131	650	898	1397	1809	1705	1584	**	2618
T_6	2387	2183	2228	818	1045	1428	2109	2130	1791	**	2768
T_7	2124	2166	2316	795	1023	1320	1815	2066	1703	**	2884
T_8	2464	1910	2323	965	1292	1542	2009	2046	1819	**	2725
T_9	1816	1603	2016	826	924	799	1664	1932	1448	**	2403
T_{10}	2373	1986	1660	528	1613	1255	1951	1982	1668	**	2976
T_{11}	2212	1798	1464	441	1477	1271	1877	1894	1554	**	2971
T_{12}	2041	1795	1689	608	832	1104	69	66	1025	**	1806
S.Em.± (kg/ha)	175	95	156	39	66	85	19	50	129	**	
C.D. at 5 %	505	274	449	112	197	246	52	144	362	278	
C.V.%	17.47	10.79	16.85	11.46	13.90	15.46	8.75	8.03	14.64		

Table 4. Economics of crop sequence pearl millet and *rabi* wheat

Treatments	*Kharif* pearlmillet					*Rabi* wheat					Total net income (Rs./ha)	Gross profit *kharif* +*rabi* (Rs./ha)	Cost of culti-vation *kharif* +*rabi* (Rs./ha)	Total CBR (Rs./ha)
	Av. yield of grain (kg/ha)	Av. yield of straw (kg/ha)	Gross return (kg/ha)	Cost of culti-vation (kg/ha)	Net income (kg/ha)	Av. yield of grain (kg/ha)	Av. yield of straw (kg/ha)	Gross return (kg/ha)	cost of culti-vation (kg/ha)	Net income (kg/ha)				
T_1	206	765	1692	4197	-2505	245	508	1966	6300	-4334	6839	3658	10497	0.348
T_2	758	2233	5644	4981	663	933	1554	7308	7473	-165	498	12952	12454	1.040
T_3	825	2302	6015	4981	1034	1512	2205	11686	8646	3040	4074	17701	13627	1.299
T_4	958	2376	6237	5373	864	1174	1918	9177	8060	1117	1981	15414	13433	1.147
T_5	1034	2774	7427	5764	1663	1584	2299	12238	8646	3592	5255	19665	14410	1.365
T_6	977	2555	6952	5763	1189	1791	2387	13731	8646	5085	6274	20683	14409	1.435
T_7	1181	2725	8040	5737	2303	1703	2251	13047	8060	4987	7290	21087	13797	1.528
T_8	906	2563	6640	6519	121	1819	2510	13988	8646	5342	5463	20628	15165	1.360
T_9	955	2561	6859	6142	514	1448	2163	11218	8060	3158	3672	18077	14202	1.273
T_{10}	1308	3134	9020	6442	2358	1668	2364	12858	8646	212	6570	21870	15088	1.450
T_{11}	1417	3287	9664	6113	3351	1554	2176	11966	8060	3906	7257	21630	14173	1.526
T_{12}	781	1673	5188	4510	478	1025	1733	8042	7813	229	707	13230	12323	1.074

Table 5. Total nutrient uptake (kg/ha) under permanent plot experiment on integrated nutrient supply systems (Year : 1986-87 to 1995-96) Consequence : Pearlmillet – Wheat

Nutrient/ Treatments		Treatments											
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
1986-87	N	17.75	62.92	81.55	97.77	79.27	86.72	76.38	78.82	76.24	87.54	82.08	79.53
	P	6.26	19.49	28.87	21.85	25.06	26.70	22.76	28.08	22.10	28.70	27.00	23.20
	K	22.60	69.97	78.86	82.48	97.07	83.02	85.18	89.84	104.04	87.83	109.79	85.95
1987-88	N	13.17	50.56	52.90	57.06	62.04	61.42	63.65	56.17	63.47	80.66	73.81	42.69
	P	5.40	20.20	19.95	18.80	20.08	20.10	22.22	21.68	22.95	24.52	23.98	14.53
	K	37.70	115.90	104.64	102.45	118.20	120.23	122.66	138.89	145.47	146.56	128.29	78.44
1988-89	N	27.28	70.43	100.33	83.19	94.08	89.33	94.54	92.75	84.00	97.00	109.16	81.15
	P	10.54	27.96	41.12	34.75	37.18	36.13	40.95	39.58	34.60	36.81	39.97	30.79
	K	40.38	105.42	154.52	123.86	151.55	140.36	159.00	163.11	143.05	143.47	154.44	133.95
1989-90	N	21.76	47.59	58.89	61.75	59.09	65.19	71.28	62.65	59.49	82.39	76.92	56.34
	P	6.10	13.68	16.11	18.21	17.77	18.17	20.19	18.44	17.68	23.45	23.77	16.67
	K	37.80	78.73	86.39	95.00	87.28	95.96	98.66	81.36	88.93	130.52	125.03	88.75
1990-91	N	8.43	16.25	19.25	19.53	19.97	21.20	20.39	21.51	20.43	25.40	26.76	20.59
	P	2.14	6.72	7.73	7.85	8.41	14.64	8.31	9.13	8.14	10.15	10.02	8.23
	K	19.66	39.51	44.60	46.00	41.00	45.33	49.59	50.89	46.88	60.36	59.34	53.24
1991-92	N	5.92	25.03	38.00	29.82	27.70	32.97	30.96	40.42	28.88	44.00	42.51	30.91
	P	2.47	12.00	17.18	14.02	14.03	15.39	15.09	18.76	13.87	21.47	20.61	13.99
	K	17.25	45.94	55.82	56.07	49.07	48.64	48.73	58.17	44.32	55.78	57.85	53.48
1992-93						........FAILED........							
1993-94	N	4.37	39.55	59.21	50.25	63.97	57.56	58.63	68.46	48.46	62.02	59.64	33.64
	P	1.76	16.04	27.83	22.68	28.76	26.25	25.68	30.15	21.21	27.64	27.30	15.65
	K	8.20	61.10	73.08	73.00	85.44	76.17	87.84	88.48	74.33	96.21	82.83	35.79
1994-95	N	1.57	21.19	30.31	19.00	40.75	48.77	41.67	48.92	37.15	52.16	45.74	4.93
	P	0.35	4.46	6.07	3.90	8.96	11.14	11.45	10.14	8.60	10.16	11.00	0.69
	K	2.97	15.66	25.08	16.04	33.93	41.70	35.71	37.54	32.82	28.60	39.63	4.16
1995-96	N	3.25	31.52	40.67	40.92	86.49	86.91	85.93	75.50	73.54	80.17	73.30	7.81
	P	0.81	7.08	10.91	11.55	26.05	22.86	17.76	18.19	15.81	21.03	17.99	1.52
	K	7.13	57.98	83.79	74.67	121.79	107.49	96.17	100.38	90.15	114.11	97.26	16.72

Table 6 : Soil fertility status (kg/ha) after *rabi* crops under permanent plots experiment on integrated nutrient supply system

(Year : 1986-87 to 1995-96) Crop sequence : Bajra – Wheat

Available Nutrients (kg/ha)		Treatments											
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
1990-91	N	142.5	147.5	152.5	149.5	152.5	146.0	142.5	144.5	152.5	146.0	147.5	152.5
	P	18.5	14.5	12.5	15.5	14.5	13.5	13.5	11.0	15.0	16.5	17.5	15.5
	K	180.5	175.5	165.5	165.5	150.6	170.0	170.5	180.5	165.5	165.5	170.5	170.5
O.C.(%)		0.12	0.14	0.14	0.13	0.25	0.15	0.10	0.21	0.23	0.21	0.17	0.14
1991-92	N	152.5	149.5	157.5	152.5	146.0	152.5	149.5	152.5	146.0	157.5	152.5	146.0
	P	14.0	15.5	17.5	15.5	18.5	14.5	17.5	18.5	13.5	14.5	15.5	15.0
	K	176.0	180.0	184.0	180.0	188.0	180.0	180.0	188.0	180.0	160.0	172.0	177.0
O.C.(%)		0.21	0.23	0.20	0.22	0.22	0.23	0.25	0.21	0.22	0.23	0.25	0.23
1993-94	N	158.0	158.0	160.0	163.0	160.0	159.0	158.0	158.0	158.0	158.0	157.0	159.0
	P	22.0	20.0	19.0	29.0	20.0	21.0	21.0	21.0	21.0	19.0	21.0	22.0
	K	193.0	199.0	202.0	207.0	199.0	204.0	209.0	199.0	204.0	207.0	207.0	199.0
O.C.(%)		0.23	0.26	0.23	0.24	0.21	0.24	0.25	0.26	0.27	0.25	0.20	0.22

recommended NPK + 25 % N through green manuring followed 75 % recommended NPK dose through fertilizer) in *rabi*. But the next treatment was T_6 (1791 kg/ha) (50 % recommended NPK + 50 % N through FYM in *kharif* followed 100 % recommended NPK in *rabi*). But, if we look into the average total grain yield of bajra and wheat crops substitution of 50 per cent N through the green manuring (guar) along with 50 per cent recommended NPK nutrients to *kharif* bajra and 100 per cent recommended NPK to wheat crop yielded (1976 kg/ha) which was closely followed by the treatment of 25 per cent N substitution through green manuring in conjunction with 75 per cent recommended N, P and K nutrients to *kharif* bajra and 75 per cent recommended N, P and K to the wheat crop. It clearly indicates that the application of green matter in combination with application in the form of inorganic fertilizers is superior to sole inorganic fertilization. Beneficial effect of green manuring (guar) and FYM application during *kharif* season on the succeeding wheat crop has also been reported by Chahal *et al.* (1984) (Table 3).

ECONOMICS

The results revealed that the highest net return of Rs.7290/ha was received from T_7 [application of 75 % recommended NPK dose through fertilizers + 25% N through FYM to pearl millet crop (80-40-00) NPK kg/ha] and 75 per cent recommended NPK dose through fertilizers to wheat crop *i.e.*, 90 kg N and 45 kg P_2O_5/ha (CBR 1.528) followed by net highest Rs.7257/ha from T_{11} (75 % recommended NPK + 25% N through green manuring to pearl millet and 75 % recommended NPK dose through fertilizers to wheat crop (90 kg N + 45 kg P_2O_5) (CBR 1.526) which are almost equal (Table 4).

It is evident that organic sources help to reduce 25 per cent nutrient requirement and also helpful for sustainable agriculture.

N, P and K uptake

The total uptake of NPK by plants was considerably higher when fertilizer applied at 100 per cent recommended level. It is evident that the higher uptake of the nutrients by the crops was contributed towards the increased grain yield which was not possible in the control (No fertilizer treatment) Table 5.

Soil fertility status

The data presented in Table 6, revealed that nutrient status was built for nitrogen, phosphorus and organic carbon whereas potash content of soil was not much affected (Table 6).

It could be inferred that in loamy sand soil, the pearl millet – wheat productivity could be improved with the application of fertilizers at 100 per cent recommended level of nutrients. It is clear that for maintenance of stable soil fertility in pearl millet – wheat cropping sequence a part of total nutrient should be applied through organic source like farm yard manure, green manure or wheat cut straw.

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POSSIBLE ALTERNATIVE CROPPING SYSTEMS FOR FARMERS OF SEMI ARID HARYANA– INDIA

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Abstract

A six year study (2000-01 to 2005-06) was undertaken in semi arid Haryana, India to identify the cropping system(s) which may be more remunerative, eco friendly and sustainable over existing cropping system(s) and are farmer's friendly so that they may be convinced to shift to the new cropping system(s). The study indicated that pearlmillet-potato-green gram was profitable and efficient cropping system over prevalent cropping systems viz. cotton-wheat and pearlmillet-wheat. It gave wheat equivalent yield of 18340.1 kg ha^{-1} and profitability of Rs 56012.8 while the same values for cotton-wheat and pearlmillet-wheat were 9942.2 and 7129.3 kg ha^{-1} and 44269.6 and 34374.4 Rs ha^{-1}, respectively. The cropping system soybean-wheat-cowpea (fodder) was better to pearlmillet-wheat cropping system in terms of both crop yield and profit. Soybean-wheat-cowpea(f) had also been a good cropping system with wheat equivalent yield of 9725.5 kg ha^{-1} and net profit of Rs 40374.4 ha^{-1}. Under comparatively less availability of irrigation water pearlmillet-mustard was found to be promising cropping system with wheat equivalent yield of 6851.5 kg ha^{-1} and profitability of Rs 31100 ha^{-1}. Pearlmillet-fieldpea-maize (fodder) cropping system did not perform well over a period of six years.

Key words: Cropping systems, wheat equivalent, profitability, economic efficiency

Diversification in agriculture is a continuous process since the advent of agriculture to manage soil health, water and other natural resources (Yadav *et al.*, 2000, Panda, 2001 and Grover *et al.*, 2002). It also meets the changing human tastes/needs. Haryana is an agriculturally advance state of India and geographically very well placed i.e. close to national capital. The food requirement of these cosmopolitan communities/ groups residing in the vicinity is diverse and therefore to meet their needs the continuity in crop diversification is eminent and is clearly visible through changing area under different cropping systems over a period of time (Annon. 1966-67 and Annon. 2004-05). In 1966-67, the major rainy season crops (July to October) were pearlmillet (48%), sorghum (15%), rice (10%) and cotton (10%), while in 2004-05 the area under pearlmillet declined to 27% and that of cotton increased to 34% and rice to 24%. Similarly in winter season crops (November to April), the area under wheat has risen from 33% to 64%; mustard from 9% to 19% while the reversal took place in chickpea area which declined from 48% to 14% during the same period. The rice-wheat, cotton-wheat and pearlmillet-wheat cropping systems have established in Haryana but now these cropping systems are not proving farmers' friendly due to higher water need and susceptibility to insects and pests and adverse effect on soil health. Moreover, in the new millennium with the opening of Indian markets to the world there will be enormous pressure on Indian farmers to produce higher quantum of quality food at low cost from

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shrinking land and natural resources to meet the need of ever growing population and export to earn foreign exchange to meet the out flow particularly on petroleum products.

In India the technocrats and planners are of the view that agriculture must diversify into more commercial sense with the objective of producing higher quantum of quality food at sustainable level to enhance profitability. Therefore the need of the hour is to develop cropping system(s) with higher productivity, sustainability and economic viability for semi arid areas and therefore an attempt has been made to study the productivity, sustainability and viability of different cropping systems which may include food crops, cash crops, oil seeds and vegetables.

Materials and Methods

Site and soil characteristics

Field experiments were conducted for six years (2000-01 to 2005-06) at the Research Farm of CCS Haryana Agricultural University, Hisar, India, located at 74 27' 28" East longitude, 27 30' East latitude, 215.2 m altitude and the mean annual rainfall is 450 mm and most of it (around 80 per cent) is received in rainy season (July to September). The monthly rainfall during the study period for Hisar is given in Table 1. The area is characterized as semi-arid.

The soil has been classified as a Typic Haplustepts , loosely aggregated with sandy loam texture. The surface (0 – 15 cm) soil layer has 60.4 % sand, 16.9 % silt and 22.7 % clay. The slope of the

Table1. Monthly distribution of rainfall (mm) at the experimental site during the study period of 6 years

Month	Crop seasons						Total	Mean
	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06		
July	59.9	209.8	12.9	279.5	-	195.3	757.4	126.33
August	8.7	133.3	22.6	119.6	86.6	9.4	380.2	63.37
September	4.7	26.2	35.9	25.2	41.0	181.3	314.3	52.38
October	-	2.5	-	-	36.4	-	38.9	6.48
November	-	-	-	-	-	3.2	3.2	0.53
December	-	-	10.0	8.6	2.0	-	20.6	3.43
January	15.0	-	6.4	16.9	22.2	-	60.5	10.08
February	9.2	35.2	30.2	-	56.5	-	131.1	21.85
March	-	2.1	2.0	-	57.2	27.2	88.5	14.75
April	46.6	-	-	21.0	16.5	-	84.1	14.02
May	102.7	-	39.3	55.1	9.7	69.2	27.6	46.00
June	48.9	168.7	7.2	61.7	71.1	74.7	432.3	72.05

study area was less than 1%. The organic carbon content of the surface layer (0 – 15 cm) was 0.38 %. The available nitrogen, phosphorus and potash in surface layer was 122.3, 17.0 and 260.9 kg ha^{-1}, respectively. The soils had no salinity or drainage problem.

Treatments and crop husbandry

The rainy season, winter season and summer season crops were grown during July to October, October / November to April and April to June, respectively. The crops were sown in well moist field at their recommended sowing times. The experiment was established as a Balanced Incomplete Block Design with seven treatments and four replications. The details of the treatments consisted of seven cropping systems are given in Table 2**.** The individual plot size was 10 m x 8.1 m with 1 m margins on both sides of plot to curtail run off to adjunct plots. Recommended rates of fertilizers were applied to all the crops each year with nitrogen applied in two split doses, half at planting and the remaining half as top dressing as per recommendation through DAP and urea, respectively. The full dose of phosphorus and potassium were applied as compound fertilizer in the seed row and covered with soil at seeding. Planting was done each year at spacing as per recommendation for individual crop. The crops were thinned as per need and a recommended space was maintained between plants. The crops were harvested at their physiological maturity. Other agronomic operations and plant protection measures followed local recommendations.

Crop Measurements

The comparison among crop

Table 2. Details of cropping systems in the experiment from 2000-01 to 2005-06.

Treatments	Cropping systems		
	Rainy season	Winter season	Summer season
Pearlmillet-wheat	Pearlmillet (*Pennisetum glaucum*)	Wheat (*Triticum aestivum*)	-
Pearlmillet-mustard	Pearlmillet (*Pennisetum glaucum*)	Mustard (*Brassica juncea*)	-
Soybean-wheat-cowpea (fodder)	Soybean (*Glycine max*)	Wheat (*Triticum aestivum*)	Cowpea (fodder) (*Vigna unguiculata*)
Sorghum (fodder)-wheat	Sorghum (fodder) (*Sorghum bicolor*)	Wheat (*Triticum aestivum*)	-
Pearlmillet-potato-green gram	Pearlmillet (*Pennisetum glaucum*)	Potato (*Solanum tuberosum*)	Green gram (*Vigna radiata*)
Pearlmillet-field pea-maize (fodder)	Pearlmillet (*Pennisetum glaucum*)	Field pea (*Pisum sativum var. arvense*)	Maize (fodder) (*Zea mays*)
Cotton-wheat	Cotton (*Gossypium hirsutum*)	Wheat (*Triticum aestivum*)	-

sequences were made by converting the yield of all crops into wheat equivalent on current price basis (Yadav and Newaj, 1990). The current rates were used for computing economic viability. The economic efficiency of the systems was calculated by dividing the net returns ha^{-1} of a crop sequence by 365 days.

Results and Discussion

Crop productivity

Seasonal crop yield

Rainy season

The productivity data in Table 3 represent a mean of yield over a period of six years ranging from 2000-01 to 2005-06. Pearlmillet is one of the main rainy season crop (July to October) in semi-arid areas of Haryana. The mean pearlmillet yield among different cropping systems varied between 2659.2 and 3256.3 kg ha^{-1} (Table 3). The pearlmillet yield was lowest (2659.2 kg ha^{-1}) in pearlmillet-field pea-maize (fodder) cropping system and highest (3256.3 kg ha^{-1}) in pearlmillet-potato-green gram cropping system. The pearlmillet yield with two crops in a year i.e. pearlmillet-wheat and pearlmillet-mustard cropping systems (where the field was fallow in summer season) was moderate and ranged between 3003.8 and 3017 kg ha^{-1} while the yield even with 3-crops in a year was higher where leguminous crop (mung bean) was grown preceding to pearlmillet. The pearlmillet yield in pearlmillet-field pea-maize(f) cropping system was low and it might be due to exhaustive maize(f) grown in summer season. The pearlmillet yield was higher in treatment preceding green gram as compared to the fields kept fallow in summer season indicated that raising of leguminous crop in summer is beneficial in two ways i.e. resulting in higher yield of succeeding pearlmillet and the economic yield received from leguminous crop (Bhargavi *et al.*, 2008). The soybean, sorghum (fodder) and cotton yield of 2179.0, 36781.3 and 1808 kg ha^{-1}, respectively was recorded in soybean-wheat-cowpea (fodder), sorghum (fodder)-wheat and cotton-wheat cropping system, respectively.

Winter season

Four crops viz., wheat, mustard, potato and field pea were grown in winter season (October-November to April) in various cropping systems (Table 2).

Table 3. Productivity of different cropping systems (mean of six years i.e. from 2000-01 to 2005-06).

Cropping systems	Yield (kg ha^{-1})		
	Rainy season	Winter season	Summer season
Pearlmillet-wheat	3017.0	4866.5	-
Pearlmillet-mustard	3003.8	1877.0	-
Soybean-wheat-cowpea (fodder)	2179.0	4967.5	21142.7
Sorghum (fodder)-wheat	36781.3	4964.2	-
Pearlmillet-potato-green gram	3256.3	25479.0	616.4
Pearlmillet-field pea-maize (fodder)	2659.2	1108.3	32056.5
Cotton-wheat	1808.0	4828.2	-

Wheat is a major crop of this region in winter season and mean wheat yield in various cropping systems varied between 4828.2 and 4967.5 kg ha^{-1} (Table 3). The wheat yield was almost comparable in soybean-wheat-cowpea (4967.5 kg ha^{-1}) and sorghum (f)-wheat (4964.2 kg ha^{-1}) cropping systems and was higher than cotton-wheat (4828.2 kg ha^{-1}) and pearlmillet-wheat (4866.5 kg ha^{-1}) cropping systems. The other winter season crops *viz.*. mustard, potato and field pea recorded a yield of 1877, 25479 and 1108.3 kg ha^{-1}, respectively. During winter season, higher wheat yield was recorded in sorghum (fodder)-wheat cropping system for the reason that sorghum fodder crop is a short duration crop and the field remained fallow for several weeks before wheat sowing. The highest wheat yield in soybean-wheat-cowpea(fodder) might be due to two leguminous crops in this system. The wheat yield was slightly stressed in intensive and exhaustive cropping system viz. cotton-wheat. The field pea did not appear to be a successful and promising crop, however, mustard and potato were successful crops in winter season in this area (Annon., 2005-06).

Summer season

During summer season (April – June) three crops viz., cowpea and maize for fodder and green gram for seeds were grown in soybean-wheat-cowpea (fodder), pearlmillet-field pea-maize (fodder) and pearlmillet-potato-green gram cropping systems, respectively (Table 3). Cowpea and maize gave a fodder yield of 21142.7 and 32056.5 kg ha^{-1} and green gram gave a seed yield of 616.4 kg ha^{-1}.

Wheat equivalent yield of cropping systems

The different crops grown in the same season had differential yield potential and economic value and therefore for fair comparison among different cropping systems, the yield of all the crops were converted into wheat equivalent on price basis (Yadav and Newaj, 1990). It was noted that the mean wheat equivalent yield over a period of six years from 2000-01 to 2005-06 varied between 6851.5 and 18340.1 kg ha^{-1} among various cropping systems (Table 4). The highest yield of 18340.1 kg ha^{-1} was recorded in pearlmillet-potato-green gram cropping system and lowest yield of only 6851.5 kg ha^{-1} was recorded in pearlmillet-mustard cropping system. Comparatively lower wheat equivalent yield of 7014.2 and 7129.3 kg ha^{-1} was also recorded in pearlmillet-field pea-maize (f) and pearlmillet-wheat cropping systems, respectively. However, comparatively higher yield had been recorded in soybean-wheat-cowpea (fodder) (9725.5 kg ha^{-1}) and cotton-wheat (9942.2 kg ha^{-1}) cropping systems. Moderate wheat equivalent yield of 8116.9 kg ha^{-1} was recorded in sorghum (fodder)-wheat cropping system. Almost similar trend was observed during the six years of experimentation (Table 4). Highest wheat equivalent yield in pearlmillet-potato-green gram cropping system was mainly due to high yield potential and economic value of produce in this cropping system. Pearlmillet-mustard cropping system had low yield potential and therefore resulted in low wheat equivalent yield. The wheat equivalent yield of other cropping systems was also related to their yield potential and economic value of the produce (Gangwar *et al.* 2003 and Gangwar *et al.* 2004).

System productivity

System productivity represented by wheat equivalent yield in kg ha^{-1} day^{-1} had a wide range of 18.8 to 50.3 (Table 4). The pearlmillet-potato-green gram

Table 4. Wheat equivalent yield of different cropping systems from 2000-01 to 2005-06, mean system productivity (kg ha^{-1} day^{-1}) and net returns (Rs ha^{-1})

Cropping system	Cropping years						Mean of 6-yrs	Mean system productivity	Mean net returns
	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06			
Pearlmillet-wheat	6568.8	7425.3	7794.5	7527.5	6842.0	6617.5	7129.3	19.5	34374.4
Pearlmillet-mustard	5608.0	7231.9	7237.6	6790.1	6342.7	7899.1	6851.5	18.8	31100.0
Soybean-wheat-cowpea (fodder)	9214.4	8881.3	11375.6	10111.1	9399.8	9372.2	9725.5	26.7	40374.4
Sorghum (fodder)-wheat	7949.9	8279.6	8836.9	8563.1	7859.3	7213.2	8116.9	22.2	34570.4
Pearlmillet-potato-green gram	18469.1	14747.7	20295.7	19683.3	23790.2	13054.9	18340.1	50.3	56012.8
Pearlmillet-field pea-maize (fodder)	7017.1	5589.1	6421.1	8762.0	7301.5	6994.1	7014.2	19.2	21236.0
Cotton-wheat	8107.1	7611.9	9592.5	12585.4	10337.9	11418.5	9942.2	27.2	44269.6
CD (p=0.05)	592.4	563.6	638.8	538.6	667.2	468.2	-	-	-

cropping system had 50.3 kg ha^{-1} day^{-1} productivity which was 267.6 and 84.9 per cent higher than the lowest and next best cropping system. The system productivity other than pearlmillet-potato-green gram cropping system varied between 18.8 and 27.2 kg ha^{-1} day^{-1}. The cropping systems viz. pearlmillet-mustard, pearlmillet-field pea-maize (fodder) and pearlmillet-wheat had system productivity less than 20 kg ha^{-1} day^{-1}, and soybean-wheat-cowpea (fodder) and cotton-wheat had system productivity around 27 kg ha^{-1} day^{-1}. The system productivity in pearlmillet-potato-green gram was very high and was more than 90% higher than all other cropping systems indicating its clear-cut superiority, which may be due to its high yield potentiality (Jamwal, 2005).

Economic Benefits

Net returns

The average net return per hectare from different cropping systems had a wide range of Rs 21236 to 56012.8 (Table 4). Significantly highest net return of Rs 56012.8 ha^{-1} was recorded in pearlmillet-potato-green gram cropping system and was followed by cotton-wheat with a net return of Rs 44269.6. The soybean-wheat-cowpea (fodder) also gave good net return of Rs 40374.4 ha^{-1}. Very low net return of Rs 21236 ha^{-1} was recorded in pearlmillet-field pea-maize (fodder) cropping system. The moderate net return of Rs 34374.4, 31100 and 34570.4 ha^{-1} was recorded in pearlmillet-wheat, pearlmillet-mustard and sorghum (fodder)-wheat cropping systems, respectively (Gawai and Panwar, 2005).

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SULPHUR REQUIREMENT OF CLUSTERBEAN (*CYAMOPSIS TETRAGONOLOBA*)-WHEAT (*TRITICUM ASTIVUM*) CROPPING SYSTEM UNDER SEMI-ARID TRACT OF RAJASTHAN

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Abstract

Soil analysis of 858 samples collected during 2003-06 from 15 villages of Dausa tehsil of Dausa district of Rajasthan (India) revealed that 79.93 per cent soil samples were rated as S deficient, 17.60 per cent under medium category while only 2.47 per cent under high available sulphur status. The field experiment conducted on S deficient soil revealed that S fertilization up to 45 kg ha^{-1} significantly increased seed and straw yields as well as S uptake by clusterbean in clusterbean-wheat sequence. Agronomic efficiency, physiological efficiency and value : cost ratio decreased up to 45 kg S ha^{-1}. S recovery increased up to 30 kg S ha^{-1} (14.0 %) and thereafter declined. Residual effect of sulphur up to 45 kg S/ha significantly improved grain yield by 34.7 per cent and straw yield of wheat by 33.2 per cent over the control. Productivity, S uptake and apparent S recovery in clusterbean – wheat system increased with the increased level of sulphur up to 45 kg S ha^{-1} while physiological efficiency was higher at 15 kg S ha^{-1}. Agronomic efficiency and value : cost ratio of system increased with increasing S levels up to 30 kg/ha. Sulphur application continuously increased the available sulphur status when applied at 30 and 45 kg S/ha.

Key words: Clusterbean, wheat, uptake, nutrient use efficiency, yield and value: cost ratio.

Sulphur is considered as the fourth major nutrient along with N, P and K for balanced fertilization. It is a key element in plant metabolism and plays important role in the synthesis of amino acids, glycosides and protein configuration. Continuous use of high analysis sulphur free fertilizers in intensive cropping system has depleted the soils of their available S-reserves. The information on inclusion of optimum dose of sulphur with NPK fertilizer application is limited. The present study was therefore, initiated with the objectives of assessing the sulphur status in soils to delineate the sulphur deficient areas in Dausa district of Rajasthan and to determine the sulphur requirement of clusterbean (*Cyamopsis tetragonoloba* L. Taubert) –wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system by the direct and residual effects under semi-arid tract of Rajasthan.

Materials and Methods

The villages falling in Dausa tehsil of Dausa district of Rajasthan where clusterbean - wheat is the major cropping system, were surveyed to collect soil samples (0-15 cm) for analysis of available sulphur and delineation of sulphur deficiency. After surveying, 858 soil samples were collected from 15 villages taking 5 villages at a time in the month of June during each year. Available sulphur in soil was extracted by 0.15 per cent $CaCl_2$ solution and

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sulphur content was determined by the method of Chesnin and Yien (1950). Soil samples containing 10 mg/kg or less considered as low or deficient in available S and 10-20 mg/kg were medium and those containing more than 20 mg/kg available sulphur were considered high in sulphur status.

A field experiment was conducted during 2003-06 on a farmer's field at Ramsignhpura village in Dausa tehsil of semi-arid eastern plain zone of Rajasthan. The experimental site was loamy sand in texture, having soil pH 6.34-6.70, EC 1.31-1.40 dS/m, organic carbon 0.13-0.18 per cent, available P_2O_5 12.12-16.50 kg/ha, available K_2O 241.08-271.80 kg/ha and available S 12.8-14.3 kg/ha. The experiment was conducted with 4 levels of sulphur (0, 15, 30 and 45 kg/ha) applied to clusterbean every year. The treatments were replicated 5 times in randomized block design. The gross plot size was 6 m x 4.5 m. Clusterbean 'RGC 936' was sown during 2^{nd} to 3^{rd} week of July using seed rate of 12 kg/ha with a spacing of 30 x 10 cm^2 during each year. Nitrogen @ 25 kg/ha through urea and diammonium phosphate, phosphorus @ 60 kg/ha through single super phosphate and diammonium phosphate and potassium @ 20 kg/ha through muriate of potash were applied at the time of sowing. The sulphur was applied through single super phosphate at the time of sowing as per treatments. All the packages of practices were followed as per recommendations.

After harvesting of clusterbean, wheat (Raj 3077) was sown in the same plots after ploughing once and harrowing twice the field to study the residual effect of sulphur fertilization. A uniform dose of 90 kg N, 20 kg P_2O_5 and 20 kg K_2O/ha was applied through urea, diammonium phosphate and muriate of potash, respectively. Wheat was sown in the third week of November using seed rate of 100 kg/ha at a spacing of 22.5 cm during all the three years. The collected plant samples of each crop were dried, ground and digested for chemical analysis of sulphur. The uptake of sulphur by clusterbean and wheat was estimated by multiplying sulphur content with corresponding yields. Apparent recovery of sulphur, agronomic efficiency, physiological efficiency and value : cost ratio were also worked out as per the standard formulae.

Results and Discussion

Sulphur status of soil

Chemical analysis of 858 soil samples collected from various villages of Dausa tehsil of Dausa district of Rajasthan revealed that available sulphur status ranged from 1.63 to 24.18 mg/kg soil (Table 1). The sulphur deficiency was highest in Shaikhpura and Rajpuria villages (98 %) while it was lowest in Bagpura-Chhareda (42 %). The overall status of Dausa tehsil revealed that out of the 858 soil samples, 79.93, 17.60 and 2.47 per cent samples were in low, medium and high sulphur status, respectively. The maximum incidence of low category of soils was mainly due to intensive cultivation without use of S-containing fertilizers and growing of oilseeds and pulses which require high amount of sulphur.

Direct effect on clusterbean

Addition of sulphur had positive and significant effect on seed and straw yields of clusterbean (Table 2). As compared to control, application of increasing levels of sulphur up to 45 kg S/ha significantly increased seed yield by 67.9 per cent and straw yield by 59.0 per cent, respectively. This may be attributed to early flowering

Table 1. Available sulphur status of soil in Dausa tehsil of Dausa district of Rajasthan (2003-04 to 2005-06)

S. No.	Villages	No. of soil samples	Available S (mg/kg) Min.	Max.	Average	Per cent samples Low	Medium	Low & medium	High
1	Ramsinghpura	50	3.46	11.98	7.19	94.0	6.0	100.0	-
2	Malwas	50	2.68	13.14	6.31	94.0	6.0	100.0	-
3	Shaikhpura	50	3.02	10.62	5.81	98.0	2.0	100.0	-
4	Rajpuria	50	1.63	12.99	6.08	98.0	2.0	100.0	-
5	Kishorepura	50	2.01	12.73	6.27	94.0	6.0	100.0	-
6	Chudiyawas	82	7.12	17.32	8.38	63.0	29.0	92.0	08
7	Udaipuria	63	8.16	19.56	9.26	71.0	21.0	92.0	08
8	Bagpura	69	6.34	18.88	7.68	58.0	36.0	94.0	06
9	Kheda	56	8.40	21.42	9.18	67.0	26.0	93.0	07
10	Pyariwas	84	9.28	24.18	8.96	69.0	23.0	92.0	08
11	Bagpura (Chhareda)	50	8.0	16.7	10.8	42.0	58.0	100.0	-
12	Kala Raman	50	3.3	20.0	8.5	80.0	20.0	100.0	-
13	Tintoli	50	4.3	11.7	8.2	90.0	10.0	100.0	-
14	Manpuriya	54	2.4	15.0	7.0	89.0	11.0	100.0	-
15	Barwal Ki Dhani	50	4.7	11.7	8.0	92.0	08.0	100.0	-
	Over all status	**858**	**1.63**	**24.18**	**7.84**	**79.93**	**17.60**	**97.53**	**2.47**

and greater pod setting. Singh *et al.* (2005) also reported similar findings. The overall agronomic efficiency in terms of yield increase was maximum under low level of sulphur i.e. 15 kg S/ha and thereafter, reduction in agronomic efficiency at higher levels was observed. Agronomic efficiency at S levels of 15, 30 and 45 kg/ha was 15.8, 12.7 and 10.2 kg/kg S, respectively. Singh *et al.* (2000) also reported similar results. The value: cost ratio also decreased with increasing levels of sulphur up to 45 kg S/ha and revealed that sulphur application was found to be more remunerative. The highest value: cost ratio was recorded at 15 kg S/ha (36.5).

Removal of sulphur by clusterbean (seed and straw) increased significantly with each increment in sulphur level and the maximum uptake was recorded at 45 kg S/ha (4.65 kg by seed and 4.42 kg by straw). Singh and Mann (2007) also reported similar findings. When judged S recovery, it was higher at S level of 30 kg/ha (14.0 %) and thereafter decreased at the highest level of S application (12.8 %). Physiological efficiency measured in terms of kg/kg uptake showed decreasing trend with each higher level

Table 2. Response of clusterbean to sulphur fertilization (pooled over 3 years)

Sulphur levels (kg/ha)	Seed yield (kg/ha)	Straw yield (kg/ha)	% response (Seed yield)	AE (kg kg^{-1})	AR (%)	PE (kg kg^{-1})	S uptake (kg/ha)		Value : cost ratio
							Seed	Straw	
0	677	1040					1.88	1.42	
15	914	1280	35.0	15.8	11.5	137.0	2.78	2.25	36.5
30	1057	1522	56.1	12.7	14.0	90.5	3.94	3.57	29.3
45	1137	1654	67.9	10.2	12.8	79.7	4.65	4.42	23.7
S.Em ±	22	33					0.09	0.09	
CD (P=0.05)	64	95					0.25	0.26	

AE: Agronomic efficiency; AR: Apparent recovery: PE; Physiological efficiency.

of sulphur application and maximum physiological efficiency was recorded at 15 kg S/ha (137.0 kg/kg).

Residual effect on wheat

There was a significant residual effect of sulphur fertilization on grain and straw yields of succeeding wheat (Table 3). Application of sulphur up to 45 kg/ha significantly improved grain yield by 34.7 per cent and straw yield by 33.2 per cent over the control. It was interesting to note that the improvement due to residual effect of S was continuous with an increasing level of S application to the preceding crop. This may be attributed to enrichment of soil with sulphur, resulting in its more uptake. The results are in close conformity with the findings of Sharma and Singh (2005).

Table 3. Response of clusterbean - wheat cropping system to sulphur fertilization (pooled over 3 years)

Sulphur levels (kg/ha)	Wheat yield (kg/ha)		Clusterbean -wheat system							
	Grain	Straw	Yield gain (kg/ha)	% response	AE (kg kg^{-1})	AR (%)	PE (kg kg^{-1})	S uptake Grain	S uptake Straw	Value: cost ratio
0	3378	4430						7.81	7.29	
15	3642	4791	501	12.3	33.4	26.3	127.2	9.83	9.22	56.6
30	4163	5432	1165	28.7	38.8	34.2	113.7	12.65	12.70	60.0
45	4549	5899	1631	40.2	36.2	34.7	104.6	15.48	15.22	53.8
S.Em ±	70	102								
CD (P=0.05)	200	293								

AE: Agronomic efficiency; AR: Apparent recovery: PE; Physiological efficiency

Productivity of cropping system

Productivity of clusterbean -wheat cropping system in terms of yield gain improved with the application of sulphur up to 45 kg/ha (Table 3). The per cent response to 15, 30 and 45 kg S/ha was worked out to be 12.3, 28.7 and 40.2 over the control, respectively. Agronomic efficiency increased up to 30 kg S/ha and thereafter declined with further increase in S level. Agronomic efficiency was 33.4, 38.8 and 36.2 kg/kg S with the application of 15, 30 and 45 kg S/ha applied to cluster bean, respectively. Increasing level of sulphur up to 30 kg /ha resulted in increase in value: cost ratio and thereafter, it declined. It showed that there are possibilities of getting good returns from added S.

Removal of sulphur by clusterbean - wheat cropping system increased with each increment in sulphur level and the maximum uptake was recorded at 45 kg S/ha (15.48 kg by seed/grain and 15.22 kg by straw). Apparent sulphur recovery increased and physiological efficiency decreased with the increased level of sulphur. Maximum apparent sulphur recovery was recorded at 45 kg S/ha (34.7 %) while physiological efficiency was maximum at 15 kg S/ha (127.2 kg/ kg S uptake).

Available sulphur status after harvest

A decrease in soil sulphur status was noticed after harvest of clusterbean – wheat cropping system under the control as well as under treatment of lower level of sulphur i.e. 15 kg S/ha as compared to initial sulphur status (Table 4).Whereas, the sulphur application at higher rates i.e. 30 and 45 kg S/ha improved the soil available sulphur status. After 3 years of continuous cropping on the fixed site, the status of available S exhausted by 46.9 and 15.6 per cent under the control and 15 kg S/ha whereas it was improved by 49.2 and 94.5 per cent at 30 and 45 kg S/ha, respectively

Table 4. Effect of cropping on available sulphur status of soil (kg/ha) (Pooled over 3 years)

Sulphur levels (kg/ha)	Available sulphur (kg/ha)	Per cent change from initial status
0	6.8	- 46.9
15	10.8	- 15.6
30	19.1	49.2
45	24.9	94.5
Initial status	12.8	

Thus it can be concluded that application of sulphur @ 45 kg S/ha through single super phosphate in clusterbean was effective in increasing the productivity of clusterbean -wheat cropping system in semi arid tract of Rajasthan.

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EFFECT OF IRRIGATION SCHEDULING AND FERTILIZER APPLICATION ON GROWTH, YIELD AND ECONOMICS OF SIMULTANEOUS GROWN SUGARCANE AND WHEAT CROPS IN WINTER SEASON IN MOLLISOL SOILS OF TARAI REGION OF UTTARKHAND

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ABSTRACT

The field experiment was conducted during winter seasons of 2003-04 and 2004-05 at Crop Research Center, GBPUAT, Pantnagar, to study the effect of irrigation scheduling and fertilizer management on growth, yield and economics of simultaneous grown sugarcane + wheat crops in winter season in Mollisol soils of Tarai region of Uttarkhand". The experiment was carried out in split plot design, keeping four irrigation options in main-plot, viz. irrigation scheduled at 0.8 (I_1), 1.0(I_2), 1.2 (I_3) IW/CPE ratio and critical stages i.e. crown root initiation, tillering, late jointing, flowering, milk and dough stages) of wheat (I_4), and four nutrient levels, *viz.* 100% (F_1), 125% (F_2), 150% (F_3) and 175% (F_4) of nutrient levels with four replications (100%recommended dose of nutrient means 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}). Maximum cane germination (35.3%) was noticed under treatment having irrigation at physiological stages of wheat, which was 3.9 to 5.5% higher over the 0.8 and 1.0 IW/CPE ratio irrigation regimes. Shoot height (379.3 cm), dry matter accumulation (199.4 g/shoot), number of millable cane (94.41 thousand/ ha), cane yield (83.85 t/ha) and green top yield (12.93 t/ha) were also maximum under plot irrigated at important physiological stages of wheat crop. Application of 175% of recommended NPK fertilizer cane and wheat yields were 8.4 to 12.7% and 16.4 to 31.9% higher as compared to 125 and 100% recommended NPK, respectively. Application of 175% recommended dose of nutrients resulted significantly higher nitrogen uptake (223.9 kg/ ha), phosphorous uptake (27.7 kg/ha) and potassium uptake (288.9 kg/ha) than that of 100, 125 and 150% recommended NPK. The maximum gain of gross return (Rs. 126992.0 /ha), net return (Rs.75882.5/ha) and B: C ratio (1.49) was obtained with irrigation at physiological stages of wheat followed by irrigation at 1.2 IW/CPE ratio over the irrigation at 0.8 and 1.0 IW/CPE ratio whereas, least net returns (Rs.48687.4/ha) and B: C ratio (1.34) was under 0.8 IW/CPE ratio. Crop fertilized with 175% recommended dose of nutrient obtained highest gross returns (Rs. 130938/ ha), net returns (Rs. 79067.4 /ha) and B: C ratio (1.53) over 100% and 125% recommended dose of nutrients. Thus, indicates that application of 175 %recommended NPK (210 kg N, 105 kg P_2O_5 and 70 kg K_2O ha^{-1}) and irrigation at critical stages of wheat is sufficient to provide nutrients for higher yield and economics of simultaneous planting of sugarcane and wheat in Mollisol soils of Tarai region of Uttarkhand.

Key words: Irrigation, Fertilizer levels, Economics, Simultaneous planting, Sugarcane, Wheat and Yield

In India, sugarcane (*Saccharum officinarum* L.) is a major cash crop which supporting sugar industry next to textile industry. It plays pivotal role in contributing 2.0 per cent share towards national gross domestic product. India is the maximum sugarcane producer in the world with annual cane production of 236.2 million tones from 4.0 million hectare acreage. The cane yield throughout the country is almost stagnant or even decline in some patches over the past few year surveys that were mainly due to imbalance and injudicious use of fertilizers application and untimely panting of sugarcane due to delay harvesting of wheat. The present scenario reveals that the burgeoning population of the country will require 25 million tonnes sugar by 2020 AD (Indian Sugar, 2005). To overcome such goals, country will require producing 415 million tonnes sugarcane by stipulated time, which only be possible through conjoint use of modern agronomic manipulations. In general autumn, spring and summer planting of sugarcane is done in northern India. However, summer planting (April /May) is pre-dominant in northern part of the country due to following sugarcane-ratoon-wheat crop system. Area under autumn (October) planted cane is very low in fact that yields are 15-20% more than spring season but its cropping intensity is much lower than spring ones. A drastic reduction in cane productivity (30 to 50%) was found in delay/summer planted sugarcane. Different scattered studies reported by Gangwar and Sharma (1997) and Shukla (2005) reveal the possibility of improving cane yield in sugarcane-ratoon-wheat crop system by simultaneous planting of sugarcane + wheat crops during winter season. The main constraints for grown sugarcane crop are canes sprouting suppression as results of prolong low temperature and limited available soil moisture in winter and high temperature and low soil moisture in summer season. In this regard, an adjustment of irrigation options coinciding with period of sugarcane germination may favour more cane sprouting. But wheat and sugarcane crops grown simultaneous may respond differently to nutrients application than grown in system. In keeping the above view, present study was taken to evaluate the growth, yield and economics of simultaneous grown winter sugarcane + wheat as influenced by irrigation scheduling and nutrient application in Mollisol soils of Tarai region of Uttarakhand.

MATERIALS AND METHODS

The field experiments were conducted two-cosecutive year of 2003-04 and 2004-05 on two crop seasons at the Crop Research Centre at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand. The crop Research Centre is located at 29^0 N latitude, 79.3 E longitude and at altitude of 243.8 meters above the mean sea level. Pantnagar is located in the *'Tarai'* region in foothills of Shivalik range of Himalayas. The experiment was laid out in split plot design, keeping four irrigation options in main-plots irrigation scheduled at 0.8 (I_1), 1.0(I_2), 1.2 (I_3) IW/CPE ratio and critical stages i.e. crown root initiation, tillering, late jointing, flowering, milk and dough stages) of wheat (I_4), and four nutrient levels, *viz.* 100% (F_1), 125% (F_2), 150% (F_3) and 175% (F_4) of nutrient levels for sugarcane in sub-plot with four replications (100% nutrient levels means 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}). A composite soil sample from 0-30 cm depth for physical constants and 0-15 cm depth for mechanical and chemical analysis was taken before planting of experimental crop (Black,1965). The soil of the experimental site was silty clay loam, rich in organic carbon (1.05%), medium in available phosphorous (14.09 kg ha^{-1}) and potassium (266.03 kg ha^{-1}) with neutral in reaction (pH 7.1). The moisture content of top layer (0-30 cm) soil at field capacity and permanent wilting point were 23.38 and 8.01%, respectively. A uniform irrigation was given at crown root initiation of wheat crop for all the treatments. Thereafter irrigation was applied as per treatments till harvesting of wheat crop and thereafter it was given as per need of the sugarcane crop. One third of nitrogen and full dose of phosphorous and potassium were applied as basal in furrows and one third nitrogen was top dressed in the month of January after irrigation at after crown root initiation of wheat crop and remaining one third nitrogen was top dressed in the month of June (after harvesting of wheat crop). In wheat, number of tillers/m row length was counted at maximum flowering (70 days after sowing). Shoot height, dry matter production g/m^2, spike length, 1000 grain weight was measured at maturity. At harvest, samples were drawn from bulk of produce and harvest index was measured. In sugarcane, germination % of sugarcane was recorded at 60 days after sowing. Highest number of shoots counts thousand/ha at 180 days after planting, dry matter production g/plant at 240 DAPS and thereafter decreased with advancement of the growth stage. Yield and yield attributes of sugarcane was recorded from each plot. Randomly selected five canes from each plot determined juice quality attributes at physiological maturity. Juice sucrose (%) was determined by Horne's dry lead Acetate Method as described by (Spencer and Meade, 1955). Schmitz's table was used to calculate juice sucrose. The purity coefficient and available sugar % in juice were calculated by using following formulae:

$$\text{Available sugar per cent} = \left[S - \left\{0.4(B - S)\right\}0.73\right]$$

Where, S is the sucrose % in juice, B is the corrected brix of juice and 0.4 & 0.73 are constant

and CCS yield (t/ha)= available sugar in cane% x cane yield (t/ha)/ 100

The nutrients uptake worked out by multiplying cane, green tops and trash yield of sugarcane and grain and straw yield of wheat along with their respective nutrients content values. The cost of cultivation was worked out by considering the current price of the inputs/ commodity used under different treatment options. The gross return and net return were worked out by multiplying cane and green tops yield of sugarcane and grain and straw yield of wheat along with their prices. For this, market price of cane (Rs. 102/q), green tops (Rs. 37.5/q), wheat grains (635/q) and straw (Rs.190/q) was kept. Accordingly benefit cost ratio was calculated. The significance of treatment were assessed using by the 'F' test was used (Panse and Sukhatme, 1967).

Results and Discussion

Effect of irrigation and fertilizer levels

Growth, yield and yield attributes of sugarcane

Irrigation scheduled at critical stages of wheat had significantly maximum cane germination (35.3 %), followed by irrigation scheduled at 1.2 IW/ CPE ratio and was 3.9 to 5.5% higher over other irrigation options (Table-1). It is pertinent to mention here that application of irrigation at critical stages (CRI, tillering, jointing, boot, flowering, milk and dough stages) of wheat increased micro-environment temperature through latent heat and made it favorable for sprouting of cane germination. On the other hand, wide interval in irrigation application under 0.8 and 1.0 IW/ CPE ratio did not save crop from severe low temperature during December and January (4.4 to 8.3^0 C) and poor germination was noticed (29.82 to 31.43%). The advantages of early crop establishment were also accrued in terms of growth and yield

Table 1. Effect of irrigation scheduling and fertilizer levels on growth and yield of sugarcane and wheat crops grown under simultaneous in winter season (mean two year)

Treatments	Germination (%)	No of shoot counts (000/ha)			Dry matter production (g/shoot)	No Millable canes (000/ha)	Cane yield (q/ha)	Green top yield (q/ha)	CSS yield (t/ha)
		June	July	August					
Irrigation scheduling									
I_1	29.82	152.3	128.4	103.5	179.6	85.11	743.0	99.8	9.60
I_2	31.43	153.5	128.5	104.6	184.6	88.34	772.0	116.7	9.67
I_3	34.37	156.3	129.4	109.3	192.8	93.90	826.4	127.1	9.74
I_4	35.30	159.1	132.8	110.5	199.4	94.41	838.5	129.3	9.90
CD (P=0.05)	4.83	11.85	12.57	12.39	12.5	7.94	61.0	16.8	0.91
Fertilizer levels									
F_1	32.07	145.7	122.0	97.7	181.9	88.8	774.3	108.7	9.08
F_2	33.34	150.0	127.2	103.4	189.3	90.8	805.3	121.5	9.97
F_3	34.33	160.5	132.4	110.0	194.0	94.2	842.0	129.9	9.94
F_4	35.17	164.3	137.6	113.8	201.2	98.8	872.2	136.8	10.21
CD (P=0.05)	NS	11.91	9.27	8.09	11.5	6.2	48.0	13.1	0.80

attributes, viz. number of tillers counts (115 to 124.4 thousand/ ha) at 180 DAP, dry matter production (199.5 g/plant), number of millable cane (94.41 thousand/ ha), cane yield (838.5 q/ha), green top yield (129.3 q /ha) and CCS yield (9.9.0 t/ha) under irrigation at critical stages of wheat. The increased juice extraction may be argued in terms of higher translocation of water and photosynthetes and its subsequent conversion in economic parts under optimal water and nutrient availability. These results also confirmed the findings of Verma and Yadav (1988) and Mehboob *et al.* (2000).

Nutrient levels had significantly influenced on growth, yield and yield attributes of sugarcane (Table 1). Crop fertilized with 175% of recommended NPK noted significantly maximum number of tillers counts (115 to124.4 thousand/ ha) at 180 DAP, dry mater production (201.2 g/plant) number of millable cane (94.4 thousand/ ha), cane yield (872.2 q/ha), green top yield (136.8 q/ha) and CCS yield (9.94 t /ha) at harvest which was statistically at par to that of 150% of recommended NPK rates. Yield gave under 175% of recommended NPK fertilized plots were 12.7 and 8.4% higher over 100 and 125% recommended NPK rates, respectively. Since both sugarcane and wheat crops shares for their nutrient demands an enhanced dose of recommended NPK might have provided optimal nutrition to supply the crop, which in turns resulted as synchrony in plants shoot counts, its height, cane length, dry matter accumulation and more leaf area (photosynthetic area) and all these physiological growth improvement resulted in maximum number of millable canes, cane length, and average cane weight and ultimately produced more cane yield. These results are also agreement with the findings of Singh *et al.* (1997) and Mehboob *et al.* (2000).

Growth, yield and yield attributes of wheat

Irrigation options had significant impact on growth, yield and yield attributes of wheat (Table 2). Irrigation scheduled at critical stages of wheat resulted significantly higher plant height (95.9cm) dry matter production (598.5 g/m^2), spike length (10.8 cm) and 1000-grain weight (43.3 g), being at par with irrigation scheduled at 1.2 IW/CPE ratio. Yield studies in wheat viz. grain; straw yield and 1000-grain weight were also higher (12.2 to 23.6%, 10.3 to 16.8% and 8.8 to 13.7%) when crop was irrigated at important critical stages over irrigation applied at 1.0 and 0.8 IW/ CPE ratio. Results are also conformity with the findings of Singh and Bhan (1998) and Verma *et al.* (1998).

Fertilizer levels had also significant impact on different growth, yield and yield attributes of wheat (Table 2). Application of 175% of recommended NPK produced significantly maximum plant height (95.9cm) dry matter production (601.8 g/m^2), spike length (11.7 cm) and 1000-grain weight (43.3 g), which was statistically on per with 150% of recommended NPK application. Application of 175% of recommended NPK gave 13.8 and 31.9% more grain yield than 125 and 100% recommended NPK (31.8 and 27.4 q/ha, respectively). Higher rate of nutrient requirement in present case may be visualized in terms of more nutrients demand though simultaneously grown both crops in winter season and therefore, total NPK demand was increased up to 150%. Since sugarcane and wheat both is very high nutrients responsive crop, lower NPK application rates would have adverse impact on productivity of both the crop. These results are in close conformity with the findings of Bandyopadhyay (1997) and Rehman *et al.* (2000).

The interaction between irrigation and nutrient levels with respect to nitrogen, phosphorous and potassium

Table 2. Effect of irrigation scheduling and fertilizer levels on yield and yield attributes of wheat and sugarcane grown under simultaneous in winter season (mean two year)

Treatments	Plant height (cm)	Dey matter accumulation (g/m^2)	Spike length (cm)	1000-Grain weight (g)	Grain yield (q/ha)	Straw yield (q/ha)
Irrigation scheduling						
I_1	85.9	527.8	8.9	37.3	27.6	53.5
I_2	90.3	551.5	9.7	39.4	31.7	57.7
I_3	93.1	581.8	10.5	41.5	35.2	60.3
I_4	95.8	598.5	10.9	43.2	36.1	64.3
CD (P=0.05)	5.1	46.4	1.06	3.6	2.8	7.5
Fertilizer levels						
F_1	85.6	524.3	8.7	36.8	27.4	53.1
F_2	90.4	550.1	9.8	39.9	31.8	57.7
F_3	93.2	583.4	10.5	41.7	35.3	60.4
F_4	95.9	601.8	11.7	43.3	36.2	65.2
CD (P=0.05)	4.75	40.8	2.5	2.0	3.9	2.3

uptake of sugarcane was not significant.

Nutrient uptake

Differences in nitrogen uptake in sugarcane crop due to irrigation levels was significant, however, phosphorous and potassium uptake due to irrigation levels was not significant (Table 4). Irrigation at critical stages of wheat removed maximum nitrogen of 208.9 kg/ ha, being at par with that of 1.2 IW/CPE ratio but significantly higher than 0.8 and 1.0 IW/CPE ratio. Differences in nitrogen, phosphorous and potassium uptake in sugarcane crop due to fertilizer levels was significant. Application of 175 per cent of recommended NPK resulted significantly higher total nitrogen uptake (223.9 kg /ha), phosphorous uptake (27.7 kg/ha) and potassium uptake (288.9 kg/ ha) over 100, 125 and 150% of recommended NPK. These types of results are also conformed by the findings of Singh and Jafri, (1990).

Nitrogen uptake in wheat crop due to irrigation levels was significant, however, phosphorous and potassium uptake due to irrigation options was not significant. Crop receiving irrigation at critical stages of wheat removed maximum nitrogen of 100.9 kg /ha, being at par with that of 1.2 IW/CPE ratio but significantly higher than that of 0.8 and 1.0 IW/CPE ratio. Nitrogen, phosphorous and potassium uptake in wheat significantly affected due to nutrient levels. Crop fertilized with 175 per cent of recommended NPK removed maximum nitrogen (115 kg/ ha), phosphorous (26.6 kg/ ha) and potassium (102.8 kg/ha), being significantly higher than that of 100, 125 and 150. These types of results are also conformed by the findings of Rehman *et al.* (2000).

Effect on economics

The maximum cost of cultivation (Rs. 49712.5 /ha) was involved when crop were irrigated at physiological stages of wheat followed by irrigation at 1.2 IW/ CPE ratio over 0.8 and 1.0 IW/CPE ratio whereas, with the application of 175% recommended dose of nutrients invested (Rs. 51860.6 /ha) over 125 and 100% recommended NPK. Economic comparison worked out (in Table 3) in terms of net returns and B: C ratio indicates that the maximum gain gross return (Rs. 126992.0 /ha), net return (Rs.75882.5/ha) and B: C ratio (1.49) with irrigation at physiological stages of wheat followed by irrigation at 1.2 IW/ CPE ratio over the irrigation at 0.8 and 1.0 IW/CPE ratio whereas, least net returns (Rs.48687.4/ha) and B: C ratio (1.34) was under 0.8 IW/CPE ratio. Crop fertilized with 175% recommended dose of nutrient gave highest gross returns (Rs. 130938/ ha), net returns (Rs. 79067.4 /ha) and B: C ratio (1.53) over 100% and 125% recommended dose of nutrients. In fact, that irrigating field during initial critical growth stages and 175% recommended nutrients doses played a vital role for enhancing cane productivity as well as wheat yield grown simultaneously, which also ultimately reflected in term of its economic viability. Similar type economics were also obtained with the findings of Shukla (2005) and Verma and Yadav (1998).

On the basis of results reveal that simultaneous planting of winter sugarcane + wheat crop receiving irrigation at critical stages of wheat significantly higher grain and cane yield. Crop fertilized with 175 per cent of recommended NPK (210 kg N, 105 kg P_20_5 and 70 kg K_2O ha^{-1}) produced significantly higher yield of cane and wheat over 100 and 125% recommended nutrients dose. Thus, indicates that with the application of 175% recommended NPK (210 kg N, 105 kg P_20_5 and 70 kg

Table 3. Effect of irrigation scheduling and fertilizer levels on economics and nutrient uptake of sugarcane and wheat crops grown under simultaneous in winter season (mean two year)

Treatments	Cost cultivation (Rs./ha)	Gross returns (Rs./ha)	Gross returns (Rs./ha)	B:C ratio	Nutrient uptake wheat (kg/ha)			Nutrient uptake sugarcane (kg/ha)		
					N	P	K	N	P	K
Irrigations scheduling										
I_1	48687.4	116367	66622.6	1.34	79.5	18.4	76.2	186.4	20.3	241.8
I_2	49201.8	120453	70093.2	1.39	90.8	20.8	92.8	190.7	21.1	247.6
I_3	49712.1	124538	73515.9	1.44	98.8	23.5	94.6	195.9	22.8	255.9
I_4	49712.5	126992	75882.5	1.49	106.9	25.6	102.4	198.2	24.5	262.8
CD (P=0.05)	-	-	-	-	8.2	NS	NS	14.8	NS	NS
Fertilizer levels										
F_1	49253.4	112053	62799.6	1.28	75.1	17.3	76.3	157.8	19.2	211.1
F_2	50109.7	119197	69087.3	1.38	89.1	20.4	83..5	186.3	22.5	243.0
F_3	50793.7	124544	73750.3	1.46	104.6	23..9	92..2	207.2	24.5	266.3
F_4	51860.6	130938	79067.4	1.53	114.8	26.6	102.8	223.9	27.8	288.9
CD (P=0.05)	-	-	-	-	5.82	1.62	5.81	13.7	1.6	14.7

K_2O ha^{-1}) with irrigation at critical stages of wheat is optimum to provide nutrients and moisture for higher yield and of simultaneous grown winter sugarcane + wheat in Mollisol soils of Tarai region of Uttarkhand.

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CHARACTERIZATION AND CONSTRAINT ANALYSIS OF FARMING SYSTEMS OF UDAIPUR DISTRICT OF RAJASTHAN

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ABSTRACT

A characterization survey of 90 farmers was conducted during 2004-05 in Udaipur district of Rajasthan. The major farming systems prevailing in Sub-humid Southern Plain and Aravalli Hills Zone (IVa) was crop + animal husbandry and crop + horticulture + animal husbandry. The findings showed that the net income/hectare increases with increase in size farm. The data also showed the per cent livelihood of different category of farmers in which all category farmers were getting their livelihood from crop production, which can be shifted to some other enterprise to some extent. Large farmers were getting Rs 11,670/- and Rs 2,740/- /ha more net income than small and medium category of farmers, respectively from crop + animal husbandry farming system while they were getting Rs13,449/- and Rs 1,892/- /ha more from crop + animal husbandry + horticulture farming system.

Non-availability of newly developed high yielding variety seeds was the most important constraint among all categories of farmers followed by imbalanced use of fertilizer in crop production. Lack of cross bred and exotic breed animals, artificial insemination and medical facilities for cattle in were the constraint in animal husbandry enterprise. Lack of availability of improved good planting materials suitable for local conditions was the important constraint followed by imbalanced use of fertilizers for all categories of farmers in horticulture enterprise.

Farming system represents integration of farm enterprises such as cropping system, animal husbandry, fisheries, forestry, poultry etc. for optimal utilization of resources bringing prosperity to the farmer. Farming system approach introduces a change in farming techniques for higher production from the farm as a whole with the integration of all the enterprises. A judicious mix of cropping system with associated enterprises like dairy, poultry, piggery, fishery, sericulture etc. suited to the given agro-climatic conditions and socio-economic status of farmer would bring prosperity to the farmer. Every farmer tries to choose the farm activities/ enterprises depending upon physical and economic conditions prevailing in his ecosystem. Integration of various farm enterprises on the farm ensures growth and stability in overall productivity and profitability. It also ensures recycling of residues optimization of resource use, minimization of risk and generation of employment. The basic aim of integrated/ sustainable farming system is to derive a set of resource development management and utilization practices that lead to a substantial and sustained increase in agriculture production. Since farming system differ in different situations such studies should be location system specific. (Singh,1998).

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Several studies conducted on farming systems showed that farming system approach is better than conventional farming (Ravishankar, *et al.*, 2007 and Singh *et al.*, 2007).

As there is no scope for horizontal expansion of our agricultural land and agriculture, only alternative left is for vertical expansion through various farm enterprises requiring less space and time but given high productivity and ensuring periodic income especially for small and marginal farmers. Before conducting any research on farming system in an area, the first step of diagnosing of research-base of farmers and constraints is very crucial and has to play a pivotal role. In view of this, on-farm study on characterization and constraints analysis of farming system of Udaipur district of Rajasthan was undertaken with the objectives to identify and characterize the major farming systems of the study area, major constraints limiting the efficiency of different farming sub-systems and suggesting technological interventions for improving profitability.

MATERIAL AND METHODS

For collection of information related to different aspects of farming systems, a survey was carried out during 2004-05 using pre-structured schedule. Survey was conducted by adopting stratified random sampling. Three stage stratified sample (Tehsil, Village and Farmer) was considered for the purpose of primary data collection on the sub-systems from the farmers. The different size groups of farmers i.e. small (36), medium (34) and large (20) were selected on the basis of probability proportion to each size groups (Table 1). Thus, a total of 90 farmers were selected from the district. The selected farmers were interviewed personally and information on existing farming system, economics of different enterprises and the constraints of different enterprises were identified. The data collected through survey were subjected to general statistical analysis.

RESULTS AND DISCUSSION

Existing Farming Systems

The major farming systems prevailing on all categories of farmers in Sub-humid Southern Plain and Aravali Hills Zone

Table 1. Selected farmers in Udaipur district of Rajasthan.

	Name of Block/ Village		Number of farmer			
			Small	Medium	large	Total
1.	Girwa	Kanpur	3	7	5	15
2.	Vallbhnagar	Gumanpura	3	6	6	15
3.	Gogunda	Bhadviguda	7	6	2	15
4.	Kotra	Narsinghpura	5	6	4	15
5.	Jhadol	Koliyari	10	4	1	15
6.	Mavli	Sangwa	8	5	2	15
	Total		36	34	20	90

(IVa) are presented in Table 2. Data showed that crop + animal husbandry was the major farming system which was adopted by 64.44 % farmers of all the categories followed by Crop + animal husbandry + horticulture farming system (35.56%).They rear the milch animals to fulfill their domestic requirement and extra milk is sold to meet the miscellaneous expenditure.

Expenditure and income from different enterprises

(i) Crop + animal husbandry farming system

It is obvious from Table 3 that group income/hectare increased with increase in farm size. Large category of farmers obtained maximum gross income (Rs 68,555/- /ha) while small farmers were getting gross income of Rs 53,160/- /ha. Data also showed that expenditure incurred by large category of farmers was more (Rs 21,685/-ha) as compared to small category of farmers (Rs 17,960/- /ha) due to more risk bearing capacity of large farmers. Net income from crop+ animal husbandry enterprises also followed the same trend as gross income. Large farmers were getting Rs 11,670/- and Rs 2,740/- /ha more than small and medium category of farmers, respectively.

The data also showed per cent livelihood from crop production, which could be shifted to some other enterprises to some extent. As the size of farm increases per cent livelihood shifted from crop production to animal

Table 2. Major farming systems prevailing in the zone IVa.

S. No.	Major farming systems	Category of the farmers			Total
		Small (0-2 ha)	Medium (2-4 ha)	Large (> 4 ha)	
1.	Crop + animal husbandry	24	20	14	58 (64.44%)
2.	Crop + animal husbandry + horticulture	12	14	6	32 (35.56%)
	Total	36	34	20	90

Table 3. Expenditure and income from crop + animal husbandry farming system.

Category of farmers	Av. size of holding (ha)	Income by crops (Rs/ha)	Income by A.H. (Rs/ha)	Gross income (Rs/ha)	Total expenditure (Rs/ha)	Net income (Rs/ha)	Per cent livelihood	
							C.P.	A.H.
Small	1.03	41139 (28758)*	12021 (6441)*	53160	17960	35200	81.7	18.2
Medium	2.71	46762 (35565)*	13705 (8565)*	60467	16337	44130	80.5	19.4
Large	6.82	52750 (37278)*	15807 (9592)*	68555	21685	46870	79.5	20.4

*Figures in parentheses refer to net income by different enterprises. C.P.: Crop production; A.H: Animal husbandry

husbandry. In the study, large category farmers were setting 20.4 per cent income from animal husbandry while the small farmers were getting 18.2 per cent income from animal husbandry.

(ii) Crop + animal husbandry + horticulture

Data presented in Table 4 revealed that net income/hectare in different category of farmers from crop + animal husbandry + horticulture enterprises. It was noticed that highest net income (Rs 55,991/- /ha) was obtained by large category of farmers in which share of Rs 35,925, Rs 8,633 and Rs 11,433/- /ha was from crop production, animal husbandry and horticulture, respectively. Whereas the lowest net income was obtained by small farmers (Rs 42,542/- /ha). As the size of the farms holding increases, the per cent livelihood shifted from crop production to horticulture and /or animal husbandry. It indicates that farmers also tend to earn from the other enterprise than crop production. This is a healthy sign where the per cent livelihood can be shifted more towards horticulture by providing them good type of planting materials from different organization like SAU's, NGO's or other private agency. This is the realistic situation in conducting survey where we can clearly see the shift of farming system.

Major constraints leading to low productivity / returns from different enterprises

Non-availability of newly developed high yielding variety seeds is the most important constraint among all categories of farmers followed by imbalanced use of fertilizer (Table 5) under crop production component. About 91 % farmers were facing non-availability of newly developed high

Table 4. Expenditure, gross and net income from crop + animal husbandry + horticulture farming system.

Category of farmers	Average holding size (ha)	Gross income (Rs/ha)	Income by crops (Rs/ha)	Income by A.H. (Rs/ha)	Income by horti-culture (Rs/ha)	Total expendi-ture (Rs/ha) (C+A.H.+ H.)	Net income (Rs/ha)	Per cent livelihood		
								C.	H.	A.H.
Small	1.47	68808	41958 (29292)*	13558 (6577)*	13292 (6733)*	26267	42542	68.8	15.8	15.3
Medium	2.78	81100	49286 (35807)*	15393 (8607)*	16421 (9685)*	27000	54099	66.1	17.9	15.9
Large	5.00	80908	50792 (35925)*	14933 (8633)*	15183 (11433)*	24917	55991	64.1	20.4	15.4

*Figures in parentheses refer to net income by different enterprise. C.P.: Crop production; A.H: Animal husbandry and H.: Horticulture.

yielding variety seeds as constraint, 84 % farmers facing imbalanced use of fertilizers as constraint and about 51 % farmers facing lack of knowledge of improved package of practices as constraint. Kadam *et al*. (2003), Singh and Singh (2005) and Choudhary *et al*. (2007) also reported similar findings.

Data also showed that major constraint in animal husbandry enterprise was lack of crossbred and exotic breed animals, which were faced by 87.7 % farmers, followed by lack of artificial insemination and medical facilities for cattle.

Data further showed that lack of availability of improved good planting materials suitable for local conditions was the important constraint for all categories of farmers in the horticulture component. This constraint accounts for 87.5 per cent farmers. Next important constraint was imbalanced use of fertilizers and accounts for 78.1 % farmers. One another constraint was lack of knowledge of improved package of practices.

Necessary Technological Interventions

The probable technological

Table 5. Ranking of major constraints in different category farmers.

Rank	Constraints	Category of farmers			Total
		Small	Medium	Large	
A. Crop					
I	Non-availability of newly developed high yielding variety seeds	35	32	15	82 (91.1%)
II	Imbalanced use of fertilizers	34	30	12	76 (84.4%)
III	Lack of knowledge of improved package of practices	22	14	10	46 (51.1%)
B. Animal husbandry					
I	Lack of crossbred and exotic breed animals	35	30	14	79 (87.7%)
II	Lack of Artificial insemination and medical facilities for cattle	30	22	16	68 (75.5%)
III	Improper maintenance balance feeding and lack of organized co-operative societies	28	20	12	60 (66.6%)
C. Horticulture					
I	Lack of availability of improved good planting material suitable for local Conditions	33	29	15	77 (87.5%)
II	Imbalanced use of fertilizers	30	21	15	66(78.1%)
III	Lack of knowledge of improved package of practices	27	20	10	57 (68.7%)

* Figures in parenthesis indicate per cent value.

interventions for higher returns from different enterprises may be:

A. Crop production

(i) Agriculture department, co-operative society and NGO's should supply seed of improved variety at panchayat samiti/village level prior to sowing.

(ii) Village level demonstrations of improved technology should be conducted for balanced use of fertilizers.

(iii) Trainings for improvement in knowledge about package of practices.

B. Animal husbandry

(i) Exotic breeds suitable for local condition be made available at village level breed improvement programme.

(ii) Medical facilities and buffer stock for feed and fodder for adverse condition should be maintained in the area.

(iii) Marketing/collection center of milk and milk products should be developed at village levels.

C. Horticulture

(i) Supply of newly developed varieties (short duration, resistant to pest and disease), fertilizers and plant protection measures.

(ii) Village level demonstrations of improved technology should be conducted for balanced use of fertilizers.

(iii) Training programmes should be conducted for the improvement of the knowledge regarding package of practices for horticultural crops.

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EFFECT OF FERTILIZER LEVELS AND PRECEDING CROPS GROWN WITH AND WITHOUT FYM ON BARLEY IN IGNP COMMAND

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Abstract

An investigation was carried out during kharif and *rabi* seasons of 2003-04 and 2004-05 on sandy loam soils of Bikaner (Rajasthan) to study the effect of fertilizer levels and preceding crops grown with and without FYM on growth and productivity of barley in IGNP command. On the basis of two years study, it may be concluded that clusterbean significantly increased the growth and yields of succeeding barley compared to mothbean and pearl millet as preceding crops. Growth and yields of barley were also improved with 10 t FYM ha^{-1} application over no FYM treatment. Among the fertilizer application treatments, it may be concluded that barley grown after clusterbean with 90 kg N + 45 kg P_2O_5 ha^{-1} fertilizer dose to barley significantly improved the grain yield of barley over the barley grown after pearl millet and mothbean with all the fertilizer doses.

Key words: Fertilizer levels, preceding kharif crops, FYM, yield

Crop production by growing two or more crops within a year, has raised serious problem of soil fertility depletion and decline in yields in western Rajasthan conditions. The exhaustive nature of cereal – cereal cropping sequence may be the reason for decline in yields (Kumpawat, 2001). Inclusion of legume crops can help in sustaining the productivity of the system as pulses have extensive root system, which are capable of enriching soil resource through leaf litter and symbiotic nitrogen fixation (Saraf and Patil, 1995). FYM is rich in organic matter and can be supplemented with the chemical fertilizers. Although it is costlier than chemical fertilizers on unit nutrient basis, the other beneficial effect that it has on soil can compensate for the added cost. Brady (1996) generalized that half of N and one-fifth of P of the applied organic manure may be recovered by the crop. Thereafter, the rest nutrients are available at slower rates to the subsequent crops. A minimum nutrient loss due to slow release of nutrients from organic manures is an added advantage here. Therefore, the residual nutrients can be utilized by next crop in a crop rotation. Fertilizers, especially, nitrogen and phosphorus play a major role in early establishment of aerial portion capable of photosynthesis and increases root development to enable more efficient use of water and nutrients. Most of the workers have been confined to ascertain the response of nutrients in isolation (as N and P). Since, N and P have additive effect on grain yield, it is utmost important to assess their response in combination. Keeping all the facts in view, the present investigation was, therefore, undertaken.

Methods and Material

A field experiment was conducted during the kharif and *rabi* seasons of 2003-04 and 2004-05 at Agricultural Research Station, Rajasthan Agricultural University, Bikaner to study the effect of fertilizer levels and preceding crops grown with and without FYM on growth and productivity of barley. The soil of the experimental plot was sandy loam in texture, saline in reaction (pH 8.30), low in organic carbon (0.08%), medium in available phosphorus (17.89 kg ha^{-1}) and high in available potassium (230.0 kg ha^{-1}). The 30 treatments were tested in split plot design as kharif crops and FYM in main plots and fertilizer levels in sub plots with three replications. The treatments consisting of 3 kharif crops (pearl millet, mothbean and clusterbean) with and without FYM (applied to kharif crops only) in main plots and 5 levels of fertilizer applied to barley only (control, 30 kg N + 15 kg P_2O_5 ha^{-1}, 60 kg N + 30 kg P_2O_5 ha^{-1}, 90 kg N + 45 kg P_2O_5 ha^{-1} and 120 kg N + 60 kg P_2O_5 ha^{-1}) in sub plots. The HHB-67, RMO-40 and RGC-986 varieties of pearl millet, mothbean and clusterbean were sown with full recommended dose of fertilizer i.e. 80 kg N + 40 kg P_2O_5 ha^{-1}, 20 kg N + 40 kg P_2O_5 ha^{-1} and 20 kg N + 40 kg P_2O_5 ha^{-1}, respectively. After harvesting of kharif crops as per their maturity, the RD – 2508 variety of barley was sown in rows, 22.5 cm apart, on November 19, 2003 and November 21, 2004. The barley crop was fertilized (N + P_2O_5) as per treatment. The whole of phosphorus and half dose of nitrogen was applied as basal through DAP and urea, respectively and the remaining half dose of nitrogen fertilizer was applied through urea as top dressing at the time of first irrigation. The harvesting of the barley was done on March 23 and March 20, during 2004 and 2005, respectively. The total rainfall in kharif season was 222.0 and 102.8 mm and in *rabi* season was 7.5 and 65.4 mm during 2003-04 and 2004-05, respectively.

Result and Discussion

Effect of preceding kharif crops

Growth characters viz. plant height at harvest, dry matter accumulation at harvest, effective tillers and flag leaf area of barley grown after kharif crops was significantly influenced during 2003-04, 2004-05 and on pooled basis. The higher values of these growth characters were recorded when barley was grown after clusterbean, which was significantly higher than barley grown after pearl millet and mothbean, respectively. The lowest plant height, number of tillers and flag leaf area were recorded in the crop of barley grown after pearl millet due to probably to its exhaustive nature leading to greater depletion and poor availability of major nutrients for succeeding crop of barley.

Different yield attributing characters of barley were affected significantly by preceding kharif crops. On the basis of pooled data, barley crop produced maximum number of effective tillers per metre row length, number of grains per spike and test weight when it was grown after clusterbean followed by mothbean with lowest number of these attributes when grown after pearl millet. This might be because of greater amount of available nitrogen in soil after clusterbean followed by mothbean as compared to pearl millet with similar variation in growth characteristics leading to improved source sink relationship and translocation of food material to reproductive organs. The results of Jain (1989) and Yadav (1991) are in accordance to the present findings.

Preceding clusterbean recorded the highest grain straw and biological yield of barley followed by mothbean with lowest yield under pearl millet. Among the preceding legumes, clusterbean recorded higher grain yield of barley by 10.05 per cent over mothbean. The favourable effect of preceding kharif legumes on the yield of barley might be

Table 1. Effect of kharif crops, FYM and fertilizer levels on plant height, dry matter production, effective tillers and flag leaf area of barley

Treatment	Plant height (cm)			Dry matter production ($g\ m^{-1}$ row length)			Effective tillers m^{-1} row			Flag leaf area (cm^2)		
	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled
Kharif crops												
Pearl millet	71.17	74.99	73.08	176.10	170.36	173.23	62.8	59.8	61.3	14.69	14.06	14.37
Mothbean	73.92	77.91	75.91	195.80	188.26	192.03	67.8	65.8	66.8	16.30	15.24	15.77
Clusterbean	81.03	80.21	80.62	213.76	211.99	212.88	74.4	72.3	73.3	16.85	16.79	16.82
S. Em. ±	1.371	0.481	0.726	2.546	4.622	2.638	0.84	0.69	0.54	0.674	0.421	0.379
CD 5%	4.320	1.517	2.143	8.024	14.565	7.784	2.66	2.18	1.61	NS	1.329	1.173
FYM ($t\ ha^{-1}$)												
Control	73.43	75.90	74.66	177.91	167.13	172.52	65.4	63.7	64.6	10.83	11.00	10.92
10	77.32	79.50	78.41	212.53	213.28	212.90	71.2	68.2	69.7	21.06	19.72	20.39
S. Em. ±	1.119	0.393	0.593	2.079	3.774	2.154	0.68	0.56	0.44	0.550	0.344	0.324
CD 5%	3.527	1.238	1.750	6.551	11.892	6.355	2.17	1.78	1.31	1.735	1.085	0.958
Fertilizer levels ($N + P_2O_5\ ha^{-1}$)												
Control	47.36	48.38	47.87	92.12	92.12	92.12	38.2	34.8	36.5	10.92	10.90	10.91
30 + 15	72.41	71.07	71.74	155.05	155.05	155.05	56.2	54.1	55.1	13.22	13.11	13.16
60 + 30	79.84	86.16	83.00	195.19	193.11	194.15	68.4	64.9	66.6	16.45	15.79	16.12
90 + 45	85.44	90.19	87.82	237.46	232.54	234.99	82.7	76.8	79.8	18.47	17.73	18.10
120 + 60	91.82	92.72	92.27	296.28	278.21	287.24	96.1	99.2	97.7	20.68	19.28	19.98
S. Em. ±	1.225	0.418	0.647	2.957	3.781	2.400	0.73	0.88	0.57	0.417	0.364	0.277
CD 5%	3.483	1.190	1.817	8.409	10.751	6.738	2.08	2.50	1.60	1.188	1.035	0.778

Table 2. Effect of kharif crops, FYM and fertilizer levels on spike length, spike weight, grains per spike and test weight of barley

Treatment	Spike length (cm)			Spike weight (cm)			Grains/Spike			Tesgt Weight (g)		
	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled
Kharif crops												
Pearl millet	7.43	7.30	7.36	1.991	1.837	1.914	38.87	36.90	37.88	41.29	40.57	40.93
Mothbean	7.62	7.46	7.54	2.090	1.933	2.011	40.06	38.82	39.44	43.02	41.92	42.47
Clusterbean	7.91	7.85	7.88	2.254	2.062	2.158	41.69	41.04	41.36	44.41	43.19	43.80
S. Em. ±	0.066	0.060	0.045	0.060	0.024	0.032	0.327	0.281	0.215	0.464	0.150	0.244
CD 5%	0.210	0.191	0.133	0.191	0.076	0.096	1.030	0.887	0.636	1.462	0.475	0.718
FYM (t ha^{-1})												
Control	7.29	7.25	7.27	1.972	1.874	1.923	37.85	37.56	37.70	41.75	41.53	41.64
10	8.01	7.82	7.91	2.252	2.014	2.133	42.56	40.28	41.42	44.07	42.26	43.16
S. Em. ±	0.054	0.049	0.036	0.049	0.019	0.026	0.267	0.230	0.176	0.378	0.123	0.199
CD 5%	0.172	0.156	0.108	0.156	0.062	0.078	0.841	0.724	0.519	1.194	0.388	0.587
Fertilizer levels (N + P_2O_5 ha^{-1})												
Control	5.38	5.13	5.26	1.191	1.079	1.135	23.07	22.95	23.01	36.03	33.68	34.85
30 + 15	7.07	6.93	7.00	1.827	1.658	1.743	36.74	36.52	36.13	40.68	40.90	40.79
60 + 30	7.85	7.86	7.86	2.192	2.075	2.134	43.04	43.16	43.10	43.24	43.77	43.50
90 + 45	8.62	8.57	8.59	2.496	2.304	2.400	47.68	45.38	46.53	46.19	44.94	45.56
120 + 60	9.34	9.19	9.27	2.852	2.603	2.727	50.49	47.59	49.04	48.41	46.18	47.29
S. Em. ±	0.078	0.059	0.049	0.051	0.026	0.029	0.595	0.342	0.343	0.416	0.240	0.240
CD 5%	0.223	0.169	0.138	0.147	0.076	0.082	1.692	0.974	0.964	1.183	0.684	0.674

due to the fact that nitrogen fixed by legumes was better utilized by the succeeding crop of barley. Further, the magnitude of response due to different legumes also varied greatly in respect of build up of soil fertility and microbial activity, which ultimately influenced their residual effect on yield attributes of succeeding cereal crop. Grain yield of barley, being a function primarily of the cumulative effect of yield attributes, increased significantly under the preceding legumes especially clusterbean due to its similar effect on yield attributes. The results are in close conformity with those of Singh *et al.* (2004) who reported significant differences in grain yield of cereal crops after different kharif crops with higher yield under legumes.

Effect of FYM applied to kharif crops

Similarly application of 10 t FYM ha^{-1} to kharif crops has significant residual effect on growth characters of barley. There were 5.02, 23.41, 7.89 and 86.72 per cent increment in plant height, dry matter accumulation, effective tillers and flag leaf area on pooled basis of analysis. This might be attributed due to the improvement in overall nutritional environment in the root zone coupled with improvement in physical, chemical and biological properties of soil due to decomposition of the manure during rainy season and greater availability of nutrients to the crop of barley with improved vigour of initial growth phase of the crop. Thus balanced nutrition under favourable environment of FYM to the crop of barley might have helped in production of new tissues and development of new shoots leading ultimately to increased plant height, dry matter production and number of tillers per metre row length. These results are in agreement with those of Sharma and Vyas (2002) who also observed improvement in growth parameters of wheat due to application of FYM in soybean.

Application of FYM @ 10 t ha^{-1} to the preceding kharif crops recorded significantly higher number of effective tillers per metre row length, spike length, grains per spike and test weight of barley over unmanured control. Application of FYM @ 10 t ha^{-1} to kharif crops recorded the higher pooled grain, straw and biological yields of barley over control. The significant increase in grain and straw yields due to the influence of FYM were largely a function of improved growth and the consequent improvement in yield attributes as mentioned above. Further FYM increased the efficiency of added chemical fertilizer in soil, activities of N fixing bacteria and increased rate of humification. Humic acid in FYM might have enhanced the availability of both native and added nutrients in soil and as a result improved growth & yield attributes and yield of the crop significantly increased (Rao *et al.* 1995).

Effect of fertilizer levels applied to barley

Fertilizer application to the barley crop significantly increased the effective tillers per metre row length, spike length, spike weight, number of grains per spike and test weight of grain in both the years as well as on the basis of pooled analysis. The positive effect of fertilizer application on yield attributing characters of barley seems to be due to cumulative effect on growth and vigour of plants. By virtue of increased supply of metabolites, there might have been significant improvement in dry matter production with increasing fertilizer application. Thus greater uptake of nutrients provided less competition

Table 3. Effect of kharif crops, FYM and fertilizer levels on yields (q ha^{-1}) of barley

Treatment	Grain yield (q ha^{-1})			Straw Yield (q ha^{-1})			Biological Yield (q ha^{-1})			Harvest Index (%)		
	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled
Kharif crops												
Pearl millet	26.76	25.99	26.38	31.14	30.46	30.80	57.90	56.45	57.18	46.40	45.84	46.12
Mothbean	27.99	28.90	28.45	33.67	34.01	33.84	61.66	62.91	62.29	45.38	45.89	45.64
Clusterbean	30.44	32.17	31.31	35.74	37.60	36.67	66.19	69.77	67.98	46.12	46.31	46.21
S. Em. ±	0.530	0.405	0.333	0.352	0.500	0.306	0.832	0.686	0.539	0.307	0.400	0.252
CD 5%	1.670	1.278	0.984	1.112	1.575	0.902	2.622	2.164	1.591	NS	NS	NS
FYM (t ha^{-1})												
Control	26.20	27.41	26.80	31.37	32.37	31.87	57.57	59.78	58.67	45.69	45.78	45.74
10	30.60	30.64	30.62	35.66	35.67	35.67	66.26	66.31	66.29	46.24	46.24	46.24
S. Em. ±	0.432	0.331	0.272	0.288	0.408	0.249	0.679	0.560	0.440	0.251	0.327	0.206
CD 5%	1.363	1.043	0.803	0.908	1.286	0.737	2.141	1.767	1.299	NS	NS	NS
Fertilizer levels (N + P_2O_5 ha^{-1})												
Control	14.93	12.33	13.63	17.48	14.38	15.93	32.41	26.71	29.56	46.09	46.09	46.09
30 + 15	25.96	24.72	25.34	29.57	29.69	29.63	55.53	54.41	54.97	46.73	45.45	46.09
60 + 30	29.26	30.24	29.75	32.91	34.40	33.66	62.17	64.64	63.41	46.98	46.67	46.82
90 + 45	34.50	36.98	35.74	41.14	43.98	42.56	75.64	80.96	78.30	45.28	45.65	45.57
120 + 60	37.34	40.85	39.09	46.49	47.67	47.07	83.82	88.51	86.16	44.56	46.19	45.37
S. Em. ±	0.452	0.465	0.324	0.389	0.374	0.270	0.746	0.637	0.490	0.931	0.735	0.593
CD 5%	1.287	1.324	0.911	1.107	1.064	0.758	2.122	1.813	1.377	NS	NS	NS

Table 4. Combined effect of kharif crops and fertilizer levels on grain, straw and biological yield (q ha^{-1}) of barley (Pooled mean)

Treatment	Grain yield (q ha^{-1}) of barley		
	Kharif crops		
Fertilizer levels (N + P_2O_5 ha^{-1})	Pearl millet	Mothbean	Clusterbean
Control	12.69	13.31	14.89
30 + 15	22.19	25.07	28.77
60 + 30	25.60	30.24	33.41
90 + 45	32.94	34.62	39.66
120 + 60	38.47	39.00	39.82
S. Em. ± F at C	0.562	C at F	0.603
CD 5%	1.579		1.721
	Straw yield (q ha^{-1}) of barley		
Fertilizer levels (N + P_2O_5 ha^{-1})	Pearl millet	Mothbean	Clusterbean
Control	14.84	16.00	16.95
30 + 15	25.85	30.39	32.65
60 + 30	30.56	33.60	36.80
90 + 45	38.31	42.31	47.06
120 + 60	44.43	46.89	49.89
S. Em. ± F at C	0.467	C at F	0.518
CD 5%	1.313		1.481
	Biological yield (q ha^{-1}) of barley		
Fertilizer levels (N + P_2O_5 ha^{-1})	Pearl millet	Mothbean	Clusterbean
Control	27.54	29.32	31.84
30 + 15	48.03	55.46	61.42
60 + 30	56.16	63.84	70.22
90 + 45	71.25	76.93	86.71
120 + 60	82.90	85.88	89.71
S. Em. ± F at C	0.850	C at F	0.932
CD 5%	2.386		2.661

between main stem and tillers, resulting in higher number of effective tillers with fertilizer application. Increased growth components due to increased fertilizer levels might have provided stability in higher supply of photosynthates towards the sink (grain / ear). The improvements in yield attributing characters with fertilizer application are in close conformity with Roy and Singh (1989), Arvind Kumar et al. (2001) and Repsiene (2001).

Combined effect of preceding kharif crops and fertilizer levels applied to barley

At lower levels of fertilizer applied to barley, there was less improvement in grain yield of succeeding barley grown after pearl millet and mothbean compared to barley grown after clusterbean. But at higher levels of fertilizer, application of 120 kg N + 60 kg P_2O_5 ha^{-1} to barley crop after clusterbean, mothbean and pearl millet were significantly at par with application of 90 kg N + 45 kg P_2O_5 ha^{-1} to barley grown after clusterbean. This might be due to the fact that clusterbean add higher biomass as residue because of higher leaf fall at harvest and complete root portion remains in soil after cutting of clusterbean plant whereas mothbean add less biomass as residue because of complete uprooting of mothbean plant as a harvesting technique. The lowest barley yield was recorded when it was grown after pearl millet due to exhaustive nature whereas inclusion of legumes (clusterbean) might helped in maintaining soil fertility and improvement in physical properties of soil to some extent.

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YIELD AND QUALITY OF MUSTARD (*BRASSICA JUNCEA L.*) AS INFLUENCED BY DIFFERENT MUSTARD BASED CROPPING SEQUENCES UNDER GRADED NITROGEN LEVELS

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ABSTRACT

Field studies were conducted during 1996-97 and 1997-98 at Crop Research Centre of the G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar–263145 (Uttarakhand) to evaluate different mustard based cropping sequences at graded N levels. The treatment included 6 cropping sequences (viz. Maize-Mustard, Soybean-Mustard, Moong-Mustard, Cowpea-Mustard, Fallow-Mustard and *Dhaincha*-Mustard as main treatments) and 5 N levels (viz. 0, 40, 80, 120 and 160 kg/ha) as subplot treatments. The soil of experimental site was silty caly loam in texture, neutral pH, high in organic carbon (1.02%), available phosphrous (56 Kg P_2O_5 /ha) and medium in available potassium (230 kg K_2O /ha). The experiment was laid out in split plot design with three replications. In case of *Dhaincha*-Mustard crop sequence, fifty days old *Dhaincha* was incorporated in the soil for green manuring, while in Moong-Mustard crop sequence moong residues were turned into soil after first plucking. All crops were raised as per recommended package and practices for the region. The result revealed that successive doses of nitrogen improved all the biometric characters significantly of the crops. In addition, the preceding grain legumes also significantly influenced the growth and yield attributes of mustard crop. Mustard grown after cowpea produced the highest growth and yield attributes. *Dhaincha*-Mustard sequence recorded higher oil yield but was *at par* with Cowpea-Mustard and Fallow-Mustard sequences. However, oil content decreased at higher rates of nitrogen application. Average grain and oil yield of Mustard (viz. 1800 kg/ha and 723 kg/ha, respectively) after cowpea was significantly higher than other preceding crops. Results have clearly indicated that mustard followed after cowpea produced maximum grain and oil yield with maximum net returns.

Key words: Yield, Quality, Mustard.

Mustard *(Brassica juncea L.)* is prominently grown as a mono crop and also after a cereal or legume crop in sequence. In India rapeseed-mustard occupied 7.06 m ha area with a production of 4.71 m ton and productivity of 667 kg/ha during 1997-98. The production and productivity figures were 6.66 m tones and 1017 kg/ha, respectively during 1996-97. Introduction of legumes in rotation has been found helpful in increasing the availability of nitrogen to the succeeding crop by improving the soil fertility. In intensive cropping system, the production of mustard can be sustained by inclusion

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of legumes and green manuring crop in sequence. Tomar and Tiwari (1990) observed maximum net return form Black Gram-Mustard and green Gram-Mustard sequences over Fallow-Mustard sequence. The importance of legumes as builder and restorer of soil fertility have long been recognized. Although the beneficial effect of legumes on the succeeding crop has been known to some extent, the information pertaining to the availability of nitrogen to the succeeding non-legumes crops have been scarce. Thus, the effect of legumes vis-à-vis cereals in sequential cropping is of immense practical significance in sustained production of rapeseed-mustard in the country.

MATERIALS AND METHODS

The field experiment was conducted during the winter seasons of 1996-97 and 1997-98 at the Crop Research Centre of the G.B. Pant University of Agriculture and Technology, Pantnagar U.S. Nagar–263145 (Uttarakhand). The experiment was laid out in split-plot design with three replications. The main plot treatment consisted of 6 cropping sequences (Maize-Mustard, Soybean-Mustard, Moong-Mustard, Cowpea-Mustard, Fallow-Mustard and *Dhaincha*-Mustard) and sub-plot consisted of five N levels (0, 40, 80, 120 and 160 kg/ha). Fifty days old Sesbania aculeate plants were incorporated into the soil for green manuring while Moong residues were

Table 1. Effect of different cropping sequences and nitrogen Levels on Plant height, Branches/plant and Total dry matter accumulation of mustard during 1996- 97 and 1997-98.

Treatments	Plant Height (cm)		No. of Branches/ plant		Total dry Matter accumulation g/plant	
	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
Cropping sequences						
Maize-Mustard	188.2	178.2	12.1	9.6	49.29	45.74
Soybean-Mustard	186.1	176.1	10.5	8.1	50.70	45.20
Moong-Mustard	191.3	180.6	13.3	10.8	51.70	46.24
Cowpea-Mustard	198.8	186.8	16.1	13.6	53.21	48.04
Fallow-Mustard	192.5	182.6	13.7	11.2	52.38	46.87
Dhaincha-Mustard	194.6	184.6	14.8	12.3	52.68	47.49
C.D. at 5%	2.7	0.12	0.8	0.8	2.40	0.30
Nitrogen Levels (kg/ha)						
0	182.8	172.8	10.0	7.6	37.26	32.92
40	191.0	179.3	12.5	10.1	44.38	38.43
80	193.5	183.0	13.7	11.3	51.90	46.80
120	195.7	185.6	14.6	12.2	60.93	56.43
160	196.10	186.6	16.2	13.8	62.33	58.40
CD at 5 %	2.20	0.16	0.5	0.5	3.03	0.29

incorporated into the soil after plucking first flush.

A uniform basal application of 40 kg P_2O_5 and 20 kg K_2O per ha was made along with 50% N. Remaining quantity of nitrogen was top dressed after first irrigation at 30 days stage, in mustard. Mustard variety Kranti was sown @ 5 seed kg/ha at a spacing of 45 cm x 15 cm. Rest of the cultivation practices are followed as per recommendations.

Results and Discussion

Cropping Sequence

The growth and yield parameters viz. plant height, number of branches, dry matter production, siliqua/plant, seeds/ siliqua and 1000 seed weight (Table 1&2) of mustard increased when grown after legumes and green manuring crop as compared to Maize-Mustard sequence. This was because of improving soil fertility which resulted in better crop growth and higher dry matter accumulation by crop in sequences involving legumes or green manuring as preceding crop. Increased number of leaves resulted in more dry matter production in Cowpea-Mustard sequence which resulted in stronger reproductive phase and in turn increased seed weight per plant. Similar findings were also reported by Trivedi et al. (1997).

The Cowpea-Mustard sequence also recorded significantly higher mustard seed yield (Table 3) over Maize-Mustard and Soybean-Mustard sequences during both the years. Maize-Mustard and

Table 2. Effect of different cropping sequences and nitrogen Levels on siliquae/plant, No. of seeds/siliquae and 1000 seed weight (g) of mustard during 1996- 97 and 1997-98

Treatments	Siliquae/plant		Seeds/siliquae		1000 seed weight (g)	
	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
Cropping sequences						
Maize-Mustard	165.5	154.4	10.9	10.6	3.1	2.9
Soybean-Mustard	161.2	150.6	10.5	10.2	3.0	2.9
Moong-Mustard	170.2	160.2	11.1	10.9	3.2	3.0
Cowpea-Mustard	184.3	174.8	11.9	11.8	3.6	3.5
Fallow-Mustard	174.2	164.0	11.6	11.2	3.2	3.1
Dhaincha-Mustard	178.3	167.1	12.4	11.5	3.3	3.2
C.D. at 5%	2.0	2.9	0.1	0.2	0.1	0.1
Nitrogen Levels (kg/ha)						
0	159.0	148.7	10.0	9.8	3.1	3.0
40	169.5	159.3	10.7	10.4	3.2	3.1
80	174.5	163.7	11.5	11.1	3.2	3.2
120	177.7	167.5	12.1	11.7	3.3	3.2
160	180.4	170.3	12.4	12.0	3.3	3.2
CD at 5 %	0.6	0.9	0.1	0.1	NS	0.1

Table 3. Effect of different cropping sequences and nitrogen Levels on seed yield, Stover yield and Nitrogen uptake of mustard during 1996-97 and 1997-98

Treatments	Seed Yield (q/ha)			Stover yield (kg/ha)		Nitrogen uptake (kg/ha)	
	1996-97	1997-98	Mean	1996-97	1997-98	1996-97	1997-98
Cropping Sequences							
Maize-Mustard	16.5	15.9	16.2	42.4	39.9	84.7	108.2
Soybean-Mustard	12.6	12.2	12.4	42.8	39.7	82.1	103.0
Moong-Mustard	16.9	16.5	16.7	43.6	39.5	88.9	110.4
Cowpea-Mustard	18.4	17.5	18.0	44.9	41.7	107.7	131.3
Fallow-Mustard	17.5	16.8	17.1	44.1	40.6	95.5	123.7
Dhaincha-Mustard	18.2	17.8	18.0	44.5	41.0	101.2	125.4
C.D. at 5%	1.7	1.8	-	0.8	0.6	5.2	5.0
Nitrogen Levels (kg/ha)							
0	13.0	12.6	12.8	24.6	38.9	51.0	72.9
40	15.3	14.9	15.1	37.6	39.6	68.7	88.7
80	16.6	15.9	16.2	45.7	40.6	89.5	114.9
120	18.9	18.4	18.7	55.3	41.8	126.1	145.1
160	19.6	19.0	19.3	55.4	41.2	133.0	163.3
CD at 5 %	1.2	1.4	-	0.7	0.8	3.6	2.6

Fallow-Mustard sequences were remained at par in seed yield. Minimum seed yield of mustard was recorded in Soybean-Mustard sequence. The interaction effect between cropping sequences and nitrogen rates significantly influenced the seed yield during both the years. Although, the oil content (Table-4) in seed did not differ significantly due to cropping sequence but in treatments where legumes preceded mustard recorded higher value. *Dhaincha*-Mustard sequence recorded higher oil yield but was at par with Cowpea-Mustard and Fallow-Mustard sequences.

Nitrogen uptake in stem and leaves increased with the advancement of crop age. However, maximum increase was recorded between 30 and 60 days stages. The Cowpea-Mustard sequence recorded highest nitrogen uptake during both the years. Similarly nitrogen uptake in seeds was significantly higher in Cowpea-Mustard sequence but was at par with *Dhaincha*-Mustard sequence during 1997-98.

Nitrogen Fertilization

The growth parameters viz. plant height, branches/plant and dry matter production (Table-1) increased significantly with increase in nitrogen levels up to 120 kg N/ha beyond which the increase was found non significant. Similarly, the yield attributes viz. siliqua/plant, seeds/siliqua, test weight

Table 4. Effect of different cropping sequences and nitrogen Levels on Oil Content and oil yield of mustard during 1996-97 and 1997-98.

Treatments	Oil Content (%)		Oil Yield (kg/ha)		
	1996-97	1997-98	1996-97	1997-98	Mean
Cropping sequences					
Maize-Mustard	39.8	39.6	658.3	639.3	648.8
Soybean-Mustard	39.0	38.0	495.9	477.5	486.7
Moong-Mustard	39.5	39.5	672.0	654.7	663.3
Cowpea-Mustard	40.5	40.1	733.8	712.7	723.2
Fallow-Mustard	40.8	40.5	711.2	693.9	702.5
Dhaincha-Mustard	40.7	40.8	744.8	730.2	737.5
C.D. at 5%	NS	NS	46.8	42.7	-
Nitrogen Levels (kg/ha)					
0	40.2	39.6	524.9	502.7	513.8
40	40.5	40.1	624.9	603.3	614.1
80	40.1	40.1	670.5	655.2	662.8
120	40.0	39.9	734.7	737.1	735.9
160	39.6	39.7	771.6	758.7	765.1
	0.1	NS	5.1	8.7	-

(Table-2) were also found significantly higher at 120 kg N/ha. This might be due to the higher rate of nitrogen exhibited better growth of the crop plant which resulted in higher yield attributes. Similar findings were also reported by Gangwar and Kumar (1986) and Kachroo (1995).

Application of 120 kg N/ha recorded significantly higher seed yield (Table-3) over all the lower nitrogen rates. The yield of mustard increased up to 160 kg N/ha rate in different cropping sequences but 120 and 160 kg N/ha rates remained at par. Increasing levels of nitrogen caused significant increase in oil content in seeds upto 40 kg N/ha beyond which oil content decreased in seeds. The effect of nitrogen rates was found significant on oil yield (Table-4) and successive increase in nitrogen rates increased oil yield of mustard.

The total nitrogen uptake in plant increased with the increase in nitrogen rates at harvest during both the years and highest uptake was recorded at 160 kg N/ha during both the years.

Therefore, it could be concluded that Cowpea-Mustard sequence should be followed with 120 kg N/ha for sustained production of mustard crop. Growing of *Dhaincha* before mustard is also desirable, it reduces the nitrogen application to 80 kg N/ha. Keeping the land fallow had no advantage.

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RESPONSE OF MUSTARD (*BRASSICA JUNCEA* L.) TO NITROGEN FERTILIZATION GROWN IN DIFFERENT CROPPING SYSTEMS

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ABSTRACT

The present investigation was carried out during winter seasons, of 1996-97 and 1997-98 at Crop Research Centre of the G.B. Pant University of Agriculture and Technology, Pantnagar. The treatments consisted of six cropping sequences (Maize-Mustard, Soybean-Mustard, Moong-Mustard, Cowpea-Mustard, Fallow-Mustard and Dhaincha-Mustard) as main-plot treatments and five nitrogen rates (0, 40, 80, 120 & 160 kg N/ha) as sub-plot treatments were tested in split plot design with 3 replications. The mustard variety Kranti was sown at a spacing of 30x15 cm. A uniform basal application of 40 kg P_2O_5 and 20 kg K_2O per ha. was made along with 50% N. Remaining quantity of nitrogen was top dressed after first irrigation at 30 days stage, in mustard. Rest of the cultivation practices are followed as per recommendation. The results revealed that the Cowpea/Dhaincha - Mustard sequence with 120 kg N/ha. gave the maximum plant height, branches/plant, siliquae/plant, seeds/siliqua, 1000-seed weight, dry matter accumulation, oil content, nitrogen uptake and seed, stover and oil yield of mustard crop.

Key words: Mustard, Nitrogen, Cropping sequence.

Mustard are most important crop of arid and semi arid regions of the country. Indian mustard (*Brassica juncea*) accounts 21% of the total area under oil seed crops and 23% of total oilseed production in the country. In intensive cropping system, the production of mustard can be sustained by inclusion of legumes and green manuring crop in sequence. Introduction of legumes in rotation has been found helpful increasing the availability of nitrogen to the succeeding crop. Tomar and Tiwari (1990) observed maximum net return form Black Gram-Mustard and Green Gram- Mustard sequences over Fallow-Mustard sequence. The importance of legumes as builder and restorer of soil fertility have long been recognized. Although the beneficial effects of legumes on the succeeding crop have been known to some extent, the information pertaining to the availability of nitrogen to the succeeding non-legumes crops have been scarce. Thus, the effect of legumes vis-a-vis cereals in sequential cropping is of immense practical significance to sustained production of rapeseed-mustard in the country. Legumes as proceeding, inter crop or green manuring crop have been reported to help in increasing the productivity and economizing fertilizer needs of coarse cereal based cropping

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system in the western parts of the country (Hegde, 1994). Keeping in view the present study was carried out to assess the response of mustard (*Brassica juncea* L.) to nitrogen fertilization grown in Different Cropping Systems.

Material and Methods

The field experiment was conducted during winter seasons, of 1996-97 and 1997-98 at Crop Research Centre of the G.B. Pant University of Agriculture and Technology, Pantnagar, taking six cropping sequences (Maize-Mustard, Soybean-Mustard, Moong-Mustard, Cowpea-Mustard, Fallow-Mustard and Dhaincha-Mustard) as main-plot treatments and five nitrogen rates (0, 40, 80, 120 & 160 kg N/ha) as sub-plot treatments in split plot design with 3 replications. The soil of experimental site was silty clay loam in texture, neutral pH, high in organic carbon, available phosphorus and medium in available potassium. Fifty days old *Sesbania aculeata* plants were incorporated into the soil for green manuring while moong residues were incorporated into the soil after plucking first flush. The mustard variety Kranti was sown at a spacing of 30x15 cm. An uniform basal application of 40 kg P_2O_5 and 20 kg K_2O per ha. was made along with 50% N. Remaining quantity of nitrogen was top dressed after first irrigation at 30 days stage, in mustard.

Results and Discussion

Effect of Cropping systems

Significantly higher seed, stover and oil yield (Table-2) of mustard was recorded in *Dhaincha*-Mustard sequence but remained at par with Cowpea-Mustard sequence. The growth characters of mustard increased when grown after legumes and green manuring crop as compared to maize-mustard sequence. This was because of better crop growth and higher dry matter production in sequences involving legumes or green manuring as preceding crops and resulted in higher seed and stover yield. The similar finding was also reported by Sharma *et al.* (1992). The oil yield is mainly depending on oil content in seeds. The oil content (Table-2) in seeds did not differ significantly due to cropping sequences but in treatments where legumes preceded mustard recorded higher value and resulted in higher oil yield in *Dhaincha*-Mustard and Cowpea-Mustard sequences.

The growth characters viz. plant height, branches/plant and dry matter accumulation/plant (Table-1) were found significantly higher in cowpea-mustard sequence followed by *Dhaincha*-mustard sequence. This might be due to legumes crop grown as preceding crop improve the soil fertility and resulted in to more plant height, number of branches/plant and dry matter production of mustard crop. The similar results were also reported by Saraf (1994).

The yield attributing characters viz. siliquae/plant, seeds/siliqua and 1000 seed weight (Table-1) were also found maximum in cowpea-mustard sequence followed by *Dhaincha*-mustard sequence. The 1000-seed weight was found higher because better availability of nutrients to the plants resulting in bolder size of seed. The nitrogen uptake at harvest was maximum in cowpea-mustard sequence and also more in treatments where mustard was preceded by a legumes crop on account increased nitrogen availability to the succeeding mustard crop which resulted vigorous plant growth and thereby increased seed yield. Trivedi *et al.*(1997) also reported the similar results.

Table 1. Effect of different cropping sequence and nitrogen rates on plant height, branches/ plant, siliquae/ plant, number of seeds/ Siliquae, total dry matter accumulation/ plant and 1000-seed weight (g) of mustard during 1996-97 and 1997-98

Treatments	Plant height(cm)		Branches/ plant		Siliquae/ plant		Seeds/ siliqua		Total dry Matter accumulation/ plant		1000-seed weight (g)	
	1996-97	1997-98 98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
Cropping Sequences												
Maize-Mustard	188.2	178.2	12.1	9.6	165.5	154.4	10.9	10.6	49.29	45.74	3.1	2.9
Soybean-Mustard	186.1	176.1	10.5	8.1	161.2	150.6	10.5	10.2	50.70	45.20	3.0	2.9
Moong- Mustard	191.3	180.6	13.3	10.8	170.2	160.2	11.1	10.9	51.70	46.24	3.2	3.0
Cowpea- Mustard	198.8	186.8	16.1	13.6	184.3	174.8	11.9	11.8	53.21	48.04	3.6	3.5
Fallow- Mustard	192.5	182.6	13.7	11.2	174.2	164.0	11.6	11.2	52.39	46.87	3.2	3.1
Dhaincha- Mustard	194.6	184.6	14.8	12.3	178.3	167.1	12.4	11.5	52.68	47.49	3.3	3.2
CD (P=0.05)	2.7	0.12	0.8	0.8	2.0	2.9	0.1	0.2	2.40	0.30	0.1	0.1
Nitrogen rates (kg N/ha)												
0	182.8	172.8	10.0	7.6	159.0	148.7	10.0	9.8	37.26	32.92	3.1	3.0
40	191.0	179.3	12.5	10.1	169.5	159.3	10.7	10.4	44.38	38.43	3.2	3.1
80	193.5	183.0	13.7	11.3	174.5	163.7	11.5	11.1	51.90	46.80	3.2	3.2
120	195.7	185.6	14.6	12.2	177.7	167.5	12.1	11.7	60.93	56.43	3.3	3.2
160	196.10	186.6	16.2	13.8	180.4	170.3	12.4	12.0	62.33	58.40	3.3	3.2
CD (P=0.05)	2.20	0.16	0.5	0.5	0.6	0.9	0.1	0.1	3.03	0.29	NS	0.1

Table 2. Effect of different cropping sequence and nitrogen rates on seed yield, seed weight, stover yield, harvest index, oil content, oil yield and total nitrogen uptake of mustard during 1996-97 and 1997-98

Treatments	Seed yield (kg/ha)		Stover yield (kg/ha)		Harvest index		Oil Content (%)		Oil yield (kg/ha)		Total Nitrogen Uptake(kg/ha)	
	1996-97	1997-98 98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
Cropping Sequences												
Cropping Sequences												
Maize-Mustard	16.55	15.92	42.4	39.9	21.1	24.3	39.8	39.6	658.3	639.3	108.20	84.76
Soybean-Mustard	12.68	12.28	42.8	39.7	16.9	19.7	39.0	38.0	495.9	477.5	103.09	82.12
Moong- Mustard	16.97	16.56	43.6	39.5	21.1	24.9	39.5	39.5	672.0	654.7	110.49	88.93
Cowpea- Mustard	18.45	17.73	44.9	41.7	21.9	25.4	40.5	40.1	733.8	712.7	131.33	107.72
Fallow- Mustard	17.50	16.89	44.1	40.6	24.4	25.0	40.8	40.5	711.2	693.9	123.75	95.54
Dhaincha- Mustard	18.29	17.88	44.5	41.0	22.3	25.8	40.7	40.8	744.8	730.2	125.42	101.25
CD (P=0.05)	1.79	1.80	0.8	0.6	0.2	0.2	NS	NS	46.8	42.7	5.01	5.25
Nitrogen rates (kg N/ha)												
0	13.07	12.67	24.6	38.9	22.6	20.5	40.2	39.6	524.9	502.7	72.90	51.04
40	15.39	14.99	37.6	39.6	21.0	23.1	40.5	40.1	624.9	603.3	88.79	68.78
80	16.67	15.94	45.7	40.6	20.2	24.2	40.1	40.1	670.5	655.2	114.91	89.51
120	18.93	18.43	55.3	41.8	19.9	26.1	40.0	39.9	734.7	737.1	145.19	126.19
160	19.60	19.04	55.4	41.2	20.4	27.0	39.6	39.7	771.6	758.7	163.30	133.08
CD (P=0.05)	1.22	1.14	0.7	0.8	0.3	0.3	0.1	NS	5.1	8.7	2.62	3.68

Nitrogen rates

The successive increase in nitrogen rates caused increase in seed, stover and oil yield (Table-2) of mustard. Application of 120 kg N/ha. gave the significantly higher seed yield over all the lower nitrogen rates, but was at par with 160 kg N/ha. The increase in seed yield of mustard due to nitrogen application may be because of the fact that nitrogen played an important role in the synthesis of chlorophyll and amino acid which constitute building blocks of proteins. The more harvest index with the application of nitrogen indicated the corresponding increase in seed yield rather than stover yield. Nitrogen influence the seed yield through source-sink relationship in addition to higher production of photosynthates leasing to increasing translocation to reproductive parts. The higher rates of nitrogen fertilization decrease the oil content (Table-2) significantly above 40 kgN/ha but increased the oil yield per hectare. Since, the oil yield is the resultant of seed yield and oil per cent, the oil yield per hectare also increased due to nitrogen application up to 120 kg/ha because of increase in seed yield. These findings are in agreement with Bishnoi and Singh, 1979 and Singh, 1989.

The growth characters viz plant height, branches/plant and dry matter accumulation/plant (Table-1) increased with increase in nitrogen rates up to 160 kg N/ha. This might be due to more activities of meristmatic tissues of the plant and producing more height and branches. Application of nitrogen caused vigorous vegetative growth due to cell division and more meristmatic activity increased leaf area and supply of photosynthates for the formation of branches and dry matter accumulation. Sharma, 1986 also reported the similar results.

The number of siliquae/plant, seeds/ siliqua, and 1000-seed weight (Table-1) were higher with the application of 160 kg N/ha because of increased translocation of food material for the formation of the seeds. The yield attributes viz. siliquae/plant, seeds/ siliqua and 1000 seed weight showed their additive effect in influencing the seed yield with increasing rates of nitrogen application. Patel *et al.* 1980 also reported highest 1000-seed weight with the application of nitrogen. The two higher nitrogen rates ie. 120 and 160 kg N/ha did not differ significantly for 1000-seed weight. The total nitrogen uptake (Table-2) increased significantly with the higher doses of nitrogen application during both the years. This might be due to the nitrogen uptake is a cumulative effect of nitrogen content in plant parts and dry matter yield which were found higher at higher nitrogen rates and resulted in to higher nitrogen uptake.

Therefore, it could be concluded that the Cowpea/*Dhaincha* - Mustard sequence be followed and applied with 120 kg N/ha. for sustained production of mustard crop.

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EFFECT OF CROP GEOMETRIES AND WEED CONTROL TREATMENTS ON YIELD AND QUALITY PARAMETERS OF IRRIGATED COTTON (*GOSSYPIUM HIRSUTUM* L.)

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Abstract

A field experiment was conducted during summer 2002, at Department of Agronomy, M.P.K.V., Rahuri, to study the, "Effect of crop geometries and weed control treatments on yield and quality parameters of cotton (*Gossypium hirsutum* L.) under irrigated conditions. The experiment comprising the 16 treatment combinations (A) Planting geometries, 90 x 90 cm (P_1) normal planting, 90-180 x 45 cm (P_2) one row skip after two rows planting and 90-270 x 45 cm (P_4) two rows skip after two rows planting (B): Weed control treatments i.e. application of fluchloralin @ 1.0 kg a.i. ha^{-1} pre plant incorporation (PPI) (W_1), hoeing 20 DAS + 2 hand weedings 40 and 60 DAS (W_2), weed free check (W_3) and weedy check (W_4) were arranged factorial randomized block design with three replications. The results revealed that the spacing of 90-180 x 60 cm (one row skipping after two rows planting) in cotton increased all the yield contributing and quality characters of seed cotton (22.21 q ha^{-1}), stalk yield (59.37 q ha^{-1}), ginning percentage (35.70 %), staple length (24.34 mm) and lint index 4.25) as compared to other plant geometries. At all growth stages of crop, weed intensity found significantly highest in weedy check followed by chemical and mechanical weed control treatments, weed dry matter (5.81 q ha^{-1}) recorded higher in treatment 90-270 x 45 cm than rest of plant geometries.

Key words : Crop geometry, yield and quality

Cotton is an important cash crop of Maharasthra. It is cultivated in about 3.0 million hectares with production of 0.48 million tonnes. State cotton productivity is 180 kg ha^{-1} as against 250 kg ha^{-1} of India (Anonymous, 2002). The low productivity of cotton in the state is mainly attributed to rainfed crop cultivation, erratic behaviour of rainfall, lack of adoption of improved agro-techniques. The major problem faced by cultivators is non-adoption, timely and effective control of weeds. Due to weed competition yield losses upto 50-60 % was observed (Balyan *et al.*, 1998). There is one major constraint of low productivity of cotton is plant population both excess as well as less plant population affects the crop yield adversely, but there is no significant effect on quality parameters due to plant geometry. Keeping this in broad view the present experiment was conducted.

Material and Methods

The field experiment to assess the effect of crop geometries and weed control treatments on growth, yield and quality parameters of cotton (*Gossypium hirsutum* L.) was carried out under irrigated conditions during summer season 2002 at Post Graduate Institute Farm, M.P.K.V., Rahuri. The soil of experimental field was clayey in texture, low in available nitrogen (147.72 kg ha^{-1}), medium in available phosphorus (17.96 kg ha^{-1}) and high in available potash (440.73 kg ha^{-1}). The experiment was laid out in a factorial randomized block design with three replications comprising 16 treatments i.e. with four levels of planting geometries and four levels of weed control treatments. The planting geometries were normal planting (90 x 90 cm), one row skip after one row planting (90-180 x 45 cm), one row skip after two rows planting (90-180 x 60 cm) and two rows skip after two rows planting (90-270 x 45 cm). The weed control treatments were herbicide [fluchloralin 45 % EC @ 1.0 kg a.i. ha^{-1} pre-plant incorporation (PPI)], mechanical weed control (one hoeing 20 DAS + 2 hand weedings 40 and 60 DAS), weed free and weedy check. The variety NHH-44 was sown on 26th April 2002, six time irrigations applied at an interval of 10 days in summer and as per requirement of irrigation in *kharif* season. Plant protection deltramethrin spraying on 1st August 2002 for control of sucking pest of boll-worms @ 250 ml in 500 lit of water ha^{-1}. Weed count taken by a quadrant (1 x 1 m^2) was randomly fixed at two places in each net plot and the monocot and dicot weed count in the area of each quadrant was recorded. After harvest of crop all the weeds in net plot were removed, oven dried for 8 hours at 65 ^{0}C and dry weight was recorded separately as per the treatments.

Results and Discussion

The plant height (158.19 cm) was significantly highest due to crop geometry 90-180 x 60 cm, than other crop geometry. Due to weed control treatments, weed free treatment recorded highest plant height (174.69 cm), which was followed by mechanical control treatment. Those results are similar to those reported by Bastia (2000). The number of sympodial branches and number of developed bolls were recorded P_3 (90-180 x 60 cm), highest (40.90) and 32.87, respectively. Weed free treatment recorded highest sympodial branches (49.17) and developed balls per plant (38.68) than rest of weed control treatments. These results are in conformity with the findings of Ghatole (1995). Seed cotton weight per boll recorded highest (3.57 g)

Table 1. Treatment details and symbol used

Sr. No.	Treatment details	Symbols
A.	**Planting geometries**	
1.	90 x 90 cm – Normal planting	P_1
2.	90-180 x 45 cm – One row skip after one row planting	P_2
3.	90-180 x 60 cm – One row skip after two rows planting	P_3
4.	90-270 x 45 cm – Two row skip after two rows planting	P_4
B.	**Weed control treatments**	
1.	Chemical control (Fluchloralin 45 % EC @ 1.0 kg a.i./ha PPI)	W_1
2.	Mechanical control (1 hoeing 20 DAS + 2 hand weeding at 40 and 60 DAS)	W_2
3.	Weed free	W_3
4.	Weedy check	W_4

PPI = Pre-plant population

DAS = Days after sowing

Table 2. Mean plant height, number of sympodial branches per plant, number of developed bolls and seed cotton weight per boll as affected by different treatments

Treatment	Plant height (cm)	Number of sympodial branches per Plant	Number of developed bolls	Seed cotton weight per boll (g)
P_1 : 90 x 90	156.40	37.16	31.42	3.34
P_2 : 90-180 x 45	154.22	34.95	29.70	3.20
P_3 : 90-180 x 60	158.19	40.90	32.7	3.57
P_4 : 90-270 x 45	155.22	33.47	27.37	3.05
S.Em ±	0.48	0.32	0.35	0.04
C.D. at 5 %	1.41	0.92	1.02	0.12
Weed management				
W_1 : Chemical control	159.73	35.92	31.36	3.30
W_2 : Mechanical control	162.18	35.54	32.18	3.36
W_3 : Weed free	174.69	49.17	38.68	4.20
W_4 : Weedy check	124.44	25.85	19.14	2.30
S.Em ±	0.48	0.32	0.35	0.04
C.D. at 5 %	1.41	0.92	1.02	0.12
Interaction				
S.Em ±	0.97	0.64	0.71	0.08
C.D. at 5 %	N.S.	N.S.	N.S.	N.S.

in crop geometry 90-180 x 60 cm and weed free control treatment showed highest (4.20 g) seed cotton weight per boll that rest of treatment. Interaction effect found to be non-significant.

The yield and quality parameters of cotton as influenced by planting geometries and weed control treatments are presented in Table 3.

Effect of planting geometry

Significantly maximum seed cotton yield was (22.21 q ha^{-1}) recorded under planting geometry P_3 (90-180 x 60 cm), and in normal planting P_1 (90 x 90 cm) produced more seed cotton yield (20.56 q ha^{-1}) than P_2 and P_4 planting geometries. Closer spacing recorded significantly higher yield over wider spacing. This might be due to higher plant density per unit area. The results are parallel with those results obtained by Sharma *et al.* (2000) and Gokhale *et al.* (2002). Similar trend was found in stalk yield also. Ginning percentage, staple length and lint index were recorded significantly highest (35.70 %), (24.34 mm) and (4.25), respectively. Similar results were obtained by Singh and Warsi (1995). The weed count per m^2 (7.78) and dry matter of weeds (4.46 q ha^{-1}) were found lowest in plant geometry (P_3) 90-180 x 60 cm than rest of plant geometries P_1, P_2 and P_4.

Table 3. Mean seed cotton, stalk yield and quality parameters of cotton

Treatment	Seed cotton yield (q ha^{-1})	Stalk yield (q ha^{-1})	Ginning percent-age (%)	Staple length (mm)	Lint index (%)	Weed count (m^2)	Weed dry wt. (q ha^{-1})
Planting geometries (cm)							
P_1: 90 x 90	20.56	55.28	35.61	24.30	4.07	9.05	4.86
P_2: 90-180 x 45	19.27	50.05	35.54	24.24	3.93	8.28	5.46
P_3: 90-180 x 60	22.21	59.37	35.70	24.34	4.25	7.78	4.46
P_4: 90-270 x 45	18.76	48.16	35.50	24.22	3.85	10.88	5.81
S.Em $\pm$	0.20	0.46	0.01	0.00	0.03	0.11	0.06
CD at 5 %	0.60	1.33	0.03	0.01	0.10	0.32	0.17
Weed control treatments							
W_1: Chemical control	21.28	53.58	35.56	24.27	4.03	6.08	3.90
W_2: Mechanical control	22.83	59.08	35.62	24.29	4.11	4.80	3.08
W_3: Weed free	24.87	64.72	35.69	24.32	4.58	0.00	0.00
W_4: Weedy check	11.82	35.47	35.48	24.23	3.39	25.12	13.61
S.Em $\pm$	0.20	0.46	0.01	0.00	0.003	0.11	0.06
CD at 5 %	0.60	1.33	0.03	0.01	0.10	0.32	0.17

Effect of weed control treatments

The treatment (W_3) weed free recorded significantly highest seed cotton yield (24.87 q ha^{-1}), stalk yield (64.72 q ha^{-1}) ginning percentage (35.67 %), staple length (24.32 mm) and lint index (3.39) recorded lowest. It was followed by mechanical, chemical and weedy check treatments. Similar trend was reported by Shelke and Bhosale (1989). Seed count (4.80 m^2) and dry matter (3.08 q ha^{-1}) were found lowest in mechanical method of weed control; however, it was at par with chemical weed control treatment. These results were in conformity with those results noted by Satao and Lahariya (2000).

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FIELD PERFORMANCE AND FEASIBILITY TESTING OF INCLINED PLATE PLANTER IN WESTERN PLANE ZONE FARMING SYSTEM OF UTTAR PRADESH

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ABSTRACT

The high seed rate and labour requirement is also common problems associate in traditional sowing of bold seeds. For bold seeds such as maize, cotton, groundnut and pigeon pea planting and fertilizer placement are the two different unit operations performed either by tractor drawn planter or manual. Performance of tractor-drawn, six-row inclined plate planter machine developed at CIAE, Bhopal for planting of gram seeds in the furrow was tested. The machine has modular hopper and an inclined plate type metering unit. A suitable furrow opener system was equipped with the machine to place the seeds in the furrow at desired depth. The power transmission to the metering unit is through a ground wheel by chain-sprockets system. The field trials were conducted for sowing of gram at farmer's field. The performance indicators of the planter viz. field capacity, efficiency and machine index were calculated using the observed data in the field. The effective field capacity was 0.348 ha/h with field efficiency of 70.4%.

In most part of the country, the bold seeds are sown by dropping the seed manually in a furrow formed by plough. After sowing the seed, furrows are covered using wooden plank. For sowing in small areas dibbling is also practiced. In traditional sowing in India it is not possible to achieve uniformity in distribution of seeds. There is also poor control over depth of seed placement, result poor germination. The high seed rate and labour requirement is also common problems associated in traditional sowing of bold seeds. For bold seeds such as maize, cotton, groundnut and pigeon pea planting and fertilizer placement are the two different unit operations performed either by tractor drawn planter or manual. Inclined plate planters ensure uniform spacing between rows and seed to seed. The tractor drawn planter is an important machine in western plane zone of Uttar Pradesh, India for improving productivity. The traditional sowing practices followed by farmers in different parts of the country are broadcasting, manually, opening furrows by a country plough and dropping seeds in the furrow through a metal funnel attached to a country plough. For sowing in small areas making slits by a stick or tool and dropping seeds by a hand is practiced. All these conventional practices are time consuming and required high seed rate. The inclined plate planter (tractor drawn) is precision equipment that can meter bold seeds and plate than at predetermined depth with uniform seed to seed and row-to-rows spacing. Thus it saves labour, time and operational cost and costly seeds. On commercial scale seed drills are in use. Although a large number of planters have been developed in India and are commercially available for cotton, maize, groundnut, soybean, etc. (Pandey *et al*1997), a very limited information is available on mechanical planting of okra. Keeping this in view the present work on development and

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performance evaluation of a prototype planter for gram seed was under taken. The field experiments for the performance evaluation of the tractor operated inclined plate planter was conducted in the experimental farm of KVK.

Material and Method

It is tractor drawn six row sowing equipment (CIAE design) suitable for maize, cotton, groundnut, gram, pigeon pea, sorghum, sunflower and pea etc. It consists of a main frame seed hopper, fertilizer hopper, ground drive wheel chain and sprocket type transmission and furrow openers. Inclined plate with cell type metering mechanism provided for each of the seed hoppers, The seed hoppers are fixed on the tool bar with clamps, The hoppers can slide on these bars for positioning according to row spacing and allowing the seed delivery point just above the furrow openers (Shoe type). The height of the seed delivery spout has been kept close to the ground to achieve seed spacing uniformity. The fertilizer box is fitted on the mainframe with fluted rollers metering mechanism. The power to the inclined plate is transmitted from the spiked ground wheel through chain and sprocket and set of bevel gears. The detail specifications of functional components of the same are given in Table-1.

Laboratory Calibration for Row to Row Variation in Seed Metering Device

Gram was filled in the three seed hoppers, the ground wheel was jacked up and 25 revaluations were given to the ground wheel. The seed discharged from each of the seed tube collected separately were counted. Ten replications were done. Statistical analysis was performed on the data and't' test was used to test the hypothesis of mean seed discharged among the rows. Series of tests at full, three fourth and one half capacity of the hopper were conducted and the change in the required seed rates were observed.

Field Evaluation

The field experiments for the performance evaluation of the tractor operated inclined plate planter was conducted in the experimental farm of KVK. The procedure for testing the performance of the planter was adopted from RNAM Test Codes. The field was prepared into fine tilth by twice harrowing by rotavator for operation of planter. The test field was a sub divided into four plots of size 36mx18m. The hopper was filled with black gram seed and the height of the seed tube was adjusted to place the seed at a depth of 60mm. The planter was operated in straight rows. The operation was replicated in four plots. The observations regarding time taken to cover the area, actual depth of placement of seed and corresponding speed were taken. The performance indicators of the planter viz. field capacity, efficiency and machine index were calculated using the observed data in the field. The theoretical field capacity is the rate of field coverage that would be obtained if the planter was operating continuously without interruptions like turning at the end filling of hopper. The effective field capacity is the actual average rate of coverage including the time lost in filling hopper and turning at the end of the rows. Field efficiency is the ratio of the effective field capacity to the theoretical field capacity as shown below. The field machine index was calculated by using the following formula, which indicates the influence of field geometry on working capacity of the machine.

Table 1. Specifications of inclined plate planter

Developed at	:	CIAE, Bhopal
Type	:	6-row tractor mounted
Suitability for crops	:	Suitable for planting of seeds like groundnut, maize, gram, mustard, sorghum, pigeon pea, etc.,
Overall dimensions	:	2500x1218x1010 mm^3
Estimated cost	:	30,000/-
Type	:	Box section frame with a rear tool bar for mounting of furrow openers with seed boxes.
Section size	:	Box section of 40x40x5 mm^3 size made by welding 40x40x5 mm^3 size angle iron.
Furrow Openers		
Type	:	Show type
No and fixing arrangement	:	Six openers clamped on bar of main frame.
Row to row spacing and method of changing Row-spacing depth control.	:	By sliding the furrow openers on rear tool bar of main frame. Row spacing, range 22.5 to 45 cm by tractor hydraulic system
Seed Metering Mechanism		
Type	:	Inclined plate with edge cells
Size of plate	:	120 mm dia, number, size of Cells and plate thickness depends on seeds to be sown
No of cells on seed metering plate for black gram	:	20
Average row spacing, mm	:	350
Ground drive wheel	:	Spiked ground wheel made of 40x5 mm^2 size MS triangular shaped spikes of 75mm long welded on periphery of wheel. Tip dia : 550mm ,Rim dia : 400mm
Power transmission	:	Power from ground drive wheel is transmitted to a small counter shaft, fixed on front side of frame. From counter shaft, the power is transmitted to a main drive shaft, fixed of rear side of frame and from this shaft the power is transmitted to individual seed box, for operating. The seed metering system. Chain and sprocket drives are used for power transmission at various stages up to seed metering system is driven by the drive shaft through set of bevel gears.
Transmission ratio	:	1:1(can be changed)
Provision for sowing for different crops	:	By selecting seed plates for different crops and by changing the transmission ratio
Provision for seed cut off	:	When planter is lifted by hydraulic system of the tractor the ground wheel also gets lifted
Hopper	:	Six seed hopper with independent metering system. Seed hopper has two compartments, and second compartment holds the seed for picking by incined plate seed metering plates. Each hopper can store about 15 kg of seed.

Table 2. Performance of Inclined Plate Planter at KVK Farm

Actual area covered, ha(total)	1.7
Labour requirement, Man hr/ha	2
Type of soil	Sandy loam/ Alluvial
Effective working width, mm	890
Average Working depth, mm	71.5
Effective field capacity, ha h^{-1}	0.38
Field efficiency, %	68
Cost of operation, Rs h^{-1}	320.00
Cost of operation Rs ha^{1}	913.00

Performance Results of Field Trials

The field trials were conducted for sowing of gram at farmer's field. Details are given in Table 3. The trials were conducted at Ikwara, Rehamapur, Manoharpur on farmer's field over an area of 1 ha for planting gram. Short term technical training of 45 minute to 1 hr was conducted for the farmers for smooth operation planter. The granular fertilizer i.e. Dia-ammonium phosphate was drilled simultaneously. The soil parameters along with cone index were also recorded by using cone penetrometer before and prior to operation. The Bulk Density of the soil was calculated by Core Method. The moisture content was evaluated by oven dry method. Average number of seeds at 10m length of furrow and average missing hills at 10m length of furrow was also recorded to observe the seed placing performance of the planter. Average plant population (plant/m^2) was also recorded. The fuel consumption of tractor (M&M B-275) was also recorded. The complete filling of the tractor fuel tank at the field and refilling of fuel tank after the operation, technique was used to find out the fuel consumption. The other recorded field performance data of inclined plate planter is listed in table-3.

Cost Economics

The total cost of planting was determined based on fixed cost and variable cost (IS: 1964-1979).The fixed cost and variable cost was considered in determining the cost of operation of the planter. Fixed cost include depreciation, interest, insurance and taxes and shelter whereas variable cost include repair and maintenance cost, fuel consumption, labour cost etc. The total cost of operation was determined as the sum of the fixed and variable cost. The total cost of operation per hour of the machine was computed. The cost of operation of the tractor was also calculated following the same procedure. The cost of fuel, lubrication and operator was added to the variable cost. The total cost of operation of the planter was determined by adding the hourly cost of operation of the planter and tractor and expressed in Rupees per hour. It was converted into area basis by multiplying it with the effective field capacity of the machine and expressed in Rupees per hectare.

$FMI = \{T_O/(T_P+T_T)\}x100$
FMI= Field Machine Index
T_O=Theoretical field time, min/plot
T_P=Total productive time, min/plot
T_T= Total turning time, min/plot

TFC=(WxS)/100, ha/h
TFC= Theoretical Field Capacity,
W=Width of coverage,
S=speed of operation,

EFC= Actual area covered in unit time

FE = EFC/ TFC
FE= Field Efficiency
EFC= Effective Field Capacity
TFC= Theoretical Field Capacity

Table 3. Field performance of inclined plate planter at farmer field

Testing at each farmer's field crop	Ikwara Gram	Rehamapur Gram	Manoharpur Gram
Date of testing	24-10-2009	25-10-2009	27-10-2009
Size of field, ha	0.3	0.35	0.2
Training to operator, hr	0.74	0.52	0.45
Training to farmer, hr	2	2	2
Total operator time, hr	1	1	1
Time loss, h (due to repair/ breakdown, please report nature of breakdowns)	0.2	0.22	0.10
Time loss is filling the hopper, hr	0.15	0.18	0.20
Type of soil	Sandy loam/ Alluvial	Sandy loam/ Alluvial	Sandy loam/ Alluvial
Effective working width mm	890	890	890
Average Working depth, mm	61.5	63.2	64.5
Cone index (before testing)	16-17	17-18	16-18
Soil moisture, % db (before testing)	14.3	15.4	13.9
Bulk density, g/cm^3 (before testing)	1.70	1.60	1.60
Average no of seeds at 10m length of furrow	518	514	521
Average missing hills at 10m length of furrow	12	17	14
Average row spacing, mm	350	350	350
Type of seed	Bold	Bold	Bold
Seed rate, kg/ha	82.5	84.3	83.6
Type of fertilizer	DAP	SSP	SSP
Fertilizer rate, kg/ha	127	185	185
Effective field capacity, ha/hr	0.37	0.35	0.31
Field efficiency, %	74	73	71
Fuel consumption, lit./ha	10	11	12.4
Average plant population ($plant/m^2$)	29.2	31.5	30.5
Break down of equipment (Please report nature of breakdowns and their occurrence)		Clogging of fertilizer tube	

The cost of manual planting was calculated by taking into account the cost of man-hour required for sowing. The man-hour requirement for planting was recorded on the test plot. The manual planting was done by farm labour. The costs thus observed under mechanical planting and manual planting were compared.

Results and Discussion

Laboratory calibration

In the laboratory the row-to-row variation in seed metering and uniformity of seed delivery were studied. The test were conducted with full, three forth and half filled hopper. The results indicated that variation of seed discharged from the average of three rows, was statistically non-significant for all the three hopper fill conditions. Overall averages of 258.3 seeds were delivered in 25 revolutions of the ground wheel. The maximum deviation of seed discharge of any row from the average was observed to be less than 2 per cent. All the deviations were within the range of 7 percent set by Indian standards. No difference in metering was observed with different hopper capacity. This was due to the partition of hopper by sliding plate. The depth of seed layer was same for all the hopper capacity in the pickup chamber, hence no difference was observed for different hopper capacity

Field capacity and field efficiency

The effective field capacity was 0.348 ha/hr with field efficiency of 70.4% due to small size of the test plot. However, the reported field capacity of the planter in the manual was 0.49 ha/hr with field efficiency of 73.4%. The cost of operation was observed Rs/ha 913 compared to manual line sowing.

Field performance test

Field performance tests were carried out of the machine. The field test was done in the farmer field. The performance data of the planter was presented in Table-3. The soil parameters like cone index (16-18), soil moisture content (13.9-15.4), bulk desity (1.60-1.70) were fond to be optimum for the sowing of gram.

A medium size tractor (35hp, M&M B-275) was used to operate the planter. An average field capacity of 0.35 ha/hr to 0.37 was obtained for continuous operation of inclined plate planter at an average speed of 2.27 km/hr. A field efficiency of 71 to 74 percent was observed which was in the prescribed range of 65-75 percent for row crop planter (Kepner et *al.*, 1987). The major loss in efficiency was due to the turns at head and adjustment of planter position before run so that the furrow formed in the previous pass were not disturbed. No break down, repairs, and adjustment of components during the operation. However, once clogging of fertilizer tube was observed. The average depth of placement of seed of ten observations randomly selected was 6.5cm. The field machine index was recorded at an average of 77.38 percent. This was due to the rectangular size of the plot and less turning time at the head land. The seed rate obtained was 81Kg/ha for gram and plant to plant spacing was 5 to 8 cm. and depth of sowing was 60-65 mm. The seed rate and depth of sowing was found with in the prescribed range. Average plant population (plant/m^2) after germination was found under the prescribed range i.e. 29.2 to 31.5.

The conducted short term technical training of 45 minute to 1 hr enhanced

Calculation of cost of operation of inclined plate planter

Assumptions:

Initial cost	:	Rs. 30,000	Salvage value	:	Rs. 3,000
Service life	:	10 Years	Annual uses	:	120 hours.

(A) Annual fixed cost :

(i)	Depreciation	(30,000-3,000)/10	=Rs. 2700.00
(ii)	Interest on investment, (@16% per annum)	{(30000+3000)/2} x16/100	=Rs. 2640.00
(iii)	Insurance taxes and housing@ of the2% of initial cost per annum	:(30000 x2/100)	=Rs. 600.00
	Annual fixed cost	: 5940.00	=Rs. 5940.00
	Fixed cost of planter per hour	: 5940/120	=Rs. 49.50

(B) Variable cost per hour :

Repair and maintenance cost/hr (@5% of initial cost per annum) : 12.50

Total cost per hour	: 49.50+12.50	=Rs. 62.00
Cost of man-hr per ha	=100/8	= Rs. 12.50

Labour cost Rs. 100/- for 8 hours of work

Calculation of cost of operation of tractor

Assumptions:

Initial cost	:	Rs. 4,00000	Salvage value	:	Rs. 40,000
Service life	:	10000 haurs	Annual uses	:	1250 hours.

(A) Annual fixed cost :

(i)	Depreciation	(4,00000-40,000)/10	=Rs. 36,000
(ii)	Interest on investment, (@16% per annum)	{(4,00000+40,000)/2} x16/100	=Rs. 35,200
(iii)	Insurance taxes and housing@ of the 2% of initial cost per annum	:(4,00000 x2/100)	=Rs 8,000.00
	Annual fixed cost	79200.00	=Rs.79200.00
	Fixed cost of planter per hour	: 79200/1250	=Rs. 63.36

(B) Variable cost per hour :

Repair and maintenance cost/hr (@5% of initial cost per annum) :16.00

Total cost per hour	: 63.36+16.00	=Rs. 79.36
Cost of Fuel	: 36x4	=Rs 144.00
Cost of operation per hours	:144+79.36	= Rs 223.36
Cost of man-hr per ha(for tractor driver)	*=200/8*	*= Rs. 25.00*

(Labour cost Rs. 200/- for 8 hours of work)

(C) Total cost of operation : 223.36+25.00 =Rs. 258.36

Cost of operation planter: Total cost per hour for planter +Total cost per hour for tractor

258.36+62.00 =Rs. 320.36

Cost of operation per ha, field capacity : 2.85x320.36 = Rs. 913.026

the skill of the farmers as well as the tractor operator for smooth operation planter. The operators understood the required speed for seeding operation and control over the depth of seed placement. The suitability of the equipment to the region is due to cropping pattern and problems existing in conventional practice with the bold seeds like pea, gram and corn etc. The prevalent farm power sources tractor is easily available. Socio economic aspects like purchasing capacity of the farmer, labour scarcity in the season, initial cost of the machine, required operational skills and repair and maintenance facilities were also found sustainable. Extent of achieving timeliness of operation and contribution of the equipment in enhancing productivity for gram through timeliness of operation is significant for line sowing due to the saving in man-hours requirement and in terms of cost of planting was quite substantial and justified to the use of planter. However, no significant saving in time was observed compared to broadcasting but improvement in quality of work, reduction in drudgery and improvement in safety was enhanced.

The cost of the planter was worked out to be Rs. 30000/- and hourly cost of operation planter only was computed to be Rs. 62.00. The man-hr requirement for planting one hectare of land was observed to be 2.00. The cost of planting by planter was Rs. 913/- per hectare as against Rs. 1488/- required for manual line sowing of gram seed. The cost of manual planting was observed to be 63per cent higher than the machine planting and required 76.6 man-hours more than machine.

Conclusions

The planter has a field capacity of 0.30 ha/hand it can be operated by a 35hp tractor. Utility and efficacy of the tractor mounted inclined plate planter in comparison to conventional method was found better for bold seed gram. Extent of achieving timeliness of operation and contribution of the equipment in enhancing productivity for gram through timeliness of operation is significant for line sowing due to the saving in man-hours requirement and in terms of cost of planting was quite substantial and justified by the use of planter. However, no significant saving in time was observed compared to broadcasting but improvement in quality of work, reduction in drudgery and improvement in safety was enhanced.

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HALOXYFOP AND TRIFLURALIN APPLICATION EFFECT OF DOSES AND TIME OF APPLICATION ON *KHARIF* SOYBEAN AND ASSOCIATED WEEDS

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Abstract

The investigation with aim to find out optimum dose and best time of haloxyfop and trifuralin in *kharif* soybean was carried out at Mahatma Phule Krishi Vidyapeeth, Rahuri during *kharif*, 2001. The experiment was laid out in randomized block design with set of three replications and eleven treatment combinations, namely post emergence application of haloxyfop @ 25, 50 and 100 g a.i. ha^{-1} 14 and 21 days after sowing, PPI application of Trifluralin @ 1200 g a.i. ha^{-1}. Weed check and weed free check was laid out. The results revealed maximum control of weeds due to application of haloxyfop @ 100 g a.i. ha^{-1} 21 days after sowing. This treatment recorded weed intensity of 16.33, 23.33, 24.33, 12.6, 6.66 per m^2 at 30, 45, 60, 75 days and stage of harvest, respectively. However, it was at par with its application 14 days after sowing. In case of weed control efficiency per cent, the treatment weed free check recorded 100 % WCE, but among the chemical weed control treatments (T_8), application of haloxyfop @ 100 g a.i. ha^{-1} 21 days after sowing gave highest (84.02 %) WCE at harvest, than rest of chemical treatments. The higher soybean grain yield (31.51 q ha^{-1}) was registered under weed free treatment, which, however, was at par with post emergence application of haloxyfop 75 g a.i. ha^{-1} 14 or 21 DAS.

Keywords : herbicides, weed control, soybean

Soybean (*Glycine max* L. Merill) is an important oil seed crop in India. In our country, it occupies about 5.5 million ha area with production of 6.0 million tonnes. In Maharashtra it has 1.1 million hectares with production of 1.34 million tonnes with productivity of 1227 kg ha^{-1} (Mani *et al.,* 1999). Season long weed crop competition reduces grain yield of soybean to the tune of 26-27 per cent (Gogoi *et al.,* 1991). Soybean is grown during monsoon season, faceing severe weed competition. Many promising herbicides namely pendimethalin, metribuzin, alachlor, metachlor and fluchloralin etc. are available for the effective control of weeds, however, it is not true in case of post emergence herbicide. Keeping this fact in view the present investigation, therefore, was undertaken.

Material and Methods

The field experiment was carried out during *kharif* season of 2001 at farm of Post Graduate Institute, M.P.K.V., Rahuri, Dist. Ahmednagar (Maharashtra). The soil of the experimental field was clayey in texture, low in available N (143.72 kg/ha), medium in available P (15.89 kg/ha) and very high in K content (470.4 kg/ha). The experiment was laid out in randomized block design with eleven treatments comprising post emergence application of haloxyfop @ 25, 50, 75 and 100 g a.i. ha^{-1} 14 and 21 days after sowing, pre plant incorporation of trifluralin @ 1200 g a.i. ha^{-1}, weedy check and weed free check. The gross and net plot sizes were 4.5 x 3.0 m^2 and 3.9 x 2.4 m^2, respectively. The meteorological data indicated that, minimum and maximum temperature ranged between 3.8 to 22.8 ^{0}C and 28.4 to 33.6 ^{0}C during the crop growth period, humidity ranged at morning and evening which was 75.7 to 93.3 and 28.9 to 81.4 per cent. The total 408.8 mm rainfall was received during crop growth period in 25 rainy days. The variety JS-335 was sown on 4 July, 2000 and 10th October 2000. The herbicides under study were sprayed before sowing and after sowing as per treatments schedule, with 500 litre of water/ha. For weed studies a quadrant (1 x 1 m^2) was randomly fixed at two places in each net plot and count of monocot and dicot weeds occurring in the area of each quadrant was recorded, total number of weeds observed in per meter square were recorded at 30, 45, 60, 75 DAS and at harvest. The quadrant weeds removed separately used for dry matter studies and they were chopped into small pieces and then put into paper bags and were dried in air for 2 days and the finally in hot air oven at 65 ^{0}C for 8 hours till constant dry weight was obtained.

Weed control efficiency was calculated by the formula.

$$\text{WCE (\%)} = \frac{\text{WPC - WPT}}{\text{WPC}} \times 100$$

Where,

WPC = Weed population in controlled plot

WPT = Weed population in treated plot

Result and Discussion

The results revealed that, the mean weed intensity was 20, 29, 34, 24 and 13 m^2 at 30, 45, 60, 75 days of crop growth and at harvest, respectively. At 30 days weed intensity was found more (24.66 m^2) in the treatment T_9 than rest of chemical weed control treatments, but it was at par with the treatment T_3, T_6 and T_7. At 45 DAS the treatment T_9 found

Table 1. Treatment details and symbols used

Treatment	Dose (g a.i./ha)	Time of application (DAS)	Symbol
Haloxyfop 10 EC	25	14	T_1
Haloxyfop 10 EC	50	14	T_2
Haloxyfop 10 EC	75	14	T_3
Haloxyfop 10 EC	100	14	T_4
Haloxyfop 10 EC	25	21	T_5
Haloxyfop 10 EC	50	21	T_6
Haloxyfop 10 EC	75	21	T_7
Haloxyfop 10 EC	100	21	T_8
Trifluron 50 %	1200	PPI	T_9
Control (weedy check)	-	-	T_{10}
Weed free check	-	-	T_{11}

DAS = Days after sowing

PPI = Pre plant incorporation

more weed intensity (33.66 m^2) than rest of chemical treatments tried for weed control but it was at par with the treatment T_6 i.e. application of haloxyfop @ 50 g a.i. ha^{-1} 21 days after sowing. At 60 and 75 DAS same trend was observed in case of weed intensity per m. But at harvest in the treatment (T_2) haloxyfop @ 50 g a.i. ha^{-1} found in the treatment and which was at par with the treatments T_6 and T_1. These results are in conformity with those results reported by Maurya *et al.*, (1990), Jain and Tiwari (1995), Chhokar *et al.* (1996) and Balyan and Pahwa (1998).

At harvest highest weed control efficiency (84.02 %) recorded in the treatment T_8 i.e. application of haloxyfop @ 100 g a.i. ha^{-1}, amongst the all weedicides tried which was followed by treatment T_{11} i.e. weed free check treatment, but it was at par with rest of the treatments T_3, T_4, T_7 and T_9. Higher WCE was recorded in treatment T_8 which might be due to selective action of haloxyfop herbicidal due to checked weed growth and infestation of weeds. Similar results were reported by Maurya *et al.* (1990).

Grain yield

The mean grain yield of soybean was found 25.23 q ha^{-1}. The weed free check treatment (T_{11}) recorded significantly higher grain yield (31.51 q ha^{-1}) than the rest of treatments tried. However, it was at par with post emergence application of haloxyfop 75 g a.i. ha^{-1} 14 or 21 DAS (T_4 and T_8) treatments. These results are parallel to those results recorded by Dubey *et al.* (1998).

Table 2. Mean weed intensity, weed control efficiency and grain yield as influenced by different treatments

Treatment	Mean weed intensity (m^2)					WCE	Grain
	30 DAS	45 DAS	60 DAS	75 DAS	at harvest	(%)	yield (q ha^{-1})
T_1	18.00	25.66	29.66	25.33	13.98	66.05	21.58
T_2	19.00	25.66	29.66	23.66	17.30	57.14	22.32
T_3	20.66	27.00	27.66	14.66	8.66	80.74	29.48
T_4	16.66	23.33	25.66	13.00	6.98	83.32	28.41
T_5	18.33	24.00	37.00	29.66	11.98	70.87	20.83
T_6	20.33	28.00	35.66	23.33	16.98	57.64	21.79
T_7	20.66	23.66	25.33	17.66	8.66	78.51	28.95
T_8	16.33	23.33	24.33	12.66	6.66	84.02	28.20
T_9	24.66	33.66	38.66	31.00	11.33	72.74	25.85
T_{10}	40.66	88.66	97.66	67.66	40.95	0.00	18.69
T_{11}	0.00	0.00	0.00	0.00	0.00	100.00	31.51
S.Em ±	1.88	1.98	2.04	1.72	1.53	3.87	1.63
C.D. at 5 %	5.55	5.84	6.01	5.08	4.51	11.41	4.82

DAS = Days after sowing

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INFLUENCE OF INTEGRATED NUTRIENT MANAGEMENT ON PRODUCTIVITY AND SOIL FERTILITY IN PEARLMILLET-WHEAT CROP SEQUENCE

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Abstract

Field experiment was conducted at Junagadh in *kharif* and rabi season of 2000-01 to 2006-07 on medium black soil to study the effect of organic and inorganic sources of nitrogen on pearlmillet-wheat crop sequence. The six year pooled results revealed that the application of nitrogen to individual crop as per soil test value through inorganic fertilizer produced significantly higher grain yield (1586 and 4033 kg ha^{-1}) and straw yield (10325 and 4945 kg ha^{-1}) of pearlmillet and wheat, respectively as well as gross (Rs. 58409 ha^{-1}) and net realization (Rs. 34223 ha^{-1}). Application of RDN to pearlmillet and wheat crops in combination of organic manures and inorganic fertilizers failed to improve available soil nutrient status after harvest of each crop, except available K_2O observed significantly maximum after harvest of pearlmillet and wheat and organic carbon after harvest of wheat when each crops were fertilized with 100% RDN through FYM. NPK uptake by grain and straw were also observed higher when RDN was applied as per soil test value except, K uptake by pearlmillet grain was maximum when 75% RDN of pearlmillet applied through inorganic fertilizer and 25% RDN through FYM and castor cake and N uptake by pearlmillet straw was significantly higher when 50% RDN of pearlmillet applied through inorganic fertilizer and 50% RDN through FYM and castor cake.

Key words: Pearlmillet, wheat, INM, RDN, FYM, crop sequence

Pearlmillet-wheat sequential cropping is becoming popular in double cropping system under irrigated conditions in arid and semi arid tracts of western and north-western India. This system is fairly exhaustive and a crop giving 2.9 tones/ha of pearlmillet and 4.2 tonnes/ ha of wheat may remove 238, 54 and 131 kg/ha N, P and K, respectively (Hegde *et al.*, 1992). Long term studies, being carried out at several locations in different cropping systems indicated that application of all the needed nutrients through chemical fertilizers has deleterious effect on soil fertility leading to unsustainable yields (Hegde, 1992, Nambiar *et al.*, 1992). Sufficient information is available on response of pearlmillet and wheat crop to fertilizer application in the sole crops. However, limited information is available on integrated nutrient management on pearlmillet-wheat cropping system. It is being realized that system based research could be more advantageous for optimizing the use of different sources of plant nutrients. Also due to escalation of fertilizer prices, the integrated nutrient supply approach would be more remunerative for getting higher returns with considerable fertilizer economy and better soil health. Keeping in view these facts, the present investigation was carried out to study the effect of organic manures in combination with chemical fertilizers on yields and nutrient uptake by pearlmillet-wheat crops in sequence of the region.

Materials and Methods

Field trials were conducted during *Kharif* and *rabi* from 2000-01 to 2006-07 at Instructional Farm, Junagadh Agricultural University, Junagadh (Gujarat). The soil of the fixed experimental site was medium black calcareous clayey containing 0.80% organic carbon, 212.0 kg ha^{-1} available N, 48.5 kg ha^{-1} available P_2O_5 , 242.0 kg ha^{-1} available K_2O, 10.3 ppm S and pH 7.9. The ten treatments consisted of combination of organic sources of nitrogen and chemical fertilizers in different proportion *viz.*, F_1- FYM (100% N), F_2- FYM (75% N) + Castor cake (25% N), F_3- FYM (50% N) + Castor cake (50% N), F_4- FYM (25% N) + Castor cake (75% N), F_5- Castor cake (100% N), F_6- Organic fertilizer (25% N, of which 50% N each from FYM and castor cake) + inorganic fertilizers (75% N), F_7- Organic fertilizer (50% N, of which 50% N each from FYM and castor cake) + inorganic fertilizers (50% N), F_8- Organic fertilizer (75% N, of which 50% N each from FYM and castor cake) + inorganic fertilizers (25% N), F_9- Inorganic fertilizers (100% as per soil test) and F_{10}- Inorganic fertilizers (100% N as per recommendation) tested in randomized block design with four replications. In treatments 1 to 8 N was applied as per recommendation instead of soil test and no P and K were applied. The N content in different organic manures was determined each year and the amount of these organic manures require for substituting a specific amount of N as per the treatment was calculated. The pearl millet cv. GHB-316 and wheat cv. GW-496 were sown under recommended package of practices. All the organic manures and chemical fertilizers were applied to individual plots in the previously opened furrows at 60 cm for pearlmillet and 22.5 cm for wheat crop as per treatments before sowing the crop and incorporated in soil. Soil samples i.e. before sowing the crop in first year and after harvest of crop every seasons were collected from each plot from 0-15 cm depth and analyzed for O.C., available N, P_2O_5, K_2O and S. The grain and straw samples were analyzed for total N, P, and K uptake by the crops during experimental period. Observations on yield and yield attributes were recorded from each plot and economics were worked out on the basis of current market prices of produce and inputs used. Other cultural operations were carried out as per recommendations made for each crop in the region.

Results and Discussions

Pearlmillet and wheat yields

Pooled results of 6 years presented in Table-1 revealed that application of chemical fertilizers as per soil test value (T_9) to individual crops resulted in significantly increase in grain (1586 $kgha^{-1}$) of pearlmillet which was comparable with T_5 (i.e. 100% N through castor cake) and T_6 (i.e. 25% N of which 50% N each through FYM and castor cake and 75% N through fertilizer).Significantly higher fodder yield of pearlmillet 10325 $kgha^{-1}$ was produced when crop was fertilized as per soil test value (T_9) and observed statistically at par with T_6 (i.e. 75% N through fertilizer and 25% N through organic manures of which 50% each through FYM and castor cake) and T_7 (i.e. 50% N through fertilizer and 50% N through organic manures of which 50% each through FYM and castor cake). Similarly, significantly maximum grain (4033 $kgha^{-1}$) and straw yields (4945 $kgha^{-1}$) of wheat was recorded when crop was fertilized as per soil test value (Table-1) and found statistically on par with T_8 (i.e. 25% N through fertilizer and 750% N through organic manures of which 50% each through FYM and castor cake). These results are in line of those reported by Hegde (1998), Roshan *et a*l. (1995) and Singh *et al.* (1999).

Table 1. Effect of different treatments on yield and economics of pearl millet-wheat crop sequence (Mean of six years)

Treatment	Yield(kg ha^{-1})				Realization(Rs. ha^{-1})			B:C ratio
	Pearl millet		Wheat		Gross	Cost	Net	
	Grain	Fodder	Grain	Straw				
T_1	1293	9286	3795	4013	52832	28560	24272	0.85
T_2	1127	8567	3692	3939	50076	28491	21585	0.76
T_3	1184	8302	3728	4135	50726	29081	21645	0.74
T_4	1371	8250	3685	4043	51658	29342	22316	0.76
T_5	1464	8325	3247	3874	48384	29587	18797	0.64
T_6	1466	9681	3497	4087	51773	24667	26906	1.09
T_7	1370	9627	3646	4215	52417	26113	26304	1.01
T_8	1282	8379	3835	4383	52606	27296	25310	0.93
T_9	1586	10325	4033	4945	58409	24186	34223	1.00
T_{10}	1338	9250	3565	4321	51229	23936	27194	1.14
C.D.(P=0.05)	149	1034	202	411				

Soil fertility

The pooled results of 6 years furnished in Table-2 indicated that application of recommended dose of nitrogenous fertilizers to pearlmillet and wheat crops in combination of organic manures and fertilizers failed to exert their significant effect on soil nutrient status after harvest of each crop, except available K_2O in soil after harvest of pearlmillet and wheat and organic carbon content after harvest of wheat was observed significantly higher when 100% recommended dose of N was applied through FYM (T_1). The increase in organic carbon content and K_2O with FYM was mainly due to addition of organic matter (Patnaik *et al.*, 1989).

Nutrient uptake

Six years pooled data presented in Table-3 showed that N, P and K uptake by grain and straw of pearlmillet were significantly affected by various treatments. Significantly higher N (24.56 $kgha^{-1}$) and P (3.19 $kgha^{-1}$) uptake by grain were recorded with the application of fertilizer as per soil test value (T_9) which was comparable with T_4, T_5, T_6, T_7, T_8 and T_{10} for N and T_5, T_6, T_7, T_8 and T_{10} for P. Incase of K uptake the significantly higher K (3.86 $kgha^{-1}$) uptake by pearlmillet grain was observed with the 75% N applied through fertilizers and 25% N of which 50% n each through FYM and castor cake (T_6) and remained statistically at par with T_5, T_7, T_8, T_9 and $T_{10.}$ Significantly higher N uptake of 92.15 $kgha^{-1}$ by pearlmillet fodder was recorded when crop was fertilized with 50% N through fertilizers and 50% N of which 50% N each through FYM and castor cake (T_7) and observed on same bar with T_5, T_6, T_8, T_9 and T_{10}. While significantly higher P (28.59 $kgha^{-1}$) and K (105.93 $kgha^{-1}$) uptake by pearlmillet fodder were recorded when crop was fertilized as per soil test value (T_9) and found statistically at par with T_2, T_4, T_5 and T_7 for P and T_1, T_2, T_5, T_6, T_7 and T_9 for K.

Table 2. Effect of different treatments on soil nutrient status after harvest of pearlmillet and wheat (Mean of six years)

Treatment	O.C. (%)	Available nutrient after pearl millet ($kg\ ha^{-1}$)			S (ppm)	O.C. (%)	Available nutrient after wheat ($kg\ ha^{-1}$)			S (ppm)
		N	P_2O_5	K_2O			N	P_2O_5	K_2O	
T_1	0.84	232.8	65.3	203.4	10.1	0.89	219.3	65.6	196.1	10.6
T_2	0.87	225.4	67.0	199.0	10.9	0.88	219.1	68.3	186.5	14.8
T_3	0.81	226.5	67.5	188.9	11.2	0.83	216.9	70.7	182.8	11.0
T_4	0.79	229.6	67.7	188.0	11.1	0.88	217.0	67.3	175.2	10.7
T_5	0.78	226.3	66.0	176.5	11.1	0.82	212.3	68.3	172.6	10.5
T_6	0.82	230.0	67.9	173.9	10.9	0.84	215.6	68.1	169.8	10.9
T_7	0.80	227.8	69.1	180.1	10.9	0.84	211.8	70.1	170.1	11.1
T_8	0.83	227.2	67.6	183.4	11.4	0.87	214.1	69.4	173.5	11.3
T_9	0.81	227.4	67.2	171.3	11.0	0.81	212.6	70.6	165.0	11.0
T_{10}	0.79	224.6	67.2	164.3	11.5	0.80	214.3	70.5	158.1	11.2
C.D.(P=0.05)	NS	NS	NS	11.42	NS	0.05	NS	NS	7.90	NS

Table 3. Effect of different treatments on uptake ($kg\ ha^{-1}$) of N, P and K by Pearl millet-wheat sequence (Six years pooled).

Treatment	Uptake ($kg\ ha^{-1}$)											
	Pearl millet						Wheat					
	Grain			Fodder			Grain			Straw		
	N	P	K	N	P	K	N	P	K	N	P	K
T_1	18.69	2.56	2.98	73.65	22.06	97.50	55.28	11.23	11.74	22.12	2.05	34.93
T_2	19.26	2.42	2.95	76.99	24.70	92.74	54.31	11.45	11.54	21.27	2.24	34.53
T_3	18.91	2.51	3.03	70.28	23.18	91.26	57.00	11.10	11.55	23.68	1.88	35.61
T_4	22.37	2.72	3.30	77.84	26.26	89.43	58.83	11.48	11.61	22.63	2.12	33.70
T_5	23.94	3.14	3.78	88.75	25.31	93.63	57.58	10.14	11.08	22.20	2.09	29.56
T_6	24.48	3.13	3.86	85.13	28.08	99.51	53.25	10.07	10.62	25.47	2.05	26.84
T_7	23.14	3.07	3.65	92.15	25.65	100.62	58.67	10.37	11.04	24.06	2.00	26.00
T_8	22.79	2.82	3.52	82.09	24.06	96.56	60.19	11.04	11.90	24.93	2.27	31.46
T_9	24.56	3.19	3.81	87.97	28.59	105.93	64.60	11.79	12.44	28.03	3.08	40.14
T_{10}	22.26	2.92	3.62	82.81	22.40	82.65	58.70	10.21	11.05	26.94	2.37	32.36
C.D.(P=0.05)	2.87	0.40	0.54	12.77	4.28	13.26	6.00	1.21	1.02	4.09	0.67	5.50

Uptake of N, P and K by grain and straw of wheat was significantly affected by various treatments (Table-3). Significantly higher N (64.60 kgha^{-1}), P (11.79 kgha^{-1}) and K (12.4 kgha^{-1}) uptake by grain and N (28.03 kgha^{-1}0 P (3.08 kgha^{-1}) and K (40.14 kgha^{-1}) uptake by wheat straw were observed when individual crops were fertilized as per soil test value (T_9) and which was at par with T_4, T_7, T_8 and T_{10} for N uptake by grain , T_1, T_2, T_3, T_4 and T_8 for P and K uptake by grain. While in case of straw T_6, T_7, T_8 and T_{10} for N uptake and T_1 and T_3 for K uptake by wheat straw, respectively. Similar results were also reported by Singh *et al*. (1999). it is evident that higher uptake of nutrients by the crops has contributed towards the increase in grain and straw yields.

Economics

Gross and net realization was also observed numerically maximum when 100% N as per soil test were applied in the form of inorganic fertilizer. More or less similar results were also reported by Patel *et al.* (1995) indicated that significantly higher pearl millet and wheat grain and straw yields were obtained when each crop were fertilized with 75% NPK + 25% NPK through green manuring and which was comparable with 100% RDF through inorganic fertilizers.

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INTEGRATED NUTRIENT MANAGEMENT IN TRANSPLANTED RICE (*ORYZA SATIVA L.*) UNDER SANDY LOAM SOILS OF UTTARANCHAL

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Abstract

A field experiment conducted at the G.B. Pant University of Agriculture & Technology, Pantnagar, Uttaranchal to study the effect of integrated nutrient management practices in transplanted rice revealed that highest grain yield of rice (29.4 q/ha) was obtained with 10 t FYM/ ha followed by BGA @ 10 kg/ha (28.2q/ha) and FYM @ 5t/ha (28.0q/ha). The rice grain yield increased significantly with NPK dose upto 100% of recommended level though the difference between 50 and 75 % NPK was statistically *on par*. The per cent increase in grain and straw yield with 100% NPK was 15.3 and 13.5, respectively over 50% NPK level. Highest net return of Rs. 7263 also recorded with the application of 10 t FYM/ ha followed by BGA @ 10 kg per ha (Rs. 7062) which registered the maximum cost benefit ratio of 1.64. Rice crop raised with 10t FYM/ha removed significantly higher amount of N, P and K as compared to control treatment. At 100% NPK level, the total N, P and K uptake were higher by 11.5, 30.2 and 15.5 per cent , respectively than that of 50% NPK. Application of NPK and organic sources had significant effect on nutrient status after rice harvest.

Key Words: INM, FYM, bagasse, economics, rice, yield.

In India, the growth of rice has kept pace with population growth in the recent past. The yield level of rice has to increase, by 25-30% over present levels of 1.9 t/ha, if the country is to remain self-sufficient by 2010. There is hardly any scope for increasing, area under rice cultivation, the only option left is to improve the yield per unit area though increased cropping intensity which demands more nutrients to sustain productivity. However, rice in cereal cropping system being fertility exhaustive crop, had resulted in decline of soil organic carbon and deteriorating soil health in general. The use of excessive chemical fertilizers and pesticides are causing environmental hazards. An integrated nutrient management system may play a vital role in sustaining both the soil health and crop production on long term basis. The INMS primarily related to combined application of different sources of plant nutrients (organic and inorganic) for sustainable crop production without degrading the natural resource base and soil on long-term basis (Banik and Sharma,2008. It is, therefore, necessary to develop a sustainable production system with maximum productivity and minimum environmental pollution. In this context integrated use of chemical fertilizers and organic like farmyard manure, green manure and crop residues assume greater significance (Yadav *et al;* 2005). Keeping this in view, an experiment was conducted to evaluate the productivity, economics and nutrient dynamics in rice crop under integrated nutrient management practices.

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Materials and Methods

A field experiment was conducted during *kharif* season of 2003 and 2004 at the crop research centre of G.B. Pant University of Agriculture & Technology, Pantnagar, on sandy loam soil with pH 7.5-7.7. The soil was low in available nitrogen (223.0 kg/ha), medium in available phosphorus (20.3 kg/ha) and potassium (222.0 kg/ha). The treatments comprising 18 combinations of organic sources viz. FYM and bagasse at 5 and 10 t/ha and BGA at 10 kg/ha beside one control, and inorganic fertilizer at 50,75 and 100% of recommended dose i.e. 120 kg N/ha, 60 kg P_2O_5/ha and 40 kg K_2O/ha were tested in randomized block design with three replications. Nutrient configuration was 0.51% N, 0.32% P and 0.55% K in FYM and 0.52% N, 0.20% P and 0.32% K in bagasse on dry weight basis. Half of the nitrogen and full dose of phosphorus and potassium were given as basal at the time of transplanting and rest of the nitrogen was applied 30-35 days after transplanting. FYM and bagasse were applied 15 days before transplanting and BGA inoculum was applied one week after transplanting of rice. The rice variety "Govind" was transplanted on July 25 and 27 in 2003 and 2004 and harvested on 29.10.2003 and 28.10.2004. Transplanting of 25 days old seedlings was done in rows 20 cm apart with a plant to plant distance of 10 cm with 2 seedlings /hill. Continuous submergence of 2-3 cm water was maintained till panicle initiation after that only one irrigation was applied at milking stage during both the years. Pooling was done over the years as the data qualified the homogeneity test.

Results and Discussion

Yield attributes and yield

Application of nutrients either through chemical fertilizers or organic sources increased the various yield attributes and grain yield significantly (Table 1). Use of 10 t/ha FYM or 10 kg/ha BGA increased the number of panicles/m^2, filled spikelets/ spike, grains weight/panicle and grain yield / ha significantly as compared to control. The maximum grain yield of rice (29.4 q/ha) was obtained with 10t/ha FYM followed by BGA @ 10 kg/ha and FYM @ 5t/ha. Though the various organic sources increase the grain and straw yield as the dose increased from 5 to 10t/ha but they failed to register significant difference than their lower doses. An increase in the levels of NPK from 50 to 100% resulted in subsequent increase in all the yield attributes and yield in rice, though the significantly higher values were recorded at highest NPK dose than that of 50% NPK dose. However each successive level did not show any significant difference among themselves with respect to yield attributes and yields. The per cent increase in grain and straw yield with 100% NPK was 15.3 and 13.5, respectively over 50% NPK. The probable reason for higher yields with highest NPK was that the application of higher amounts of nutrients increased the availability of nutrients in root zone, and thus greater uptake of nutrients by plants resulted in higher grain and straw production. Singh, (2006) and Verma *et al.* (2001) also reported similar results.

Economics

The highest net return of Rs. 7263 with a benefit: cost ratio of 1.56 was obtained with the application of 10t/ha FYM followed by BGA @ 10 kg per ha which registered the maximum cost benefit ratio (1.64). The respective increase over control was Rs. 1015. The

Table1. Effect of different organic and inorganic sources on yield and yield attributes of rice

(Pooled data of 2 year)

Treatment	No. of panicle/ m^2	Filled spikelets/ panicle	Unfilled spikelets/ panicle	Grain weight/ panicle (g)	1000-grain weight (g)	Grain yield (q/ha)	Straw yield(q/ha)	Net return Rs/ha	B: C ratio
Organic Source									
Control	188	100	19.8	1.95	21.0	26.2	29.0	6248	1.59
5t/ha FYM	202	107	16.0	2.12	21.9	28.0	31.1	6773	1.57
10t/ha FYM	212	108	16.0	2.29	22.3	29.4	32.9	7263	1.56
5t/ha Bagasse	197	104	18.0	2.08	21.8	25.0	27.4	4986	1.44
10t/h Bagasse	204	107	18.0	2.11	21.9	27.4	27.8	5982	1.51
10kg/ha BGA	207	109	17.5	2.24	22.2	28.2	31.3	7062	1.64
CD(P= 0.05)	16	8	3.8	0.18	NS	2.0	NS	-	-
NPK levels (% of recommended dose)									
50	189	104	19.3	2.08	21.4	26.1	28.1	7289	1.61
75	202	106	16.8	2.16	22.0	27.5	29.8	6148	1.53
100	215	108	17.0	2.26	22.1	30.1	31.9	5720	1.52
CD (P= 0.05)	14	4	2.0	0.12	NS	1.8	NS	-	-

Table2. Effect of different organic and inorganic sources on nutrient uptake and chemical properties of soil after rice harvest

Treatment	Nutrient uptake (kg/ha)			Organic carbon		Available N (Kg/ha)		Available P (Kg/ha)		Available K (Kg/ha)		pH	
	N	P	K	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
Organic source													
Control	42.5	11.0	59.9	1.057	1.087	231	239	21.9	22.9	224	226	7.69	7.74
5t/ha FYM	46.7	14.2	65.4	1.103	1.133	232	243	21.9	23.1	229	230	7.68	7.7
10t/ha FYM	50.6	15.5	71.5	1.117	1.134	234	247	22.6	24.5	239	248	7.61	7.63
5t/ha Bagasse	42.9	11.7	55.7	1.098	1.13	232	240	22	22.9	226	227	7.67	7.69
10t/ha Bagasse	42.5	12.7	58.1	1.124	1.135	235	245	22.3	23.1	234	243	7.63	7.64
10kg/ha BGA	46.0	13.7	66.2	1.103	1.13	235	246	22	23.1	230	240	7.6	7.62
CD(P=0.05)	6.0	2.3	8.4	0.05	0.04	3	6	NS	NS	NS	NS	NS	NS
NPK levels (% of recommended dose)													
50	53.2	11.6	59.5	1.101	1.122	226	238	21.7	22.4	226	233	7.65	7.68
75	58.0	12.7	60.1	1.102	1.134	232	243	22	23	229	235	7.65	7.68
100	59.3	15.1	68.7	1.104	1.135	238	249	22.7	24.5	236	239	7.63	7.66
CD(P= 0.05)	5.2	2.1	6.2	NS	NS	7	8	0.8	1.8	10	5	NS	NS

highest benefit: cost ratio under BGA treated plots was mainly due to low purchase cost of BGA and comparatively better net returns.

Nutrients uptake

The total nutrient uptake of N, P and K varied significantly with different organic and inorganic sources (Table 2). Maximum uptake of N and P obtained with FYM @ 10 t/ha. Being significantly higher than all other treatments except FYM @ 5 t/ha and BGA @ 10 kg/ha. The similar trend was also noticed in respect of potassium uptake through grains and straw. Increasing NPK level from 50 to 100% significantly increased the N uptake, whereas under 75 and 100% NPK, being *on par* resulted significantly higher uptake of P and K than that of 50% NPK dose. At 100% NPK level, the total N, P and K uptake were higher by 11.5, 30.2 and 15.5 per cent, respectively than that of 50% NPK. This might be due to additional amount of nutrient supplied by FYM as well as the beneficial effect of organic matter addition and which were derived in connection with the physical and chemical properties of the soil. Similar findings were reported by Khanda *et al.* (2005).

Soil fertility status

Application of NPK and organic sources had significant effect of soil nutrient status after rice harvest (Table 2). Different organic sources at higher doses increased the soil available nutrients and organic carbon, however the differences were significant only in organic carbon and available N. Application of 10 t/ha FYM or bagasse, being *on par* resulted in significantly more organic carbon and available N as compared to control. BGA @ 10 kg/ha was next in the order. The increased availability of these nutrients in soil might be due to their subsequent release from organic sources. These results confirm the findings of Yadav *et al.* 2005. The treatments effects were also noticed due to NPK levels applied to rice. The maximum available NPK was observed with 100% NPK level followed by 75% NPK and minimum with 50% NPK. However, a dose of 100% NPK level was significantly superior over 50% NPK only. The pH remained unaffected due to various organic sources and chemical fertilizers.

Thus, it can be concluded that integration of farmyard manure @ 10 t/ha with recommended dose of NPK fertilizer gave highest yield, returns and maintained soil residual fertility in rice crop grown under *tarai* condition of Uttaranchal.

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INTEGRATED NUTRIENT MANAGEMENT IN BARLEY – MOTH CROP SEQUENCE IN PARTIALLY IRRIGATED WESTERN ARID PLAIN ZONE OF RAJASTHAN

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Abstract

Field experiment was conducted at Agricultural Research Station, Bikaner (Rajasthan) in *Rabi* and *Kharif* season of 2002-03 to 2006-07on sandy loam soil to study the effect of organic manures and fertilizer nutrients on barley and its residual effect on mothbean. The results revealed that application of organic manures with fertilizer significantly improved the yield of barley. Application of 10 t Compost ha^{-1} + 50% of RDF to barley significantly increased the yield of barley and residual effect of 10 t Compost ha^{-1} increased the yield of mothbean. Consequently, application of 10 t Compost ha^{-1} + 50% of RDF to barley significantly increased the barley grain equivalent yield, gross and net return of barley – mothbean crop sequence.

Key words: Barley, Compost, Fertilizer, Mothbean, Residual effect, Vermi–compost

Barley – mothbean crop sequence is one of the cropping systems which are gaining popularity under intensive cultivation in several partially irrigated areas of western Rajasthan. A dose of 80 kg N + 40 kg P_2O_5 ha^{-1} (RDF) for barley and 20 kg N + 40 kg P_2O_5 ha^{-1} (RDF) for mothbean are recommended for partially irrigated western arid plains of India agro-climatic situation. Generally, fertilizer application is recommended on the basis of individual crop without taking care of residue of nutrients applied in crop grown in sequence. An experiment was therefore, conducted on fixed site to study the direct effect of organic manures and fertilizer to barley and their residual effect on mothbean in partially irrigated western arid plain zone of Rajasthan.

Materials and Methods

A field experiment was conducted during the *Rabi* and *Kharif* seasons of 2002-03 to 2006-07 on fixed site at Agricultural Research Station, Rajasthan Agricultural University, Bikaner (Rajasthan) to study the effect of integrated nutrient management on yield and economics in barley – mothbean crop sequence. The soil of the experimental plot was sandy loam in texture, saline in reaction (pH 8.30), low in organic carbon (0.08%), medium in available phosphorus (17.9 kg ha^{-1}) and high in available potassium (230.0 kg ha^{-1}). The 10 treatments were tested in randomized block design with three replications. The treatments consisting of control, 5 t Compost ha^{-1}, 10 t Compost ha^{-1}, 2.5 t Vermi – Compost ha^{-1}, 5 t Vermi – Compost ha^{-1}, 80 kg N + 40 kg P_2O_5 ha^{-1} (RDF), 5 t Compost ha^{-1} + 50% of RDF, 10 t Compost ha^{-1} + 50% of RDF, 2.5 t Vermi – Compost ha^{-1} + 50% of RDF, 5 t Vermi – Compost ha^{-1} + 50% of RDF were applied to barley plots only. The RD –2508 variety of barley was sown in rows, 22.5 cm apart. The organics were applied before sowing and mixed in

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soil as per treatment. The barley crop was fertilized as per treatment where whole of phosphorus and half dose of nitrogen was applied as basal through DAP and urea, respectively and the remaining half dose of nitrogen fertilizer was applied through urea as top dressing at the time of first irrigation. After harvesting of barley crop, the RMO-40 variety of mothbean was sown on residue of barley without application of fertilizer in mothbean.

Results and Discussion

Direct effect on barley

Direct effect of organic manures and fertilizer was significant on grain and straw yield of barley (Table 1). Application of 10 t Compost ha^{-1} + 50% of RDF gave significantly highest grain (3246 kg ha^{-1}) and straw (3687 kg ha^{-1}) yield of barley as compared to other treatment combinations tested. This treatment recorded 213.32 and 11.27 per cent higher grain and 169.71 and 4.92 per cent higher straw yield of barley as compared to control and recommended dose of fertilizer (RDF) applied in barley. On the basis of pooled data, the difference in grain and straw yield of barley due to application of 10 t Compost ha^{-1} + 50% of RDF and 5 t Vermi – Compost ha^{-1} + 50% of RDF was non – significant. This could be due to increase in microbial population on addition of manure / fertilizer causing greater mineralization of added leaf fall, root biomass, incorporated crop trash, native nutrients and also due to high enzymes activity. Kumawat (2003) also observed that application of FYM @ 10t ha^{-1} applied to barley crop significantly enhanced the grain and straw yield of barley and succeeding crop clusterbean. The maximum net return and B:C ratio of barley – clusterbean sequence were obtained with combined application of FYM @ 7.5 t ha^{-1} + 60 kg N ha^{-1} to barley. Similarly, Patel *et al.* (2004) reported that application of 120 kg N + FYM to pearl millet with 120 kg N ha^{-1} to wheat produced significantly highest yield of pearl millet. While, in absence of FYM, significantly highest yields were recorded with application of 120 kg N to pearl millet and 160 kg N ha^{-1} to wheat.

Residual effect on mothbean

The residual effect of organic manure and fertilizer applied to barley crop found significant on grain and straw yield of mothbean. This indicates that the carry over effect of organics and fertilizers on subsequent crop is obvious. Application of 10 t Compost ha^{-1} to barley recorded significantly highest grain (1069 kg ha^{-1}) and straw (2197 kg ha^{-1}) yield of mothbean followed by treatments 10 t Compost ha^{-1} + 50% of RDF to barley and 5 t Vermi – Compost ha^{-1} to barley. Due to residue of 10 t Compost ha^{-1}, there was 28.79 and 20.38 higher grain yield of mothbean compared with control and recommended dose of fertilizer (RDF) applied in barley treatments. Application of compost or vermi – compost as organic manure might have conditioned soil atmosphere congenial for better growth and development of plant by the way of providing the structural development of soil and balance nutrition to the succeeding crop. Manures increased the activities of N fixing bacteria and increased rate of humification. Humic acid might have enhanced the availability of both native and added nutrients in soil and as a result improved yield of the crop significantly. Similar results were found by Kumawat (2003).

Effect on barley – mothbean crop sequence

The results shows (Table 2) that

Table 1. Effect of integrated nutrient management on yield of barley and mothbean

Treatment	Grain Yield of Barley (q ha^{-1})						Straw Yield of Barley (q ha^{-1})					
	2002-03	2003-04	2004-05	2005-06	2006-07	Pool	2002-03	2003-04	2004-05	2005-06	2006-07	Pool
Control	1549	963	901	926	840	1036	2086	1210	1259	1271	1007	1367
5 t Compost ha^{-1}	1642	1296	1123	1173	1099	1267	2481	1667	1358	1395	1319	1644
10 t Compost ha^{-1}	1883	1790	1469	1481	1321	1589	2500	2346	1592	1581	1585	1921
2.5 t Vermi – Compost ha^{-1}	1630	1234	1222	1222	1074	1276	2228	1667	1390	1395	1289	1594
5 t Vermi – Compost ha^{-1}	1685	1419	1346	1370	1284	1421	2302	1988	1595	1580	1541	1801
80 kg N + 40 kg P_2O_5 ha^{-1} (RDF)	4062	2716	2704	2716	2386	2917	4951	3457	3136	3160	2864	3514
5 t Compost ha^{-1} + 50% of RDF	3253	2284	2864	2840	2272	2703	3907	2963	3148	3185	2726	3186
10 t Compost ha^{-1} + 50% of RDF	4068	2718	3383	3333	2728	3246	4512	3243	3679	3729	3274	3687
2.5 t Vermi – Compost ha^{-1} + 50% of RDF	3898	2099	2568	2556	2333	2691	4265	2531	3000	3197	2800	3159
5 t Vermi – Compost ha^{-1} + 50% of RDF	3963	2654	2954	3012	2469	3010	4432	3333	3568	3642	2998	3595
CD 5%	612.2	394.2	307.8	229.9	186.0	319.3	749.7	555.9	507.3	195.9	209.0	306.1
Treatment	**Grain Yield of Mothbean (q ha^{-1})**						**Straw Yield of Mothbean (q ha^{-1})**					
	2002-03	2003-04	2004-05	2005-06	2006-07	Pool	2002-03	2003-04	2004-05	2005-06	2006-07	Pool
Control	1062	790	864	730	702	830	2383	1556	1803	1408	1385	1707
5 t Compost ha^{-1}	1099	926	963	819	762	914	2519	1975	2049	1595	1488	1925
10 t Compost ha^{-1}	1345	1099	1111	910	880	1069	2642	2296	2247	1901	1898	2197
2.5 t Vermi – Compost ha^{-1}	1111	914	963	770	705	893	2420	1926	2025	1499	1400	1854
5 t Vermi – Compost ha^{-1}	1321	975	1012	882	719	982	2617	2074	2222	1650	1405	1994
80 kg N + 40 kg P_2O_5 ha^{-1} (RDF)	1148	914	938	742	700	888	2407	1951	2025	1417	1390	1838
5 t Compost ha^{-1} + 50% of RDF	1111	926	988	758	716	900	2543	1951	2148	1450	1402	1899
10 t Compost ha^{-1} + 50% of RDF	1345	1074	1062	915	856	1050	2655	2247	2197	1990	1800	2178
2.5 t Vermi – Compost ha^{-1} + 50% of RDF	1148	914	938	765	760	905	2605	1901	2049	1488	1470	1903
5 t Vermi – Compost ha^{-1} + 50% of RDF	1247	938	988	788	796	951	2642	2049	2099	1506	1530	1965
CD 5%	120.1	69.2	121.9	96.3	102.6	46.1	365.0	116.7	186.5	208.5	306.2	115.3

Table 2. Effect of integrated nutrient management on barley equivalent yield, gross and net return, B:C ratio of barley – mothbean crop sequence (Pooled data of 2002-03 to 2006-07)

Treatment	Barley Grain Equivalent Yield (q ha^{-1})	Gross Return (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net Return (Rs ha^{-1})	B:C Ratio
Control	2950	23104	12084	11020	0.91
5 t Compost ha^{-1}	3375	26472	14084	12388	0.88
10 t Compost ha^{-1}	4056	31579	16084	15495	0.96
2.5 t Vermi – Compost ha^{-1}	3336	26061	18334	7727	0.42
5 t Vermi – Compost ha^{-1}	3686	28754	24584	4170	0.17
80 kg N + 40 kg P_2O_5 ha^{-1} (RDF)	4967	38556	13718	24838	1.81
5 t Compost ha^{-1} + 50% of RDF	4779	37098	14901	22197	1.49
10 t Compost ha^{-1} + 50% of RDF	5670	43810	16901	26909	1.59
2.5 t Vermi – Compost ha^{-1} + 50% of RDF	4779	37078	19151	17927	0.94
5 t Vermi – Compost ha^{-1} + 50% of RDF	5206	40381	25401	14980	0.59
CD 5%	337.40	2477.14	—-	2477.14	0.170

application of 10 t Compost ha^{-1} + 50% of RDF to barley only significantly increased the barley grain equivalent yield (5670 kg ha^{-1}) of crop sequence. This treatment recorded highest barley equivalent grain yield which is 92.20, 8.91 and 14.15 per cent higher compared with control, 5 t Vermi – Compost ha^{-1} + 50% of RDF and recommended dose of fertilizer (RDF) applied in barley treatments. The data on economics of the treatments tried in barley indicates that there was no benefit with application of compost and vermi – compost alone. But highest net return was recorded with treatment application of 10 t Compost ha^{-1} + 50% of RDF to barley followed by treatment 80 kg N + 40 kg P_2O_5 ha^{-1} (RDF) to barley only. While highest B:C ratio of barley – mothbean crop sequence was recorded with the treatment 80 kg N + 40 kg P_2O_5 ha^{-1} (RDF) to barley followed by 10 t Compost ha^{-1} + 50% of RDF to barley and 5 t Compost ha^{-1} + 50% of RDF to barley. Similarly Patel et al. (2004) also observed higher net return and B:C ratio with application of organic manures in crop sequence. Singh (2002) considered that under semi arid condition of Agra, 10 t FYM with 100-50-50 kg NPK ha^{-1} to pearl millet and 90-45-30 kg NPK to wheat would be beneficial to maximize the productivity.

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RELATIVE PERFORMANCE OF DIFFERENT CROPPING SYSTEMS IN CENTRAL MAHARASHTRA PLATEAU ZONE

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Experiment on Cultivator's Field Scheme, Marathwada Agricultural University, Parbhani (MS) – 431402 (India)

ABSTRACT

A field experiment was conducted during 2004-2007 on farmer's field under experiments on cultivator field scheme, Marathwada Agricultural University, Parbhani to study the performance of different cropping systems under rainfed condition in central Maharashtra Plateau zone. The result indicates that blackgram + Pigeon pea intercropping system (4:2) recorded significantly higher net monetary return (Rs. 33414) over all other cropping systems. The soybean and pigeon pea intercropping by stem (4:2) recorded net monetary return of Rs. 26656/ha. The Soybean *rabi* sorghum and Black gram *rabi* sorghum cropping system recorded significantly less net monetary returns than intercropping system. The blackgram + pigeon pea intercropping system had recorded relative economic efficiency 113.67 % and system profitability of Rs. 91.55/ ha / day.

Key words: Intercropping, Blackgram, Soybean, Pigeon Pea, relative economic efficiency, system profitability.

Central Maharashtra Plateau Zone comes under the VII agro climatic zone of Maharashtra state comprising of Beed, Latur, Parbhani, Nanded and Aurangabad district of Marathwada region. The average rainfall of the zone is 750 mm which is often erratic along with long dry spells, particularly in the month of August. The soils are predominately black to brown in colour derived from basalt rocks, medium to heavy in texture, fairly high in clay content, mostly neutral to alkaline in reaction. The organic carbon and nitrogen is low, medium in phosphorus and high in available potassium content. The sowing of *kharif* crops are generally delayed up to second fortnight of July due to late commencement of monsoon. Thus, growing of *kharif* crops prolongs resulting in late harvesting of preceding crops and ultimately causes delay in sowing of *rabi* crops. Soybean- sorghum is the predominant cropping system of the Central Maharashtra Plateau Zone.

The productivity of this cropping system is showing decline trend due to depletion of soil fertility, infestation of several insect pests and disease in soybean and sorghum crop. Taking into consideration the above fact, there is a need to identify the compatible cropping systems with high productivity and profitability to achieve the stability and sustainability in the yields. Based on the principle " Seeing is Believing " and the farmers being the right persons to judge the suitability of different cropping systems in their locality, the present investigation was undertaken on the farmers field to find out the alternate cropping systems for this zone under rainfed conditions.

MATERIALS AND METHODS

Field experiments were carried out on farmer's field in different villages of Beed, Latur and Parbhani districts of Central

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Maharashtra Plateau Zone for four consecutive years during 2004-05 to 2007-08. The experiments were conducted to testify the productivity and profitability of four cropping systems under rainfed condition (Table 2). The grain yield data of each crop component were recorded during 2004-05 to 2007-08 and average yields of four years were computed. The villages/locations were treated as replications. The net monetary returns (Rs/ha), relative economic efficiency (%) and system profitability (Rs/ha/day) were worked out. The relative economic efficiency (%) was calculated by using the formula REE (%) = (DNR-ENR)/ ENR x100, where DNR denotes the net returns obtained in improved /diversified system , ENR denotes the net returns obtained in existing system. System Profitability (Rs/ ha/day) was calculated by dividing the net returns /ha /year by 365 days.

Results and Discussion

Net monetary returns

The *kharif* and *rabi* crops were grown under rainfed conditions. The details of variety, fertilizer dose and spacing of crop components of respective cropping systems are furnished in Table 1. The data presented in Table 2 elucidate that treatment T4 – Black gram + Pigeon pea (4:2) was found significantly superior with net returns of Rs. 33414/- over the treatment T1 and T2 but was at par with the treatment T3 – Soybean + Pigeon pea (4:2) intercropping system which recorded the net returns of Rs.26656/-. Though the average yield of treatment T4 – Black gram + Pigeon pea was less as compared to treatment T3 – Soybean + Pigeon pea but due to high market price for black gram more net returns were achieved in Black gram + Pigeon pea intercropping system. This indicates that high value crops should be incorporated in the cropping system to fetch more returns. These findings are in close conformity with the findings of Upadya et al (2005) and Dhoble et al (1987). Soybean + Pigeon pea (T3) intercropping system was the next best treatment with regard to net monetary returns (Rs. 26656/-).

Relative economic efficiency

The relative economic efficiency (%) examined over a period of 4 years explicate that the highest value (113.67 %) was observed in treatment T4 – Black

Table 1. Treatment details of different cropping systems

Treatments	Cropping Systems	Verities	Fertilizer Dose (kg/ha)	Spacing (cm^2)
T1	Soybean–	JS-335	30:60:30	45x5
	Rabi Sorghum	SPV-1411	80:40:40	45x15
T2	Black gram–	TAU-1	25:50:00	30x10
	Rabi Sorghum	SPV-1411	80:40:40	45x15
T3	Soybean +	JS-335	30:60:30	45x5
	Pigeon pea (4:2)	BSMR-853	25:50:00	45x20
T4	Black gram +	TAU-1	25:50:00	45x5
	Pigeon pea (4:2)	BSMR-853	25:50:00	45x 20

Table 2. Average yield and net returns of different cropping systems (Mean of 4 years)

Treatments	Cropping Systems	Yield (kg/ha)	Net returns (Rs./ha)	Relative economic efficiency (%)	System profitability (Rs/ha/ day)
T1	Soybean–	2034	15638	-	42.84
	Rabi Sorghum –	1423			
T2	Black gram –	1159	19994	27.86	54.78
	Rabi Sorghum	1400			
T3	Soybean +	1428	26656	70.46	73.03
	Pigeon pea (4:2)	1413			
T4	Black gram +	960	33414	113.67	91.55
	Pigeon pea (4:2)	1350			
CD at 5 %		-	8353	-	-

gram + Pigeon pea followed by treatment T3 – Soybean + Pigeon pea (70.46%). The lowest relative economic efficiency was observed in treatment T2 – Black gram – Rabi Sorghum (27.86%). Thus, the higher values of relative economic efficiency (%) of Black gram + Pigeon pea and Soybean + Pigeon pea signify that these both cropping systems are suitable for large scale adoption.

System productivity

The highest system profitability of Rs. 91.55 / ha/day was benefited in treatment T4 – Black gram + Pigeon pea followed by treatment T3 – Soybean + Pigeon pea i. e. Rs. 73.03 /ha/day. The low returns of Rs. 54.78 and Rs. 42.84/ ha /day were achieved in Black gram – Rabi sorghum (T2) and soybean – Rabi sorghum respectively. From the above findings it is clear that Black gram + Pigeon pea (T4) and Soybean + Pigeon pea (T3) cropping systems are highly profitable as they provide more returns per hectare per day.

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PROFITABILITY, YIELD AND NITROGEN UPTAKE OF FORAGE SORGHUM (*SORGHUM BICOLOR* (L.) MOENCH) AS INFLUENCED BY INTEGRATED WEED MANAGEMENT TREATMENTS

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ABSTRACT

The experiment was carried out during two consecutive K*harif* seasons of 2001 and 2002, to evaluate the profitability, yield and nitrogen uptake of forage sorghum [(*Sorghum bicolor* (L.) Moench] as affected by integrated weed management treatments with consisted ten treatments *viz*. one hand weeding at 20 days after sowing (T_1); one and half time seed rate 45 kg/ha (T_2); Pendimethalin 1.0 kg /ha (T_3); Atrazine at 1.0 kg/ha PE (T_4); Alachlor at 2.0 kg/ha PE (T_5); Atrazine at 0.5 kg /ha PE + one hand weeding at 30 days after sowing (T_6); Atrazine at 0.5 kg/ha PE + 0.5 kg/ ha at 10 days after sowing (T_7); cowpea as intercrop (T_8); weed free (T_9) and weedy check (T_{10}) tested in randomized block design with three replications. The sorghum crop was infested with *Cyperus spp*. (38.9%) and *Echinochloa colona* (28.0%) of major weeds and other weeds (33.1%), which reduced 75.00 and 43.98 per cent of green forage yield during both the years, respectively. Application of atrazine at 0.5 kg/ha PE + 0.5 kg /ha at 10 days after sowing significantly reduced weed population, dry weight. Nitrogen uptake by weeds in T_6 was at par with that of atrazine at 1.0 kg/ ha PE, one hand weeding at 20 days after sowing and atrazine at 0.5 kg /ha PE+ one hand weeding at 30 days after sowing over other treatments in both the years. Application of atrazine at 0.5 kg/ ha PE + 0.5 kg/ ha at 10 DAS produced more plant height, dry matter accumulation per shoot, leaf area per plant which contributed more green and dry fodder yield and nitrogen uptake of the forage sorghum, being at par with that of atrazine at 1.0 kg ha^{-1} PE, one hand weeding at 20 DAS and atrazine 0.5 kg/ha ha PE + one hand weeding at 30 DAS but significantly higher than other treatments in both the years. Application of atrazine at 0.5 kg/ ha PE + 0.5 kg/ ha at 10 DAS recorded highest et returns (Rs.16085 and 19675/ha) and B: C ratio (2.26 and 2.19), followed by atrazine at 1.0 kg /ha PE, one hand weeding at 20 DAS and atrazine at 0.5 kg/ha PE + one hand weeding at 30 DAS over weedy check conditions (Rs. -270 and 7905/ha) and (-0.04 and 0.82) during both the years

Key words: Profitability, Forage Sorghum, Integrated weed wanagement, Nitrogen uptake and Yield

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the important crops of the world grown for cereal as well as for fodder. In India, it is known as a poor man's crop, and has the potentialities of being used solely either as food, feed or fodder. In *kharif* season, it is widely grown for fodder purpose due to high tolerance to abiotic and biotic stress conditions. It plays a major role in intensive livestock and dairy development, as forages are the cheapest source of feed for animals. In India, it is not possible to enhance the area under fodder crops. Therefore, alternative left is to increase productivity of the good quality fodder through suitable agronomic management practices. In modern cutting edge agronomic practices, weeds are major problematic factor and causes high loss in fodder yield. Sorghum crop faces severe weed competition because of wider row spacing, high temperature and light interception just after sowing which favours grand growth of weeds. Sorghum is estimated that 45% of total annual loss of agricultural produce is due to weeds only in India. Fast growth of weeds during rainy season cause harm to growing seedlings of sorghum crop which have slow growth at early stage that cannot compete with the weeds. A study at New Delhi reported that decline in forage yield of sorghum due to more crop-weed competition, which has been estimated from 31.5 to 90% (Setty and Rao, 1979).

Pulses as intercrop reduced the population and dry matter of weeds and reported weed smothering efficiency of pulses ranged from 28.3 to 36.2% over sole crop of sorghum (Main *et. al.,* 1968). Cowpea is one of the fast growing leafy, succulent, palatable and nutritious legume crop grown in *Kharif* as well as *Zaid* season in India. Inter-cropping of non-legume with legume crops for fodder without involving costly inputs has been considered to be one of the attempts for achieving nutritious fodder production per unit area by 48.81% over sole crop of cereals summer season (Rao, 2000). In weed management practices physical or traditional methods of weed control are very effective in reducing weed growth, but it is costly, tedious, time consuming and also not possible due to continuous rains. The new strategies of herbicidal/ chemical weed management methods for reducing weed density in wide range of condition and found higher degree of weed control in shorter period and cheaper than hand weeding. However, a little information are available on this issue but gradually now days it is becoming popular in recently; therefore, the present investigation was planned to study the response of integrated weed management treatments on profitability, yield and nitrogen uptake of forage sorghum.

Materials and Methods

A field experiment was conducted from year 2001 and 2002, respectively, in *kharif* season, at Instructional Dairy Farm of G.B. Pant University of Agriculture and Technology, Pantnagar. The experiment was laid out in randomized block design with having ten treatments *viz.* one hand weeding at 20 days after sowing (T_1); one and half time seed rate 45 kg/ha (T_2); Pendimethalin 1.0 kg /ha (T_3); Atrazine at 1.0 kg/ha PE (T_4); Alachlor at 2.0 kg/ha PE (T_5); Atrazine at 0.5 kg/ha PE + one hand weeding at 30 days after sowing (T_6); Atrazine at 0.5 kg/ha PE + 0.5 kg/ha at 10 days after sowing (T_7); cowpea as intercrop (T_8); weed free (T_9) and weedy check (T_{10}) tested with three replications. The soil of the experimental plot was analyzed by standard procedures (Black, 1965), which was Silty clay loam having pH 7.8, rich in organic carbon (0.96%), and medium in available P_2O_5 (26.0 kg/ ha) and K_2O (265.6 kg/ha). Sorghum variety 'Rio' was sown apart fro 30 cm row spacing with seed rate of 30 kg/ha. Cowpea grown as intercrop treatment using seed rate at 20 kg/ha for cowpea and seed rate of sorghum is reduced to half (15 kg/ha) using same row spacing i.e. 30 cm. Crop was fertilized with 60 kg/ha nitrogen and 60 kg/ha phosphorus through urea and Diammonium phosphate, respectively. Herbicides were sprayed uniformly and carefully by using 800-1000 liters of water per hectare by Maruti foot sprayer having flat fan nozzle as per treatment. Data on weed density weed samples were collected randomly by placing quadrate of 50 cm 50 cm size at one place in each plot at 30 and 60 days after sowing and at harvest stage of forage sorghum. After weeds were cut down from ground level, identified, counted and the samples were kept in hot air oven at 70 ± 1^0C until they got constant weight. Maximum weed population was recorded at 30 DAS whereas maximum weed dry weight at 90 DAS. The growth and yield attributes of fodder sorghum were also recorded in each plot at 30 and 60 days after sowing and at harvest stage. The data collected on weeds were subjected to logarithmic transformation (x+1) for statistical analysis. The significance of treatment were assessed using by the 'F' test was used (7). The cost of cultivation was worked out by considering the current price of the inputs/ commodity used under integrated weed management techniques. The gross return and net return were worked out by multiplying green fodder yield of sorghum along with their prices. For this, market price of green fodder sorghum (Rs. 600/t) was kept. Accordingly benefit cost ratio was calculated. The nitrogen uptake of sorghum and weed worked out by multiplying dry matter yield of sorghum and dry weight of weed with their respective nitrogen content values.

Result and Discussion

Effect on weeds

There were different weed species belonging to families in the experimental site. The major weeds i.e. *Cyperus spp.* (38.9%) and *Echinocloa colona* (28%) and other weds i.e. *Eleusine indica*, *Cynodan dactylon*, *Digitaria sanguinalus*, *Trianthema monogyma*, *Bracharia ramosa*, *Parthenium hysterophorus* and *Commelina benghalensis* were recorded in the experimental plots. Mukherji et *al.* (2000) and Rathore et *al.* (1985) also reported these type results. Weed density and there dry matter production was significantly different due to integrated weed management strategies (Table 1). Maximum weed population (442 /m^2) and dry matter accumulatio0n (233.4 g/ m^2) were found in weedy check condition.

Table 1. Effect of integrated weed management techniques on density dry, matter production and nutrient uptake of weeds in forage sorghum

Treatments	Density of total weeds/m^2	Dry weight of total weeds (g/m^2)	N-uptake by crops (kg/ha)	Weed index (%)
T_1	5.03 (165)	3.78 (50.1)	4.7	15.2
T_2	5.55 (298)	4.44 (130.0)	19.2	45.3
T_3	5.40 (234)	4.36 (85.3)	11.4	30.9
T_4	5.09 (165)	3.71 (48.4)	5.9	16.1
T_5	5.31(165)	4.44 (87.2)	9.3	18.5
T_6	4.95 (152)	3.93 (54.9)	6.7	18.3
T_7	4.78 (134)	3.06 (38.3)	4.9	8.9
T_8	5.74 (324)	5.08 (162.0)	17.2	49.9
T_9	0.00 (0.00)	0.00(0.00)	0.00	0.00
T_{10}	6.06 (442)	5.44 (233.6)	27.7	56.2
CD (P = 0.05)	0.52	0.52	13.6	-

Note: Original values are given in parenthesis

Application of atrazine 0.5 kg /ha PE + 0.5 kg/ha 10 DAS gave significantly lowest weed density and dry matter production, though at par with that of atrazine 1.0 kg/ha PE, atrazine 0.5 kg/ ha PE + one hand weeding at 30 DAS and one hand weeding at 20 DAS over other treatments (alachlor, pendimehalin, cowpea as intercrop, one and half time seed rate). Alachlor and pendimehalin were observed inferior by atrazine and hand weeding treatments and superior over cowpea as intercrop, one and half time seed rate and weedy check condition. Similar trend was found in weed index for reduction of green and dry fodder yield of sorghum. Lowest nitrogen uptake of weeds was recorded with application of atrazine at 0.5 kg/ha PE + 0.5 kg/ha at 10 DAS (4.67 kg/ha), one hand weeding at 20 DAS (4.94 kg/ha), followed by atrazine at 1.0 kg/ha PE (5.88 kg/ha), one hand weeding at 20 DAS (6.9 and 2.5 kg/ha), and atrazine at 0.5 kg/ha PE + one hand weeding at 30 DAS (6.69 kg/ha) over alachlor, pendimethalin, cowpea as intercrop, one and half time seed rate and weedy check conditions (27.7 kg/ha) in Table 2. Atrazine treated plots showed that keeps the free from weeds for longer time and resulted in better crop growth, yield and yield attributing characters of forage sorghum. These results were conformity in sorghum crop by the findings of Singh et *al.* (1987) and Kauskik et *al.*(2005).

Effect on crop

Growth, yield and yield attributing characters of fodder sorghum were significantly affected due to integrated weed management techniq**u**es (Table 2). Application of atrazine 0.5 kg ha/ PE + 0.5 kg/ha at DAS gave significantly higher plant height (2.94cm), dry matter production (82.3 g/plant) and green forage yield (431 qt/ ha), being at par with that with of atrazine at 1.0 kg/ ha

Table 2. Effect of integrated weed management techniques on growth, yield, nutrient uptake and profitability of forage sorghum

Treatments	Plant height (cm)	Dry matter Production (g/plant)	Green fodder yield (qt/ha)	N-uptake by weeds (kg/ha)	Cost of cultivation (Rs./ha)	Net returns (Rs./ha)	B: C ratio
T_1	2.88	80.7	388.5	149.9	8800.5	15641.5	1.77
T_2	2.3	54.9	291.5	68.7	7632.5	6956.5	0.84
T_3	2.43	76.6	249.5	113.8	8589.5	12806.5	1.48
T_4	2.46	79.7	419.0	145.9	8007.5	15958.5	1.97
T_5	2.94	78.6	355.0	115.4	8527.5	13863.5	1.63
T_6	2.75	79.2	368.0	137.6	9100.0	14111.0	1.42
T_7	2.75	82.3	431.0	158.5	8121.5	17880.5	2.23
T_8	2.41	57.8	280.5	87.7	7532.5	7708.5	0.93
T_9	2.86	91.5	449.0	176.2	10341.5	16595.5	1.85
T_{10}	2.34	47.7	237.0	59.7	7407.5	7635	0.78
CD (P = 0.05)	.11	4.67	25.6	16.4	-	-	-

PE, one hand weeding at 20 DAS and atrazine 0.5 kg /ha PE + one hand weeding at 30 DAS over other treatments (alachlor, pendimethalin, cowpea as intercrop, one and half time seed rate and weedy check conditions). Alachlor 2.0 kg/ha PE gave significantly higher plant height, dry matter production and green forage yield, being at par with pendimethalin 1.0 kg/ha PE over cowpea as intercrop, one and half time seed rate and weedy check conditions and inferior to atrazine treated and hand weeding plots. Weedy check recorded significantly lower green and dry fodder yield and yield attributing characters of sorghum which was due to more weed density per m^2 area and poor crop growth and less dry matter production and higher degree of crop weed competition (Table 1). Uncontrolled weedy check caused 55.83%, respectively, reduction on green fodder yield of sorghum as compared to weed free treatment. Atrazine treated plots and one hand weeding treatment recorded maximum weed suppression and more water, nutrient and light interception and vigorous crop growth and more photosynthetic area over weedy check condition. With depth in crop canopy the solar radiation decreased downward due to shady effect by weeds much more under weedy check condition, which inhibit light interception. Increased light interception by sorghum has also reported by Mukherji et *al.* (2000), Singh et *al.* (1987) and Kauskik et *al.*(2005).

Cowpea as intercrop showed better yield in quantity and quality due to smoothing effects on suppression of weed growth and gave more nutritious and palatable fodder of cattle. Intercropping of nonlegume with legume crops for fodder without involving costly inputs has been considered to be one of the attempts for achieving nutritious forage production per unit area by 48.81% over sole crop of cereals summer season (2). Lowest weed index (8.86%) was recorded with application of atrazine at 0.5 kg/ha PE + 0.5 kg/ha at 10 DAS, one hand weeding at 20 DAS (15.16%), followed by atrazine at 1.0 kg/ha PE (16.07%), and atrazine at 0.5 kg/ha PE + one hand weeding at 30 DAS (18.26%) than alachlor, pendimethalin, cowpea as intercrop, one and half time seed rate and weedy check conditions (50.15%) in Table 2. Significantly maximum nitrogen uptake of fodder sorghum was recorded with application of atrazine at 0.5 kg/ ha PE + 0.1 kg /ha at 10 DAS (158.52 kg/ ha), followed by one hand weeding at 20 DAS (145.96 kg/ha), atrazine at 1.0 kg /ha PE (145.93 kg/ha) and atrazine at 0.5 kg/ ha PE + one hand weeding at 30 DAS (137.6 kg/ha) than that of alachlor, pendimethalin, cowpea as intercrop, one and half time seed rate (59.74 kg/ha) and weedy check (59.74 kg/ha). These results also reported by Singh et *al.* (1987), Kauskik et *al.*(2005) and Wicks and Burnside(1972).

Effect on profitability

Maximum cost of cultivation (Rs. 9100 /ha) was invested in forage production with atrazine at 0.5 kg/ha PE + one hand weeding at 30 DAS, followed by one hand weeding at 20 DAS (Rs.8800 /ha), atrazine at 0.5 kg/ha PE + 0.5 kg ha at 10 DAS (Rs.8122 /ha) and atrazine at 1.0 kg /ha PE (Rs.8008 /ha) than weedy check (Rs.7406 /ha) (Table 2). Application of atrazine at 0.5 kg/ ha PE + 0.5 kg/ ha at 10 DAS gave maximum net returns (Rs.178881 /ha) and B: C ratio (2.23), followed by atrazine at 1.0 kg /ha PE Rs.159591 /ha) and B: C ratio (1.97), one hand weeding at 20 DAS (Rs. 15641 /ha) and B: C ratio (1.77) than weedy plots (Rs.3819 /ha) and B: C ratio (0.39). These results also conformity by the findings of Mukherji et *al.* (2000), Singh et *al.* (1987).

On the basis of results clearly indicate that application of atrazine 0.5 kg/ha PE + 0.5 kg /ha at DAS obtained highest growth, yield and yield attributing characters and nitrogen uptake of forage sorghum. It also noted more economic net return and B: C ratio due to lowest density and dry matter of weeds. The results can also found better if atarzine supplemented with one hand weeding at 30 DAS of fodder sorghum.

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RESIDUAL EFFECT OF FYM APPLIED TO KHARIF CROPS AND DIRECT EFFECT OF FERTILIZER LEVELS ON DM, LAI, CHLOROPHYLL, CGR, RGR, NAR, LAD AND YIELD OF BARLEY

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Abstract

A field experiment was conducted at Agricultural Research Station, RAU, Bikaner to study the residual effect of FYM applied to Kharif crops and direct effect of fertilizer levels on dry matter production, LAI, chlorophyll content, CGR, RGR, NAR, LAD and yield of barley. Dry matter production, LAI and chlorophyll content of fresh leaves recorded at different growth stages of barley were significantly increased when barley was grown after clusterbean as a preceding kharif crop. CGR, RGR, NAR and LAD recorded at different growth phase were significantly influenced due to residual effect of clusterbean as compared to mothbean and pearl millet. Application of 10 t FYM ha^{-1} to kharif crops had significant residual effect on dry matter production, chlorophyll content of fresh leaves, LAI, CGR of barley at all the growth phases. While, there was non-significant effect on relative growth rate of barley at all the growth phases. Application of 10 t FYM ha^{-1} to kharif crops significantly increased the net assimilation rate and LAD of barley recorded at all the growth phases except NAR at 60-90 DAS and LAD at 0-30 DAS phase. Fertilizer application @ 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased dry matter production, LAI and chlorophyll content of fresh leaves of barley measured at all the growth stages. Significantly higher CGR of barley were observed at different growth phase when fertilized with 120 kg N + 60 kg P_2O_5 ha^{-1}. Application of fertilizer significantly influenced the RGR of barley at all the growth stages over control. Whereas, at 90 DAS-harvest stages, RGR was significantly lower under fertilizer treatment than control. Successive increase in fertilizer levels up to 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased the NAR and LAD at all the growth phases.

Crop production by growing two or more crops within a year, has raised serious problem of soil fertility depletion and decline in yields in western Rajasthan conditions. The exhaustive nature of cereal – cereal cropping sequence may be the reason for decline in yields (Kumpawat, 2001). Inclusion of legume crops can help in sustaining the productivity of the system as pulses have extensive root system, which are capable of enriching soil resource through leaf litter and symbiotic nitrogen fixation (Saraf and Patil, 1995). FYM is rich in organic matter and can be supplemented with the chemical fertilizers. Although it is costlier than chemical fertilizers on unit nutrient basis, the other beneficial effect that it has on soil can compensate for the added cost. Brady (1996) generalized that half of N and one-fifth of P of the applied organic manure may be recovered by the crop. Thereafter, the rest nutrients are available at slower rates to the subsequent crops. A minimum nutrient loss due to slow release of nutrients from organic manures is an added advantage here. Therefore, the residual nutrients can be utilized by next crop in a crop rotation. Fertilizers, especially, nitrogen and phosphorus play a major role in early establishment of aerial portion capable of photosynthesis and increases root

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development to enable more efficient use of water and nutrients. Most of the workers have been confined to ascertain the response of nutrients in isolation (as N and P). Since, N and P have additive effect on grain yield, it is utmost important to assess their response in combination. Keeping all the facts in view, the present investigation was, therefore, undertaken to find out the residual effect of FYM applied to Kharif crops and direct effect of fertilizer levels on dry matter production, LAI, chlorophyll content, CGR, RGR, NAR, LAD and yield of barley.

Methods and Material

A field experiment was conducted during the *kharif* and *rabi* seasons of 2003-04 and 2004-05 at Agricultural Research Station, Rajasthan Agricultural University, Bikaner to study the effect of fertilizer levels and preceding crops grown with and without FYM on growth and productivity of barley. The soil of the experimental plot was sandy loam in texture, saline in reaction (pH 8.30), low in organic carbon (0.08%), medium in available phosphorus (17.89 kg ha^{-1}) and high in available potassium (230.0 kg ha^{-1}). The 30 treatments were tested in split plot design as kharif crops and FYM in main plots and fertilizer levels in sub plots with three replications. The treatments consisting of 3 kharif crops (pearl millet, mothbean and clusterbean) with and without FYM (applied to kharif crops only) in main plots and 5 levels of fertilizer applied to barley only (control, 30 kg N + 15 kg P_2O_5 ha^{-1}, 60 kg N + 30 kg P_2O_5 ha^{-1}, 90 kg N + 45 kg P_2O_5 ha^{-1} and 120 kg N + 60 kg P_2O_5 ha^{-1}) in sub plots. The HHB-67, RMO-40 and RGC-986 varieties of pearl millet, mothbean and clusterbean were sown with full recommended dose of fertilizer i.e. 80 kg N + 40 kg P_2O_5 ha^{-1}, 20 kg N + 40 kg P_2O_5 ha^{-1} and 20 kg N + 40 kg P_2O_5 ha^{-1}, respectively. After harvesting of kharif crops as per their maturity, the RD – 2508 variety of barley was sown in rows, 22.5 cm apart, on November 19, 2003 and November 21, 2004. The barley crop was fertilized (N + P_2O_5) as per treatment. The whole of phosphorus and half dose of nitrogen was applied as basal through DAP and urea, respectively and the remaining half dose of nitrogen fertilizer was applied through urea as top dressing at the time of first irrigation. The harvesting of the barley was done on March 23 and March 20, during 2004 and 2005, respectively. The total rainfall in kharif season was 222.0 and 102.8 mm and in *rabi* season was 7.5 and 65.4 mm during 2003-04 and 2004-05, respectively.

Result and Discussion

Effect of kharif crops

Dry matter production of barley at different growth stage significantly influence by residual effect of kharif crops. After clusterbean, barley produced dry matter of 6.73, 38.54, 142.92 and 212.88 g m^{-1} row length at 30, 60, 90 DAS and harvest stage. On pooled basis, barley grown after clusterbean produced 10.86 and 22.89 percent higher dry matter at harvest as compared to grown after mothbean and pearl millet, respectively. Similarly, chlorophyll content of fresh leaves of barley crop estimated at 30 and 60 DAS were significantly higher when barley was grown after clusterbean as compared to mothbean and pearl millet. After clusterbean, on pooled basis of analysis, there were 6.82 and 12.96 per cent higher chlorophyll content at 60 DAS as compared to mothbean and pearl millet, respectively.

Table 1. Effect of kharif crops, FYM and fertilizer levels on dry matter production of barley

Treatment	Dry matter production (g m^{-1} row length)											
	30 DAS			60 DAS			90 DAS			Harvest		
	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled
Kharif crops												
Pearl millet	5.11	5.42	5.26	34.21	32.21	33.21	125.11	106.22	115.67	176.10	170.36	173.23
Mothbean	6.19	5.86	6.03	35.13	34.78	34.96	136.09	117.95	127.02	195.80	188.26	192.03
Clusterbean	6.96	6.51	6.73	37.85	39.22	38.54	151.18	134.76	142.97	213.76	211.99	212.88
S. Em. ±	0.197	0.113	0.113	0.814	0.564	0.495	1.732	3.436	1.924	2.546	4.622	2.638
CD 5%	0.621	0.358	0.335	2.567	1.780	1.462	5.458	10.828	5.676	8.024	14.565	7.784
FYM (t ha^{-1})												
Control	5.65	5.16	5.40	32.25	32.12	32.18	125.72	111.90	118.81	177.91	167.13	172.52
10	6.52	6.70	6.61	39.21	38.69	38.95	149.20	127.38	138.29	212.53	213.28	212.90
S. Em. ±	0.160	0.092	0.092	0.665	0.461	0.404	1.414	2.805	1.571	2.079	3.774	2.154
CD 5%	0.507	0.292	0.274	2.096	1.453	1.194	4.456	8.841	4.634	6.551	11.892	6.355
Fertilizer levels (N + P_2O_5 ha^{-1})												
Control	3.61	3.39	3.50	16.92	16.92	16.92	58.27	55.82	57.04	92.12	92.12	92.12
30 + 15	5.05	4.52	4.78	28.17	25.73	26.95	110.81	99.07	104.94	155.05	155.05	155.05
60 + 30	5.94	5.84	5.89	36.85	36.52	36.69	139.89	120.47	130.18	195.19	193.11	194.15
90 + 45	7.32	7.15	7.23	43.55	45.00	44.27	171.48	145.71	158.59	237.46	232.54	234.99
120 + 60	8.49	8.76	8.63	53.16	52.86	53.01	206.86	177.15	192.01	296.28	278.21	287.24
S. Em. ±	0.185	0.131	0.113	1.026	0.728	0.629	2.717	2.124	1.724	2.957	3.781	2.400
CD 5%	0.526	0.373	0.318	2.918	2.071	1.766	7.728	6.039	4.871	8.409	10.751	6.738

It is evident from the data that there was significant influence of kharif crops on leaf area index (LAI) of barley crop during 2003-04, 2004-05 and pooled basis at all the stages of crop growth except at 30 DAS in 2003-04. The maximum LAI of barley crop was recorded when barley was grown after clusterbean and there was 10.15, 22.66 and 11.31 per cent significantly higher LAI at 30, 60 and 90 DAS respectively as compared to barley grown after pearl millet.

Kharif crops significantly enhanced the crop growth rate (CGR) of barley at 30-60 DAS, 60-90 DAS and 90 DAS-harvest stage during 2003-04, 2004-05 and on pooled basis except at 30-60 DAS in 2003-04 and 90-harvest stage during 2004-05, where the differences were non – significant. When compared pooled mean at 30-60 DAS, 60-90 DAS and 90 DAS-harvest phases, CGR of barley grown after clusterbean was improved by 13.73, 26.63 and 18.94 per cent than barley grown after pearl millet. It is apparent from data that relative growth rate (RGR) at 30-60 and 60-90 days growth phase was significantly influenced due to residual effect of kharif crops during 2003-04 and pooled analysis while during 2004-05, the differences were found non - significant. When compared pooled mean at 60 to 90 DAS, RGR of barley grown after clusterbean was improved by 0.10 and 1.29 mg $g^{-1}sqm^{-1}day^{-1}$ than barley grown after mothbean and pearl millet, respectively. RGR estimated at 90 to harvest phase was found statistically non – significant.

It is reflected from the data that there was significant effect of kharif crops on net assimilation rate of barley crop only at 60-90 DAS growth phase during 2003-04 and pooled basis. The significant maximum net assimilation rate (1.963 mg $sqm^{-1}day^{-1}$) was recorded when barley was grown after clusterbean. While, on the basis of pooled mean, the difference between net assimilation rates of barley recorded after clusterbean and mothbean was found non – significant at 60 to 90 DAS stage.

Kharif crops significantly enhanced the LAD of barley crop at all the growth phases except during 2003-04 at 0 – 30 days growth phase. On the basis of pooled mean, the maximum LAD was estimated when barley was grown after clusterbean as compared to mothbean and pearl millet. There was 0.61, 4.79 and 7.25 more days due to residual effect of clusterbean during 0 – 30, 30 – 60 and 60 – 90 days growth phase compared with LAD recorded when barley grown after pearl millet.

An appraisal of data revealed that grain yield of barley crop grown after clusterbean and mothbean were significantly higher than barley crop grown after pearl millet. There were 13.75, 23.78 and 18.69 per cent higher grain yield of barley crop when grown after clusterbean than pearl millet during 2003-04, 2004-05 and on pooled basis, respectively. Data show that straw yield of barley was significantly increased by residual effect of kharif crops. The highest straw yield of barley was recorded under treatment barley grown after clusterbean, which was 19.06 and 8.36 per cent higher than grown after pearl millet and mothbean, respectively on the basis of pooled analysis. Significantly lowest straw yield (30.80 qha^{-1}) of barley was recorded after pearl millet as compared with mothbean and clusterbean as previous kharif crops.

Among kharif crops, legumes are known to fix atmospheric nitrogen in their root zone, which is made available to succeeding cereal crop favouring

Table 2. Effect of kharif crops, FYM and fertilizer levels on chlorophyll content (mg g^{-1}) and leaf area index of barley

Treatment	Chlorophyll content (mg g^{-1}) of fresh leaves						Leaf area index								
	30 DAS			60 DAS			30 DAS			60 DAS			90 DAS		
	2003-4	2004-5	Pool	2003-4	2004-5	Pool	2003-4	2004-5	Pool	2003-4	2004-5	Pool	2003-4	2004-5	Pool
Kharif crops															
Pearl millet	1.650	1.746	1.698	1.991	1.834	1.914	0.386	0.402	0.394	1.183	1.270	1.227	1.752	1.855	1.804
Mothbean	1.785	1.809	1.797	2.116	1.932	2.024	0.402	0.421	0.412	1.234	1.519	1.377	1.775	2.018	1.897
Clusterbean	1.952	1.849	1.901	2.262	2.062	2.162	0.420	0.449	0.434	1.346	1.665	1.505	1.897	2.137	2.008
S. Em. ±	0.101	0.114	0.076	0.060	0.024	0.032	0.0086	0.0076	0.0057	0.0205	0.0375	0.0214	0.0282	0.0310	0.0209
CD 5%	NS	NS	NS	0.191	0.076	0.096	NS	0.0240	0.0170	0.0648	0.1184	0.0632	0.0889	0.0978	0.0618
FYM (t ha^{-1})															
Control	1.660	1.620	1.640	1.989	1.874	1.931	0.398	0.417	0.408	1.222	1.367	1.294	1.745	1.916	1.831
10	1.931	1.982	1.957	2.257	2.014	2.136	0.407	0.431	0.419	1.287	1.603	1.445	1.859	2.090	1.975
S. Em. ±	0.082	0.093	0.062	0.049	0.019	0.026	0.0070	0.0062	0.0047	0.0168	0.0306	0.0174	0.0230	0.0253	0.0171
CD 5%	0.261	0.294	0.184	0.156	0.062	0.078	NS	NS	NS	0.0529	0.0966	0.0516	0.0725	0.0978	0.0505
Fertilizer levels (N + P_2O_5 ha^{-1})															
Control	1.088	1.199	1.144	1.234	1.079	1.156	0.328	0.345	0.337	1.036	1.116	1.076	1.334	1.372	1.353
30 + 15	1.551	1.904	1.727	1.827	1.658	1.743	0.380	0.400	0.390	1.188	1.313	1.250	1.621	1.815	1.718
60 + 30	1.875	1.892	1.884	2.192	2.075	2.134	0.439	0.434	0.422	1.278	1.515	1.396	1.810	2.004	1.907
90 + 45	2.111	1.910	2.010	2.519	2.304	2.411	0.439	0.463	0.451	1.358	1.684	1.521	2.101	2.297	2.199
120 + 60	2.354	2.101	2.228	2.844	2.603	2.723	0.457	0.479	0.469	1.412	1.796	1.604	2.145	2.530	2.337
S. Em. ±	0.061	0.093	0.056	0.049	0.026	0.028	0.0040	0.0042	0.0029	0.0138	0.0207	0.0124	0.0186	0.0182	0.0130
CD 5%	0.175	0.265	0.157	0.139	0.076	0.078	0.0116	0.0121	0.0082	0.0394	0.0591	0.0350	0.0530	0.0520	0.0366

better plant growth in terms of increased leaf area index of barley under the influence of preceding crop of clusterbean which is reflected in terms of increase in CGR and LAD under this treatment followed by mothbean. The lowest LAI was recorded in the crop of barley grown after pearl millet due probably to its exhaustive nature leading to greater depletion and poor availability of major nutrients for succeeding crop of barley. As crop, dry matter production is a function of cumulative effect of growth parameters, higher dry matter production of barley was recorded when grown after clusterbean and lower after pearl millet due to similar variations in growth parameters of barley grown after these kharif crops. These finding are in close conformity with the results obtained by Kumpawat (1996) and Patil (1997). Balyan (1997) also reported that wheat produced significantly higher dry matter and taller plants in the plots preceded by legumes compared with pearl millet.

Higher dry matter accumulation in barley grown after clusterbean and lower after pearl millet could be further evidenced in similar variation in the extent and size of crop canopy (LAI) and its active duration (LAD) leading to similar variation in interception of solar radiation and net photosynthesis in terms of CGR and RGR (Table 4.9 and 4.12) of barley grown in sequence with different kharif crops. Jain (1989) and Yadav (1991) also reported the similar results.

Effect of FYM

Application of FYM @ 10 t ha^{-1} to kharif crops significantly increased the dry matter production of barley at 30, 60, 90 DAS and at harvest stage and chlorophyll content of fresh leaves of barley estimated at 30 and 60 DAS. At harvest, there was 19.46, 27.61 and 23.41 higher dry matter production with the application of FYM during 2003-04, 2004-05 and on pooled basis, respectively. The increment was in a tune of 16.33, 22.35 and 19.33 per cent at 30 DAS and 13.47, 7.47 and 10.62 per cent higher chlorophyll content in fresh leaves at 60 DAS with the application of FYM during 2003-04, 2004-05 and pooled basis, respectively. Data further indicated that application of 10 t FYM ha^{-1} to kharif crops significantly increased the LAI of barley at all the growth stages except at 30 DAS. The mean LAI increased due to application of 10 t FYM ha^{-1} compared with control plot were 11.67 and 7.86 per cent at 60 and 90 DAS, respectively.

Application of 10 t FYM ha^{-1} to kharif crops significantly increased the CGR of barley at all the growth phases during both the years of experimentation as well as in pooled analysis. On the basis of pooled mean, application of 10 t FYM ha^{-1} improved CGR by 20.72, 14.65 and 35.00 per cent over control, respectively at 30-60 DAS, 60-90 DAS and 90 DAS - harvest growth phase. Data further indicated that there was non – significant effect of application of 10 t FYM ha^{-1} to kharif crops on relative growth rate of barley during 2003-04, 2004-05 and on the basis of pooled means at all the growth phases.

Application of 10 t FYM ha^{-1} to kharif crops significantly increased the net assimilation rate of barley at all the growth stages during both the years of experimentation as well as in pooled analysis except at 60-90 DAS stage during 2004-05. On the basis of pooled mean, application of 10 t FYM ha^{-1} improved net assimilation rate by 12.92 and 6.36 per cent over control, respectively at 30-60 and 60-90 DAS

Table 3. Effect of kharif crops, FYM and fertilizer levels on NAR and CGR of barley

Treatment	NAR ($mg^{-1} m^{-2} day^{-1}$)						Crop Growth Rate ($g\ m^{-2} day^{-1}$)								
	30 – 60 DAS			60 – 90 DAS			30 - 60 DAS			60 - 90 DAS			90 DAS to Harvest		
	2003-4	2004-5	Pool	2003-4	2004-5	Pool	2003-4	2004-5	Pool	2003-4	2004-5	Pool	2003-4	2004-5	Pool
Kharif crops															
Pearl millet	1.327	1.139	1.233	1.999	1.526	1.762	0.970	0.893	0.932	3.030	2.467	2.749	1.699	2.147	2.085
Mothbean	1.255	1.092	1.174	2.195	1.546	1.870	0.964	0.964	0.964	3.365	2.772	3.069	1.990	2.677	2.334
Clusterbean	1.265	1.137	1.201	2.280	1.647	1.963	1.029	1.090	1.060	3.778	3.185	3.481	2.086	2.874	2.480
S. Em. ±	0.037	0.025	0.022	0.041	0.058	0.035	0.027	0.019	0.017	0.059	0.113	0.063	0.088	0.163	0.092
CD 5%	NS	NS	NS	0.131	NS	0.105	NS	0.062	0.050	0.186	0.356	0.188	0.278	NS	0.273
FYM (t ha^{-1})															
Control	1.174	1.085	1.130	2.031	1.586	1.808	0.887	0.898	0.893	3.116	2.660	2.888	1.740	2.174	1.957
10	1.391	1.160	1.276	2.285	1.560	1.923	1.089	1.066	1.078	3.666	2.956	3.311	2.110	3.174	2.642
S. Em. ±	0.030	0.020	0.018	0.034	0.047	0.029	0.022	0.016	0.013	0.048	0.092	0.052	0.072	0.133	0.075
CD 5%	0.096	0.064	0.054	0.107	NS	0.086	0.071	0.051	0.041	0.152	0.290	0.153	0.227	0.420	0.223
Fertilizer levels (N + P_2O_5 ha^{-1})															
Control	0.725	0.688	0.707	1.151	1.031	1.091	0.444	0.451	0.447	1.378	1.297	1.338	1.129	1.543	1.336
30 + 15	1.089	0.927	1.008	1.976	1.576	1.776	0.771	0.707	0.739	2.755	2.445	2.600	1.475	2.187	1.831
60 + 30	1.352	1.178	1.266	2.245	1.613	1.929	1.030	1.022	1.026	3.435	2.799	3.117	1.843	2.767	2.305
90 + 45	1.490	1.340	1.415	2.498	1.705	2.101	1.208	1.261	1.235	4.264	3.357	3.811	2.199	3.228	2.713
120 + 60	1.756	1.479	1.618	2.920	1.940	2.430	1.489	1.470	1.480	5.123	4.143	4.633	2.981	3.646	3.314
S. Em. ±	0.048	0.033	0.029	0.069	0.041	0.040	0.036	0.024	0.021	0.097	0.071	0.060	0.145	0.146	0.103
CD 5%	0.137	0.096	0.082	0.196	0.118	0.113	0.103	0.069	0.061	0.278	0.202	0.170	0.414	0.417	0.290

growth phase of barley. Data further indicated that application of 10 t FYM ha^{-1} to kharif crops significantly increased the LAD of barley. On the basis of pooled mean, application of 10 t FYM ha^{-1} improved LAD by 9.52 and 9.43 per cent over control, respectively at 30 – 60 and 60 – 90 days growth phase of barley.

Application of FYM @10 t ha^{-1} to kharif crops significantly increased the grain yield of barley during 2003-04, 2004-05 and on pooled basis. The higher grain yield of barley was recorded with FYM @10 t ha^{-1}, which was 16.79, 11.78 and 14.25 per cent higher than control during 2003-04, 2004-05 and on pooled basis, respectively. FYM @ 10 t ha^{-1} applied to kharif crops have significant residual effect on the straw yield of barley during 2003-04, 2004-05 and on pooled basis. Application of FYM @10 t ha^{-1} increased the straw yield by 13.68, 10.19 and 11.92 per cent over control plot during 2003-04, 2004-05 and on pooled basis, respectively.

It is evident from pooled analysis of results that application of 10 t FYM ha^{-1} to kharif crops significantly increased the growth of succeeding barley crop in terms of chlorophyll content, leaf area index and dry matter accumulation at all the growth stages compared with unmanured control. This might be attributed to the improvement in overall nutritional environment in the root zone coupled with improvement in physical, chemical and biological properties of soil due to decomposition of the manure during rainy season and greater availability of nutrients to the crop of barley with improved vigour at initial growth phase of the crop. Thus balanced nutrition under favourable environment of FYM to the crop of barley might have helped in production of new tissues and development of new shoots leading ultimately to increased dry matter production and yield. These results are in agreement with those of Sharma and Vyas (2002) who also observed improvement in growth parameters of wheat due to application of FYM in soybean. Similarly, Thakral and Singh (2002) under saline soil conditions observed that higher plant height of barley was recorded when FYM was applied @ 20 t ha^{-1} during kharif season as compared to unmanured control.

Effect of Fertilizer level

Barley crop fertilized up to 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased the dry matter production and chlorophyll content of fresh leaves estimated at different growth stages during both the years as well as pooled basis of analysis. Successive increase in N+P levels significantly increased the dry matter production and chlorophyll content of fresh leaves over their respective lower levels. The increment in dry matter production was 68.31, 25.22, 21.04 and 22.23 per cent with increase in fertilizer level from control to 120 kg N + 60 kg P_2O_5 ha^{-1} on pooled basis, at harvest of crop. Similarly, the increment in chlorophyll content was 50.78, 22.43, 12.98 and 12.94 per cent with increase in fertilizer level from control to 120 kg N + 60 kg P_2O_5 ha^{-1} on pooled basis at 60 DAS.

It is evident from the data that fertilizer treatment up to 120 kg N + 60 kg P_2O_5 ha^{-1} recorded significantly higher leaf area index (LAI) as compared to lower levels at 30, 60 and 90 DAS, during both the years and pooled basis. The per cent increase was 39.17, 49.07 and 72.73 with 120 kg N + 60 kg P_2O_5 ha^{-1}, in LAI at 30, 60 and 90 DAS, respectively over control plot on pooled basis of analysis.

It is evident from the data that

Table 4. Effect of kharif crops, FYM and fertilizer levels on relative growth rate and leaf area duration of barley

Treatment	Relative Growth Rate (mg $g^{-1}m^{-2}day^{-1}$)									Leaf Area Duration								
	30 - 60 DAS			60 - 90 DAS			90 DAS to Harvest			0-30 DAS			30-60 DAS			60-90 DAS		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
Kharif crops																		
Pearl millet	27.15	25.54	26.34	18.23	17.11	17.67	5.54	8.18	6.86	5.79	6.03	5.91	23.53	25.09	24.31	44.02	46.88	45.45
Mothbean	24.41	25.44	24.92	19.80	17.93	18.86	5.03	7.35	6.19	6.04	6.32	6.18	24.55	29.11	26.83	45.14	53.06	49.10
Clusterbean	24.23	25.79	25.01	19.83	18.09	18.96	5.42	7.27	6.35	6.30	6.74	6.52	26.48	31.71	29.10	48.37	57.03	52.70
S. Em. ±	0.549	0.446	0.354	0.410	0.397	0.285	0.273	0.531	0.298	0.130	0.114	0.086	0.313	0.643	0.358	0.463	0.694	0.417
CD 5%	1.731	NS	1.044	1.295	NS	0.842	NS	NS	NS	NS	0.359	0.255	0.988	2.028	1.056	1.459	2.188	1.231
FYM (t ha^{-1})																		
Control	24.83	26.19	25.51	19.30	18.11	18.71	5.53	7.07	6.30	5.97	6.26	6.12	24.30	26.76	25.53	44.51	49.25	46.88
10	25.69	24.99	25.34	19.28	17.30	18.29	5.13	8.13	6.63	6.11	6.47	6.29	25.41	30.51	27.96	47.19	55.40	51.30
S. Em. ±	0.448	0.364	0.289	0.335	0.324	0.233	0.223	0.433	0.243	0.106	0.093	0.070	0.256	0.525	0.292	0.378	0.566	0.340
CD 5%	NS	1.148	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.807	1.656	0.862	1.191	1.786	1.005
Fertilizer levels (N + P_2O_5 ha^{-1})																		
Control	22.33	23.38	22.86	17.39	17.03	17.21	7.12	8.94	8.03	4.92	5.18	5.05	20.47	21.92	21.19	35.56	37.33	36.45
30 + 15	24.94	25.24	25.09	20.08	19.60	19.84	4.85	7.36	6.11	5.70	6.00	5.85	23.52	25.70	24.61	42.13	46.92	44.53
60 + 30	26.44	26.56	26.50	19.44	17.43	18.44	4.79	7.50	6.15	6.15	6.51	6.33	25.32	29.24	27.28	46.31	52.79	49.55
90 + 45	25.90	26.75	26.32	19.85	16.98	18.42	4.65	7.30	5.97	6.59	6.95	6.77	26.95	32.20	29.58	51.88	59.71	55.79
120 + 60	26.68	26.03	26.36	19.67	17.49	18.58	5.23	6.90	6.06	6.85	7.19	7.02	28.03	34.12	31.08	53.35	64.88	59.11
S. Em. ±	0.705	0.548	0.446	0.549	0.383	0.335	0.462	0.483	0.334	0.061	0.064	0.044	0.223	0.333	0.200	0.360	0.404	0.270
CD 5%	2.005	1.558	1.253	1.562	1.090	0.940	1.315	1.373	0.938	0.174	0.182	0.124	0.636	0.948	0.563	1.024	1.150	0.760

successive increase in nitrogen with phosphorus levels up to 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased the CGR at all the growth phases. Application of 120 kg N + 60 kg P_2O_5 ha^{-1} recorded significant increase by 1.033, 3.295 and 1.978 g $m^{-2}day^{-1}$, when compared with a pooled mean of 0.447, 1.338 and 1.336 g $m^{-2}day^{-1}$ estimated under control plots during 30-60 DAS, 60-90 DAS and 90 DAS - harvest phase, respectively. Application of fertilizer levels significantly influenced the relative growth rate of barley at all the growth phases over control. At 90 DAS to harvest phase, the RGR was significantly reduced due to application of fertilizer where the highest value was recorded under control. On the basis of pooled mean, there was significant increment in RGR up to 60 kg N + 30 kg P_2O_5 ha^{-1} at 30 to 60 DAS phase and during 60 to 90 DAS phase, the significant increment was only up to 30 kg N + 15 P_2O_5 ha^{-1}.

It is evident from the data that successive increase in nitrogen and phosphorus levels up to 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased the NAR and LAD at all the growth phases. When compared with a pooled mean, net assimilation rate of 1.618 and 2.430 mg m^{-2} day^{-1} during 30-60 and 60-90 DAS phase were recorded under 120 kg N + 60 kg P_2O_5 ha^{-1} which was significantly higher by 0.911 and 1.339 mg $sqm^{-1}day^{-1}$ over control, respectively. Similarly, application of 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased the LAD by 39.00, 46.67 and 62.17 per cent, when compared with a pooled mean of 5.05, 21.19 and 36.45 LAD (days) recorded under control during 0-30, 30-60 and 60-90 phase, respectively.

A perusal of data indicated that application of nitrogen and phosphorus nutrients in combinations significantly influenced the grain and straw yield of barley. The highest grain yield of barley was recorded in treatment 120 kg N + 60 kg P_2O_5 ha^{-1} which was significantly higher than all other treatments. Application of treatment 120 kg N + 60 kg P_2O_5 ha^{-1} significantly increased the grain yield by 186.79, 54.26, 31.39 and 9.37 per cent over control, 30 kg N + 15 kg P_2O_5 ha^{-1}, 60 kg N + 30 kg P_2O_5 ha^{-1} and 90 kg N + 45 kg P_2O_5 ha^{-1}, respectively on the pooled basis of analysis. Application of 120 kg N + 45 kg P_2O_5 ha^{-1} increased the straw yield by 195.48, 58.86, 39.84 and 10.60 per cent over control, 30 kg N + 15 kg P_2O_5 ha^{-1}, 60 kg N + 30 kg P_2O_5 ha^{-1} and 90 kg N + 45 kg P_2O_5 ha^{-1} treatments, respectively on the pooled basis of analysis.

Successive increase in fertilizer levels from control to 120 kg N + 60 kg P_2O_5 ha^{-1} applied to barley significantly enhanced the plant growth parameters *viz.* dry matter production and leaf area index observed at different growth stages. It is well known fact that adequate fertilization to crops is known to improve various physiological and metabolic processes in the plant system. Nitrogen is the most important mineral nutrient since it is essential constituent required in synthesis of protein, chlorophyll and other organic compounds in plant system. Phosphorus is the second most indispensable nutrient required for growth and development of plant and plays an important role in the conservation and transfer of energy in the metabolic reactions of living cells including biological energy transformation. It is the main constituent of co-enzymes, ATP and ADP, which act as energy currency within the plants. Thus phosphorus application affects photosynthesis, biosynthesis of proteins, phospholipids and nucleic acids, membrane transport and

Table 5. Effect of kharif crops, FYM and fertilizer levels on yields (q ha^{-1}) and harvest index of barley

Treatment	Grain yield (q ha^{-1})			Straw Yield (q ha^{-1})			Biological Yield (q ha^{-1})			Harvest Index (%)		
	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled	2003-4	2004-5	Pooled
Kharif crops												
Pearl millet	26.76	25.99	26.38	31.14	30.46	30.80	57.90	56.45	57.18	46.40	45.84	46.12
Mothbean	27.99	28.90	28.45	33.67	34.01	33.84	61.66	62.91	62.29	45.38	45.89	45.64
Clusterbean	30.44	32.17	31.31	35.74	37.60	36.67	66.19	69.77	67.98	46.12	46.31	46.21
S. Em. ±	0.530	0.405	0.333	0.352	0.500	0.306	0.832	0.686	0.539	0.307	0.400	0.252
CD 5%	1.670	1.278	0.984	1.112	1.575	0.902	2.622	2.164	1.591	NS	NS	NS
FYM (t ha^{-1})												
Control	26.20	27.41	26.80	31.37	32.37	31.87	57.57	59.78	58.67	45.69	45.78	45.74
10	30.60	30.64	30.62	35.66	35.67	35.67	66.26	66.31	66.29	46.24	46.24	46.24
S. Em. ±	0.432	0.331	0.272	0.288	0.408	0.249	0.679	0.560	0.440	0.251	0.327	0.206
CD 5%	1.363	1.043	0.803	0.908	1.286	0.737	2.141	1.767	1.299	NS	NS	NS
Fertilizer levels (N + P_2O_5 ha^{-1})												
Control	14.93	12.33	13.63	17.48	14.38	15.93	32.41	26.71	29.56	46.09	46.09	46.09
30 + 15	25.96	24.72	25.34	29.57	29.69	29.63	55.53	54.41	54.97	46.73	45.45	46.09
60 + 30	29.26	30.24	29.75	32.91	34.40	33.66	62.17	64.64	63.41	46.98	46.67	46.82
90 + 45	34.50	36.98	35.74	41.14	43.98	42.56	75.64	80.96	78.30	45.28	45.65	45.57
120 + 60	37.34	40.85	39.09	46.49	47.67	47.07	83.82	88.51	86.16	44.56	46.19	45.37
S. Em. ±	0.452	0.465	0.324	0.389	0.374	0.270	0.746	0.637	0.490	0.931	0.735	0.593
CD 5%	1.287	1.324	0.911	1.107	1.064	0.758	2.122	1.813	1.377	NS	NS	NS

cytoplasmic streaming. The greater availability of nutrients in soil due to increasing fertilizer application might have enhanced meristematic activity (multiplication and elongation of cells) leading to increased plant height and dry matter accumulation.

Significant improvement in leaf area index and chlorophyll content in leaves might have resulted in better interception and utilization of radiant energy leading to higher photosynthetic rate and finally more accumulation of dry matter by the crop. These results are in close conformity with findings of Singh et al. (2003) and Sutaliya et al. (2003).

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EFFECT OF ARBUSCULAR MYCORRHIZAL FUNGI ON THE NUTRIENT UPTAKE BY FINGER MILLET PLANT AT DIFFERENT CONCENTRATIONS OF ZINC

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ABSTRACT

Phytoextraction has been proposed in recent years as a cost effective and environmently friendly clean up technology for remediation of heavy metals contaminated soils .A pot experiment was conducted to study the effect of arbuscular mycorrhizal (AM) fungi on plant growth and nutrients uptake by finger millet (*Eleusine coracana* L.) was studied in soil supplemented with zinc @ 0,150,300 and 450 mg Zn kg^{-1} soil . Three different mycorrhizal fungi namely *Gigaspora* ACP-1 (M_1), *Glomus* ACP-2 (M_2) and *Scutellospora* ACP-2 (M_3) were studied. In absence of Zn all the three fungal strains were equally effective in promoting plant growth and nutrients uptake but when Zn was added to soils, the plant growth and uptake of nutrients were decreased over control. *Glomus* ACP-2 (M_2 strain) was found to be the most tolerant strain to the increasing levels of Zn addition to soil over the other two strains.

Keywords: AM fungi, Zinc, finger millet

Arbuscular mycorrhizal (AM), fungi plays an essential role in providing acess to minerals nutrients at all the stages of plant development. This is achieved largely through their ability to mobilize key nutrients such as phosphorus and nitrogen, consequently mycorrhizal fungi also influenced plant fitness and survival and the development of plant community structure. With the advent of environmental problems originating from pollutants having been transmitted upto the constant food chain, the concept of ecological pollution has been the focal issue. Today, agriculture practices being full environmental concern into account are of great importance. This phenomenon has urged consistent cultivation system to be developed and implemented. The purpose of agri ecosystem is to ensure alternatives with the population of natural species is to be sustained and the likelihood hazardous effect is to be minimized. One of the alternatives proposed is that soil microorganism might be used in agriculture; thereby natural protection may be promoted. Arbuscular mycorrhizal (AM) fungi are among the most common of all soil fungi and they form symbiotic association with the roots of most vascular plants. However, little is known about their potential to adapt to toxic metals concentrative in soil. Heavy metals have been regarded to reduce or completely eliminate AM infection of plant roots in pot experiments, often at concentrations where phytoxic effects are not observed (Wang and Chao, 1991). Higher metal concentrations may therefore interfere with possible beneficial effects of the mycorrhizal association on plant nutrition, drought resistance and root health (Reddell and Milnes, 1992).Among soil microorganism mycorrhizal fungi are the only ones providing a direct link between soil and roots therefore, is of great importance in heavy metal availability and toxicity to plants (Leyval *et al*, 1997). The objective is to investigate the possibilities of utilization of AM fungi in mitigating pollution in soil.

Material and Methods

A pot experiment was conducted during 2005 to study the effects of inoculation of AM fungi (uninoculated as control) inoculated with *Gigaspora* ACP-1 (M_1), *Glomus* ACP-2 (M_2) and *Scutellospora* ACP-2 (M_3) were obtained from soil microbiology laboratory, G. B. Pant University of Agriculture and Technology, Pantnagar, India and were multiplied under sterile conditions with wheat as a host plant for 45 days. At the same time, the control mycorrhizal inoculums were also prepared under same conditions. The inocula were air dried and sieved (2mm) and each consisted of a mixture of rhizospheric soil from pure pot culture containing spores, hyphae and mycorrhizal and root fragments (the control without AM fungal propogules). The soil used in the study was collected from Crop Research Centre, Pantnagar B_6 plot. It had pH 7.32, available P 10.1 kg ha^{-1} (Olsen *et. al*, 1954), organic carbon 1.17%, DTPA extractable Zn 4.40 µg g^{-1} (Lindsay & Marvell, 1069). The soil was sieved (4mm) and mixed with sand in 3:1 ratio. The different metal adding aqueous solution of zinc sulphate at the rates of 0, 150, 300 and 450 mg Zn kg^{-1} soil. After carefully mixing the metal solution with the soil, this was allowed to stabilize for 15 days before using, AM spores 100 spores was placed in pot of 5 kg capacity below 2 cm soil surface. A basal dose of 40 N kg ha^{-1}, nitrogen in solution in soil in form of $(NH_4)_2$ SO_4 and potassium @ 20 K_2O kg ha^{-1} as (KCl) was given in all treatments. Finger millet variety VL 146 was sown on 25-28- 05 after surface sterilization of finger millet seeds with 0.5 % sodium hydrochloride for 15 minutes three replications per 16 treatments were establish. The crop was harvested on 7 -12-05 plant height at 30, 60 and 150 (maturity) days after sowing was recorded. The dry plant material was digested in diacid HNO_3:$HClO_4$ (9:4) ratio and extracts were used to estimate nutrient content in plant material.

Result and Discussion

The addition of increasing doses of Zn reduced logarithmically plant height in the non mycorrhizal finger millet plant at 30, 60 and 105 DAS (table 1) when no metal was added, mycorrhizal inoculations with all the three strains significantly increased plant growth. Taking into account that plants were growing in a soil with very low phosphorus content, these results suggested that finger millet is very much dependent on mycorrhiza for optimal growth. However, at the highest dose of Zn applied (150 mg kg^{-1} and 300 mg kg^{-1}) inoculated plants were significantly taller than the uninoculated ones. Inoculation with *Glomus* ACP-2 (M_2) caused maximum increase in plant height followed by *Scutellospora* ACP-2(M_3) and *Gigaspora* ACP -1 (M_1) strains at all the stages of plant growth and was increased significantly over control in Zn treated plants. Increasing doses of zinc application alone caused significant reduction in plant height in both uninoculated and inoculated plants.

The interaction effect between mycorrhizal fungal strains and doses of zinc significantly reduced the height of plant at all the stages of plant growth. The inhibition of plant growth of mycorrhizal plants was logarithmically related metal addition this inhibition was more pronounced with *Gigaspora* ACP-1(M_1) than with *Scutellospora* ACP -2 (M_3) and *Glomus* ACP **-1 (M_3) (table 1).**

Table 1. Plant height as influenced by AM fungi, zinc concentration and their interaction in finger millet crop at 30, 60, and 105DAS

Strain	Plant height (cm/ plant)														
	30 DAS					60 DAS					105 DAS				
	Zn 0	Zn 150	Zn 300	Zn 450	Mean	Zn 0	Zn 150	Zn 300	Zn 450	Mean	Zn 0	Zn 150	Zn 300	Zn 450	Mean
M0	50.0	48.6	46.0	45.0	47.5	88.0	85.0	80.0	74.0	82.0	102.0	96.0	92.0	92.0	95.5
M1	53.3	50.0	47.6	49.0	50.0	90.0	87.0	83.0	80.0	85.0	113.0	100.0	100.0	99.0	103.0
M2	57.6	55.0	48.3	46.0	51.9	96.0	94.0	93.0	92.0	93.7	121.0	112.0	110.0	105.0	112.0
M3	56.0	51.3	50.6	48.3	51.7	98.0	95.0	90.3	88.0	93.0	115.0	91.0	107.0	98.0	107.0
Mean	54.2	51.2	48.1	47.6	-	93.0	90.5	86.7	83.5	-	112.7	104.5	112.2	98.5	-

	M	Zn	M x Zn	M	Zn	M x Zn	M	Zn	M x Zn
SEM±	0.66	0.66	1.32	0.64	0.64	1.29	1.10	1.10	2.20
CD(0.01)	2.56	2.56	5.13	2.50	2.50	5.01	4.27	4.27	8.54
CD(0.05)	1.90	1.90	3.81	1.86	1.86	3.72	3.17	3.17	6.35

P concentration in leaves of mycorrhizal plants was also depressed significantly by high levels of Zn in soil. The sensitivity of AM endophytes to high amounts of heavy metals expressed as a reduction or delay of its colonization ability similar results have been reported previously (Gildon and Tinker 1981, Heggo *et. al.* 1990; Vidal *et. al.* 1996)

Table 2. Effect of mycorrhizal fungi doses of Zn and their interaction of nitrogen uptake in shoot at 60 and 105 DAS

Strain	Nitrogen uptake in shoot (mg/pot)									
	60 DAS					105 DAS				
	Zn 0	Zn 150	Zn 300	Zn 450	Mean	Zn 0	Zn 150	Zn 300	Zn 450	Mean
M0	26.22	22.09	19.55	17.62	21.37	32.34	36.37	25.08	23.24	29.25
M1	36.84	35.24	31.35	30.59	33.50	62.90	51.68	47.94	30.55	48.26
M2	42.19	37.05	35.11	33.25	36.90	76..44	70.19	55.94	38.95	60.24
M3	37.34	32.43	31.63	29.16	32.64	55.265	47.15	42.36	33.95	44.68
Mean	35.64	31.70	29.41	27.65	-	56.73	51.34	42.83	32.53	-

	M	Zn	M x Zn	M	Zn	M x Zn
SEM±	0.39	0.39	0.79	0.25	0.25	0.50
CD(P= 0.01)	1.54	1.54	3.08	0.97	0.97	1.95
CD (0.05)	1.14	1.14	2.29	0.72	0.72	1.45

Table 3. Effect of mycorrhizal fungi doses Zn and their interaction on phosphorus uptake in shoot at 60 and 105 DAS

Strain	Phosphorus uptake in shoot (mg/pot)									
	60 DAS					105 DAS				
	Zn 0	Zn 150	Zn 300	Zn 450	Mean	Zn 0	Zn 150	Zn 300	Zn 450	Mean
M0	2.14	1.70	1.56	1.35	1.68	5.0	4.32	4.26	3.94	4.38
M1	3.87	3.27	2.90	2.56	3.15	9.32	7.31	6.87	4.78	7.12
M2	4.69	3.93	3.58	3.11	3.85	11.30	10.60	87.74	6.33	9.24
M3	4.08	3.41	2.96	2.75	3.30	8.19	7.32	6.39	5.73	5.72
Mean	3.69	3.07	2.75	2.44	-	8.45	7.43	6.56	5.19	-

	M	Zn	M x Zn	M	Zn	M x Zn
SEM±	0.07	0.07	0.14	0.07	0.07	0.15
CD(P= 0.01)	0.27	0.27	0.54	0.29	0.29	0.59
CD (0.05)	0.20	0.20	0.40	0.22	0.22	0.44

Inoculation with individual strains of introduced mycorrhizal fungi significantly increased uptake of nitrogen, phosphorus and potassium by shoot, the maximum being with M_2 strain followed by M_3 and M_1 strain at both the stages of plant growth over the control. Increasing dose of zinc resulted in a significant reduction in nitrogen and potassium uptake by shoot at 60 and 105 DAS this may be explained by Mitchell (1994) be attributed to the fact that the mycorrhizal fungi have been found to ameliorate the toxic effect of heavy metals with the increase in N sulphate associated binding of metals to wats. Addition of zinc with increasing concentration along with mycorrhizal strains reduced the uptake of phosphorus by the plant in comparison to only mycorrhizal inculcation plant. However, uptake of phosphorus due to interactions was higher over the absolute control. Though zinc and phosphorus elements are mutually antagonistic to each other when either element exceeds a threshold value, increasing availability of phosphorus due to mycorrhizal inoculation help in the reduction of toxic effects of zinc as phosphorus has been reported to directly affect zinc detoxification in plants because of formation of more phytic acid molecules which are involved in Zn sequestration by some plants (Van Sterink *et. al.* 1987).

Metal addition negatively affected nutrient uptake by mycorrhizal plants. The abundance of external mycelium produced by the AM fungi can be important for the heavy metal fixing ability of the fungi and consequently for their plant protecting action.

The main objective of this study was to check whether arbuscular mycorrhizal fungi produce a beneficial effect on plant growing in soil contaminated with heavy metal was it has been reported is some cases (Dehn and Schuepp, 1089; Heggo et. al. 1990)

Table 4. Effect of mycorrhizal fungi doses Zn and their interaction on potassium uptake in shoot at 60 and 105 DAS

Strain	Phosphorus uptake in shoot (mg/pot)									
	60 DAS					105 DAS				
	Zn 0	Zn 150	Zn 300	Zn 450	Mean	Zn 0	Zn 150	Zn 300	Zn 450	Mean
M0	24.63	18.76	17.73	16.66	19.4	36.26	32.26	30.49	29.01	32.00
M1	37.30	34.46	30.93	30.56	33.31	69.40	55.83	50.33	35.84	52.85
M2	46.06	40.10	36.86	34.63	39.41	86.49	76.30	63.16	47.00	68.23
M3	39.60	33.40	31.93	30.10	33.75	60.40	48.93	44.20	39.67	48.30
Mean	36.89	31.68	29.36	27.98	-	63.13	53.33	47.04	37.88	-

	M36.89	Zn	M x Zn	M	Zn	M x Zn
SEM±	0.29	0.29	0.58	1.24	1.24	2.49
CD(P= 0.01)	1.13	1.13	2.27	4.82	4.82	9.65
CD (0.05)	0.84	0.84	1.68	3.59	3.59	7.18

It can be concluded that inoculation with AM fungi protects plant from the potential tonicity caused by zinc but the degrees of protection varies according to the fungus plant combination. However, more knowledge of the mechanisms for how AM fungi contribute to plant growth and the absorption and translocation of heavy metal.

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EFFECTS OF ARBUSCULAR MYCORRHIZAL FUNGI AND PAPER MILL EFFLUENT ON AVAILABILITY OF NUTRIENTS IN *MOLLISOLS*

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Abstract

A pot experiment was conducted in rabi season of 2004-05 on surface (0-15cm) soil, samples collected from Crop Research Centre of G.B.Pant University of Agriculture and Technology, Pantnagar in order to examine the effect of arbuscular mycorrhizal fungi and paper mill effluent on availability of nutrients in soil with four isolates of mycorrhizal fungi viz. uninioculated control (M_0) ,*Glomus* ACP1(M_1), *Scutellospora* ACP 2(M_2) and *Gigaspora* ACP 3(M_3) with four concentrations of paper mill effluent viz., 0%,25%,50% and 100% added in soil to find out the effect of inoculation availability of nutrients in soil. Availability of nitrogen, phosphorus, and potassium and root inoculation of mycorrhiza increased significantly under inoculation with mycorrhizal fungi as compared to the uninoculated control. Irrigation with 25% concentration paper mill effluent (E_{25}) caused significant increase in available N, P and K in soil over the irrigation with normal irrigation water (E_0).Available phosphorus and potassium increased with increase in successive concentration of effluent .

Key words: Mycorrhiza, Paper mill effluent, Nutrients availability, *Mollisol*

Pulp and paper industry is the one, which ranks high both in terms of water usage and pollution loads. The water requirement in paper industry varies from 250-300 m^3 (large papers mills) to 200-300 m^3 (small paper mills) per tonne of the product. The volume of effluents discharged per tonne of paper product depends on the water economy followed in the mill through recycling and reuse. Assuming a value of 6000 gallons of effluents per tone of all kinds of paper produced, the total volume of effluents discharged by the industry has been estimated to be 131 million gallons per day (Aggarwal, 1996). Application of waste water to land provides a good option for its disposal as soil is believed to have a capacity for receiving and decomposing wastes and pollutants. Pulp and paper mill effluents not only contain nutrients that enhance the plant growth but also have toxic materials that interfere with the soil ecosystem. Various efforts have also been made to nullify the deleterious effects of paper mill effluent by use of effluent. Present investigation was therefore, under taken to evaluate the effect of arbuscular mycorrhiza and papers mill effluents on availability of nutrients(N, P and K) and root colonization of mycorrhizal fungi in *Mollisols* of *Tarai*.

Materials and Methods

A green house study was made using a symmetric (4x4) compeletly randomized design taking four treatments with arbuscular mycorrhizal fungi – uninoculated control (M_0), *Glomus* ACP1(M_1),*Scutellospora* ACP 2(M_2) and *Gigaspora* ACP 3(M_3) with four concentrations of paper mill effluent viz., 0%, 25%, 50% and 100% added in soil.The effluent was diluted by tap water which was used to irrigate the pots having no effluent treatment. Thus,there were 16 treatment combinations. Pot experiment during *rabi* season of 2004-05 was conducted using soil from crop research centre ,Pantnagar and the mycorrhizal cultures were obtained from the soil Micriobiology lab ,G.B.P.U.A&T,Pantnagar. The paper mill effluent was collected from the discharge point, in century pulp and paper mill, Lalkuan (Uttarakhand).The soil based AM culture contaning 100 spores were put in a uniform layer in each pot at a depth of 5 cm.Ten seeds of wheat variety(UP 2425) was grown in pots.A basal dose of N @ 120 kg/ha and potassium @ 40 kg/ha were applied in all pots .No phosphorus was added in any pot .On germination , plants were thinned to six plants per pot.The four concentrations of paper mill effluent viz, 0%,25% ,50% and 100% were applied for irrigation after germination .The details of the composition of paper mill effluent are given in table 1. Initial soil samples (Table-2) and post harvest soil samples (Table-3) were analyzed for available nitrogen (Subbiah and Asija, 1956, available phosphorus (Olsen *etal*; 1954 and Murphy and Riley, 1962); available potassium (Headway and Heidel, 1952) and available Sulphur (Chesnin and yield, 1950).

Results and Discussion

All the mycorrhizal strains with 25% concentration of effluent caused available nitrogen statistically at par when compared with their individual response.Inoculation with all the strains along with 50% and 100% concentration of the effluent also remarkably increased available nitrogen than the respective effluent concentration. An increase in available nitrogen status of soil under the paper mill effluent irrigator treatments was also registered by several other workers. (Kannan and Oblisami, 1990; Achari *et al*; 1999; Chhonkon *et al*, 2000 and Dhevagi *et al*; 2000).Except

Table 1. Characterstic of paper mill effluent

Characteristics	Value
pH	7.2
Colour	Yellowish brown
EC(ds/m)	1.44
Organic carbon (%)	1.2
Total solids(mgl^{-1})	1068.6
Total dissolved solids (mgl^{-1})	990.0
Total suspended solids(mgl^{-1})	78.6
Nitrogen(mgl^{-1})	2.1
Phosphorus(mgl^{-1})	5.3
Potassium(mgl^{-1})	130
Sulphate(mgl^{-1})	98
Calcium(mgl^{-1})	120
Magnesium(mgl^{-1})	18
BOD(mgl^{-1})	4.9
COD(mgl^{-1})	218

Table 2. Available nitrogen, phosphorus and potassium contents in initial soil samples

S.No	Soil Property	Value
1	pH	7.42
2	Organic Carbon (%)	1.12
3	Nitrogen(Kg ha^{-1})	230
4	Phosphorus(Kg ha^{-1})	10.4
5	Potassium(Kg ha^{-1})	270
6	CEC cmol(p+) kg^{-1}	17.80
7	Water holding Capacity g/g	0.39

mycorrhizal strain *Gigaspora* ACP 3(M_3) , *Glomus* ACP1(M_1) and *Scutellospora* ACP 2(M_2) strains significantly increased available phosphorus and except 100% concentration of effluent ,25% and 50% concentrations significantly increased it over their respective controls. It is noe

Table 3. Availability of nutrients in soil as influenced by paper mill effluent

Strain	Available Nitrogen (kg ha^{-1})					Available Phosphorus(kg ha^{-1})					Available Potassium(kg ha^{-1})				
	E0	**E25**	**E50**	**E100**	**Mean**	**E0**	**E25**	**E50**	**E100**	**Mean**	**E0**	**E25**	**E50**	**E100**	**Mean**
M_0	112	102.7	97.2	92.0	101	9	10.7	11.1	7.8	9.7	118.8	124.8	126.7	128.1	124.6
M_1	123.8	117.6	110.9	101.6	113.5	11.3	12.7	13.4	8.6	11.5	125.4	127.8	134.2	134.9	130.6
M_2	120	113.2	105.0	97.3	108.9	10	11.6	12.2	7.7	10.4	123.9	126.9	131.9	133.5	129.1
M_3	114.7	109.8	98.1	93.2	104	9.4	11	11.7	6.6	9.7	120.1	125	132.3	133.1	127.6
Mean	117.6	110.8	102.8	96	-	9.9	11.5	12.1	7.7	-	122.1	126.1	131.3	132.4	-

	M	**E**	**MXE**	**M**	**E**	**MXE**	**M**	**E**	**MXE**
SEm±	1.9	1.9	3.9	0.2	0.2	0.4	2.3	2.3	4.5
CD(0.05)	5.6	5.6	11.2	0.6	0.6	1.1	6.5	6.5	13.0

worthy that irrigation with paper mill effluent either alone or in conjuction with introduced mycorrhizal strain remarkably increased available phosphorus in soil after the crop harvest.The paper mill effluent containing substantial amount of phosphorus (5.3 mg l^{-1}) might have played a key role in increasing available phosphorus content of soil. All the interactions between mycorrhizal fungi and effluent concentrations resulted remarkable increase in soil available potassium, maximum being with M_1E_{100} interaction followed by M_1E_{50} ,M_3E_{100} and M_3E_{50} interactions in decreasing order. Potassium increased with increase in successive concentrations of effluent and was maximum at M_0E_{100} treatment which was at par with M_0E_{50}. It suggested that as far as potassium availability in concerned, effluent application in more advantageous in coarse textured soils where fixation sites (clay) are limited than in fine textured soils. Irrigation with paper mill effluent was also reported to increase the available potassium status in soil by Kahhan and Oblisami (1990); Achari *et al.* (1990); Dhevagi *et al.* (2000).Increase in available nutrients of soil irrigated with paper mill effluent for a season (short term) can be attributed partly to the addition of these nutrients through the effluent and party to a possible increase in the availability of the native nutrients.

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NUTRIENT BALANCE STUDIES UNDER FARMING SYSTEMS IN RAINFED VERTISOLS OF TAMIL NADU

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Abstract

Field experiments were conducted on farming systems in rainfed vertisols of the western zone of Tamil Nadu. Crops, pigeon, goat, buffalo, agroforestry and farm pond were the enterprises integrated in the system. Four cropping systems formed the cropping enterprise and were supplied with manure generated on the farm either from the buffalo unit or goat unit at different production levels compared with no manure and recommended dose of fertilizers. Fodder sorghum + fodder cowpea – chickpea + coriander system left more residues in the soil which added valuable plant nutrients followed by fodder maize + fodder cowpea – chickpea + coriander system. Highest uptake of nutrients was also recorded with the same system while the soil available nutrients after the crop harvest was highest with grain sorghum + grain cowpea system. Nutrient balance studies showed that a N balance of 1.5 to 8 kg/ha, P balance of 1.8 to 9.7 kg/ha and K balance of 0.5 to 9.5 kg/ha was recorded after the two year cycle, immediately after the harvest of the second year crop.

Key word: Cropping systems, Nutrient uptake, Residue addition, Nutrient balance

Sustainable agriculture should emphasize practices that maintain or enhance soil productivity since soil degradation is the most significant threat to sustainable agriculture in arid and semi-arid areas. Conventional dry farming involving growing crops solely is a risky proposition. The uncertainty of the onset and progress of the monsoon is one of the key elements that determine the output and hence farmers are reluctant to invest in crop production. The amount of fertilizers used by the farmers is most certainly at a very low or no application level. A farming systems approach would address such issues including that of poverty alleviation, increased food productivity, economic sustainability and ecological stability leading to more stable households. Though the types of interaction are varied amongst different enterprises, their implications are always significant to small and marginal farmers. In integrated farming system animal manure becomes one of the principal sources of nutrients for soil fertility maintenance and crop production. When sufficient quantity is applied on a continuous basis, it might permit stable intensified crop production. Integrated system approach is not only a reliable way of obtaining a fairly high productivity with substantial fertilizer economy, but also a concept of ecological soundness leading to sustainable agriculture (Swaminathan, 1987).

A farming system experiment was conducted under rainfed conditions in the western zone of Tamil Nadu on a vertisol with crops, pigeon, goat, buffalo, agroforestry and farm pond as the enterprises in combination. This paper deals with the nutrient balance aspect in

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a farming system approach wherein the cropping systems were fertilized with manure from the linked animal enterprises.

Materials and Methods

A farming system experiment was conducted under rainfed conditions for two years at the research farm of Tamil Nadu Agricultural University, Coimbatore as a model for the western zone of Tamil Nadu. The soil at the experimental site was vertisol, the initial soil available N, P and K status was 182, 13.4 and 477 kg/ha respectively. The enterprise combination included cropping on 0.80 ha, agroforestry on 0.10 ha, pigeons (10 pairs) on 0.01 ha, goats (5:1 female : male, Tellicherry breed) and / or buffaloes (2 milking and 1 calf, local breed) on 0.05 ha and farm pond on 0.04 ha so as to collectively represent a 1 ha farm area.

The manure produced from the goat and buffalo units was recycled to cropping after composting at 100% and 75% of the production level. The entire amount of manure produced related to 100% production level, here accounted to be 7250 kg of composted buffalo manure and 1250 kg of composted goat manure (Table 1). The amount of inorganic fertilizer added for each crop for the respective treatment is also given in Table 1. The cropping systems experiment was conducted in a split plot design with three replications.

Under cropping enterprise, four cropping systems were included. The treatments in the main plots were CS I – fodder maize + fodder cowpea – chickpea + coriander; CS II – fodder sorghum + fodder cowpea - chickpea + coriander; CS III – grain sorghum + grain cowpea and CS IV - sunflower + coriander. The sub plot treatments were

Table 1. Nutrient concentration of manures and amount of inorganic fertilizers used

Particulars	Buffalo manure (composted)	Goat manure (composted)
Nutrient concentration		
N (%)	0.87	1.82
P (%)	0.39	0.95
K (%)	0.52	0.92

Crop	Fertilizer Schedule		
	N	P	K
Fodder maize	40	20	0
Fodder sorghum	40	20	0
Grain sorghum	40	20	0
Sunflower	40	20	20

S_0- no manure; S_1- recommended dose of NPK; S_2 - composted buffalo manure (100% production); S_3 - composted buffalo manure (75% production); S_4 - composted goat manure (100 % production); and S_5 - composted goat manure (75% production).

The amount of crop residues added after each crop was estimated by digging the soil upto a depth of 30 cm in an area of 0.25 m using the quadrat and washing treatment-wise in a drum with continuous flow of water as suggested by Long (1951). The crop residues were collected, dried and weighed. Residue added was calculated in kg ha^{-1} for individual crops and expressed for cropping systems as a whole. The NPK nutrients added by the crop residues were estimated and computed for each cropping system. Soil samples were collected before the start of the experiment and after the harvest of the crop and analysed for organic carbon, available N, P and K as per the standard methods. The plant samples were analysed for N, P and K uptake at harvest stage. Soil available nutrient balance in the cropping system was computed for different treatments as per the procedure suggested by Sadanandan and Mahapatra (1973).

Results and Discussion

Crop residues and nutrient addition

The amount of crop residues and thereby the nutrients added in the different cropping systems varied with the application of organic manures from different sources (Table 2). During both years, CS II (fodder sorghum + fodder cowpea – chickpea + coriander) varied from the other treatments with regard to the production of the highest amount of residue. It was followed by CS I (fodder maize + fodder cowpea – chickpea + coriander). A similar trend was observed with regard to the nutrients added to the soil from residues in terms of nitrogen, phosphorus and potassium. Higher amount of residues in CS I and CS II were due four crops in the cropping systems and production of high biomass.

All treatments had a strong influence on the amount of residues left causing a significant difference among the quantities. In all the cropping systems, S_2 produced comparable residues with

Table 2. Total crop residue addition (kg ha^{-1}) and NPK added through residues (kg ha^{-1}) in the cropping systems

Treatment	2000-01				2001-02			
	Crop residue	N	P	K	Crop residue	N	P	K
Cropping system								
CS I	1858	9.9	3.2	18.4	2245	14.1	4.2	24.9
CS II	2350	13.7	4.3	25.4	2530	15.9	4.7	28.0
CS III	1211	7.4	2.3	13.3	2176	13.6	4.1	24.2
CS IV	411	2.6	0.7	4.5	623	4.0	1.2	6.9
SEd	53	0.05	0.08	0.27	24	0.14	0.06	0.14
CD (P=0.05)	130	0.13	0.20	0.66	60	0.35	0.14	0.34
Nutrient management								
S_0	1063	6.3	2.0	11.8	1272	8.0	2.3	14.1
S_1	1639	10.0	3.1	18.1	2209	13.9	4.1	24.5
S_2	1573	9.6	3.0	17.3	2222	14.0	4.2	24.6
S_3	1487	9.1	2.7	16.5	2082	13.2	3.8	23.1
S_4	1353	7.9	2.5	14.7	1863	11.6	3.5	20.5
S_5	1328	7.5	2.4	14.0	1714	10.8	3.3	19.3
SEd	53	0.20	0.11	0.29	53	0.22	0.12	0.20
CD (P=0.05)	108	0.40	0.23	0.59	107	0.46	0.24	0.40

S_1, as also the addition nutrients (N, P and K) to the soil from residues across all the systems. Imposing a reduction in the composted buffalo manure application by 25 per cent (S_3) recorded comparable residue with S_2. In the second year (2001-02) of study, a similar trend existed in all cropping systems though the quantity of residue obtained with the addition of composted buffalo manure at 100 per cent production level (S_2) was slightly higher and comparable to that with recommended NPK fertilizers (S_1). Composted goat manure applied treatments added lesser nutrients compared to composted buffalo manure applied treatments. Least amount of residue was left when no manure was applied (S_0) during both years in all cropping systems.

Nutrient uptake

Uptake of nutrients by the individual crops was estimated and the cumulative NPK uptake for each cropping system was computed for both years, as given in Table 3. Nitrogen, phosphorus and potassium uptake was significantly higher with CS I system in both years followed by CS II. Higher nutrient uptake might be due to the fact that two crops were raised in sequence in these systems leading to production of more biomass as against grain sorghum + grain cowpea system and sunflower + coriander system where only a single crop was raised in the season. Lowest nutrient uptake was recorded in CS IV (sunflower + coriander). Comparable N uptake was recorded with the application of

Table 3. Total nutrient uptake (kg ha^{-1}) in the cropping systems

Treatment	2000-01			2001-02		
	N	P	K	N	P	K
Cropping system						
CS I	93.5	26.2	94.2	100.9	28.4	110.1
CS II	84.1	24.1	92.5	94.3	26.1	105.7
CS III	54.1	18.4	38.9	83.7	21.2	70.2
CS IV	33.2	13.4	32.0	44.4	20.3	35.9
SEd	1.4	0.4	1.3	1.6	0.7	1.2
CD (P=0.05)	3.3	1.0	3.2	3.8	1.8	2.9
Nutrient management						
S_0	47.8	12.0	48.8	56.5	13.4	60.0
S_1	79.0	28.7	75.3	93.5	29.8	90.3
S_2	77.4	29.3	73.7	97.8	32.8	93.6
S_3	72.5	23.5	69.4	89.2	25.6	86.8
S_4	62.0	15.7	61.1	77.3	19.1	78.6
S_5	58.6	13.9	58.2	70.8	16.1	73.5
SEd	2.1	0.8	1.9	2.1	0.7	1.6
CD (P=0.05)	4.1	1.7	3.8	4.2	1.5	3.1

composted buffalo manure at 100 per cent production level (S_2) and recommended NPK fertilizers (S_1) during the first year of study. However, in the second year (2001-02), highest uptake was recorded with S_{2}- treatment. Phosphorus and potassium uptake also followed a similar trend. N, P and K uptake was lesser with application of composted goat manure at either level as compared to that with composted buffalo manure, the treatments being significantly different from each other during both years. Steady and continuous availability of nutrients due to chelation effect of organic acids released during the decomposition of organic matter (Tomar *et al.*, 1984, Vasanthi and Kumaraswamy, 2000) and higher nutrient availability with increased manure rates might have resulted in higher nutrient uptake recorded with application of composted buffalo manure at 100 per cent production level. Also, organic manures reduce the capacity of soil minerals to fix P and increase its availability through release of organic acids as reported by Sims (1993).

Soil available nutrients

The post harvest available soil nutrient status is given in Table 4.

Organic carbon : During the period

Table 4. Post-harvest organic carbon (per cent) and available nutrients (kg ha^{-1}) in the cropping systems

Treatment	2000-01				2001-02			
	Organic carbon	N	P	K	Organic carbon	N	P	K
Cropping system								
CS I	0.57	130	14.6	426	0.59	114	14.5	387
CS II	0.57	141	14.8	419	0.59	121	16.3	389
CS III	0.55	177	15.1	456	0.56	138	14.1	420
CS IV	0.52	194	14.4	455	0.53	173	14.5	439
SEd	0.004	9	0.3	12	0.006	7	0.2	12
CD (P=0.05)	0.01	22	NS	28	0.02	16	0.5	29
Nutrient management								
S_0	0.48	139	7.4	428	0.47	103	6.8	388
S_1	0.54	171	17.9	439	0.54	153	17.7	414
S_2	0.63	184	17.9	457	0.66	167	18.9	432
S_3	0.60	170	17.5	448	0.63	151	17.9	421
S_4	0.55	151	14.2	433	0.57	125	14.6	401
S_5	0.52	148	13.4	429	0.54	121	13.4	398
SEd	0.009	8	0.3	7	0.007	7	0.5	13
CD (P=0.05)	0.02	18	0.5	18	0.02	14	1.1	26

of study, soil organic carbon built up with advancement in years. Higher values were recorded at the end of second year of experimentation in all the cropping systems. In 2000-01, significantly higher organic carbon content was recorded in CS II followed by CS I. The higher organic carbon status of these two systems over the other two cropping systems tried might be due to the legume intercropping (Duraisamy *et al.*, 2001) as well as the higher nutrients added from the crop residues in the system (Subramanium and Kumaraswamy, 1989).

Among the treatments imposed, application of composted buffalo manure at 100 per cent production level consistently recorded significantly higher organic carbon content followed by application at 75 per cent production level during both years of study. Composted goat manure at 100 per cent production level (S_4) has also improved the soil organic carbon status in the second year compared to application of NPK fertilizers, though both recorded comparable per cent content in the first year. Lowest organic carbon per cent was registered with no manure application and soil status was poor in the second year with this treatment.

***Nitrogen*:** Highest soil available N was recorded with CS IV (sunflower + coriander) followed by CS III. CS I and CS II recorded comparable soil available N but was lesser than the other two cropping systems during both years of experimentation. The soil available nitrogen was highest with the application of composted buffalo manure at 100 per cent production level (S_2) in all systems during both years of study.

The application of composted goat manure at 100 per cent and 75 per cent production levels left the soil in lower but comparable available N status. No manure application rendered the soil less fertile over years. Increasing rates of application of manure led to higher available N content.

***Phosphorus*:** The cropping systems tried did not exert a significant influence on the post harvest soil P status during both years except for CS II (fodder sorghum + fodder cowpea – chickpea + coriander) during 2001-02. The study indicated a positive influence of application of composted buffalo manure at 100 per cent production level (S_2).

***Potassium*:** A significant variation in soil available K status was recorded between the cropping systems evaluated. CS III (grain sorghum + grain cowpea) and CS IV (sunflower + coriander) recorded comparable and higher post harvest soil available K than CS II and CS I which were on par. A similar trend existed in the second year of study also. The organic manure applied from different sources did not exhibit marked variations in the soil available K status though application of composted buffalo manure recorded consistently higher status of availability compared to that with composted goat manure.

The post harvest available nutrients showed a decrease because of the higher uptake of nutrients by the crop. However, the application of manures increased the nutrients in the available pool with time which might be due to higher solubilization as a result of mineralization and humification. However, since the sampling was done immediately after crop harvest, lower values were observed.

Nutrient balance

Nutrient balance in terms of net gain or loss of NPK was computed after each crop cycle in both years (Table 5). At the end of first year, among the different

Table 5. Net nutrient balance (kg ha^{-1})

Treatments	Nitrogen								Phosphorus								Potassium							
	CS I		CS II		CS III		CS IV		CS I		CS II		CS III		CS IV		CS I		CS II		CS III		CS IV	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
S_0	3.3	-5.4	4.3	-4.0	5.8	2.9	4.6	2.3	7.0	5.7	7.4	5.8	3.6	1.4	1.5	0.8	9.1	6.4	5.4	3.5	-5.2	-8.8	-5.3	-7.1
S_1	11.1	10.1	13.1	11.3	17.1	7.5	11.7	-4.0	-3.7	-8.2	-4.8	-7.6	4.2	2.9	-0.7	-2.2	31.9	29.1	22.4	20.9	0.9	6.4	1.1	-4.2
S_2	14.9	13.7	16.8	9.2	21.2	12.2	13.4	4.6	9.9	8.0	8.1	6.2	5.3	3.0	0.2	-1.1	41.5	51.0	25.3	31.5	3.1	8.1	-5.0	-9.1
S_3	11.9	10.6	13.4	7.4	17.0	8.8	11.5	3.9	8.2	7.5	7.6	5.4	4.8	2.9	-1.0	-2.5	30.2	33.3	21.4	27.7	2.1	5.3	-7.0	-8.5
S_4	7.8	6.3	10.3	5.1	11.3	6.4	7.2	2.3	9.0	6.9	8.7	6.3	6.0	2.7	-1.3	-3.4	19.5	12.4	15.4	14.9	0.2	3.5	-11.6	-13.4
S_5	6.2	5.8	8.0	4.2	9.6	4.9	6.9	1.1	10.2	6.3	9.4	5.7	2.6	1.8	-1.0	-3.7	13.9	9.6	10.6	8.0	-1.2	2.6	-16.0	-18.1

cropping systems, there was a gain of 2-8 kg of nitrogen ha^{-1}. A positive balance was observed in CS III (grain sorghum + grain cowpea). Among the various nutrient management treatments imposed, application of composted buffalo manure at 100 per cent production level (S_2) was found with the highest N balance and was comparable with S_1 and S_3.

The gain in nitrogen was 1.5 to 8 kg ha^{-1}at the end of the second year. Positive balance was observed in CS I followed by CS III. A similar trend as that of the first year was noticed among the different organic manures applied. N being mobile, is easily lost especially when added through inorganic fertilizers. However, the inclusion of legumes in the cropping system helped in improving the fertility status in the inorganic fertilizer applied treatment. Application of composted goat manure at either level indicated a lower balance which might be due to the quick release of N resulting in lesser residual effect.

The variation in the addition of P indicated by the balance ranged between 1.8 and 9.7 kg ha^{-1} between the cropping systems during both years. CS I and CS II were found to enhance the P status through organic manure application (composted buffalo manure or composted goat manure) over other systems. There was a decrease in the P balance due to the application of recommended inorganic fertilizers (S_1). The second year estimation also revealed a similar trend as that of the first year with regard to cropping systems. However, CS IV (sunflower + coriander) showed a negative P balance in the second year across all treatments. The pulse crop in the cropping system has removed more P from the soil, thereby recording a reduction in the P balance.

An increase in the K status was indicated from K balance studies over two years of experimentation. CS I and CS II added higher K to increase the balance in both years. Increase at a decreasing trend was noticed in CS III while a decrease was observed in CS IV. Application of organic manures either as composted buffalo manure or composted goat manure or application of 100 per cent inorganic fertilizers increased the K balance in the soil. The magnitude of increase was higher in S_2. Higher biomass production in the second year has led to greater nutrient uptake and decrease in soil availability. Crop residues left in the soil added NPK nutrients and also mineralization over time may have increased nutrients in the available pool before the start of the crop season.

Thus it can be concluded that under farming systems with the above mentioned enterprise combination, recycling of the buffalo manure produced on the farm at 100% production level was sufficient to maintain a positive balance with slow build up of nutrients over time. Except for sunflower + coriander systems, the other cropping systems evaluated did not have a negative effect on the nutrient balance of the soil.

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IDENTIFICATION OF INDICATORS FOR SUSTAINABILITY OF AGRICULTURE: A FARMERS' PERCEPTION APPROACH

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Sustainability is a complex concept, which includes spatial and temporal aspect as well as biophysical, economic and social dimensions .The term "sustainable agriculture means an integrated system of plant and animal production practices having a site-specific application that will, over the long term, satisfy human food and fiber needs, enhance environmental quality and the natural resource base upon which the agricultural economy depends, make the most efficient use of non-renewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls, sustain the economic viability of farm operations and enhance the quality of life for farmers and society as a whole *(Farm Bill,1990)."* Further *Paroda (1995)* defined sustainable agriculture as "the appropriate use of crop and livestock system and the agricultural inputs supporting their system and the agricultural inputs supporting their activities which maintain economics & social viability while preserving the high productivity and quality of land".

There are several measures to examine the sustainability of agriculture; development of sustainability indicator is one of them. The term indicator in its normal sense means a number or other descriptor that is representative of asset of condition, and which conveys information about a change or trend in these conditions.

It can also represent in summarized from the total effect of many variables. Sustainability indicators are quantifiable and measurable variables that are judged to be related to sustainability *(Panel and Schilzzi, 1999*). They can be derived from qualitative and quantitative measurement. However, they become standardized and comparable only when they are transformed in to a numerical form *(Pieri et al. 1995*). Their purpose is to guide policy changes and management decisions at all levels, from the farm to the national level and even global level. Indicators are needed for example, to monitor the effects of agricultural policies on status of soil fertility, water resources, farming practices and organizational structure. Indicators are already in regular use in some areas, especially at the farm level. To make sustainable agriculture a management goal, it is important to clarify what is being sustained, for how long, at what level, at what cost and for whose benefit, over what area and measured by what indicators and their criteria. Therefore, indicators need to be developed to the evaluate changes in the quality of soil fertility, water resources, farming practices and organizational structure, land recourses at a district or block level. This study has been undertaken to examine the sustainability of agricultural system by developing a composite indicators of sustainability of agriculture.

The idea of sustainable agriculture has been around a long time. Since the very first crop was sown and animal was penned, farmers have tried to ensure that their land produces a similar or increasing yield of products year after back-breaking year; recent attempts to popularise the concept build on this tradition.

The fact is, sustainability cannot be measured directly; it is too elusive a concept and it operates over too long a time scale. The best we can do is to identify measurable phenomena that, when put together, suggest how sustainable our system might be. These are called indicators.

Few would argue that the definition and principles of sustainability are not thoroughly worthy. But the question remains: how can we measure sustainability?

Making indicators relevant to farmers

The process of consulting with farmers about sustainability indicators was just as informative as the outcomes themselves. Early on, facilitators found it necessary to 'bring the indicators to life' by explaining their background and justifying the need for them. Without such justification, farmers were profoundly uninterested!

So, why should farmers pay any attention to indicators of sustainability? The advanced five possible reasons:

- indicators can help farmers notice changes at an early stage and seek advice if required;
- profitability indicators can highlight strengths and weaknesses and show trends;
- land and water quality indicators can highlight natural resource issues which may be 'sleepers' and not obvious to the eye until they are well advanced and difficult to address;
- managerial skills self-auditing can assist individual business partners to appraise honestly their talents and to plan for professional development; and
- off-site impact monitoring can ensure that individual businesses maintain quality standards and do not contribute to problems for the wider community.

Data and Methodology

The present study was conducted in Muzzfarnagar district of agriculturally developed western region of Uttar Pradesh. The primary data, with the help of specially structured and pre-tested schedules, were collected from 40 randomly selected farmers from two randomly selected villages of Kandhala block. The data pertaining to agricultural year 2007-2008.

To examine the sustainability of agriculture, certain indicative variables like soil condition and soil nutrient management, ground water and surface water irrigation management, forestry and animal husbandry and farm organizational characteristics were identified. Further soil conditions have been examined by recording the farmers' perceptions about rate of soil erosion, soil life, soil structure and soil fertility (Table - 1). Nutrient management was recorded in terms of application of FYM, Compost, Green Manuring, insecti-ploughing of stables and plants residuals, use of bio-fertiliser, practicing of fallow (long and short) and balanced use of chemical nutrients (Table-2). Regarding water recourse management, farmers' perceptions were recorded on groundwater conditions like state of ground water table and the rate of change

Table 1. Scores Assigned for Different Soil Conditions

Rate of Soil erosion	Very High	High	Medium	Low	Nil
Score	0	1	2	3	4
Soil Life	<2 Year	2-5 Year	5-10 Year	10-25 Year	25 Year
Score	0	1	2	3	4
Soil Structure	Very Bad	Bad	Normal	Good	V. Good
Score	0	1	2	3	4
Soil Fertility	Very Low	Low	Medium	High	Very High
Score	0	1	2	3	4

Table 2. Scores Assigned for Different Nutrient Management

Application of FYM	No Application	Once in>= 4 year	Once in 3 year	Alternate Year	Every Year
Score	0	1	2	3	4
Application of Compost					
Score	0	1	2	3	4
Green Manuring (Time Basis)	Absent	After more Than 4Year	After 3 Year	Alternate Year	Every Year
Score	0	1	2	3	4
Green Manuring (Area Basis)	Not Practiced	Practiced on 0-25% Area	Practiced on 25-50% Area	Practiced on 50-75% Area	Practiced on 75-100% Area
Score	0	1	2	3	4
Instiploughing of Plants Stubbles and Residuals	Not Practiced	Practiced on 0-25% Area	Practiced on 25-50% Area	Practiced on 50-75% Area	Practiced on 75-100% Area
Score	0	1	2	3	4
Biofertilizers	Not Practiced	Practiced on 0-25% Area	Practiced on 25-50% Area	Practiced on 50-75% Area	Practiced on 75-100% Area
Score	0	1	2	3	4
Long Fallow period (All season)	Not Practiced Practiced	Practiced after 5 Years	Practiced after 4 Years	Practiced after 3 Years	Alternate Year
Score	0	1	2	3	4
Short Fallow Period (one/two season)	Not Practiced	Practiced During kharif	Practiced During Rabi	Practiced During Zaid	Practiced During Rabi & Zaid
Score	0	1	2	3	4
NPK in Wheat					
Scores					
NPK in Sugarcane					
Scores					

of water table over the preceding years. Irrigation management were studied by examining the timelines, numbers of irrigation and methods of application of ground water as well as canal water irrigation for Wheat and Sugarcane crops (Table-3). Further a number of perennial plants as well as agro-forestry plants per hectare, number of livestock per hectare (table-4) and farm organizational characteristics like farming system, ownership of cultivated land, crop rotation followed and adoption of plant protection measures were recorded (Table-5).

Five scores ranging from zero to four were used for each variable for very severe, severe, moderate, good very good implications for sustainability of agriculture. Finally, composite indicators of sustainability of agriculture as well as soil condition and soil nutrient management, groundwater and surface

Table 3a. Scores Assigned for Different Water Resources Management

Groundwater					
Water Table (depth)	75 Feet	50-75 Feet	25-50 Feet	£10 Feet	10-25 Feet
Score	0	1	2	3	4
Water Table (Change/year)*	2Feet Decrease	1-2 Feet Decrease	Stable	Increase 1-2 Feet	Increase 2 Feet
Score	0	1	2	3	4
Ground Water (Irrigation Application)	Irrigation during rain (without Requirement)	Irrigation during rainy season (Without Requirement)	Excess Irrigation than Requirem-ent	Irrigation According to Irrigation schedule (Recommen-ded)	Irrigation According to Actual requirement
Score	0	1	2	3	4
Groundwater (Method of Irrigation)	Flood Irri. With unclean Kuchcha field channels	Flood Irri. With Clean Pucca field channels	Flood Irri. in sub plots with Kuchcha field channels	Irrigation in subplots with Pucca field channels	Irrigation with water saving method
Score	0	1	2	3	4
Groundwater irrigation Sugarcane (Number)	>=12	10-12	5-10	<5	0
Score	0	1	2	3	4
Groundwater irrigation Wheat (Number)	5	4-5	2-3	<2	No
Score	0	1	2	3	4

Table 3b. Scores Assigned for Different Water Resources Management

Canal water					
Canal Water (Irrigation Application)	Irrigation with water saving method	Irrigation in subplots with Pucca field channels	Irrigation in sub plots with Kuchcha field channels	Irrigation With Clean Pucca field channels	Irrigation with Kuchcha field channels
Score	0	1	2	3	4
Canal water (Method of Irrigation)	Irrigation with water saving method	Irrigation in subplots with Pucca field channels	Flood Irri. in sub plots with Kuchcha field channels	Flood Irri. With Clean Pucca field channels	Flood Irri. With unclean Kuchcha field channels
Score	0	1	2	3	4
Canal water irrigation Sugarcane (Number)	No	<2	2-5	5-8	8
Score	0	1	2	3	4
Cana lwater irrigation Wheat (Number)	No	<2	2-3	4-5	5
Score	0	1	2	3	4

*Scores of water table (change/year) depend on water table (50-75 feet deep) in the study area.

water irrigation management, forestry and animal husbandry and farm organizational. The composite as well as other indicators were also prepared for Marginal (<1 ha) small (1-2 ha) and others (>2 ha) categories of farmers to examine the sustainability of agriculture among different farm sizes. These indicators will affect present as well as future sustainability of agriculture of a particular region.

CONCLUSION

Indicators can play an important role in regional policy making. It provides information on indicators at two different scales: that relevant to regional/national rural industry policymaking, and that relevant to on-farm management decisions. It is intended as a learning tool by which farmers and others can familiarise themselves with issues relevant to sustainable agriculture.

The word on sustainable agriculture: it will feed into a wider process of indicator development which itself is only part of the quest for sustainability. But indicators help us to define that buzz-word, sustainability, and to work out what more we need to do to achieve it.

Table 4. Scores Assigned for Other Indicators

A. Livestock Population & Existence of Perennial plants (Per hectare)					
Animals Number	No Animal	<2	3-4	4-8	>8
Score	0	1	2	3	4
Perennial plants Number/Area	Does Not Exists	Tree £5 year	Trees 5-10 year	Trees 10-20 Year	Trees 20 Year
Score	0	1	2	3	4
Social Forestry	Does Not Exists	Poplar One Side	Poplar Around	Around & Line Between Field	Full field
Number Area					
Score	0	1	2	3	4
B. Types of farming					
Farming system	Single cropping	Mixed Cropping	Mixed Cropping +Dairy	Mixed +Dairy +Garden	Garden
Score	0	1	2	3	4
Ownership of holding	Purely Leased in	Owned +Leased in+Leased Out	Owned +Leased in	Owned +Leased out	Purely owned
Score	0	1	2	3	4
Use of Biological Control measures	Does Not Exit	Chemical + Biological	Mechanical + Biological	Biological	IPM
Score	0	1	2	3	4
Plant Protection Measures	Higher use Of Chemicals	Moderate use of Chemical measures	IPM Use (Mechanical + Chemical)	Mechanical+ Biological measures	Biological
Score	0	1	2	3	4
Crop Rotation	Followed	Follow (Without Legume)	Follow With Legume after 3 yrs	Follow With Legume after 2 Year	Followed With Legume Every year
Score	0	1	2	3	4

Table 5. Sustainability Indicators Developed from Farmers' Response

	Categories	Indicators	Others	Marginal	Small	All
1	Soil	Soil condition	0.525	0.708333	0.575	1.808333
		Soil life	0.5	0.5	0.5	1.5
		Soil erosion	0.5	0.5	0.5	1.5
		Soil fertility	0.525	0.416667	0.53825	1.479917
		All	2.05	2.125	2.11325	6.28825
2	NRM	App. FYM/Compost	0.18667	0.173333	0.27	0.63
		Green manuring time/area basis	0.04	0	0	0.04
		Instiploughing of plants stubbles & residues	0.44	0.146667	0.3	0.886667
		Biofertilizers	0.02667	0	0	0.026667
		NPKwheat/sugarcane	0.54667	0.246667	0.39	1.183333
		All	1.24	0.566667	0.96	2.766667
3	Ground water	Water table (depth/change)	0.9375	0.486667	0.51	1.934167
		Ground water Irri application	0.475	0.733333	0.3934	1.601733
		Ground water (W/S)	0.257	0.143867	0.1494	0.550267
		Canal water Irrigation application	0.38125	0.0876	0.2502	0.71905
		Canal water (W/S)	0.78	0.333333	0.35	1.463333
		All	2.83075	1.7848	1.653	6.26855
4a	Live stock	Animals/ha	0.09367	0.169333	0.1485	0.4115
		Perennial plants/ha	0.1379	0.045	0.628	0.8109
4b	Types of Farming	Types of farming	0.5	0.466667	0.5	1.466667
		Crop rotation	0.65	0.383333	0.6	1.633333
		Long/short fallow period	0.015	0.022167	0.01155	0.048717
		All	1.49657	1.153167	2.06305	4.712783

ANOVA

		Sum of Squares	df	Std. Error	F	Sig.
Holding size	Between Groups	11933.365	2		32.116	0.000
	Within Groups	6874.058	37			
	Total	18807.423	39	3.45		
Application of FYM/compost	Between Groups	6.208E-02	2		1.422	0.254
	Within Groups	0.808	37			
	Total	0.870	39	2.36		

Green manuring (time/area) basis	Between Groups	1.500E-02	2		0.826	0.44
	Within Groups	0.336	37			
	Total	0.351	39	1.500		
Bio fertilizers	Between Groups	6.667E-03	2		1.779	0.183
	Within Groups	6.933E-02	37			
	Total	7.600E-02	39	6.98		
Instiploughing of Plants Stubbles & Residuals	Between Groups	0.646	2		8.334	0.001
	Within Groups	1.433	37			
	Total	2.079	39	3.65		
NPK	Between Groups	0.675	2		30.950	0.000
	Within Groups	0.404	37			
	Total	1.079	39	2.63		

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OPTIMIZING THE TIME OF RELEASE AND SIZE OF FISH FINGERLINGS IN RICE—FISH FARMING SYSTEMS

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Integrated fish farming has received considerable attention in recent years in many developing countries of Asia, Africa and America. Rice-cum fish culture was beneficial in increasing land productivity as well as eliminating weeds, mollusks and pests (Rekha Ghosh *et al.,* 1994). Herbivorous fish serve the purpose of biological weed control in lowland rice. Growth of fish in rice field in an organized way is almost non-existent in India. The reasons being increasing use of inorganic fertilizers and pesticides in rice fields which have deleterious effects on fish.

Weeds are one of the principal causes of low rice production, reducing the yield by 60 – 70 per cent (Rekha Ghosh *et al.,* 1994). Herbicide alone or in combination with other components like fish provides better weed control and helps to realize the highest yield potential of a crop. A successful herbicide should not only control the weeds effectively but also be safer to the soil flora and fauna. Increasing the use of biological methods for aquatic weed control was being suggested all over the world and many different organisms were assessed (Zon, 1978). Herbivorous feeding habits of many fish species in intensive rice-cum-fish culture offered the opportunity for biological weed control under controlled water supply (Vinke and Micha, 1985). Fish species like tilapia, silver carp, grass carp etc., were herbivorous fishes that feed on aquatic weeds (Dahama, 1996). Grass carp can be very effective for controlling most aquatic weeds. The most effective way to use grass carp is to control weeds initially with an herbicide and then use grass carp to prevent regrowth of weeds. The grass carp because of its plant eating diet have a great potential for the control of aquatic weeds. The grass carp is primarily a 'grazer', it tends to feed on the surface and in shallow water. Grass carp prefers submersed plants and the soft tips of young tender plants.

The indiscriminate use of herbicides, careless handling, accidental spillage or discharge of untreated effluents into natural waterways have harmful effects on the fish population and other forms of aquatic life and may contribute long term effects in the environment. Herbicides cause changes in the quality of water in and near sprayed areas. After herbicide applications, decrease in dissolved oxygen in the water, along with an increase in temperature effects the survival of cold water fish species. Fish breathe by movement of water, dissolved oxygen and any water contaminants present, in and out through their gills. Most herbicides have an irritating effect on lung tissue when inhaled. Hence, with the above background, a pot culture experiment was conducted for fixing the optimum size and time of fish fingerlings to be released into the rice fields after the application of pre-emergence herbicides.

The experiment for fixing the optimum size and time of fingerlings to be released into the rice fields after the application of pre-emergence herbicides was conducted in the pot culture yard of

Annamalai University Experimental Farm. The cement pots of size 45 x 30 x 28 cm were filled with field soil to a height of about 5 cm and water to a height of about 20 cm. Fish fingerlings of three different sizes *viz.*, 2-3, 3-4 and 4-5 cm were released into the pots at 4, 8 and 12 days after the application of

Table 1. Size and time of releasing fish fingerlings after herbicide application

Size of fingerlings	Time of release of fingerlings	Herbicide	Mortality rate of fingerlings after release(%) 2nd day	4th day	6th day	8th day	10th day
2-3 cm	4 days after herbicide application	Butachlor	100	-	-	-	-
		Oxyfluorfen	100	-	-	-	-
		Thiobencarb	80	20	-	-	-
	8 days after herbicide application	Butachlor	100	-	-	-	-
		Oxyfluorfen	100	-	-	-	-
		Thiobencarb	60	40	-	-	-
	12 days after herbicide application	Butachlor	60	20	20	-	-
		Oxyfluorfen	100	-	-	-	-
		Thiobencarb	40	40	20	-	-
3-4 cm	4 days after herbicide application	Butachlor	80	20	-	-	-
		Oxyfluorfen	100	-	-	-	-
		Thiobencarb	80	20	-	-	-
	8 days after herbicide application	Butachlor	40	20	-	-	-
		Oxyfluorfen	60	20	-	-	-
		Thiobencarb	40	-	20	-	-
	12 days after herbicide application	Butachlor	20	-	-	20	-
		Oxyfluorfen	40	20	-	-	-
		Thiobencarb	20	-	20	-	-
4-5 cm	4 days after herbicide application	Butachlor	40	-	20	-	-
		Oxyfluorfen	40	20	20	-	-
		Thiobencarb	20	20	40	-	-
	8 days after herbicide application	Butachlor	-	-	-	-	-
		Oxyfluorfen	20	-	-	-	-
		Thiobencarb	-	-	-	-	-
	12 days after herbicide application	Butachlor	-	-	-	-	-
		Oxyfluorfen	-	-	-	-	-
		Thiobencarb	-	-	-	-	-

butachlor 1.5 kg ha^{-1}, oxyfluorfen 0.25 kg ha^{-1} and thiobencarb 1.5 kg ha^{-1}. The experiment was conducted in a completely randomized block design with five replications. Observations were made on mortality and survival of fish fingerlings on every alternate day.

Fingerlings of size 4-5 cm, when released 12 days after herbicide application, was observed to be safe with 100 per cent survival (Table 1). This could be due to the fact that within 12 days which was the longest time gap tried, these herbicides might have dissipated considerably and with increasing size, the physiological tolerance of the fingerlings towards the herbicides and their ability to metabolize them increased, imparting higher survival rates. The difference among herbicides in causing mortality at lesser time intervals of release after application and lesser size of the fingerlings could be due to their differences in toxicity and solubility characters. Larger sized fingerlings of size 4-5 cm (with comparatively better tolerance) when released leaving sufficient time for the moderately toxic herbicides to metabolize in water, withstood the negative impact of herbicides better, contributing to their survival. The half life of butachlor in transplanted rice fields was observed to be 3 to 4 days (Kathiresan, 2001). In addition to similar rapid degradation, rice herbicides like butachlor and thiobencarb were observed to be only of moderate toxicity to fishes with LC50 at 0.5 – 10 ppm (Ooi and Lo, 1992). Further reports by WHO, 1988 indicate that the acute oral and dermal toxicities of thiocarbamate (thiobencarb) compounds are generally low. These are in line with the present study which revealed that 100 per cent survival of fishes of size 4-5 cm is possible if released even at 8 days after thiobencarb application.

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EFFECT OF AZOTOBACTER AND NITROGEN ON YIELD AND NUTRIENT UPTAKE BY WHEAT

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An integrated approach for use of biofertilizers with chemical fertilizers is considered as the need of hour, as biofertilizers are not replacement of fertilizers but can supplement their requirement. Therefore, its use in wheat, which is heavy feeder of nitrogen, is much more relevant. The increase in eco – friendly production of wheat can be made possible by nitrogen management through biofertilizers. Hence, present investigation was carried out to study the effect of use of biofertilizer and inorganic nitrogen on wheat production.

The experiment was carried out at research farm of R.B.S. College Bichpuri, Agra during the winter season 2004 – 05 and 2005 – 06 in sandy loam soil. The available N, P and K contents in soil were 180, 9.2, 100 kg ha^{-1}, respectively with pH 8.2. The experiment was laid out in randomized block design with three replications comprising three nitrogen (60, 80 and 120 kg ha^{-1}) levels and two levels of Azotobacter (uninoculated and inoculated). The wheat grains were inoculated with the culture solution then dried under shade before sowing. Wheat UP – 2338 was sown on 22 and 24 November of 2004 – 05 and 2005 – 06, respectively, @ 100 kg ha^{-1} between 20 cm apart rows at a depth of 3 cm from the top of the soil in lines. The full dose of recommended phosphorus (60 kg P_2O_5 ha^{-1}), potassium (40 kg K_2O ha^{-1}) and half of nitrogen was applied as per treatments at the time of sowing as basal dose and rest of N at two equal splits, at crown root initiation and ear initiation stage. Adopting standard agronomic practices raised the crop. The crop was harvested at maturity and grain and straw yields were recorded. The grain and straw were analysed for their N and P content by adopting standard procedures. Soil samples collected after harvest were analysed for available N and P content (Jackson 1973).

The grain and straw yield of wheat increased significantly with inoculation of Azotobacter over no inoculation. The increase in grain and straw yield was 14.3 and 14.2 percent over uninoculated one, respectively. The increase in yield might have resulted from the growth regulating substances produced by application of Azotobacter besides fixation of additional nitrogen from atmosphere, thereby, increasing the nitrogen availability in the soil through out the crop growth. Kachroo and Razdan (2006) also reported similar findings. Increasing levels of N applied in wheat increased grain and straw yield significantly over 60 kg N ha^{-1}. Application of 180 kg N ha^{-1} significantly increased the grain and straw yields by 32.5 and 33.2 % compared with the 60 kg N ha^{-1}. Such spectacular responses to N application are obviously attributable to low

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Table 1. Effect of Azotobacter and nitrogen on yield, uptake of N and P in wheat and status in soil

Treatments	Yield ($t\ ha^{-1}$)		Nitrogen ($kg\ ha^{-1}$)		Phosphorus ($kg\ ha^{-1}$)		Avail. N ($kg\ ha^{-1}$)	Avail P ($kg\ ha^{-1}$)
	Grain	Straw	Grain	Straw	Grain	Straw		
Azotobacter								
Uninoculated	4.46	12.55	101.6	70.5	9.5	12.9	176.1	8.8
Inoculated	5.10	14.34	118.5	86.3	11.6	16.0	184.0	8.9
SEm±	0.05	0.11	1.19	0.89	0.29	0.62	1.41	0.04
CD at 5%	0.15	0.34	3.60	2.70	0.89	1.86	4.25	NS
Nitrogen ($kg\ ha^{-1}$)								
60	4.00	11.20	88.0	58.2	8.0	10.0	173.0	8.7
120	5.05	14.24	116.1	82.0	11.1	15.6	178.0	8.8
180	5.31	14.92	126.3	95.0	12.7	18.0	189.1	9.1
SEm±	0.06	0.14	1.46	1.09	0.36	0.76	1.73	0.05
CD at 5%	0.19	0.42	4.42	3.31	1.09	2.28	5.99	NS

available N status of the soil and relatively high N requirement of the crop. Similar results were obtained by Kachroo and Razdan (2006). Inoculation of Azotobacter increased the N uptake by grain and straw significantly over no uninoculation. The increase was owing to enhanced N content in the soil due to inoculation of Azotobacter. Maximum N uptake was associated with the highest (180 kg ha^{-1}) dose of nitrogen applied to wheat. The N uptake by wheat noted at 180 kg N ha^{-1} was significantly superior to reduced levels of N. This was mainly due to the fact that better N utilization by more healthy and vigorous plants under 180 kg N ha^{-1} level and resulting in more dry matter accumulation, which ultimately increased the uptake of nitrogen. Cumulative effect of increase in P content and grain and straw yield might have resulted in increase in P uptake with increasing N level up to 180 kg N ha^{-1}.

Available N content in soil increased significantly with Azotobacter inoculation as compared to uninoculation. The increase was owing to enhanced nitrogen content in the soil due to inoculation of Azotobacter. Available N status was higher at higher dose of N than lower doses of N and no nitrogen (control), which may be due to considerable gain of N content in the soil than control plots. The available P content in soil did not show any significant variation due to Azotobacter inoculation. Application of N did not affect the status of available P in soil after crop harvest significantly. However, a slight increase in available P status was noted with 180 kg N ha^{-1}.

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INTEGRATED FARMING SYSTEMS, AN ALTERNATIVE MEANS OF LIVELIHOOD FOR COMMON FARMERS

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Orissa being an agrarian state depends mainly on agriculture and allied sector to meet the livelihood security of 82 percent of its population. The production and productivity has not yet made headway because of several challenges such as lower per capita holding size and unfavorable climatic conditions. Poor family income of majority of the farming community still continues even under irrigated conditions due to less awareness of the farmers to consolidate various farming system components in a single platform. As such efforts were made in irrigated conditions of Athagarh sub division in Cuttack district to enhance the productivity, family income and employment security of a medium farmer with the available resources in his farm area.

An on farm field experiment was conducted for two years (2007-08 and 2008-09) in the farm area (2.4 ha) of Shri Hrushikesh Behera of Dorada village under Athagarh subdivision in Cuttack district. Different farming system modules designed and given to the farmer with need based technical interventions for various components are presented under table 1. In case of crop components rice (var.Swarna) - wheat (var.Sonalika) and rice-pumpkin (var Guamal) systems were taken up and compared with horticultural crops i.e. chilli (var Utkala Ragini) and diascorea (var Shree Jaya) to study the performance of each component. The crop yield of the system is converted to rice equivalent yield using prevailing market price of the crops.

In case of animal component, one deshi cow along with two crossbreds owned by the farmer were used in the investigation. The recommended quantity of mineral mixture along with four percent urea treated straw was fed to the animals in addition to the normal diet.

The performance of IFS modules was compared with the conventional cropping system practices of the farmer to establish the superiority of the system.

The results of the investigation carried out over a period of two years are presented under Table 1. The Integrated Farming Systems conducted involving field crops, horticultural crops and dairy animals generated the findings as detailed here under.

Crop components

Under this module rice-wheat and rice-pumpkin were the cropping systems followed in the farmer’s field. Rice - wheat was the new cropping system introduced in the area. The intervention imposed were integrated weed management practice keeping normal package of practice intact. Results indicated higher productivity of rice (2.42t/ 0.4 ha) and wheat (1.3t/0.4ha) resulting rice equivalent yield of 4.04 t/ year. This system could provide employment of 105 mandays to the farm family besides generating net monetary return (NMR) of Rs. 14,360/year with BCR 1.80. Similar results were obtained

Table 1. Income and Employment Generation under Integrated Farming Systems

Enterprises Under IFS	Area (ha/no)	Technical Interventions	Yield (t/year) 2007-08	Yield (t/year) 2008-09	Yield (t/year) Mean	REY (t/year)	Family Labour engaged Male	Family Labour engaged Female	Family Labour engaged Total	Net Return (Rs/ha)	BCR
Crop component											
Rice-wheat	0.4	Herbicide	R-2.54	R-2.30	R-2.42	4.04	85	20	105	14,360	1.80
		(Butachlor)	W-1.40	W-1.20	W-1.30						
Rice-pumpkin	0.8	IAA	R-4.8	R-4.6	R-4.7	8.70	155	20	175	39,600	2.32
			P-8.4	P-7.6	P-8.0						
Horticultural Components											
Diascorea	0.8	Neem Cake	6.3	5.8	6.05	6.05	100	25	125	28,400	2.42
Chili	0.4		3.8	4.5	4.15	7.78	45	25	70	44,250	3.45
Animal Components											
Deshi cow	1	Mineral Mixture	188ltr	196ltr	192lts	0.288	-	25	25	804	1.53
Cross bred cow	2	Mineral Mixture	1980ltr	2060ltr	2020ltr	3.030	10	45	55	10,940	1.82
Total						**29.88**	**395**	**160**	**555**	**1,38,354**	**-**
Conventional System											
Rice local	2.4		5.6	4.8	5.2	5.2	10	100	110	15,800	1.53
Deshi cow	1		174ltr	186ltr	180ltr	0.270	25	-	25	960	1.80

by Kalyan Singh *et.al.*(2007).

In rice –pumpkin (summer vegetable) system with technical intervention of IAA to pumpkin recorded higher rice equivalent yield of 8.70t/year. The system could generate net monetary return of Rs. 39,600/year and BCR of 2.32.

Horticultural Components

In irrigated medium land condition good marketing facilities of horticultural crops could exhibit superior performance in terms of productivity and profitability. The farmer obtained an average yield of 6.05t/0.8ha/year which resulted in higher NMR (Rs.28,400/year) and BCR(2.42) in diascorea. The REY (7.78t/year), NMR (Rs.44,250/year) and BCR(3.45) were still better in case of chilli which yielded 4.15 t from a land area of 0.4ha. This confirmed the findings of Nanda *et. al.* (2007). It was worth while to indicate that favourable soil and land type along with assured irrigation could enhance the productivity. Better communication to near by markets encouraged the farm family to grow horticultural crops.

Dairy Components

The milk produced by two crossbred cows with an average lactation period of 200days/year was around 2020 liters which could earn a monetary return of Rs. 10,940/year. Integration of crop with cattle proved to be beneficial as reported by Ravisankar *et.al.* (2007).

It was obvious that the farmer could successfully use the cow dung and urine etc from one deshi and two cross bred cows in the crop fields as manure to build the soil health and increase crop productivity. The urea treated paddy straw was used as dry fodder for the milchy animals.

It may be concluded that Integrated Farming Systems under irrigated medium land condition is more profitable and provide higher employment to family labourers with little or minor technical interventions as compared to the conventional system.

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INTEGRATED WEED MANAGEMENT IN PEARLMILLET-PIGEONPEA INTERCROPPING SYSTEM

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The pearlmillet + pigeonpea is one of the most productive and remunerative intercropping system. Area under pearlmillet and pigeonpea in India was 8.85 and 3.50 million ha and in Maharashtra, it was 1.74 and 1.84 million ha, production was 5.65 and 0.87 million tonnes with productivity in Maharashtra was 649 and 472 kg, respectively (Anonymous, 2000). Yield losses due to weeds infestation in pearlmillet + pigeonpea intercropping recorded 70-79 per cent (Tewari, 1989). Control of weeds in intercropping system through mechanical or cultural method may be difficult due to narrow inter row spacing which necessitates use of herbicides alone or incombination with mechanical method. Hence, present investigation on, Integrated weed management in pearlmillet – pigeonpea intercropping system was taken.

The field experiment was conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri during *khaif* 2003. The soil of experimental site was clayey in texture, low in available nitrogen (155.8 kg ha^{-1}), medium in available phosphorus (16.42 kg ha^{-1}) and rich in available potash (470.90 kg ha^{-1}), with slightly alkaline in reaction (pH 8.1). The field experiment comprised eight treatments were laid out in randomized block design with three replications (Table 1).

Effect on pearlmillet

Among the various treatments of weed management, the weed free treatment produced significantly more earheads per plant (2.93), length of earhead (18.20 cm), girth of earhead (9.05 cm), grain weight per earhead (19.72 g), 1000 grain weight (14.30 g), grain yield (14.98 q ha^{-1}) and stover yield (35.41 q ha^{-1}) than other treatments. However, this treatment was at par with T_6 i.e. herbicidal spraying of pendimethalin @ 0.75 kg a.i. ha^{-1} + H.W. (40 DAS). In all respect, grain and yield contributing characters of pearlmillet in above two treatments as compared to other weed control treatments may be attributed to less comeptation with weed resulting into better utilization of resources namely nutrients, moisture, light and space etc. The stover yield of pearlmillet was also more in the same treatment. This might be due to positive integrated effects of growth attributing characters *viz.*, number of leaves, leaf area and dry matter, towards stover yield. These results were in conformity with the results obtained by Malik *et al.* (2000).

Effect of pigeonpea

Weed free treatment produced significantly higher number of pods per plant (186), seed per pod (4), seed weight per plant (39.72 g), 1000 seed weight (113.9 g), seed yield (10.77 q ha^{-1}) and stick yield (31.11 q ha^{1}). The weed free treatment also recorded highest values of yield contributing characters. However, which was at par with pendimethalin PE @ 0.75 kg a.i. ha^{-1} + H.W. (40 DAS) (T_6). These results were inconformity with those results recorded by Rajput *et al.* (1994) and Chauhan *et al.* (1995). Lowest number of pods per plant, seed per pod,

Table 1. Details of treatments with their symbol used

Treatment	Symbol
Weedy check	T_1
Weed free check	T_2
Two hand weeding (20 ands 40 DAS)	T_3
Hoeing (20 DAS) + hand weeding (40 DAS)	T_4
Pendimethalin PE @ 1.5 kg a.i. ha^{-1}	T_5
Pendimethalin PE @ 0.75 kg a.i. ha^{-1} + Hand weeding (40 DAS)	T_6
Fluchloralin PE @ 1 kg a.i. ha^{-1}	T_7
Fluchloralin PE @ 1.0 kg a.i. ha^{-1} + Hand weeding (40 DAS)	T_8

DAS = Days after sowing

Table 2. Yield and yield attributing characters of pearlmilet as influenced by different weed control treatments

Treatment	Earhead per pant	Earhead length (cm)	Earhead girth (cm)	Grain weight per earhead (g)	1000 grain Weight (g)	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})
T_1	1.40	13.67	6.81	15.40	10.60	8.46	22.08
T_2	2.93	18.20	9.05	19.72	14.30	14.98	35.41
T_3	2.53	15.86	8.14	18.33	13.29	13.53	32.76
T_4	1.87	14.06	7.91	17.95	12.83	12.07	29.38
T_5	2.07	15.20	8.31	17.99	13.17	12.24	30.80
T_6	2.70	16.93	8.79	18.67	13.57	13.78	34.00
T_7	1.60	13.26	7.81	16.99	12.17	9.98	24.75
T_8	1.83	13.73	7.91	17.75	12.60	10.14	26.17
S.Em ±	0.11	0.74	0.54	0.43	0.31	0.56	0.99
C.D. at 5 %	0.33	2.26	NS	1.31	0.94	2.38	3.03

seed weight, 1000 seed weight, seed yield and stick yields were found in weedy check treatment, which was mainly attributed to more competation for resources in favour of weeds than crop.

Effect of weeds

Among the weed control treatment (T_6) i.e. application of pendimethalin PE @ 1.5 kg a.i. ha^{-1} + H.W. (40 DAS) recorded significantly lowest weed intensity (45 m^2) and lowest dry weight of weeds (4.15 g) than rest of treatments. However, which was at par with treatment (T_8) fluchloralin PE @ 1.0 kg a.i. ha^{-1} + H.W. (40 DAS). Weed free

Table 3. Yield and yield attributing characters of pigeonpea as influenced by different weed control treatments

Treatment	Pods per plant	Seeds per pod	Seed weight per plant (g)	1000 seed weight (g)	Seed yield (q ha^{-1})	Stick yield (q ha^{-1})
T_1	122.67	3.40	26.93	97.76	6.27	20.83
T_2	186.00	4.00	39.72	113.87	10.77	31.11
T_3	152.33	3.93	37.81	107.60	9.25	28.49
T_4	139.67	3.53	35.81	106.30	8.29	25.64
T_5	169.33	3.80	31.76	106.40	9.17	28.07
T_6	182.73	3.93	38.25	112.72	10.59	28.56
T_7	131.60	3.53	27.07	100.00	7.65	23.15
T_8	136.87	3.60	28.51	102.83	8.51	24.04
S.Em ±	8.31	0.14	1.56	3.22	0.40	1.48
C.D. at 5 %	25.20	NS	4.75	9.78	1.21	4.48

Table 4. Mean weed intensity, dry weight, weed control efficiency and weed index as influenced by different treatments

Treatment	Weed intensity (m^2)	Dry weight of weeds (g)	Weed control efficiency (%)	Weed index (%)
T_1	157.00	11.15	0.00	42.20
T_2	0.00	0.00	100.00	0.00
T_3	64.00	4.55	59.17	12.93
T_4	77.00	6.27	50.96	21.79
T_5	90.00	5.30	42.53	16.10
T_6	45.00	4.15	71.27	3.73
T_7	103.00	5.52	34.26	23.60
T_8	52.00	4.40	66.86	24.62
S.Em ±	2.35	0.16	1.38	3.00
C.D. at 5 %	7.12	0.49	4.19	9.11

treatment found best weed control efficiency (100 %) and weed index (0.00 %) but treatment (T_6) application of pendimethalin PE @ 1.5 kg a.i. ha^{-1} + HW (40 DAS) found economically best for WCE and weed index. The results indicates that, the herbicides in integration with hand weeding were found to be superior for controlling weeds in pearlmillet + pigeonpea intercropping system. These results are in conformity with those reported by Rajput *et al.* (1994) and Chauhan *et al.* (1995).

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RESPONSE OF DIFFERENT VARIETIES OF MUSTARD (BRASSICA JUNCEA) TO VARIED SPACINGS

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Among the oil seed crops, member of genus brassica are important source of edible oil in northern and eastern part of the India. Repeseed-mustard is second most important oil seed crop after groundnut contributing nearly 40% of the total oil seed production in India. Maintenance of optimum and uniform plant population is a prerequisite for obtaining high yields. The optimum plant population and crop geometry would, however, vary with species/ variety soil type and soil fertility. Fertilizer and improved varieties are two most important agronomic factors which play pivotal role in achieving the potential yield of any crop. The response of different varieties in one environment or a single variety in different environment can be quite different with varying plant population. Hence in the present study an attempt was made to assess the suitable varieties, and the effect of plant densities on the productivity of mustard.

A field experiment was conducted during rabi season (winter) 2004-2005 at Agronomy research farm of Chaudhary Charan Singh, Shiv Dhan Singh P.G. College, Iglas, (Aligarh) U.P. The soil was sandy loam in texture low in organic carbon and available nitrogen, medium in available phosphorus, high in available potash with PH 7.4 The experiement was laid out in split plot. design with four replications. There were 12 treatment combinations, comprising four varieties and four row spacing. The mustard crop was sown with the help of hand plough on November 7th 2004. Using seed rate 5 kg/ha, full dose of P_2O_5 $ZnSO_4$ and half dose of N were applied at the time of sowing and the remaining half dose of nitrogen was applied after first irrigation. The source of nitrogen and phosphorus were urea (46%) and single superphosphate (16% P_2O_5) respectively.

Effect of the variety

Among mustard varieties number of primary branches and dry matter accumulation was higher in type 59 than RH-30 and Pusa Jai Kishan. The difference in dry matter and primary branches could be attributed to their genetic constitutions and superiority. Similar resutls had also been reported by Butter and Aulakh (1999), Bali et al (2000) and Singh et al (2003). Mustard cultivar Type 59 recorded significantly higher yeild attributes i.e. siliquae per plant, seed per siliqua, 1000-seed weight, seed yield and stover yield per hectare than the cultivar RH-30 and Pusa Jai Kishan. Increase in yield attributes and yield due to cultivar Type 59 could be attributed due to their genetic characteristics. The differences in yield attributes and yield of various brassica species have been well documented by Thakur (1999) and Singh et al (2003), variety Type –59 recorded highest oil yield than variety RH-30 and Pusa Jai Kisha. Highest oil yields per hectare of variety Type –59 might be ascribed to its higher oil content as well as seed yield.

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Similar results had also been reported by Sharma *et al* 1997, Bali *et al* (2000) and Singh et al (2003.

Effect of Spacing

Dry matter accumulation was higher due to wider spacing (45x5cm and 30/60x5vm) than the closer spacing (30x15 cm and 20/40x15cm). Increases in dry matter accumulation with wider spacing may be attributed to better environment condition, better penetration of solar radiation to the shaded leaves. Variation in dry mater accumulation by spacing has also been observed by Bali et at (2000) and Singh et al (2003). All the treatments of spacing failed to influence the number of primary branches per plant. Although number of primary branches were higher with the wider spacing. Reason for more number of primary branches under wider spacing may be that per plant availability of nutrients is more under wider spacing than under narrower iner and intra row spacing . Bali et al (2000) and Singh et al (2003) also reported similar effects on primary branches. All the yields attributes could not reach the level of significance due to all treatments of row spacing. Treatments of plant spacing 30x15cm and 20/40x15cm produced significantly higher seed yield and stover yield. This could mainly be attributed to more number of plants per unit area under these spacing. Similar results have been reported by Butter and Aulakh (1999) Singh et al (2003).

Table 1. Effect of varieties and row spacing on dry matter accumulation, number of primary branches, number of siliquae per plant, number of seeds/ siliqua. 1000 seed weight, seed yield, stover and oil yield (kg/ha).

Treatment spacing (cm)	Dry matter accumul-ation per plant(g) at harvest	No. of primary banches pr pant	No. of siliquae per plant	No. of seeds per siliqua	1000 seed weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Oil content (%)	Oil yield (kg/ha)
51(30*15)	23.6	6.1	300	12.8	5.3	1701	7121	40.3	687
52(45*15) S3	27.5	6.5	317	14.0	5.6	1524	5941	40.0	614
20/40*15) S4	25.8	6.3	302	12.7	5.4	1800	7225	40.4	730
30/60*15)	25.9	6.7	323	12.7	5.5	1438	5872	40.5	582
SE m+-	0.73	0.20	14.26	0.13	0.09	41	121.3	0.27	18
CD at 5% level	2.34	NS	NS	0.14	NS	131	387.8	NS	59
Varieties	-	-	—	-	-	-	-	-	-
V1 (RH-30)	24.7	6.4	311	13.1	5.5	1610	6598	40.4	650
V2 (Pusa Jai Kishan)	23.3	5.5	293	12.7	5.2	1531	6316	40.1	613
V3 (Type 59)	26.8	7.1	355	13.3	5.7	1705	6706	40.7	697
Se m+	0.28	0.13	3.21	0.06	0.03	12	64.7	0.06	4.3
CD at 5% level	0.82	0.38	9.37	0.19	0.08	37	189	0.20	12.9

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RESPONSE OF ORGANIC AND INORGANIC SOURCES OF NUTRIENTS ON YIELD OF SPROUTING BROCCOLI (*BRASSICA OLERACEA* L. VAR. *ITALICA* PLENCK) AND SOIL QUALITY UNDER SEMI-ARID CONDITIONS OF RAJASTHAN

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The cultivation of sprouting broccoli is now gaining popularity with Indian growers for the last couple of years obviously due to increasing awareness of its high nutritive value and high market price. Broccoli contains indole-3-carbinol which helps to fight breast and lung cancer (Anon., 2006). Broccoli sprouts are also rich source of glucosinolates, a compound associated with reducing risk of cancer (Aires et al., 2006)

The use of organic manures is an important factor, which has direct influence on the growth, yield and quality of the crop. Integrated nutrient supply system for the crop by judicious mixture of organic manures along with inorganic fertilizers has great significance. Among various organic sources, vermi-compost and poultry manure are excellent sources being slow releasing and contain most of the macro as well as micro-nutrients in chelated form thus increase nutrient uptake by fulfilling the nutrient requirements of plants at longer period (Abusaleha, 1992).

A field experiment on sprouting broccoli cv. C. B. H.-1 was conducted during the winter season of 2005-06 at Horticulture farm, S.K.N. College of Agriculture, Jobner, Jaipur (Rajasthan). The soil of the experimental site was loamy sand with pH 8.5, EC 2.24 dS/m· organic carbon 0.15% and available N, P_2O_5 and K_2O of 132, 15.0 and 142 kg/ ha, respectively. The treatments comprised of five levels of organic manures (control, vermi-compost and poultry manure @ 2.5 and 5.0 t/ ha each) and four levels of recommended doses of NPK fertilizers (control, 75, 100 and 125%). The experiment was laid out in factorial randomized block design with three replications. The recommended dose of NPK for sprouting broccoli was 100, 80 and 60 kg/ ha. The application of urea was given in two doses, first at the time of transplanting and remaining half in two split doses *i.e.* 30 days after transplanting and at the time of head initiation. Single super phosphate, murate of potash, vermi-compost and poultry manure was applied at the time of transplanting of the crop. The observations on various traits like central head, secondary head and total head yield /ha and biological yield /plant were recorded as per standard methods. After harvest of the crop soil samples up to 0-15 cm were taken to analyze for available NPK and organic carbon in the soil as per standard procedures.

Organic sources

Yield

A critical examination of data presented in Table 1 revealed that yield of central head, secondary head and total head yield/ ha were significantly increased by different organic sources. The maximum yield of central head (149.66 q/ ha), secondary head (77.99 q/ ha) and total head yield (227.65 q/ ha) were recorded with vermicompost 5.0 t/ ha which was found to be significantly higher over control, 2.5 t/ ha vermicompost and 5.0 t/ ha vermicompost but statistically at par with 5.0 t/ ha poultry manure. The increase in yield of central head, secondary head and total head yield/ ha under 5.0 t/ ha vermicompost was found to be 57.09, 13.05 and 19.01 per cent in central head, 58.00, 13.90 and 19.22 in secondary head and 57.40, 13.53 and 19.07 in total head yield/ ha more over control 2.5 t/ ha vermicompost and 5.0 t/ ha vermicompost, respectively.

Application of different levels of organic manure increased the average weight of central head, secondary head and total head yield/ha (Tables 1). Data showed that the application of 5.0 t ha^{-1} vermicompost enhanced all the above parameters significantly over control, 2.5 t ha^{-1} vermicompost and 2.5 t ha^{-1} poultry manure but found statistically at par to poultry manure @ 5.0 t ha^{-1}. The beneficial effect of vermicompost on yield attributes and yield might be due to enhanced supply of macro and micro-nutrients during entire growing season. Significant increase in yield under the influence of vermicompost was largely a function of improved growth and the consequent increase in different yield attributes and yields as mentioned above. The significant improvement in yield attributes and yield on account of 5.0 t/ ha vermicompost along with nutrients from soil particularly at latter stage of crop growth might have enhanced the rate of photosynthesis which further increased vegetative growth and provided more sites for translocation of photosynthates which ultimately increased the yield. The increased yield

Table 1. Effect of organic and inorganic sources of nutrients on days taken to central head initiation, weight of central head, secondary head and total head yield and vitamin C content in head.

Treatments	Yield of central head (q/ha)	Yield of secondary head (q/ha)	Total head yield (q/ha)
Organic sources			
Control	95.27	49.36	144.63
Vermicompost @ 2.5 t/ ha	132.38	68.47	200.86
Vermicompost @ 5.0 t/ ha	149.66	77.99	227.65
Poultry manure @ 2.5 t/ ha	125.75	65.42	191.18
poultry manure @5.0 t/ ha	114.37	75.65	220.03
CD at 5%	10.55	5.24	15.18
Inorganic sources			
Control	94.35	49.93	144.27
RDF 75%	125	65.84	190.84
RDF 100%	144.81	74.64	219.45
RDF 125%	153.8	79.12	232.92
CD at 5%	9.44	4.69	13.58

RDF = Recommended dose of NPK

and yield attributes with poultry manure might be because of rapid availability and utilization of N for various internal plant processes for carbohydrate production. Later on these carbohydrates undergo hydrolysis and get converted into reproductive sugars which ultimately helped in increasing yield. Singh *et al.* (1970) reported that high carbohydrates content due to application of poultry manure might be attributed to balanced C : N ratio and increased activity of plant metabolism.

Available nutrient content of soil

The available NPK and organic carbon content of soil after crop harvest increased with the increase in the organic sources (Table 2). The application of vermicompost @ 5 t/ha recorded significantly higher available N (138.80 kg/ ha), P (17.20 kg/ ha), K (170.10 kg/ ha) and organic carbon (0.175 kg/ha) over control, vermicompost 2.5 t/ ha and poultry manure 2.5 t/ ha but found statistically at par with 5.0 t/ ha poultry manure. The per cent increase in N,P and K content under vermicompost @ 5 t/ha treatment is 27.33, 7.68 and 10.77, 44.53, 12.42 and 16.22 and 27.70, 8.00 and 11.17 over control, vermicompost 2.5 t/ ha and poultry manure 2.5 t/ ha, respectively. Under vermicompost @ 5 t/ha treatment organic carbon content was also 43.44, 12.17 and 15.89 % higher over control, vermicompost2.5 t/ ha, poultry manure 2.5 t/ ha and poultry manure5.0 t/ ha.

Increased availability of NPK and organic carbon in soil due to organic manures application may be because of the direct addition of nutrients through organic manure to the soil (Table 2). The decomposition of organic matter is accompanied by the release of appreciable amount of CO_2, which when dissolved in water, form carbonic acid which is capable of decomposing certain primary minerals. After proper decomposition and mineralization of organic manures, the manure supplied available nitrogen directly to the plants and also had solubilizing effects on fixed form of nutrients. In fact all the available nutrients in soil are not utilized by the plants and rest remained in soil which increased their availability after harvest.

Inorganic sources

Yield

The application of different inorganic sources also affected significantly the yield of central head, secondary head and total head yield/ ha. The maximum yield of central head (153.80 q ha^{-1}), secondary head (79.12 q ha^{-1}) and total head yield (232.89 q ha^{-1}) were registered with 125% recommended dose of NPK but significantly higher over control and 75% recommended dose of NPK and at par to 100 % recommended dose of NPK. The increase in 100 % recommended dose of NPK treatment in respect of yield of central head, secondary head and total head yield/ha was found to be 53.48, 15.85% in central head, 49.48, 13.36 % in secondary head and 52.11, 14.99 % in total head yield/ ha higher over control and 75% recommended dose of NPK treatment, respectively.

The application of 100% recommended dose of NPK significantly increased the average weight of central head, secondary head and total head yield /ha (Table 1). This might be due to the fact that increased NPK levels, helped in the expansion of leaf area and chlorophyll content which coupled with increased net photosynthetic rates and in turn increased the supply of carbohydrates to plants. The application of NPK favoured the metabolic and auxin activities in plant and ultimately resulted in increased head weight (central head and secondary head), biological yield and finally the total yield. However, potassium does not increase the yield of plant but indirectly supported to yield.

Available nutrient content of soil

The application of inorganic sources also affected NPK and organic carbon content in soil after harvest significantly. The maximum N (135.80 kg ha^{-1}), P (16.76 kg ha^{-1}), K (171.10 kg ha^{-1}) and organic carbon (0.176%) content was recorded under 125% recommended dose of NPK. The treatment 125% recommended dose of NPK was at par with 100 % recommended dose of NPK but significantly higher over control and 75 % recommended dose of NPK. The per cent increase in N, P and K content under 100% recommended dose of NPK treatment was 14.50 and 4.87, 19.33 and 6.68 and 20.92 and 6.60% over control and 75% recommended dose of NPK, respectively. The per cent increase in organic carbon content under 100% recommended dose of NPK treatment was 24.42 and 5.16 % over control and 75 % recommended dose of NPK, respectively.

Data presented in Table 2 showed that the application of inorganic fertilizers significantly increased NPK and organic carbon availability in the soil after crop harvest, over control. The highest available NPK and organic carbon with 125% recommended dose of NPK. This might be due to better utilization of native N, P and K with increase in rate of N, P, K and organic carbon application. The favourable effect of nitrogen fertilization in improving the K status is an outcome of increased proliferation of roots and microbial activity, which in turn released the organic acids lowering dose of the pH of

Table 2. Effect of organic and inorganic sources of nutrients on available nitrogen, phosphorus, potassium and organic carbon in soil after harvest

Treatments	Nitrogen (kg/ ha)	Phosphorus (kg /ha)	Potassium (kg/ ha)	Organic carbon (%)
Organic sources				
Control	109.0	11.9	133.2	0.122
Vermicompost @ 2.5 t/ ha	128.9	15.3	157.5	0.156
Vermicompost @ 5.0 t/ ha	138.8	17.2	170.1	0.175
Poultry manure @ 2.5 t/ ha	125.3	14.8	153.0	0.151
poultry manure @5.0 t/ ha	138.6	16.6	169.4	0.170
CD at 5%	10.40	1.24	12.20	0.012
Inorganic sources				
Control	116.5	13.24	136.2	0.131
RDF 75%	127.2	14.81	154.5	0.155
RDF 100%	133.4	15.80	164.7	0.163
RDF 125%	135.8	16.76	171.1	0.176
CD at 5%	9.30	1.11	10.90	0.012

RDF = Recommended dose of NPK

Table 3. Combined effects of organic and inorganic sources of nutrients on biological yield per plant (kg)

Treatments	Control	Vermi-compost		Poultry manure	
		2.5 t/ ha	5.0 t/ ha	2.5 t/ ha	5.0 t/ ha
Control	0.83	1.06	1.21	1.04	1.11
RDF 75%	0.96	1.21	1.61	1.21	1.61
RDF 100%	1.07	1.60	1.69	1.35	1.64
RDF 125%	1.12	1.64	1.72	1.62	1.65
CD at 5%	0.16				

RDF = Recommended dose of NPK

soil and releasing the native potassium from the soil.

Interaction effect

The application of F_1V_2 treatment combination reduced the quantity of inorganic fertilizers for the crop and also reduced the residual effect of these inorganic fertilizers. The vermicompost is having N, P and other micro-nutrients solubilizing bacteria. They solublized the N, P and other micronutrients in soil near the root zone of the crop. They provide nutrients in the readily available chelated form to the plants such as nitrate, exchangeable phosphorus, soluble K, Ca and Mg. They also contain biologically active substances such as plant growth regulators. It may be also due to the reason as vermicompost having a material which has high porosity, aeration, drainability and water holding capacity, thus, it is capable to improve the physical conditions of soil with yield of vegetable crop, when applied in the combination of chemical fertilizers. This is due to the fact that application of fertilizers alone have supplied only one or two nutrients but combined use of organic and inorganic fertilizers have provided all the essential nutrients in proper amount, required by plants for its growth and development.

It can be inferred from present investigation that optimum yield with best quality of broccoli can be obtained with the application of 5.0 t ha^{-1} vermicompost or poultry manure along with 75% of recommended dose of NPK, which also reduced the cost of cultivation.

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FRONTLINE DEMONSTRATION AN EFFECTIVE SOURCE FOR TRANSFER OF TECHNOLOGY UNDER SOYBEAN – WHEAT CROPPING SYSTEM IN MARATHWADA REGION OF MAHARASHTRA

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Oilseeds have to be grown in the multiple cropping systems for sustainable production. The progressive shrinkage of per capita land availability warrants the temporal and spatial intensification of cropping system (Shivran et al., 2000). The evolution of short duration and input responsive variety of soybean viz. JS-335 have opened up new avenues in this direction as wheat could be grown in quick succession.

Soybean, a miracle crop with 20 % oil and 40% protein has gained quite popularity among the farmers of Marathwada region. Area under this crop is increasing consistently due to its short duration and better market price. In Maharashtra the soybean is cultivated in *kharif* season on an area of 26.62 lakh ha with an average productivity of 1221 kg/ ha which is very low as compared to the production potential (30-35q/ha) of the crop. Soybean – wheat has emerged one of the productive, profitable and sustainable cropping system next to soybean- sorghum cropping system in the Marathwada region. Therefore, the farmers of this region are more interested towards the soybean – wheat cropping system. However, the yield levels of these crops on farmer's field are low as compared to its production potential. Thus, the present frontline demonstration (FLD) was undertaken to create awareness among the farmers towards the adoption of seed treatment, improved varieties, balanced application of fertilizers and other agro techniques for enhancing the crop yield of soybean – wheat cropping system.

Participatory Rural Appraisal (PRA) survey was undertaken in the selected villages prior to start of the frontline demonstrations. Based on the PRA survey, constraints were identified and accordingly the interventions were decided. Major constraints identified in Marathwada region were lack of seed treatment, use of local and uncertified seeds, imbalance application of fertilizers, lack of plant protection measures and poor management practices. Considering the factors under the guidelines of PDCSR, Modipuram, Meerut, the interventions like seed treatment, use of certified seed, balanced application of fertilizers and necessary plant protection measures were supplied to the farmers. A total of 40 FLDs on soybean – wheat cropping systems were conducted with soybean variety JS-335 in *kharif* and wheat variety HD-2189 in Rabi season during the year 2004-05 to 2007-08.

It is clear from Table 1, that grain yield of FLD plot of *kharif* soybean ranged from 21.88 to 27.10 q/ha and *rabi* wheat ranged from 31.46 to 38.40 q/ha. This shows an increase in soybean yield from 13.69 to 36.93 % and increase in wheat

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Table 1. Yield performance of soybean – wheat cropping system under FLD and farmers' practice

Sr. No.	Year	No. of Demonstrations	Crop	Average yield (q/ha)		% increase in yield
				FLD	FP	over FP
1	2004-05	10	Soybean	27.10	20.60	31.55
			Wheat	38.40	29.43	30.47
2	2005-06	10	Soybean	24.99	18.25	36.93
			Wheat	35.55	26.50	34.15
3	2006-07	10	Soybean	24.16	21.25	13.69
			Wheat	34.05	27.00	26.11
4	2007-08	10	Soybean	21.88	17.45	25.38
			Wheat	31.46	26.45	18.94
Total / Average		40	Soybean	21.88	17.45	25.38
			Wheat	31.46	26.45	18.94

yield from 18.94 to 34.15 % over farmer's practice. Thus, the average overall increase in yield of *kharif* soybean was 26.50 and 27.49 % in *rabi* wheat over farmer's practice. Further, it is observed that comparatively low yield levels were achieved in soybean and wheat crop in the farmer's practice due to use of local varieties with poor yielding capacity, lack of seed treatment, inadequate application of fertilizers and lack of plant protection measures. On other hand, timely and proper implications of the technology under the guidance of university scientists has proved to have a clear cut yield differences between the farmer's practice and FLD plots.

The data depicted in Table 2 revealed that there was an increase of 14.75 and 24.86 q/ha yield of soybean and wheat crop respectively over the average yield of the district. Thus, the performance of FLD confirms that there is a wide gap between the potential of FLD and the yield at Farmer's field. This gap can be filled up by motivating the farmers towards the adoption of improved production technology through the various extension activities including the block or village demonstrations in large area along with timely supply of quality inputs and technical guidance. This will create a sort of confidence among the farmers to achieve the higher yield/profit and ultimately the area under soybean-wheat cropping system will increase in the region. These results are nearly similar to the findings of Singh et al. (2005) and Chavan et al. (2008).

From the present study it can be concluded that to bridge the yield gap and to make the soybean – wheat cropping system more remunerative, the wide publicity of improved varieties and improved production technology through various extension activities including FLD with sound technical back up needs to be explored. The front line demonstrations are fruitful for increasing the production and productivity of

Table 2. Yield gap between FLD and average yield of the district

Sr. No.	Year	Average yield FLD (q/ha)		Average district yield (q/ha)		Yield gap (q/ha)		% increase in yield over district average yield	
		Soybean	Wheat	Soybean	Wheat	Soybean	Wheat	Soybean	Wheat
1	2004-05	27.10	38.40	8.73	10.65	18.37	27.75	210.42	260.56
2	2005-06	25.00	35.55	10.35	09.40	14.65	26.15	141.54	278.19
3	2006-07	24.16	34.05	08.79	10.30	15.37	23.75	174.85	230.58
4	2007-08	21.88	31.46	11.27	09.65	10.61	21.81	94.13	226.00
	Mean	24.53	34.87	09.78	10.00	14.75	24.86	155.13	248.83

soybean – wheat cropping system on farmers' fields in Marathwada region of Maharashtra state.

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RESPONSE OF RICR RICE CROP SEQUENCE TO N, P AND K IN SOUTH KONKAN COASTAL ZONE OF MAHARASHTRA

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Rice- rice is the most widely adopted cropping system in lowland areas of south konkan coastal zone of Maharashtra. It is followed over an area of about 30,000 ha. mainly in Konkan and Vidarbha region. The continuous practice of rice- rice sequence reduces the soil fertility in specific rootzone which altimately threatened the sustainability of Konkan region of Maharashtra. Imbalanced use of chemical fertilizers also results in deficiency of nutrients other than the applied and disturbs the natural balance of nutrients in soil (Singh *et. al.*, 1999). The response of food grain crops to the applied fertilizers is decreasing immensely from 115 kg grain/kg.applied fertilizer in 2001-02 (Tiwari, 2002). Hence the efforts were made to asses the current response of rice- rice crop sequence to major nutrients in prevailing conditions of Konkan region.

An experiment on 'Response of Rice-Rice system to N, P and K' was conducted during 2005-06 and 2006-07 on 24 farmers' field in Sindhudurg district of Maharashtra in MH1 NARP zone. The experiment consist of five treatments viz. T1 – control (no fertilizer), T2 – Recommended dose of N (100:0:0 for *kharif* and 120:0:0 for *rabi*), T3- Recommended dose of N and P (100:50:0 for *kharif* and 120:50:0 for *rabi)*, T4- Recommended dose of N and K (100:0:50 for *kharif* and 120:0:50 for *rabi*), T5- Recommended dose of N, P and K (100:50:50 for *kharif* and 120:50:50 for *rabi*). Rice hybrid variety Sahyadri was grown for *kharif* season for both the years and rice variety Sahyadri 2 and Ratnagiri 1 were grown during *rabi* season for the year 2005-06 and 2006-07 respectively. The experiment was laid out in RBD in 200 sq. m. plot with 24 replications (number of farmers serving number of replications). The soils of the experimental site were poor in available N (221 to 251 kg/ha.) with pH range of 4.91 to 5.33, EC range of 0.05 to 0.07 dSm-1 and organic carbon from 0.72 to 0.92 %. The climate of the experimental site is hot and humid with an average rainfall of 3500 mm.

Productivity and net returns

Two years results revealed that balanced doses of all the three major nutrients for both the seasons resulted significantly highest grain yield of rice (Table 1). Each fertilizer treatment increased grain and straw yield over preceding level of fertilizer application. Among the two nutrient combinations (NP and NK), NK application was found significantly superior over NP. On the basis of total yield NPK recorded highest yield (113.42 q/ha. during 2005-06 and 107.44 q/ha. during 2006-07) followed by NK (103.78 q/ha. during 2005-06 and

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Table 1. Grain yield, total yield and net returns as influenced by different treatments in rice – rice crop sequence (2005-06 to 2006-07)

Treatments	Grain yield (q/ha)				Total Yield (q/ha.)		Net Returns (Rs./ha)	
	2005-06		2006-07		2005-06	2006-07	2005-06	2006-07
	Kharif	*Rabi*	*Kharif*	*Rabi*				
T_1 - control	40.97	38.82	41.52	32.81	79.79	74.33	5656	4739
T_2 - only N	47.25	41.56	46.44	35.71	88.81	82.15	6716	5934
T_3 - NP	53.78	43.35	54.70	38.67	97.13	93.37	7200	7433
T_4 - NK	58.39	45.39	58.28	40.13	103.78	98.41	7593	8448
T_5 - NPK	65.59	47.83	64.15	43.29	113.42	107.44	9676	9998
CD 5%	1.89	2.10	2.10	1.08	-	-	-	-

98.41 q/ha. during 2006-07), NP (97.13 q/ha. during 2005-06 and 97.37 q/ha. during 2006-07) and N alone (88.81 q/ha. during 2005-06 and 82.15 q/ha. during 2006-07). The lowest total yield was observed in control (No fertilizer) treatment (79.79 q/ha. during 2005-06 and 74.33 q/ha. during 2006-07). These results are similar with the findings of Sharma and Sharma (2002) and Alokkumar *et. al.* (2006)

In economic analysis, it was noticed that maximum profit to the tune of Rs. 9676/- per hectare (2005-06) and Rs. 9998/- per hectare (2006-07) was earned when recommended dose of NPK (T5) was given to rice- rice sequence.

Response of nutrients

The response of nutrients viz. N, P and K (kg grain/kg nutrient) was calculated for complete crop sequence (Table 2). It was evident that potassium gave a high level of response (10.63 kg grain per kg K_2O during *kharif* and 4.55 kg grain per kg K_2O during *rabi).* The role of phosphorus was found to be next in order. The response of all the nutrients is higher during *kharif* season as compared to *rabi* season. Response of potassium to rice crop is higher which may be due to higher content of potassium and it might be due to release of potash from lattice layer of potassium bearing minerals present in the soil and

Table 2. Response of nutrients N, P and K (kg grain per kg nutrient) in rice – rice cropping system

Nutrients	Year 2005-06		Year 2006-07		Average	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
Nitrogen	6.28	2.74	4.92	2.90	5.60	2.82
Phosphorus	7.20	2.44	5.87	3.16	6.54	2.80
Potassium	11.81	4.48	9.45	4.62	10.63	4.55

also from applied potassium which become more soluble. Goswami *et.al.* (1976) reported that rice responded to K better than other cereals like wheat. The mean response of Rice crop over several years in intensive cropping system ranged from 5 to 10 kg grain per kg K_2O (Singh *et. al.*,1992)

The experiment results revealed that for successful production from rice rice crop sequence, the component crops needed balanced doses of N, P and K which may lead them towards better productivity.

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