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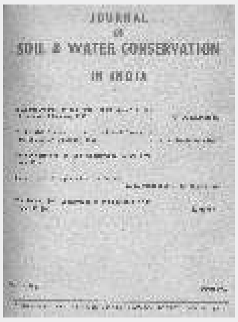

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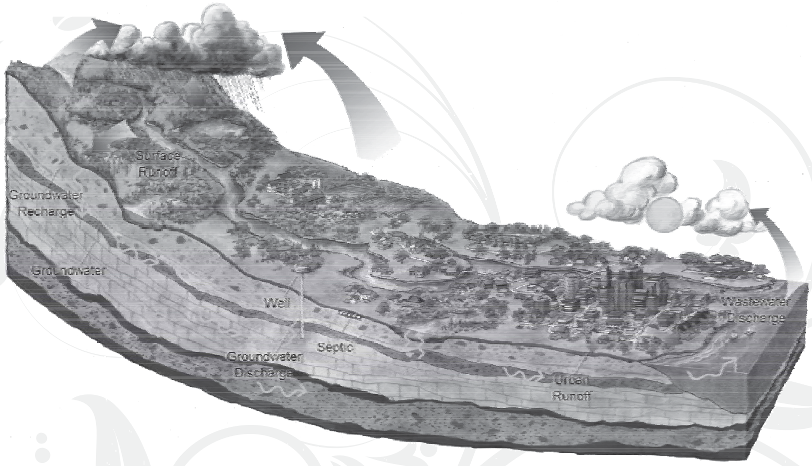
Contents

Pledge

J.S. Bali



I pledge to conserve Soil,
that sustains me.
I pledge to conserve Water,
that is vital for life.
I care for Plants and Animals and the Wildlife,
which sustain me.
I pledge to work for adaptation to,
and mitigation of Global Warming.
I pledge to remain devoted,
to the management of all Natural Resources,
With harmony between Ecology and Economics.

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Soil related constraints in crop production and their management options in North Western Himalayas

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ABSTRACT

In this paper, various soil related constraints in crop production have been elucidated pertaining to North-Western Himalayan soils, along with their control measures. Soil erosion, soil acidity, alkalinity in terms of salinity and sodicity, as well as fragmentation of land holdings have been found to be the main constraints in crop productions under such soil conditions. Soil erosion is the main factor which is responsible for the degradation of the arable land in terms of its physical, chemical and biological respects. To control this constraint, one has to follow all the soil and water conservation measures like agronomic, mechanical or engineering and biological. Similarly, to control the acidity and sodicity, the farmers must be advocated to use amendments like lime and gypsum. In calcareous soils, whatever quantity of organic manures is available must be added to overcome this constraint.

Key words: erosion, soil conservation, foothill region, kandi, watershed management

INTRODUCTION

The major soil constraints occurring in North West Himalayan soils, covering the states of Uttranchal, Himachal Pradesh and Jammu and Kashmir are land degradation, soil erosion, loss of soil fertility, soil acidity resulting into deficiency of available P, Ca^{+2}, Mg^{+2}, and toxicity of Fe^{3+} and Al^{3+}, and occurrence of salinity and alkalinity to some extent in certain areas. The fertilizer use is also limited in the soils of this Himalayan tract. Moreover, the limited use of fertilizers is being made indiscriminately. This can be conjectured by deciphering the ratio of N, P and K fertilizers consumption in Jammu and Kashmir state (Gupta and Singh, 2006). In Jammu region, NPK ratio is 66.5: 18: 1 and in Kashmir region, it is 21.2: 7.5: 1 against an ideal ratio of 4: 2: 1. Due to all these factors, the crop production suffers badly. In this paper, therefore, aforesaid soil related crop production constraints have been narrated briefly along-with management practices or control measures.

Land degradation

Definition and kinds of land degradation: Land degradation is defined as "loss of its capacity to support plant growth on sustainable basis." It is of three kinds *viz*., physical, chemical and biological. The description of different types of degradation is presented in Table 1.

In India, these days on an average at least two (0.8 ha) out of 3 acres (1.2 ha) of land is poor in health. It is also known that at least half of the sick land *i.e*., one-third of the total is almost completely unproductive. Another one-third is partially productive and it is only the remaining one-third which is in good health. Similarly, nowadays, about half of the area in the Himalayan region has turned into degraded conditions (Sharma, 2004). Like other Himalayan areas, the North Western Himalayan region is highly degraded. Out of the total geographical area of Jammu and Kashmir, Himachal Pradesh and Uttarakhand about 31, 75 and 72 per cent is under degraded conditions, respectively (Gupta and Sharma, 2007).

Causes of land degradation

The most serious threat to the land degradation in the North Western Himalayan states is posed by deforestation which results in soil erosion (Arora *et al*., 2006). The soils are prone to soil erosion due to their occurrence on hilly terrain. Soil erosion is as high as 168 tonnes ha^{-1} ($t\ ha^{-1}$) $year^{-1}$

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Table 1. Types of degradation and their characteristics

Type of degradation	**Characteristics**
Physical degradation	It means deterioration in physical properties of soil. It consists of compaction, hardening of soil by reducing structural pores, especially in soils where rice-wheat is the main cropping sequence. Soils prone to compaction and hard setting are susceptible to accelerate run-off losses and soil erosion.
Chemical degradation	Chemical degradation of land leads to a lot of changes in the soil. Major one among them is depletion of nutrients, followed by alteration in physico-chemical properties (pH, EC, CEC) and base saturation.
Biological degradation	There is reduction of soil organic matter, decline in biomass carbon, decrease in the activity and diversity of macrofauna, microfauna and microflora – bacteria, actinomycetes, BGA, fungi.

especially in Siwaliks of Uttarakhand, Himachal and J&K (Sharma, 2004) as well as Punjab and Haryana. Recently, Singh (2007) has reported loss of soil to the extent of as high as 225 t ha^{-1} $year^{-1}$ in some of the watersheds or catchments. The soils of *Karewas* of Kashmir having undulating topography also suffer from excessive soil leaching and erosion problems. The cold arid zone of Ladakh, Lahaul and Spiti / Kinnaur of Himachal and high altitude areas of Uttarakhand have a serious problem of glacial erosion.

The other factors responsible for soil erosion besides deforestation are landslides, improper land use, overgrazing of the pastures, unplanned construction of roads / buildings, blasting of mountains etc. (Gupta *et al.*, 1992).

Control measures of soil erosion

Soil erosion can be checked by following agronomical, mechanical or engineering methods and biological techniques. Almost all soil and water conservation measures or methods basically possess an aim at reducing soil and water losses and maintaining and building of overall fertility and productivity of the soil. The necessary details of all these methods already stand mentioned in separate publications (Gupta and Banerjee, 1991; Gupta and Sharma, 2007). Generally, four kinds of measures *viz.*, land capability classification, mechanical or engineering structures, agronomic methods and biological measures, are taken into considerations to control soil erosion and run-off losses. Briefly, they have been described in Table 2.

Although soil erosion can be checked by using all the aforesaid methods (Table 2) yet the most important requirement is to keep the land under the plant cover for as long as possible. It is because under such situation there is minimum loss of soil and water. Hence, biological methods must be preferred as they are cheap and easy to follow. Apart from the methods given in the Table 2, following anti-erosion and flood control measures are absolutely necessary:

(*i*) In the first instance, the factors which cause soil erosion should be eliminated. They are overgrazing of the pastures, deforestation of the remnants of the forest, illicit cutting of vegetation.

(*ii*) The provision of forest law to keep 25 percent of forest area under closure for regeneration should be enforced without further delay. The most glaring example in this connection is of Rui Watershed developed by Eco Task Force located in the Samba-Mansar / Udhampur road in Jammu region, Jammu and Kashmir State.

(*iii*) Rehabilitation of the eroded area by planting suitable local tree species or bushes is the need of the hour (Table 3). The table illustrate about the quick growing tree species, fodder tree species, fuel-wood species and bushes meant for rehabilitation of eroded / degraded areas of the North West Himalayan region. Not an inch of soil of any categories should remain naked. All marginal soils should be covered with grasses.

(*iv*) Prefer to grow grasses as grass provides effective vegetation cover to the land surface, improves soil aggregates, builds-up soil fertility and reduces run-off losses. Grasses also supply fodder and protect soil conservation structures likes bunds, terraces and waterways.

(*v*) No cultivation on steep slopes is permitted rather planting of grasses, forest tree species and fruit trees be encouraged to grow depending upon land capability classification.

In *Kandi* belt of Jammu, building up of check dams through Watershed Development Projects have proved boon for the farmers for storing the rain water during the lean periods to irrigate the crops (Gupta *et al.*, 2009). Hitherto the rainwater used to go waste in small rivulets and caused flash floods and lot of soil erosion.

Table 2. Soil and water conservation measures and land capability classification

S. No.	Control Measures	Description
I.	**Land Capability Classification**	
(a)	Criteria	Soils are classified on the basis of their limitations *viz.*, depth of the soil, its texture, structure, permeability, relief as expressed by slope, extent of soil erosion, soil pH and degree of wetness, stoniness in hill terrain.
(b)	Capability classes	The soils exhibiting greater capabilities for response to management and least limitations are classified into Class I and those with little capabilities and greatest limitations are classified into Class VIII.
(c)	Capability classes suitable for cultivation	The first four land capability classes *viz.*, Class I to Class IV are profitability used for cultivation of crops.
(d)	Capability class suitable for grazing	Class V.
(e)	Capability classes for grazing and forestry	Class VI and Class VII.
(f)	Capability class for wildlife / recreation	Class VIII.
II.	**Mechanical or Engineering Methods:** If properly built and maintained, these methods can improve the land over a long period of time.	They constitute various engineering structures which can supplement the biological measures. Contour tillage, contour trenching, contour bunding and terracing are the main measures which are followed under mechanical measures. Practices such as basin listing, pan breaking and for gully control check dams, overflow dams are the other measures in this respect.
III.	**Agronomic Measures:** The main aim of agronomic measures is to maintain soil fertility as well as to conserve soil and water.	Agronomical methods used in soil and water conservation are strip cropping, crop rotations, mulching and cover crops. Strip cropping consists of contour strip cropping, field strip cropping, wind strip cropping and buffer strip cropping.
IV.	**Biological Methods**	Reforestation or afforestation, planting of grasses, maintenance of vegetative covers and enclosures are some of the techniques which belong to biological control.

Table 3. Quick growing tree / shrub species for the rehabilitation of eroded / degraded areas of the North West Himalayas

Quick growing species	**Fodder tree species**	**Fuelwood species**	**Bushes/shrubs**
Leucaena leucocephala	*Grewia optiva*	*Acacia nilotica*	*Carissa spinarum*
Albizia spp.	*Albizia* spp.	*Albizia lebbeck*	*Dodonaea viscosa*
Sesbania spp.	*Aeqle marmelos*	*Albizia procera*	*Adhatoda vasica*
Eucalyptus spp.	*Bauhinia variegata*	*Albizia stipulata*	*Vitex negundo*
(on suitable sites only)	*Morus alba*	*Acacia catechu*	*Flacourtia indica*
Populas spp.	*Cordia dichotoma*	*Dalbergia sisso*	*Datura innoxia*
(on sub-temperate and temperate climatic zones besides subtropical irrigated)	*Celtis australis*	(suitable on Siwalik Himalayas)	(suitable for denuded areas of Siwalik Himalayas)
Black locust and honey locust	*Leucaena leucocephala*	*Aesculus indica*	
(suitable for sub-temperate zones)	(all these species are suitable for Siwalik Himalayas, including *Kandi* belts of Jammu, Punjab and Himachal Pradesh)	*Quercus* spp. (suitable for lesser to great Himalayas)	

Poor soil fertility

As there is soil loss due to soil erosion, which varies from less than 1 t ha^{-1} year^{-1} in soils of dense forests to more than 80 t ha^{-1} year^{-1} or upto 225 t ha^{-1} year^{-1} in some catchments with an average soil loss of 16 t ha^{-1} year^{-1}, so there is loss of plant nutrients with the soil particles. In North West Himalayan region there are certain eroded areas where top soil has already been washed away as can be seen in areas of Himachal Pradesh, Uttarakhand and Jammu and Kashmir (Gupta and Sharma, 2007). With the loss of the top soil its nutrients necessary for plant growth are lost (Hadda and Arora, 2006). Indeed, the nutrient loss is greater than might be expected at first glance. For instance, if one-tenth of the top soil is washed away, then more than one-tenth of the nutrients of the top soil are lost since the available nutrients are mostly confined to upper soil layers. The loss of plant nutrients may be large or small depending upon the amount of soil erosion and landuse pattern (Table 4). It indicated that soils under eroded lands and cultivated unmanaged lands had low amount of nutrients as compared to those under non-eroded cultivated lands and non-eroded forest lands.

Many areas of Jammu and Kashmir are suffering from all kinds of soil erosion *viz.*, sheet erosion, rill erosion, gully erosion and ravines (Table 5). Due to heavy erosion of soil, the soils of most of these places have become shallow in depth, ranging from 40 to 100 cm.

Control measures

All methods which have already been given under land degradation sub-head, be followed strictly. Application of well-decomposed organic manures (FYM, compost, vermin-compost, poultry manure) should be applied well in time. Wherever it is possible, practice of green manuring may be revived. On very steep slopes cultivation of crops be discouraged.

Soil acidity

Soil acidity is another constraint in crop production. It indicates the quality of soil in respect of acid or sourness. Acid soils are characterized by low pH *i.e.*, less than 7.0 theoretically and / or less than 6.5 practically. About 90 million hectare (m ha) (Sharma and Sarkar, 2005) or 100 m ha area

Table 4. Status of organic carbon, total N, Ca^{+2}, Mg^{+2} and other properties in eroded versus non-eroded soils (based on average values)

Parameter	Eroded lands	Cultivated unmanaged lands	Non-eroded cultivated lands	Non-eroded forest lands
pH	7.5	7.2	7.0	7.1
EC	0.18	0.20	0.23	0.19
OC%	0.22	0.35	0.52	0.73
Total N%	0.030	0.043	0.056	0.077
C: N ratio	7.4	8.1	9.3	10.5
CEC (me 100 g^{-1})	7.4	9.3	12.6	14.2
Ca^{+2}	5.4	6.6	7.5	7.8
Mg^{+2}	1.5	1.6	2.3	2.6
K^{+}	0.07	0.10	0.17	0.17
Na^{+}	0.06	0.09	0.14	0.14
Base saturation	95.4	90.1	80.0	76.6

Source: Gupta *et al*. (2005)

Table 5. Areas of Jammu and Kashmir suffering from soil erosion, showing low soil fertility

Kind of Soil Erosion	Areas
Sheet Erosion	A number of villages on Mansar-Suriansar, Suriansar-Sidhra, Samba-mansar, Dansal-Jindra, Kote Bhalwal-Amb Garota, parts of Akhnoor like Kaleeth, Sole Bhallabag as well as parts of *Karewas* of Kashmir. Infact, whole of the *Kandi* belt of Jammu is affected by sheet erosion.
Rill Erosion	A number of longitudinal valleys like Udhampur, Jhajjar Kotli, Dansal – known as *Duns* (*Dadhals*), Kainthgali, Panchari, Landhar belt, Jasrota to Kathua, Basohli to Kathua and Kathua to Billawar, Sanasar, Chenani and Mantalai area of Udhampur as well as Kalakote in Rajouri and Loran in Poonch. Half of the Kashmir valley suffers from excessive rill erosion. It is also quite prevalent in Ladakh region.
Gullies and Ravines	The soils of Aitham Narka series in uplands and ridges of Siwaliks of Jammu, soils of Choha series of Udhampur present on undulating / rolling topography are heavily afflicted with gullies and ravines. Similarly, soils of Janakha and Tara soil series found on foothills and along the banks of *nallahs,* are subjected to severe erosion, resulting in the formation of ravines and gullies. Foothills of Pir Panjal and North Kashmir have been eroded with loss of top soil leaving behind unproductive mass of gravels / stones.
Glacial Erosion	Glacial erosion is reflected by furrowings, cutting and abrasing of land mass. The cold arid zone of Ladakh and Marwah / Warban region of Doda district have a serious problem of this kind of erosion.

Source: Gupta (2002)

(Mandal, 1997) of acid soils are present in our country. However, nearly 25 m ha are critically degraded having pH less than 5.5. Although an exact area of acid soils found among North West Himalayan soils is not still available yet in Uttarakhand, Himachal Pradesh and Jammu and Kashmir it is roughly 2.9, 5.0 and 15.5 m ha, respectively which may be reckoned as Acid Soil Region. Acids soils to an extent of 15.5 m ha area as reported by Mandal (1997), however needs to be thoroughly probed.

Occurrence of acid soils was reported as early as Kaul (1956), Gupta (1967) and Gupta *et al.* (1980) in various parts of Jammu and Kashmir and even in apple growing areas of Kashmir and *Kandi* belt of Jammu (Gupta *et al.*, 1992).

Conditions for development of soil acidity

(*i*) **High rainfall:** Owing to high rainfall there is leaching of Ca^{+2}, Mg^{+2}, K^{+} leaving behind Fe^{+3} and Al^{+3} which increase soil acidity.

(*ii*) **Type of vegetation:** Coniferous type of vegetation produces more acidity as compared to that of deciduous type. It is attributed to the richness of silica in the needles of the conifers.

(*iii*) **Organic matter or humus:** Soils rich in organic matter develop acidity due to the presence of organic acid groups like carboxyl, phenolic and amino. These groups are capable of bonding H^{+} ions. Such H^{+} ions, however, act as weak acids. However, it is significant factor for development of soil acidity in peat and muck soils as well as mineral soils containing large amount of organic matter.

(*iv*) **Acidic parent material:** Soils developed from acidic parent material such as granite have low pH than 7.0.

(*v*) **Use of acid forming fertilizers:** Acid forming fertilizers such as $(NH_4)_2SO_4$, NH_4NO_3 and urea increase the soil acidity, if their use is prolonged. Use of urea continuously on the sloppy lands has produced soil acidity under Jammu soil conditions. Indiscriminate use of nitrogenous fertilizer poses health problems, details of which have been reviewed (Gupta and Singh, 2006).

Acid soils are deficient in available plant nutrients like Ca^{+2}, Mg^{+2} and to some extent of K^{+} as well as P and Mo and B. Strongly acidic soils contain Fe^{+3} and Al^{+3} in toxic concentrations. There is also poor microbial activity. Due to all the aforesaid reasons, the productivity of these soils is affected considerably. And as such these soils require to be managed for reclamation.

Reclamation of acidic soils

To reclaim or to manage the acidic soils, application of liming has been found to be the best method to control acidity. Its application assists not only in checking soil acidity but in increasing crop productivity. Leguminous crops have been known to respond more to lime application (Sharma and Sarkar, 2005) followed by those of cotton, maize, sorghum, wheat and linseed.

In Jammu and Kashmir the above said studies are lacking. It is because not much work has been carried out so far regarding occurrence and / or presence of acidic soils in compact area (Gupta *et al.*, 1992; Bhan, 1999 and Gupta *et al.*, 2007). It is, therefore, required to take up this kind of work on priority. Soil Scientists / Agronomists should come forward in this line. Till our own technology generates, lime application at the rate of 4–2 q ha^{-1} should be recommended in acidic soils of Jammu as identified by Bhan (1999) and Gupta *et al.* (2007). It should be applied in powder form in furrows along the basal dose of fertilizers.

Soil salinity and soil sodicity

Salinity and sodicity are the other problems of the soils of Jammu and Kashmir and those of Himachal Pradesh. These problems are due to the presence of salt affected soils or saline and sodic soils, which though are not as common as are found in soils of Punjab, Haryana and Uttar Pradesh.

Salinity is due to the presence of soluble salts like HCO_3, Cl and NO_3 of Ca^{+2} and Mg^{+2} (Gupta *et al.*, 1992; Sharma *et al.*, 2012). Electrical conductivity of these soils is always greater than 4 mmhos cm^{-1} and pH is less than 8.5. It exists in soils of *Kandi* belt of Jammu and Himachal Pradesh, alluvial soils of Jammu and Kashmir (Gupta *et al.*, 1988) vis-à-vis soils of some areas of cold arid zone – Ladakh and Lahaul and Spiti.

Sodicity is due to the occurrence of higher concentration of exchangeable Na^{+} which always exceeds more than 15 per cent of the total CEC (cation exchange capacity). The pH of these soils is always greater than 8.5. Najar *et al.* (2005) has reported macro and micronutrient status of some salt affected soils of Jammu, stating that they are low in available P and Zn. Characterization and classification of salt affected soils of Jammu district of Jammu and Kashmir have also been studied (Najar *et al.*, 2006).

Reclamation of salt affected soils

Although salt affected soils are potentially productive yet without suitable technology for their reclamation it becomes cumbersome to have to harvest production at desired level. A number of organic and inorganic amendments tried by various scientists to reclaim such soils for increasing food production which have been reviewed (Najar and Gupta, 1996). The results of the study regarding the effect of gypsum, FYM, *dhaincha*, gypsum + *dhaincha* and gypsum + FYM on physico-chemical properties of soil and yield of rice in the salt affected area in Jammu, indicated improvement in soil properties with concomitant increase in yield of rice (Table 6). Of the various treatments, application of gypsum + growing of *dhaincha* as green manure has proved more effective in increasing rice yield followed by FYM + gypsum.

Calcareous soils

Soils having free $CaCO_3$ in the diffused or segregated form are called calcareous soils. More than 5 percent of this form of carbonate in soils may produce a lime-induced chlorosis in many plants resulting in the depression of crop yields. Lime induced chlorosis is due to Fe-deficiency owing to high pH which make the soil iron unavailable to the plant. Excess of Ca^{+2} ion also causes deficiency of P and Zn.

Many soils of Jammu and Kashmir, Himachal Pradesh and Uttarakhand which owe their origin to Murree clays intercalated with sandstones, calcareous, shales and limestone, are afflicted with this problem (Thakur *et al.*, 2012). A number of soils of Jammu and Kashmir have been reported to possess lot of free $CaCO_3$ (Gupta *et al.*, 1980; Gupta *et al.*, 1992).

Control measures

Crop productivity of such soils can be enhanced by the use of organic materials like FYM, compost, vermin-compost. In rice growing soils, like-induced chlorosis can be overcome through green manuring coupled with adequate water management to keep the soil saturated or flooded all the time. Deficiency of Zn can be corrected by giving 2-3 foliar sprays of Zn solution.

Fragmentation land holdings

In India, land holding are being fragmented and subdivided due to increase in population, which is presently 1100 million. An average land holding has been worked out to be 1.4 ha in size. Merely 15 per cent of the farmers can be called large farmers having more than 1 ha of land and the rest 85 percent are small and marginal farmers. The Indian Agriculture is, therefore, heading towards a crisis owing to uneconomical holdings.

Like other Indian states, the human population of North Western Himalayan states has also increased tremendously. For example at 1981 census, population of Jammu and Kashmir was 59,87,389 which rose to 1,00,69,917 during 2001 census. Thus in a span of 20 years 40,82,529 mouths have added to the state's population inventory. In other words, on an average population grew by 2,04,126 person annum^{-1}. Thus, in the state of Jammu and Kashmir, out of 1.3 million holdings, more than half are below half an hectare. In other words, 52 per cent of the farmers hold just one-twentieth part of the hectare of land (1 kanal). Another 28 per cent of the farmers hold their land between one-twentieth and twentieth of hectare (1 to 20 kanals). Next there are nearly 0.2 million farmers who hold 1 to 2 hectare of land, constituting about 14 per cent of the farmers. Thus, 80 percent of the farmers of the state are marginal (having less than 1 hectare of land) and 14 percent are small (having land 1 to 2 hectare). It is point to mention that during 1991-1992, the percentage of marginal farmers was 74, which has now arisen to 80, while the percentage of small farmers has come down from about 17 to 14.

Table 6. Effect of amendments on soil ionic composition and rice yield

Treatments	**pH**	**EC (dS m^{-1})**	**Ionic composition (meq L^{-1})**					**Yield (q ha^{-1})**	
			CO_3^-	HCO_3^-	NO_3^-	Cl^-	SO_4^{2-}	Grain	Straw
Dhainacha	7.9	0.19	2.0	5.0	0.56	8.0	1.76	13.2	27.8
Dhaincha+gypsum	7.5	0.14	1.0	2.9	0.47	5.0	1.78	14.7	28.7
Farm yard manure	8.0	0.19	2.2	6.6	0.51	6.0	1.54	13.1	27.2
FYM+Gypsum	7.9	0.19	1.8	6.0	0.49	3.0	1.77	13.3	28.1
Gypsum	7.8	0.15	2.0	6.5	0.53	5.2	1.84	12.6	24.9
Control	8.3	0.34	2.6	8.7	0.60	9.5	1.86	11.7	23.7
CD (5%)	-	0.11	0.63	1.45	0.04	1.47	0.17	0.63	0.60

Source: Najar and Gupta (1996)

Similar is the situation of the holdings of Himachal Pradesh and Uttarakhand, where about 80 per cent of land holdings of the farmers have been found to have less than 1 hectare of land. These holdings like those of Jammu and Kashmir are far-off from viable equation. Moreover, these holdings are not compact but are scattered and are still being fragmented. The yield of the crops is very low. They grow only food crops for their own consumption.

Control measures

To increase the productivity of the crops of marginal farmers, it is required to evolve low cost technology for more effective use. The location specific technologies which stands generated by the State Agricultural Universities or Departments must be got advocated. Diversified agriculture is one of the options that needs to be popularized among farming community.

Emergence of monoculture

One of the main negative results of the "Green Revolution" in Indian Agriculture including that of North West Himalayas was the emergence of monoculture. It is now self-evident that maintenance of monoculture has lead to an increase in an ecological vulnerability and sustainability. Monoculture here means to growing of rice and wheat continuously in the past so many years. It was not only in North West Himalayan States but also in cereal-dominated agricultural production States like Punjab, Haryana, Uttarakhand and Western Uttar Pradesh, it has totally imbalanced the cropping system. It was, infact, the outcome of the high yielding varieties of rice and wheat requiring more water and fertilizers / pesticides during "Green Revolution". But the "Green Revolution" has reached a plateau and is now sustained with "Diminishing Returns and Falling Dividends" Excessive use of fertilizers, water and pesticides have caused soil sickness, diminishing underground water resources and emergence of new insects as well as waterlogging conditions and salinity (Gupta and Singh, 2006).

Soil sickness here refers to deterioration of soil structure, high bulk density values from the normal, deficiency of macro and micro-nutrients, change of biological characteristics, etc.

Control measures

In the light of the above, the only option is to follow timely and effectively space utilization in agriculture by adopting diversified agriculture and indigenous technology.

(*i*) **Diversified agriculture:** Diversified agriculture is an arrangement of farming enterprises which are managed in response to the physical, biological and socioeconomic environment. In this system of farming much more emphasis is given to cultivate pulses, oil seeds, fruits and vegetables *vis-a-vis* income generating avocations like mushroom cultivation, bee-keeping, sericulture, livestock rearing etc. Apart from these enterprises, there is lot of potential to grow medicinal plants.

(*ii*) In *Kandi* belt of Punjab, many farmers are now growing medicinal plants like *harar* (*Terminalia chebula*), *bahera* (*Terminalia belerica*), *amla* (*Phylanthus indica*). These plants are also being grown in *Kandi* area of Jammu. Many of the farmers are growing *neer brahmi* (*Bacopa moniera*), *ashwaganda* (*Withania somnifera*), *kawar gandhal* (*Aloe vera*) as well as fruit trees and forest tree species (Jamwal and Gupta, 2007).

(*iii*) **Use of indigenous technology:** Whichever quantity of FYM, compost, poultry manure is available with the farmers, they must be advocated to use them without any hesitation. However, these organic manures must be well decomposed prior to their using. Green manuring practice should also be used. Indigenous technology for nutrient management (Gupta *et al.*, 2001) should be followed wherever it is possible.

(*iv*) **Use of cow's urine:** When cow's urine is sprayed at 10 percent concentration to diseased plants, they soon recover and become healthy. Cow's urine is also used as foliar application to prevent withering of crop plants due to N deficiency.

(*v*) **Technology for preventing soil erosion:** In the degraded or eroded / denuded lands a number of shrubs are used by the farmers for controlling soil erosion (Gupta *et al.*, 2001). Growing of pulses like black gram on the raised bunds of paddy fields and maize helps not only to check soil but also enhances soil fertility.

(*vi*) **Adoption of organic farming / integrated nutrient management:** It is the need of the hour. However, organic farming alone will not increase food production for the requirement of burgeoning population, but both organic and inorganic sources of nutrients are needed, which is known as Integrated Nutrient Management.

Poor monsoon

"A poor monsoon refers to starvation deaths in the countryside and sharp rise in food prices in the urban areas. Contrary to this, rich monsoon would suffice an entire country in a sense of well-being." The effect of poor monsoon decline in crops has been felt since 1998. Failure of monsoon during 2002 resulted in a 3.2% decline in agriculture against 5.7% rise in 2001-2002 to bring down the overall growth from 5.6% to 4.3%. The farmers of Himachal, Uttarakhand and Jammu region of J&K suffered badly during *Kharif* 2004. Many of them could not sow crops because of delayed monsoon. During *Kharif* 2005, out of 524 districts, 276 districts of the country including some districts of North West Himalayas had scanty monsoon rainfall, which eventually wilted a number of crops.

Control measures

(*i*) **Rainwater harvesting:** Harvest rainwater in tanks / ponds after their construction / renovation.

(*ii*) **Setting up of agro-forestry:** Various systems of agro-forestry be set-up *viz.*, Agro-Forestry, Agro-Forestry-Horticulture, Agro-Forestry-Pastoral.

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Effect of organic and inorganic mulches on soil-moisture retention, weed suppression, yield and economics of eureka lemon (*Citrus limon Burm*) under rainfed condition in shiwalik foothills of Himalayas

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ABSTRACT

An experiment on Eureka lemon (Citrus *limon* Burm) was carried out during the 2009-2011 to assess the effect of different mulches viz bajra straw (*Zea mays*), maize straw (*Pennisetum glaucum*), grasses; Bermuda grass+ Johnson grass (*Cynodon dactylon + Sorghum halepense*)), brankad (*Adhotada vassica*), farmyard manure and black polyethylene). Both organic and inorganic significantly increased the soil moisture status in various soil depths. Black polyethylene mulch recorded the maximum moisture percentage followed by farm yard manure and brankad. Black polyethylene and farmyard manure were found to be more effective in producing maximum growth extension than rest of the treatments although the difference were non significant among the treatments. Plots treated with black polyethylene mulch recorded highest yield (1848 kg / ha) followed by farmyard manure (1780 kg / ha) and brankad (*Adhotada vassica*) (1744 kg / ha) while minimum in control (1560 kg / ha). The poor aeration, non decomposable nature and high cost are the constraints of using black polyethylene as mulch material. Higher benefit: cost (B: C) ratio (6.52) was observed under application of organic mulch of brankad (*Adhotada vassica*) compared to that of inorganic or synthetic mulches (3.85). Among the organic mulches evaluated, brankad (Adhotada vassica) showed best performance followed by bajra straw, maize straw and grasses.

Key words: Mulches, weed suppression, moisture conservation, yield, rainfed

INTRODUCTION

In Eureka lemon (*Citrus limon Burm)* has become the important fruit crop of rainfed condition of arid and semi arid regions of the country because of its precocity, thornlessness and heavy bearing nature, it becomes an important lemon cultivar all over the world. The Eureka grows year-round and abundantly. This is the common supermarket lemon. In these soils the major constraints are moisture stress and inherently poor soil fertility. The conservation of soil moisture by application of mulches becomes essential for profitable cultivation under rainfed condition of semi arid ecosystem. Mulches not only conserve soil moisture, but also impart other beneficial effects, like suppression of extreme fluctuation of soil temperature, reduce water loss through evaporation, resulting more stored soil moisture (Shirugure *et al.*, 2003), suppression of weed growth (Barman *et al.*, 2008), improvement in growth and yield (Shukla *et al.*, 2008). Under water scarcity conditions, irrigation is the most suitable option for water management. Various studies have indicated that in fruit crops like apple, sapota, and acid lime, mulching improves soil moisture status, growth, yield and quality of these fruits, besides reducing weed growth (Shirugure *et al.*, 2005). The application of mulches on soil surface is a very common practice in high-value crops. Mulching not only increases growth and yield of crops, but also improves the soil-moisture status, nutrient utilization, weed suppression, disease control and temperature regulation of upper layers of the soil (Solaiappan *et al.*, 1999) Keeping this in view, the present investigation was carried out to test the performance of various organic and inorganic mulches on the crop productivity as well as weed suppression, moisture conservation in the Eureka lemon so as to find the most suitable one for rainfed conditions of Jammu.

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MATERIALS AND METHODS

A study was carried out on 2 year old plants of air layered Eureka lemon which were planted in 2007 at distances of 5m x 5m and treated with different types of mulches at Rainfed Research Sub-Station for Sub-tropical Fruits Raya, SKUAST-J during 2009-10 to 2010-11. The treatments were: T_1, no mulch (hand-weeding), T_2, Bajra straw, T_3, Maize straw, T_4, Grasses, T_5, Brankad, T_6, Farmyard manure and T_7, black polyethylene. The experiment was laidout in a randomized block design replicated four times. Ten centimeter thick mulches viz. bajra straw, maize straw, grasses, brankad (*Adhotada vassica*) (20 kg) and Farmyard manure 6 bucket (30 kg) in each basin cover were during April. Inorganic mulching black polyethylene was spread on plant basin covering the soil surface around the plant basin. In control no mulch was applied. Soil moisture was taken gravimetrically from the 0-15 and 15-30 cm soil layers at monthly intervals. The density of weeds was recorded at 60 days of applying mulch in the basin of fruit plants. The manure, fertilizer and another horticultural operation were carried out as per standard practices under rainfed conditions. The fruits were harvested in the last week of August. The cost of production was analyzed in order to find out the most economic treatment of mulch material. All input costs including the cost for lease of land and interests on running capital were used in computing the total cost of production. The benefit cost ratio (BCR) was calculated as follows:

Benefit cost ratio=Gross return per hectare / Total cost of production per hectare

RESULTS AND DISCUSSION

Moisture conservation

The data in Table 1 showed that the increase in soil moisture content in mulching treatment was significant at both soil depth (0-15 cm and 15-30 cm). The higher soil moisture content was observed in black polyethylene at (0-15 cm and 15-30 cm) after days of mulching at both depths and the lowest soil moisture content was recorded in the basins of rainfed no mulch trees. These findings are in agreement with those of Singh *et al.* (2008). The higher soil moisture content in mulching treatments could be due to reduction in water erosion, reduction in soil surface evaporation, weed suppression regulation of soil temperature at, resulting in more stored soil moisture, and the lower soil moisture in control plots was due to higher evaporation from the bare soil surface of

Table 1. Effect of mulches on soil moisture content (%) 0-15 cm and 15-30 cm soil depths.

Treatment	Soil moisture content 0-15 cm							
	Days after mulching (DAM)							
	50 DAM		80 DAM		110 DAM		140 DAM	
	2009-10	2010-11	09-10	10-11	09-10	10-11	09-10	10-11
Control	5.82	6.82	6.11	7.12	9.12	10.12	13.53	14.12
Bajra straw	7.60	8.60	7.65	8.65	11.91	13.93	15.52	16.52
Maize straw	7.05	8.05	7.27	8.25	11.50	13.50	15.04	16.04
Grasses	6.58	7.58	7.11	8.12	11.04	13.04	14.61	15.92
Brankad	7.84	8.84	8.13	9.13	13.51	14.10	16.18	17.18
FYM	8.52	9.52	8.63	9.63	14.14	15.09	17.05	18.05
Black polyethylene	9.14	10.16	9.52	10.52	15.52	16.04	18.17	19.17
SEm±	0.11	0.21	0.18	0.27	0.16	0.22	0.15	0.22
CD (P=0.05)	0.33	0.63	0.54	0.83	0.50	0.68	0.45	0.68
15-30 cm								
Control	6.40	7.12	7.74	8.24	11.37	12.32	15.26	16.26
Bajra straw	9.03	10.03	9.08	10.08	12.83	14.58	17.86	18.91
Maize straw	8.72	9.78	8.81	9.81	12.32	14.32	16.92	17.77
Grasses	8.22	9.22	8.31	9.31	12.04	14.04	16.20	17.28
Brankad	9.12	10.12	9.22	10.22	13.51	15.50	18.04	19.04
FYM	9.83	10.83	9.96	10.71	14.14	15.94	19.32	20.32
Black polyethylene	10.83	11.83	10.98	11.98	15.52	16.52	20.52	21.50
SEm ±	0.25	0.27	0.21	0.22	0.22	0.24	0.25	0.37
CD (P=0.05)	6.40	7.12	7.74	8.24	11.37	12.32	15.26	16.26

the basin (Pande *et al*., 2005). The characteristics of polythene film prevented the loss of evaporable water from the underneath surface and condensed it under surface on cooling. Grasses was relatively less efficient in retaining soil moisture which might be due to its early decomposable nature which would have favoured the adsorption of evaporated water from the surface of the soil and in turn allowed it to get evaporated from its surface layer into the surrounding atmosphere. The organic and inorganic mulching provided consistently improved available soil moisture in plant basin due to which the plant roots remained probably active throughout the irrigation season resulting in optimum availability of nutrient and proper translocation of food materials which accelerated the fruit growth and development in Eureka lemon.

Vegetative parameters

Plant height

The data pertaining to growth of plant is presented in Table 2. The increase in plant height was recorded highest in black polyethylene, followed by farm yard manure and brankad mulch. The increase in growth of plant was possible due to increase in availability of soil moisture, nutrients and moderate evaporation from soil surface (Shirugure *et al*., 2005). The lowest growth of plant was recorded under control (no mulch), followed by grasses owing to high evaporation and less nutrient availability. Mulching with maize straw, bajra straw, grasses were found to be intermediate in their influence on plant growth. The positive response of most of the mulches on plant growth may be attributed to improve in plant growth. The higher soil moisture availability, addition of nutrients and less weed growth associated with mulches can be attributed to higher extension of growth under mulching treatment. These results are in conformity with the findings of Pande *et al*. (2005) and Singh *et al*. (2008).

Plant spread

The data presented in Table 2 depicted that the plant spread branches of (north-south) was the highest in the black polyethylene (2.15m) followed by farm yard manure (2.10 m) and brankad (2.04 m). While lowest was in control (1.79m). Similar trend was observed in the same treatment as (east-west) was the highest in the black polyethylene (2.11m) followed by farm yard manure (2.07 m) and brankad (2.00 m). The lowest growth of plant spread was recorded under no mulch (1.76m). The positive response of mulching treatments on growth characteristics might be attributed to congenial environment in root zone due to lower weed population, optimum soil moisture level, increased availability of nutrients and favourable soil temperature. These findings are in the agreement with those of Shirugure *et al*., (2003), Pande *et al*. (2005) and Singh *et al*. (2008).

Weed suppression

Weed flora of the experimental field of Eureka lemon consisted mainly of grasses viz. *Cynodon dactylon* and *Sorghum halenpense*; whereas broad-leaf weeds like *Amaranthus Virdis* and *solanum nigrum*; among sedges only *Cyperus rotundus*. The highest weed population was in control (hand weeding) (80 m^2) followed by maize straw, brankad (*Adhotada vassica*), bajra straw, grasses, FYM and the lowest weed population was observed in the black polyethylene mulch (35 m^2). Different mulch significantly affected the weed type and population because mulches on the soil surface (whether organic or inorganic) restrict the weed growth (Swenson *et al*., 2004).

Table 2. Effect of mulching on weed suppression and yield of Eureka lemon

Treatment	Plant height (m)	Plant spread (m)		Yield / plant (kg)	Yield / ha (Kg)	Weed population m^2
		North-South	East -West			
No mulch (hand weeding)	2.59	1.79	1.76	3.90	1560.00	80
Bajra straw	2.81	1.93	1.90	4.25	1700.00	50
Maize straw	2.93	1.98	1.94	4.30	1720.00	60
Grasses	2.75	1.88	1.86	4.20	1680.00	40
Brankad	3.00	2.04	2.00	4.36	1744.00	58
FYM	3.09	2.10	2.07	4.45	1780.00	38
Black polyethylene	3.16	2.15	2.11	4.62	1848.00	35
SEm ±	0.05	0.03	0.04	0.02	11.49	4.05
CD (P=0.05)	0.15	0.11	0.12	0.08	34.41	10.4

Yield

The fruit yield was significantly influenced by different mulches (Table 2). Plants treated with various mulches were more pronounced with respect to fruit yield compared with control. The increase in yield was mainly attributed to increase in availability of soil moisture for longer duration. Mulching with black polyethylene and farmyard manure recorded the highest growth resulting in increased yield. The highest fruit yield was recorded with black polyethylene (1,848 kg/ha) followed by farmyard manure (1,780 kg/ha), brankad (*Adhotada vassica*) (1,744 kg/ha) and lowest was in no mulch treatment (1,560 kg/ha). Yield with mulch by using maize straw, bajra straw and grasses were found to be intermediate, but superior to control (no mulch). Similar results of increased yield due to mulch were reported in citrus and other crops by Shirugure *et a*l. (2003), Neilsen *et al*. (2006) and Singh *et al*. (2008). They described that black polyethylene mulch increased 56-60% fruit yield as compared to un-mulched control which was due to better conservation of soil moisture, regulating temperature and suppressing weed growth.

Economic Analysis

The data in Table 3 depicted that the highest gross return (Rs 27,720 ha^{-1}) was recorded from black polyethylene mulch and the second highest gross return (Rs 26,700 ha^{-1}) was recorded from farm yard manure mulch. The lowest gross return (Rs 23,400 ha^{-1}) was recorded from control (hand weeding). However, the highest net return (Rs 22,100 ha^{-1}) was recorded from, brankad (*Adhotada vassica*) and the second the highest net return (Rs 22,800 ha^{-1}) was recorded from grasses. The lowest net return (Rs 17,400 ha^{-1}) was obtained from control (hand weeding). The highest benefit cost ratio (6.52) was recorded from brankad although black polyethylene mulch treatment gave the highest yield (1,848 kg ha^{-1}) and gross return (Rs 27720 ha^{-1}). The lowest benefit cost ratio (3.85) was recorded from black polyethylene mulch treatment. The use of polyethylene mulch was more expensive than those of other mulching treatments used. The increase in gross and net return and Benefit: Cost ratio under different mulch treatments was mainly due to higher early and total yield. These findings are in agreement with those reported by Nagalakshmi *et al.* (2002).

CONCLUSION

The study demonstrate the significant effects of organic and inorganic mulches on soil-moisture conservation, weed suppression, yield and economics of Eureka lemon under rainfed condition of Shiwalik foothills of Himalayas. Considering the situation of the present experiment, all organic and inorganic mulch materials were beneficial in getting higher yield especially black polyethylene mulch was more beneficial in terms of fruit yield. However, from economics point of view brankad (*Adhotada vassica*) was the best for increasing the productivity of Eureka lemon, which was biodegradable in nature with and is locally available organic materials.

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Table 3. Effect of mulching on economics of Eureka lemon

Treatment	Grass return (Rs ha^{-1})	Cost of production (Rs ha^{-1})	Net return (Rs ha^{-1})	Benefit : Cost ratio
No mulch (hand weeding)	23400	6000	17400	3.90
Bajra straw	25500	4800	20700	5.31
Maize straw	25800	4800	21000	5.37
Grasses	25200	4400	20800	5.72
Brankad	26100	4000	22100	6.52
FYM	26700	6000	20700	4.45
Black polyethylene	27720	7200	20520	3.85

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Introduction of pulse crop in rice-fallow system through use of conservation agriculture practices in western Odisha

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ABSTRACT

In eastern India, vast areas are lying fallow after the rice (*Oryza sativa* L.) crop is harvested. Rice-fallow areas can be better utilized in establishing pulse crop utilizing the residual soil moisture through conservation agricultural practices. To exploit these rice fallow areas with pulses, location specific and economically viable technology for better performances of pulses are required to be standardized through proper understanding of the system ecology and constraints. Conservation agriculture practices may help to establish the pulse crops like greengram, black gram, lentil, pea, etc. with the help of zero tillage (ZT) and residue mulching. Zero tillage helps in conserving in-situ residual moisture and timely sowing of crops after rice harvest and residue mulch helps in maintaining/conserving the soil moisture for longer period, thus enhancing the crop productivity. A field experiment was conducted for 2 consecutive years during 2011 and 2012, to study the effect of conservation agricultural practices on greengram (*Vigna radiata* L.) after the harvest of rice crop by utilizing the residual soil moisture. The study revealed that the grain yield, stover yield, yield attributes, system productivity and net returns were significantly improved with conservation agricultural practice involving zero tillage and rice residue cover on soil surface @ 3.0 t/ha with the maximum grain, stover yield, system productivity and net returns of 0.545, 1.641 and 5.60 t/ha, and ₹39,102/ha, respectively. Crop residue cover over ZT helped in conserving the soil moisture and creating better micro-climate for crop growth and development. The energy requirement for greengram cultivation was the minimum of 5491 MJ/ha in zero tillage without residue, while its requirement was maximum of 44,065 MJ/ha in conventional tillage with residues. It was concluded that a pulse crop like greengram can be successfully grown with the help of conservation agriculture practices with maximum yield and profit in rice-fallow areas, thus enhancing the system productivity and profitability.

Key words: Rice-fallow, pulse, conservation agriculture, Western Odisha

INTRODUCTION

In India, about 11.7 m ha area of kharif rice remains fallow in the subsequent *rabi* due to number of biotic, abiotic and socioeconomic constrains (Ghosh *et. al.*, 2012). Rice fallows basically imply to those low lands *kharif* sown rice areas which remained uncropped during *rabi* (winter) season due to various reasons such as lack of irrigation, cultivation of long duration varieties of rice, early withdrawal of monsoonal rains leading to soil moisture stress at planting time of winter crops, water logging and excessive moisture in November/December, lack of appropriate varieties of winter crops for late planting and stray cattle menace etc. (Ali, 2014). Pulses on account of low input requirements, short duration, ability to establish with surface broadcast and soil fertility restoration property are ideal for rice fallows. To exploit these rice fallow areas with pulses, location specific and economically viable technology for better performances of pulses are required to be standardized through proper understanding of the system ecology and constraints. There should have strong research support to deliver appropriate

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varieties, and matching crop management technology, suited to rice fallows cultivation. If this area is brought under cultivation it may help in improving the livelihood of millions of farmers.

Crop productivity in rice fallows is generally poor due to various bio-physical, biotic and abiotic stresses, poor crop management practices and socio-economic constraints. Among the abiotic constraints soil and water are the two major limiting factors which lead to low or stagnated pulse production in rice fallows. After harvesting of rice crop, low moisture content in the soil followed by fast decline in water table with the advancement of rabi season results in mid-and-terminal drought at flowering and pod filling stages adversely affecting the productivity of pulses. Soil hardiness, low organic matter, low microbial activity (*Rhizobium*) etc. are some of the constraints in rice fallow areas for pulse production. Under relay (*paira*) cropping, plant population is often low due to low seed rates, poor contact of seed with soil, seed rotting as well as dryness of soil in patches.

Resource conservation technology (RCT) which deals with soil moisture conservation, organic matter build-up and improvement in soil structure and microbial population could be an appropriate approach to address the problems in rice fallows. Therefore, if crop residues are retained on the soil surface in combination with suitable planting techniques, it may alleviate terminal drought condition in pulses by conserving soil moisture and bringing overall improvement in resource management. Minimum soil traffic by adoption of suitable technology involving no-tillage and minimum soil disturbance and management of crop residues could lead to favourable effect on soil properties that further enhance the overall resource use efficiency and productivity capacity in rice-fallows.

Productivity and profitability from second crops in rice fallow can be improved with suitable crop management technique even by utilizing residual soil moisture. Choice of appropriate crops and varieties, introducing early to medium duration varieties of rice to enable farmers to grow pulses on residual moisture in time and short duration varieties of pulses should be used that can escape terminal moisture and heat stress.

Taking the above into consideration, a study was conducted at the Instructional Farm and farmers' field with the objective to establish a pulse crop (greengram) in rice-fallow system and evaluate greengram on conservation agriculture practices via-a-vis conventional tillage practices.

MATERIALS AND METHODS

The field experiment was conducted at the Instructional Farm of College of Agriculture, Chiplima, Odisha, India (21° 52' N, 84° 16' E and 178.8 m above mean sea level) during 2011 and 2012. The experimental site falls under the sub-humid climatic condition in the eastern part of the country with average annual rainfall of 1530 mm, concentrated mostly in the months of June to October. The experiment with four treatments i.e., Conventional tillage without residues (CT-R), Conventional tillage with residues @ 3 t/ha (CT+R), Zero tillage tillage without residues (ZT-R) and Zero tillage with residues @ 3 t/ha (CT+R) was conducted in a randomised complete block design with 6 replications. The on-farm trials were conducted in farmers' field of the village Rupapali during 2012 only. These trials were conducted in collaboration with ATMA programme of the line agriculture department. The soil at the experimental site is of lateritic sandy loam type with pH 6.8, organic C 0.56%, total Kjeldahl N 0.07%, Olsen's P 21 kg/ ha and NH_4OAc-K 140 kg/ ha.

Greengram var "PDM 1" was sown at a uniform seed rate of 25 kg/ha in the 4th and 2nd week of January, 2011 and 2012, respectively with the help of zero-till seed-drill at 4-5 cm depth. The row to row spacing was maintained at 30 cm. Seeds were drilled directly into uncultivated (zero-till or no-till) seed beds, with specially designed inverted 'T' type furrow openers which create furrow grooves with reduced surface exposure and thereby help to maintain the in-groove humidity in a reasonably wet soil for better germination of seeds and emergence of seedlings. Rice crop residues were applied @ 3.0 t/ha just after sowing of greengram. A fertilizer dose of 20 kg N and 40 kg P_2O_5/ha was applied using the fertilizer sources as urea and SSP. These fertilizers were applied in the furrow of seed drill at the time of sowing.

Total number of pods in 10 plants was counted at harvesting and average value was expressed as pods/plant. Similarly, 10 pods were selected from each plant, and number of seeds/pod was recorded. From the final produce, about 500 g of sample was taken. One thousand seeds were counted, weighed and expressed as 1000-seed weight.

All the pods were picked from each plot and the finally harvested plants were threshed after sun-drying and cleaned by winnowing. The produce was weighed and expressed as grain yield in kg/ha. Bundle weight of the finally harvested plants was taken after sun-drying (before threshing). Stover yield was calculated after subtracting the seed yield, and expressed in kg/ha.

For estimation of energy inputs and outputs (expressed in MJ/ha) for each item of inputs and agronomic practices, equivalents were utilized as suggested by Mittal and Dhawan (1988); Baishaya and Sharma (1990); Panesar and Bhatnagar (1994); Singh *et al.* (1997). Energy efficiency, energy productivity and energy intensity were calculated using the following formula as suggested by Burnett (1982); Mittal and Dhawan (1988); Singh *et al.* (1997).

$$\text{Energy efficiency} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Net energy (MJ/ha)} = \text{Energy output (MJ/ha)} - \text{Energy input (MJ/ha)}$$

$$\text{Energy productivity (kg/MJ)} = \frac{\text{Output (grain + by-product) (kg/ha)}}{\text{Energy input (MJ/ha)}}$$

Economic analysis

The economic analysis in terms of gross and net returns and benefit: cost ratio (gross returns per rupee invested) was worked out on the basis of existing rate of inputs and output in local market. Total variable cost included the cost of input such as seeds, fertilizers, irrigation and various cultural operations such as ploughing, sowing, weeding, harvesting, threshing etc.

Gross returns = Value of greengram seed + value of green gram stover;

Net returns = Gross returns – total variable costs;

Benefit: cost ratio = Gross returns/total variable cost

System productivity: Productivity of rice-greengram cropping system was calculated in terms of rice equivalent yield (REY) by using following expression

REY of greengram = (Greengram yield x greengram price) / Rice price.

System productivity = Rice yield + REY of greengram

Statistical analysis

The data recorded for different parameters were analyzed with the help of standard analysis of variance (ANOVA) technique for randomized complete block design using MSTAT-C software. The results are presented at 5% level of significance (P=0.05).

RESULTS AND DISCUSSION

Growth parameters

Germination

The crop was sown on residual soil moisture after harvest of rice. The moisture content in the soil varied from 15 to 16%. The seed was sown at a depth of about 2.5 to 3.0 cm. The germination percentage in different treatments was similar. However, a more uniform and 2 days early germination was recorded in zero-tillage and conservation tillage in comparison to conventional tillage. The uniform germination in ZT and conservation tillage was due to the fact that the seeds were placed at a uniform depth with the help of ZT-seed drill, while in case of conventional tillage, the seeds were put at a variable depth, which led to differential germination. Moreover, the inverted ‘T’ type furrow openers of ZT-seed drill machine creates furrow grooves with reduced surface exposure, which helps to maintain the in-groove humidity in a reasonably wet soil for better germination of seeds and emergence of seedlings.

Plant height, dry-matter production and leaf area index

The plant height of greengram was initially higher in ZT, but subsequently taller plants were recorded in CT. Effect of residue became visible at later stages. At initial stages, plant height and dry matter production were almost similar in different treatments, but at the later growth stages, the treatments effects were visible (Table 1). Similarly, the plant height and dry matter production were significantly lower in zero tillage than conventional tillage at later growth stages. It is obvious that under zero tillage the soil became hard, in contrast to conventional tillage where the soil remained loose and facilitated root growth, nutrient uptake etc. resulting in better plant growth and dry matter production at early stages. It was significantly influenced by tillage and residue management practices. Treatment CT+R produced significantly higher dry matter than all other tillage and residue management treatments, except at 15 and 45 DAS, where it was statistically similar to ZT+R. The residue addition had positive impact under both CT and ZT practices.

Table 1. Dry matter accumulation and leaf area index in summer greengram under different tillage and residue management practices

Treatment	Dry matter accumulation (g/m^2)				Leaf area index		
	15 DAS	30 DAS	45 DAS	60 DAS	15 DAS	30 DAS	45 DAS
CT-R	3.84	31.44	120.95	183.80	0.068	0.570	1.844
CT+R	5.12	36.28	132.20	233.50	0.078	0.668	1.936
ZT-R	3.92	22.56	109.60	193.15	0.060	0.524	1.701
ZT+R	4.28	23.11	124.70	215.15	0.075	0.615	1.879
CD (P=0.05)	0.60	4.10	14.48	15.38	0.010	0.064	0.079

The Leaf area index (LAI) reached to its peak on 45 DAS. Tillage and residue management had significant effect on LAI. Continuously higher values were recorded under conventional tillage. The maximum LAI was observed in CT+R compared to other treatments while the lowest LAI was observed in ZT-R. Residue had positive effect on drymatter and LAI in all the stages.

Yield and yield attributes

Tillage and residue management resulted in significant differences in yields of greengram. Conventional tillage with residue treatment produced significantly higher seed yield than all other treatments (Table 2). Zero tillage with residue also produced significantly higher seed yield over ZT-R. In general, residue application over the years resulted in significantly higher seed yield than the treatment without residue application. The highest seed yield (580 kg/ha) and stover yield (1668 kg/ha) was recorded with CT+R. The lowest yields were obtained with ZT-R. Residue addition had significant impact in both conventional and zero tillage practices. Conventional tillage develops a favourable environment for crop growth and better nutrient use by the crops. Studies conducted by Sharma *et al.* (1999) revealed an increase of 18% plant height, 60% root length and 38% grain of greengram in conventional tillage than zero tillage. Similarly, 10.0 to 15.8% increase in yield was reported from a study conducted at Sriganganagar, Rajasthan (Siag, 2006). Conventional tillage had a positive impact on germination and crop growth rate (36% increase) in comparison to no-tilled plots (Sangakkara, 2007). However, in this study, the germination of greengram was not significantly influenced due to tillage practices. The yield improvement in conventional tillage with residue over only zero tillage was 52%. Similarly the difference between CT+R and ZT+R were nonsignificant.

Energy requirement

The tillage and residue management influenced the energy output significantly. The highest energy output from grain and stover was obtained from CT+R, followed by ZT+R. The total energy output was also highest in CT+R followed by ZT+R (Table 3). The lowest energy output was obtained from CT-R. In general, the energy output from stover was about three-fold higher than the energy obtained from grain. In general, zero tillage exhibited higher net energy, energy efficiency and energy productivity than conventional tillage. Application of crop residues drastically reduced the net energy and energy efficiency because of its higher energy input or requirement. On the other hand the same trend was not reflected in energy output and productivity because of improvement in almost all the growth and yield parameters and the yields (Table 1 & 2).

Gross and net returns

Conservation tillage with residues fetched the highest gross returns of Rs. 24, 050 closely followed by zero- till with residues (Rs. 22,612). The net returns were also higher due to application of residues irrespective of the tillage practices (Table 4), because

Table 2. Yield attributes and yields of summer greengram as influenced by cropping system and tillage-residue management

Treatment	Pods/ plant	Grains/ pod	1000-seed weight (g)	Branches/ plant	Seed yield (kg/ ha)	Stover yield (kg/ ha)	Biological yield (kg /ha)	Harvest Index
CT-R	7.08	4.04	21.80	1.40	376.3	1366	1742	0.22
CT+R	8.00	4.09	22.38	1.65	580.4	1668	2248	0.26
ZT-R	6.82	3.99	22.15	1.64	381.1	1437	1738	0.22
ZT+R	6.90	4.00	22.38	1.70	544.8	1641	2186	0.25
CD (P=0.05)	0.90	0.04	NS	0.21	50.6	139	105	0.02

Table 3. Energy relations in greengram as affected by tillage and residue management practices

Treatment	Energy requirement (MJ)	Energy output (MJ/ha)			Net energy (MJ/ha)	Energy efficiency	Energy productivity (kg/MJ)
		Grain	Straw	Total			
CT-R	6567	5532	17075	22607	16040	3.44	0.077
CT+R	44,065	8532	20850	29382	-14683	0.67	0.076
ZT-R	5491	5602	17962	23564	18073	4.29	0.074
ZT+R	42,991	8008	20512	28520	-14471	0.66	0.077
CD (P=0.05)		1045	2472	3,240			0.009

Table 4. Economics of cultivation of greengram as influenced by and tillage and residue management

Treatment	Gross returns (Rs/ha)			Cost of production (Rs/ha)	Net returns (Rs/ha)	Benefit : cost ratio
	Grain	Straw	Total			
CT-R	15,052	683	15,735	7720	8015	2.04
CT+R	23,216	834	24,050	10720	13,330	2.24
ZT-R	15,244	718	15,962	6510	9452	2.45
ZT+R	21,792	820	22,612	9510	13,102	2.38
CD (P=0.05)	2042	70	3,014		3014	0.24

Table 5. System productivity of rice-greengram under different tillage and residue management practices

Treatment	Rice yield (t/ha)	REYG* (t/ha)	System productivity in terms of REY(t/ha)	Net returns of system (Rs)
Rice - fallow	4.5	0	4.5	26,000
Rice-greengram (CT-R)	4.5	0.67	5.17	34,015
Rice-greengram (CT+R)	4.5	1.11	5.61	39,330
Rice-greengram (ZT-R)	4.5	0.79	5.29	35,452
Rice-greengram (ZT+R)	4.5	1.10	5.60	39,102

REYG: Rice equivalent yield of greengram

of higher yield due to better conservation of depleting soil moisture due to mulching effect of crop residues. On the other hand, withholding residues application resulted in the less gross returns in the range of Rs. 15,735 to Rs. 15,962 and net returns of Rs. 8015 to Rs.9452/ha irrespective of the tillage practices. However, zero tillage showed the higher benefit to cost ratio of 2.38 to 2.45 as compared to 2.04 to 2.20 with conventional tillage practices.

System productivity

After the harvest of rice crop, greengram crop was taken in different tillage and residue management practices. However, the general practice in the region is rice-fallow. Hence, the productivity of rice-greengram was compared with rice-fallow system and the system productivity was calculated under different tillage and residue management (Table 5). The system productivity in terms of rice equivalent yield (REY) was maximum of 5.61 t/ha in rice-greengram with CT+R, which was similar to rice-greengram with ZT+R (5.60 t/ha). These two treatments recorded 24.4 % higher productivity compared to only rice crop (rice-fallow system). Similarly, the maximum returns of Rs. 39,330 and 39,102 were obtained in rice-greengram with CT+R and rice-greengram with ZT+R, respectively. These two treatments recorded 50-51% % higher net returns compared to only rice crop (rice-fallow system).

CONCLUSION

Conservation agricultural practices involving zero tillage and residue recycling (ZT+R) helped in increasing the greengram productivity with increase in 45% grain yield over conventional tillage without residue recycling (CT-R) in rice – fallows. It is concluded that in rice-fallows, a pulse crop like greengram can be successfully established with the help of conservation agriculture practices with system productivity and profitability of 5.6 t/ha and Rs. 39,102/ha, respectively.

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Soil loss from agricultural lands in Eastern Ghat of Odisha - a case study of Koraput district

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ABSTRACT

Soil loss was estimated from agricultural lands of Koraput district in **Eastern Ghats of Odisha** applying Universal Soil Loss Equation (USLE). Annual soil loss to the tune of 13333.35 thousand tonnes was observed from the crop fields of the district covering 3.04 lakh ha area at the rate of 43.86 t ha^{-1} $yr^{-1.}$ Single cropped, double cropped and fallow lands contributed 68.8%, 20.7% and 10.5% of total soil loss, respectively. Maximum rate of soil loss (98.38 t ha^{-1} yr^{-1}) was found in case of fallow land. Under single cropped lands, maximum (68.53 t ha^{-1} yr^{-1}) and minimum (26.85 t ha^{-1} yr^{-1}) soil loss were obtained in case of *mung*-fallow-fallow and jowar-fallow-fallow, respectively. Under double cropped lands, maximum(53.71 t ha^{-1} yr^{-1}) soil loss was obtained in case of both maize-fallow-*kulthi* and maize-fallow-maize, and minimum (24.76 t ha^{-1} yr^{-1}) soil loss in case of small millets-fallow-other pulses. From double cropped lands, 70% less soil loss was observed when compared to single cropped lands of the district. Higher soil loss under single cropped lands may be due to upland situations and longer fallow period. Lower soil loss under double cropped lands may be attributed to mild slopping conditions, thick crop canopy due to better soil moisture and shorter fallow period. Restricting fallow period with good crop coverage and adoption of suitable soil and water conservation measures may help largely to curb soil loss and land degradation in Koraput district.

Key words: Eastern ghat; soil loss; erosivity; crop land; land degradation; strategy

INTRODUCTION

In India, out of 328 M ha, 187.8 million ha (57%) area is suffering from various forms of degradation (Sehgal and Abrol, 1994). Panigrahi *et al*. (2009) stated that any forms of agriculture involve alteration of ecological system and cause large-scale land degradation. Agriculture can result in soil erosion when improper management is applied on arable land (Oldeman, 1997). Pimentel *et al*. (1995) reported nearly one-third of the world's arable land has become unsuitable for cultivation due to water erosion only. Major portion (98%) of total soil loss from a watershed is from the cultivated croplands (Suresh *et al*., 2002). As a result of soil erosion, the total annual loss of productivity of major crops in India is 7.2 million tonnes (Brandon *et al*., 1995). Dass *et al*. (2009) reported that land degradation, subsistence farming with poor crop harvest has resulted into poverty in Eastern Ghats of Odisha. The Eastern Ghats of Odisha is spread over its 10 districts and is severely affected by various forms of erosion (Sikka *et al*., 2000). Koraput district falls under this region and is a true representation of Easten Ghat (Barman, *et al*., 2011). The rising population, limited cropping land and more food requirement has resulted into extension of cultivation on steep slopes in this region which are vulnerable to erosion. Undulating terrain, high intensity monsoon rainfall and runoff, and severe soil erosion are the major problems of Koraput district. It ranks first in severity of land degradation (412 thousand ha) including 400 thousand ha area affected by soil erosion **(**Maji *et al*., 2010). Keeping these land degradation problems in view, an attempt has been made under the present study to quantify the soil loss from the agricultural lands of Koraput district applying the Universal Soil Loss Equation (USLE). For

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predicting soil erosion, Universal Soil Loss Equation, popularly known as USLE model is most widely used throughout the world for estimating annual soil loss from agricultural basins (Ahmad and Verma, 2013). Soil loss from agricultural lands may be quite helpful in planning suitable conservation measures.

MATERIALS AND METHODS

Koraput district lies between latitude of 17º 4' N to 20º 7' N and longitude of 81º 24'4" E to 84.2º E at altitude varies from 500 to 1600 m above mean sea level. The total geographical area of the district is 881 thousand ha constituting 34.5 %, 21 % and 24 % cultivable land, forest, and barren & uncultivable land respectively. Soils are predominantly red, mixed red and yellow having sandy loam to sandy clay loam texture. Soils of Koraput district are low in N, P and organic matter content and having low nutrient value index (Patnaik et al., 2004). The annual rainfall in the district is 1567 mm distributed over in 83.9 rainy days. 79 % rainfall is recorded in 62 numbers of rainy days due to south-west monsoon. Most of the monsoon rain water is let off as high speed free surface flows which has a 'scour potential' and inflicts tremendous loss of valuable topsoil converting the fields into fallow (Panigrahi and Bhattacharya, 2008). More fallow fields and land degradation cause continuous decrease in net sown area in the district. Naik *et al*. (2013) reported cultivation on steep slopes locally called "*Podu chasa*" is prevalent among the resource poor tribal farmers of the district and is a major concern for environmental degradation and ecology.

Detailed information on land uses, soil type & texture, major crops / cropping pattern and rainfall in respect of Koraput district were collected from State Agriculture Department, Directorate of Soil Conservation, Bhubaneswar and the Soil Conservation Office (Survey), Bhubaneswar (Odisha), CSWCRTI, Research Centre, Sunabeda (Koraput), published reports i.e. District Statistical Hand Book of Koraput, Odisha Agricultural Statistics etc. The distribution of cultivable land, extent of slope and elevation derived from the district planning maps prepared by Survey of India, Bhubaneswar (Odisha). Other relevant information on physical characteristics of the crops were collected from published manuscripts and personal interview with scientists of Krishi Vigyan Kendra (KVK),Semiliguda (Koraput).

Soil loss from agricultural lands was determined applying Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) as given in equation 1. Rainfall Erosivity factor (R) was estimated using rainfall data from 1986 to 2012 employing equation 2 developed by Sudhishri and Patnaik (2004) for the Koraput region. Considering the local traditional cropping practice, R value for total crop growing seasons (*Kharif* + *Pre-rabi* + *Rabi*) was taken for soil loss calculation. The value of soil erodibility factor (K) was determined as 0.12 for Koraput district referring the published Technical Report,"Soil Erosion Odisha" NBSSLUP Publ.126 (2005). The value of slope length and slope gradient factor (LS) was computed by interpolating the LS data suggested by Panda *et al*. (2000) for the same region. They had used the formula suggested by NRCS Engineering Division, USDA as given in equation 3 to calculate the 'LS' factor for each slope gradient percentage(1-45%) with the help of remote sensing imagery and GIS technique. The values of crop management factor (C) of crops were adopted from different published journals and reports, whereas, for other local crops the values were approximated taking into consideration the canopy cover, shape and height and fraction of canopy cover (Panigrahi, 2007). The value of C was considered as 1 when the field was left fallow. The value of supporting conservation practice factor (P) was determined as 0.73 and assumed same for all the cropping systems referring the published Technical Report,"Soil Erosion Odisha" NBSSLUP Publ.126 (2005).

$$A = R\,K\,L\,S\,C\,P \qquad (1)$$

Where, A is the average soil loss (tonnes ha^{-1} yr^{-1}), R is the rainfall erosivity factor, K is the soil erodibility factor, L is the slope length factor, S is the slope gradient factor, C is the crop management factor and P is the supporting conservation practice factor

$$\text{Monthly } R = 6.02 + 0.464\,P \qquad (2)$$

Where, P is the monthly rainfall in mm and R is the rainfall erosivity factor in m ton.cm / ha.hr

$$LS = \sqrt{}\,(\lambda\ /\ (100(0.136 + 0.097\,s + 0.0139\,s^2)$$

(3) Where λ is measured slope length in the ûeld and s is slope gradient in percentage.

RESULT AND DISCUSSION

Major field crops grown in the district are paddy, ragi (finger millet), maize, niger and pigeon pea. During kharif paddy covers highest area of 114.28 thousand ha followed by ragi (73.02 thousand ha), niger (38.14 thousand ha), maize (18.85 thousand ha) and pigeon pea (5.45 thousand ha) (Odisha Agriculture Statistics). The details of cropping pattern of Korput district is given in Fig.1.

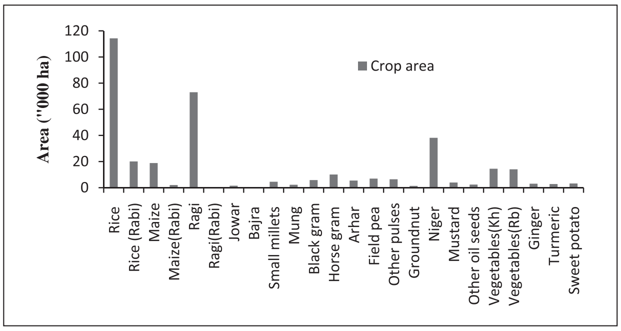

Fig. 1. Cropping pattern in *Kharif* and *Rabi* in Koraput district

The value of erosivity factor (R) was determined using equation 2 and found varied between 6.94 m ton.cm / ha.hr (in January) to 184.43 m ton.cm / ha.hr (in July). The annual R-factor was found as 755.36 m ton.cm / ha.hr which comes under higher erosivity range (>700 m ton.cm / ha.hr). Highest (1259.72 m ton.cm / ha.hr) and lowest (470.77 m ton.cm / ha.hr) value of R was found in the year 1990 and 2009 respectively. Due to high rainfall, more erosivity was observed during July to September compared to other months. The year and month wise rainfall and values of erosivity factor determined were given in Table 1 & 2.

Applying USLE, crop sequence wise annual soil loss from the agricultural field was calculated (Fig. 2 & 3). Soil loss to the extent of 13333.35 thousand tonnes was found annually at the rate of 43.86 t ha^{-1} yr^{-1} from the agricultural fields of the Koraput district. Single and double cropped agricultural fields contributed 68.8% and 20.7% of total soil loss at the rate of 44.23 and 38.92 t ha^{-1} yr^{-1} respectively. Maximum rate of soil loss (98.38 t ha^{-1} yr^{-1}) was found in case of fallow land sharing 10.5% total soil loss. Under single cropped lands, maximum (68.53 t ha^{-1} yr^{-1}) and minimum (26.85 t ha^{-1} yr^{-1}) soil loss was obtained in case of *mung*-fallow-fallow and jowar-fallow-fallow. Under double cropped lands, maximum(53.71 t ha^{-1} yr^{-1}) soil loss was obtained in case of both maize-fallow-*kulthi* and maize-fallow-maize, and minimum (24.76 t ha^{-1} yr^{-1}) soil loss in case of small millets-fallow-other pulses. From double cropped lands, 70 % less soil loss was observed when compared to single cropped lands of the district. Higher soil loss under single cropped lands may be due to upland situations and longer fallow period. Lower soil loss under double cropped lands may be attributed to mild slopping conditions, thick crop canopy due to better soil moisture and shorter fallow period.

Table 2. Month wise average rainfall and erosivity factor (R) for the period 1986-2012

Month	Rainfall (mm)	R(m ton.cm / ha.hr)
January	10.15	6.94
February	13.2	10.14
March	27.67	17.74
April	49.32	28.23
May	92.21	48.80
June	205.56	101.40
July	384.51	184.43
August	335.45	161.67
September	232.84	114.06
October	97.39	51.21
November	39.34	23.60
December	10.1	7.14
Total	1497.74	755.36

Table 1. Year wise rainfall and erosivity factor (R) for the period 1986-2012

Year	Rainfall (mm)	R(m ton.cm / ha.hr)	Year	Rainfall (mm)	R(m ton.cm / ha.hr)
1986	1401.70	722.63	2000	1189.30	606.02
1987	1213.80	635.44	2001	1411.40	715.09
1988	945.80	505.07	2002	1234.20	626.85
1989	1556.40	776.35	2003	1781.10	892.65
1990	2572.20	1259.72	2004	1677.30	844.49
1991	1845.40	916.47	2005	1271.80	656.34
1992	1470.30	742.42	2006	2156.40	1054.75
1993	1327.90	676.35	2007	1616.10	810.07
1994	1851.20	913.14	2008	1097.20	569.30
1995	2099.60	1040.43	2009	910.80	470.77
1996	1289.80	652.65	2010	1575.90	797.44
1997	1091.80	572.82	2011	1151.60	588.52
1998	1551.20	779.96	2012	1617.10	810.53
1999	1531.81	758.92	Average	1497.74	755.38

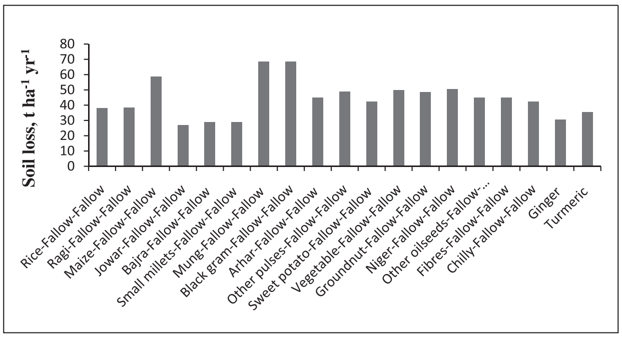

Fig. 2. Soil loss from single cropped lands

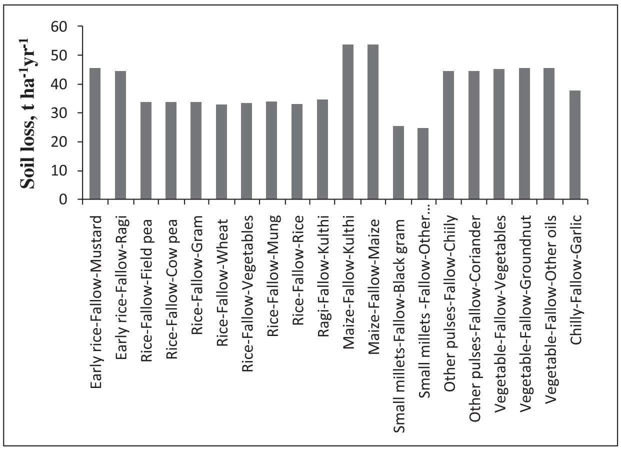

Fig. 3. Soil loss from double cropped lands

Strategy to check erosion

To curb soil loss and land degradation in the district, fallow period is to be restricted with good crop coverage on crop lands. Suitable low cost conservation measures are to be adopted on crop lands like field bunding, contour cultivation, land levelling in combination with field bunding, cultivation of erosion resistant crops and other agronomical practices. Provision for proper drainage for safe disposal of over land flow and runoff will prove highly beneficial to control erosion. On sloppy crop lands, where the erosion is more, land terracing may be adopted. The upper catchment area should be treated with in-situ conservation works viz contour trenching, contour ditching, staggered contour trenching, and vegetative measures to tackle the land degradation problem.

CONCLUSION

Quantitative assessment of soil loss revealed that soil to the extent of 13333.35 thousand tonnes was lost annually from the cultivable area of Koraput district at the rate of 43.86 t ha^{-1} yr^{-1}. Single and double cropped agricultural fields contributed 68.8% and 20.7% of total soil loss at the rate of 44.23 and 38.92 t ha^{-1} yr^{-1} respectively. Maximum rate of soil loss (98.38 t ha^{-1} yr^{-1}) was found in case of fallow land sharing 10.5% total soil loss. Keeping in view the severity of erosion, it is strongly recommended for adoption of appropriate soil and water conservation measures as discussed in strategy above besides keeping crop lands without fallow for erosion control and sustainable agricultural production.

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Modelling soil organic carbon using RothC model

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ABSTRACT

Soil organic matter turnover plays a key role in greenhouse gas emissions, soil structural stability, ion exchange, water quality and ecosystem sustainability. Soil organic carbon models may help in predicting and understanding future changes in SOC in response to changing climate, land use and land management practices. Soil organic carbon models have been used successfully to predict changes in soil organic matter content in the short or long- term and on different spatial scales. Among different SOC models, Rothamsted Carbon Model (RothC) is one of the simplest model and has been widely tested across different cropping systems in the world. This paper reviews the basic concepts of SOC modelling and estimation of soil organic carbon using RothC. It is suggested that RothC can be modified for different conditions by (i) adjusting rate constants, (ii) adding additional parameters and (iii) relating pools in Roth C to measured pools.

Key words: carbon, modelling, RothC

INTRODUCTION

Globally soils constitute the third largest global carbon (C) pool after oceanic (38 000 Pg) and geologic (5000 Pg) pools (Lal, 2004). The SOC pool, estimated at 1550 Pg to 1 meter depth is about twice the atmospheric pool (760 Pg) or 2.8 times the biotic pool (560 Pg) (Lal, 2008). Soil organic matter (SOM) consists of carbon, hydrogen, oxygen, nitrogen, phosphorus and sulphur.

It is difficult to measure SOM, but there are several reliable methods to determine SOC from which SOM can be calculated by the formula: SOM (%) = SOC (%) x 1.724 (Baldock and Skjemstad, 1999).

Organic matter in soils exists in different forms including colloidal organic matter, living micro- and macro-organisms, living plant roots, dead but little-altered plant remains, partly decomposed plant remains, and inert organic matter (Buringh, 1984). The main inputs of organic carbon are plant residues and soil amendments such as manures or compost. The loss of SOC from the soil includes respiration as a result of during decomposition of organic matter, leaching of organic carbon into the ground water, erosion of organic matter-rich top soil and burning of plant residues. Soil organic matter decomposition is a complex multi-stage process which is mediated by microorganisms. More than 90 % of SOM is decomposed by microorganisms (bacteria and fungi), but protozoa, earthworms, nematodes, molluscs and arthropods also play also a significant role. The rate of decomposition is affected by climate, substrate quality, and soil type. As a general rule, simpler compounds decompose more quickly than more complex compounds and decomposition is slower in climatic extremes. However, chemical composition and environmental conditions alone cannot explain observed decomposition rates and other factors such as changes in microbial community composition, have also been found to be important in determining decomposition rates (Schmidt et al. 2011). Therefore, decomposition of SOM is a complex process and the use of SOM models is an important research tool to understand SOC dynamics and develop management strategies to optimize the inputs for C sequestration.

Models are mathematical representations of the real system. Most SOM models are computer softwares and the user provides the input data to determine how SOC is exchanged between soil and the atmosphere. To date, there are 250 models for predicting SOC dynamics and nutrient turnover (Manzoni and Porporato, 2009). These models

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differ in underlying assumptions and the processes responsible for SOM decomposition. The aims of diûerent models are numerous and include, for example: inûuence of climate change on nutrient cycling in soils (Moorhead et al., 1999); prediction of feedbacks between terrestrial ecosystems and global climate (Moore et al., 2005); prediction of changes in soil C and N cycles related to land use changes (Findeling et al., 2007); and forecasts of crop productivity and system response under speciûc physical soil changes (Henriksen and Breland, 1999).The main aim of this review is to outline the basic concepts of SOC modelling and the processes used in decomposition of organic carbon using Rothamsted Carbon Model (RothC) which is a simple and transparent model and have been widely tested across the world under cropping, forest and grassland ecosystems (Coleman et al., 1997, Guo et al., 2007, Kaonga and Coleman, 2008, Nakamura et al., 2010).This review also provides information on application and modifications of RothC at regional, national and world scale, and measurable versus modelled pools.

Modelling of soil organic carbon

A model is a mathematical representation of the real system with well-defined boundaries. Turchin (1998) classified models into three types according to the goal of the model in question.

1) **Descriptive models** –are used to identify and obtain information on the characteristics of a particular issue and merely describe something mathematically. Common statistical models in this category include the mean, median, mode, range, and standard deviation.
2) **Explanatory models** –are used to understand phenomena by describing relationships among variables in a system
3) **Predictive models** –are used to predict a certain phenomena on the basis of hypotheses and general relationships among variables.

Among these models, the predictive models are most valuable for SOC, but also the most challenging.

The use of SOC models is an important research tool to understand SOC dynamics and develop management strategies to optimize inputs for C sequestration. Models can

1. quantify expected results
2. help understand the contribution of different underlying mechanisms to the observed results
3. explore the relationship between various components simultaneously
4. make future projections of changes in SOC under different management and/or climate scenarios
5. extrapolate results to other situations within the calibration conditions

Classification of soil organic carbon models

Models can be classified based on input, output, scope and application. Different classification schemes have been proposed to compare SOC models. Jenkinson (1990) classified SOC models into the following categories:

A. Single homogenous compartment models: These models assume a single compartment and have been applied mainly to organic N and C. Mathematically, they can be written as: $C= C_o\ (1-e^{-kt})$ where C is total C mineralized over a given time period, C_o is the potentially mineralizable fraction of organic C, k is the proportional rate constant. This equation assumes that the amount of organic material in the soil declines exponentially with time and the relative rate of decomposition is constant.

B. Two compartment models: These models assume that incoming plant material is divided into two pools, a fast and a slow pool, which decompose according to first order kinetics. Mathematically this can be written as : $C = C_s\ (1-e^{-st}) + C_f\ (1-e^{-ft})$, where C represents total C mineralized over a given time period t, C_s and C_f are the stable and labile fractions of organic C, respectively, and s and f are the proportional rate constants for C mineralization for the stable and labile fractions, respectively.

C. Non-compartmental decay models: The assumption behind these models is that during decomposition the organic matter moves down a quality scale. The quality of organic matter varies between zero for resistant plant material and one for fresh organic material.

D. Multi-compartmental models: These models assume that SOC is decomposed into various pools which in turn, decay by first order kinetics. Examples are CENTURY (Parton et al., 1988), RothC (Jenkinson, 1990), DAISY (Jensen et al., 1997) and DNDC (Li et al., 1997). Models in categories A and B are static (environmental variables remain constant), whereas the models in categories C and D are dynamic (environmental variables vary with time) (Falloon and Smith, 2000). The dynamic models can be further split into following four broad classes (Paustian, 1994):

i. **Process-orientated models:** simulate the processes controlling the flow of energy and matter transformations. Hence, SOC pools are linked to each other by C flow from one pool to another over time and these pools have different turnover time. The models in this category include CENTURY (Parton et al., 1988), RothC (Jenkinson, 1990), DAISY (Jensen et al., 1997), CANDY (Franko et al., 1997) and DNDC (Li et al., 1997) etc.

ii. **Organism-orientated models:** quantify the flow of nutrients and energy in soil biota, through various functional or taxonomic groups. For example the model for Rhizosphere C flow (Darrah, 1991).

iii. **Integrated models:** link process models to organism-orientated models. For example, SOMM (Soil organic matter dynamics in relation to decomposer organisms, Chertov and Komarov, 1996).

iv. **Cohort models:** convert SOM into different cohorts which are further divided into pools. Unlike process-orientated models where SOM decomposition is regulated by physical and biochemical processes, these models consider microbial physiology as the main driving factor for SOM decomposition (Batlle-Aguilar et al., 2010). For example, SOMCO (soil organic matter cohort, Gignoux et al., 2001).

As pointed out earlier, there are 250 models for predicting SOC dynamics and nutrient turnover (Manzoni and Porporato, 2009).Most of these SOM models divide SOC into different pools with distinct properties and rate constants. Another class of models determine SOC decomposition by an attribute called "quality". An example is Q model (Bosatta and Agren 1985) where the rate of SOM decomposition is related to a continuous change in "quality".

Rothamsted carbon model

Among the SOC models, RothC (Jenkinson and Rayner 1977, Jenkinson et al. 1987, Coleman and Jenkinson 1996) is used worldwide. RothC includes five pools of SOM: decomposable plant material (DPM, labile– cellulose and hemicellulose), resistant plant material (RPM, recalcitrant – lignin), microbial biomass (BIO, soil microbes), humidified SOM (HUM, humus) and inert organic matter (IOM) that is highly resistant to biological transformations (Coleman and Jenkinson, 1996). The incoming plant material is divided into DPM and RPM but the DPM / RPM ratio depends upon the vegetation type (1.44 for crops and grasses, 0.25 for deciduous or tropical woodlands and 0.67 for unimproved grassland and scrubland). Both DPM and RPM decompose to form CO_2, BIO and HUM (Figure 1). Biomass and humus further decompose into CO_2, biomass and humus pools but at a slower rate than DPM and RPM.

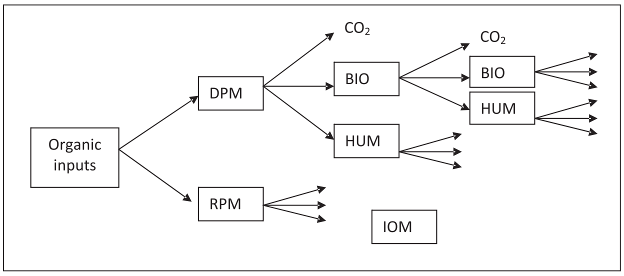

Figure 1: Structure of the RothC model

The amount of C (y) lost from each pool, except IOM, is described by first order exponential decay:

$y = y_0\ (1-e^{-abckt})$

where y_0 = initial amount of C in a particular pool; a, b and c are rate modifying factors for temperature, moisture and plant retainment, respectively; k is the rate constant for the given pool expressed per year and t is 1 / 12 to convert k to a monthly time-step.

The rate modifying factor 'b' accounts for the soil moisture deficit which is a function of soil clay content, monthly average rainfall and pan evaporation. Decomposition in the RothC model is also sensitive to whether the soil is bare or covered by vegetation. The modifier is 0.6 for actively growing vegetation (reduces decomposition rates by 40%) and 1 for bare soil. The size of the pools is defined by the rate constant, proportion of BIO to HUM (fixed in the model) and the ratio of CO_2 to BIO + HUM which varies according to the clay content with lower clay content leading to higher relative CO_2 release. The rate constant 'k' is 10 yr^{-1} for DPM, 0.30 yr^{-1} for RPM, 0.66 yr^{-1} for BIO and 0.02 yr^{-1} for HUM.

The inputs required to run the model are divided into three types:

1. Soil data : Initial SOC (t C ha^{-1}), clay content (%), depth of soil layer sampled (cm)
2. Land use and management data: soil cover, monthly input of plant residue (t ha^{-1}), and farm yard manure (t ha^{-1}).
3. Climate data: Monthly rainfall (mm), monthly open pan evaporation (mm) and average monthly mean air temperature (°C)

These input parameters must be known to run the model but plant input is rarely known and can be generated by the model by running it in inverse mode.

Evaluation, comparison and application of RothC

Once a model has been developed, its performance needs to be evaluated to:

1. assess how well the model performs in the situation for which it was developed.
2. understand the reasons if the model fails to perform well in a given situation.
3. predict future changes in SOC with confidence and a maximum degree of accuracy.

Models can be evaluated at point, regional or global scale. The performance of models depends upon required inputs, availability of input data at appropriate scale and hypotheses made for developing the model. Smith et al. (1997) evaluated nine SOC models against data from seven long term experiments under arable land use, grassland and woodland. Their results showed that six models (RothC, DNDC, CANDY, CENTURY, DAISY and NCSOIL) performed well with no significant difference in accuracy; the residual mean square error of these models was lower than the other group of models (ITE, Verberne and SOMM). Similarly, five SOC models (RothC, DNDC, CENTURY, EPIC and SOCRATES) were evaluated by Izaurralde et al. (1996) at a site specific and a regional scale in Canada. Among these models, SOCRATES was best for simulating long term SOC trends at site specific levels, but CENTURY was superior in predicting SOC trends at regional level because it, unlike SOCRATES, allows for different management strategies. Among all models, CENTURY (Parton et al., 1988) and RothC (Jenkinson et al., 1987) are most widely used for studying the impact of climate and land-use change on SOC. Using RothC, simulated SOC contents were an acceptable approximation of measured SOC in long-term experiments in Germany, Australia, Czech Republic, England and the USA (Coleman et al., 1997). RothC has also been successfully applied in Thailand (Shirato et al, 2005), China (Guo et al., 2007), Kenya (Kamoni et al., 2007), European Russia and the Ukraine (Smith et al, 2007), Zambia (Kaonga and Coleman, 2008), Slovakia (Barancikova et al., 2010), West Africa (Nakamura et al., 2010) and Japan (Yokozawa et al., 2010; Koga et al., 2011). Gottschalk et al. (2010) found that the ability of RothC to simulate SOC after deforestation can be improved after incorporating a new SOC pool (labile but protected carbon fraction). Cerri et al. (2003, 2007) used a chronosequence approach for studying changes in SOC after conversion of forest to pasture in the Brazilian Amazon and showed that RothC accurately simulated a decline in SOC following clearing and conversion to pasture. Gottschalk et al. (2012) simulated the impacts of future climate on global SOC stocks predicting an overall increase in global SOC stocks by 2100 under all scenarios.

Other RothC applications include prediction of future European forest SOC stocks (Smith et al., 2005), understanding the effect of interaction between soil moisture and C ûuxes on C sequestration (Marhan et al., 2009), simulating the C sequestration potential of calcareous grassland in north-western Switzerland (Niklaus and Falloon, 2006), determining of SOC turnover times under New Zealand forests and grasslands (Tate et al. 1995) and estimating SOC recovery times in degraded New Zealand soils (Parshotam and Hewitt, 1995). RothC can be used to simulate SOC adequately under different pastures provided a correct proportion of pasture production is used as soil carbon input (stubble retention factor as 0.65 and root / shoot ratio as 0.53 for annual pasture and 0.74 for perennial pasture) (Liu et al., 2009). Senapati et al. (2014) simulated SOC using RothC in irrigated Vertisols under cotton cropping systems in the sub-tropical Australia and concluded that rate modifying factors for tillage and soil erosion are required for accurate prediction of SOC using RothC.

Modifications of RothC for subsoils, waterlogged, salt-affected soils and Andosols

According to Coleman and Jenkinson (2005), RothC should be used cautiously on subsoils, soil from tundra and taiga regions, soils on recent volcanic ash and is not suitable for waterlogged soils. Later, Jenkinson and Coleman (2008) parameterized RothC for subsoils after incorporating two parameters, p (for downward movement of organic C) and s (for slow decomposition of SOM at depth). Shirato et al. (2004) modified RothC for Andosols of Japan by changing the rate constant of humic pool and setting inert organic matter to zero. They found that with the modified RothC, there was a good agreement between measured and modelled SOC inlong-term experiments on these soils. Further, Shirato et al. (2005) modified the decomposition rate constants of RothC by a factor of 0.2 in summer and 0.6 in winter for better performance of this model for paddy soils of Japan. Jiang et al. (2013) used the modified version of Shirato et al. (2005) to simulate SOC in paddy soils of long-term experiments in southern China. They found that RothC modified for paddy soils satisfactorily simulated SOC at all paddy-upland rotation sites and in all plots without organic matter application in double rice cropping system sites, but overestimated SOC in plots with organic matter application in double rice cropping system. These results suggest that RothC needs further modification for paddy soils which cover 32% of cropland in Southeast and South Asia (Xiao et al., 2006). Soil pH is one of the controlling factors for CO_2 emission from soils. Leifeld et al. (2008) found that ignoring soil pH effects in models may not simulate SOC accurately in the Swiss Alps. Setia et al. (2011) modified RothC for saline soils by incorporating decomposition rate modifier and plan input modifier for salinity. Their results suggested that due to the reduced plant input, SOC stocks in saline soils are predicted to be substantially lower than previously estimated. These studies suggest that RothC can be parameterized for different conditions by adjusting rate constants or adding additional parameters. However, there are no studies which included modifications of RothC for eroded, sodic and alkaline soils.

Measurable and modelled pools in RothC

The input pools in the model can be approximated to pools measurable either by chemical analyses or decomposition studies of different plant residues. Smith et al. (2002) showed that a measured pool is equivalent to a modelled pool only when it is unique and non-composite. Most studies initialize RothC using only measured total soil organic carbon and other input parameters, however there are a few studies where conceptual pools of the model were replaced by measured SOC pools. Skjemstad et al. (2004) showed that RPM, HUM and IOM pools of RothC could be replaced by POC (C associated with particles > 53 µm), humus (C associated with particles < 53 µm excluding char-C) and char-C (condensed aromatic C), respectively. They found a good agreement between measured and modelled pools after changing the decomposition rate constant (k) of RPM from 0.30 to 0.15 per year and retaining the original rate constant values for the other pools as proposed by Jenkinson et al. (1987). Similarly, Zimmermann et al. (2006) used a fractionation scheme to divide SOC pools into five fractions namely POC, DOC, C associated with silt plus clay (S_{SOC}), C associated with sand and stable aggregates (A_{SOC}), and resistant C (R_{SOC}). They found that POC+DOC could be replaced with DPM + RPM, S_{SOC} (minus R_{SOC}) and A_{SOC} with HUM+BIO and R_{SOC} with IOM. Xu et al. (2011) also used the fractionation scheme of Zimmermann et al. (2007) to partition the measured SOC into the pools required in RothC and they found that difference between measured and modelled RPM pool should be constrained to be less than 10% for accurate prediction of total SOC in the grassland soils of Ireland. However, Poeplau et al. (2013) found that the fractionation scheme of Zimmermann et al. (2007) was not described precisely enough for relating measurable pools with modelled pools. Shirato and Yokozawa (2006) identified DPM and RPM fractions in RothC by acid hydrolysis of plant materials. They divided C in plant material into three pools: labile pool I (obtained by hydrolysis with 5 N H_2SO_4), labile pool II (obtained by hydrolysis with 26 N H_2SO_4 and then with 2N H_2SO_4) and recalcitrant pool (unhydrolyzed residue). They found that labile pool I approximated the DPM pool and labile pool II plus recalcitrant pool approximated the RPM pool in RothC. Ludwig et al. (2003) compared measured and modelled pools of RothC using the ^{13}C technique. Total organic C and maize derived C in the <63 µm fraction were correlated with the sum of modelled total and maize derived C in the humic pool, inert organic matter and microbial biomass. Todorovic et al (2010) changed the rate constant of the humic pool from 0.02 to 0.009 y^{-1} and of the RPM pool from 0.3 to 0.6 y^{-1} to describe decomposition of ^{14}C-labeledstraw more accurately in a long-term ^{14}C-turnover field experiment in Austria. Rethemeyer et al. (2007) initialised RothC using IOM which was measured using three approaches: (i) estimation via total soil organic carbon (SOC) as proposed by Fallon et al (1998) (II) by quantifying the amount of black carbon as an indicator of IOM and (III) radiocarbon and mass balance (^{14}C). They found that all approaches gave a similar good agreement between measured and modelled data in the soils with recent organic matter but the ^{14}C approach was successful in matching the measured data of soil with a fossil carbon.

CONCLUSION

Due to the importance of SOC for future climate and soil fertility, it is crucial to understand SOM / SOC turnover. Calibrated and validated SOC models, such as. RothC can be used to provide estimates of the effects of management practices and future climate on the amount of C stored in soil. RothC is a simple and transparent model and can be used to estimate both SOC stocks and CO_2 release in regions, countries or globally over time scales ranging from a few days to centuries and millennia taking into account different climate and management scenarios. This model can be easily calibrated and modified for different cropping systems and soil conditions, but further research is required for waterlogged and degraded soils.

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Changes in microbial biomass carbon of soils amended with different organic manures and tillage practices in rice-wheat system

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ABSTRACT

A field experiment was conducted at IARI, New Delhi for two years (2006-08) with rice-wheat cropping system to see the changes in microbial biomass carbon of soils amended with different organic manures and tillage practices. Treatments in main plots comprised two tillage treatments viz. puddled and non-puddled in rice and with tillage and no-tillage in wheat. The sub-plots included seven fertilizer treatments including recommended doses of urea (120 kg N ha^{-1}), urea + FYM, urea + green manure (GM), urea + municipal solid waste (MSW) compost. Results showed that grain yield of rice and wheat was higher under puddle/ tilled condition compared to non-puddled/ no-tillage conditions. Integrated application of organic manure with mineral fertilizer gave the higher grain and straw yield compared to other treatments. Application of organic matter with or without mineral fertilizer increased the soil microbial biomass carbon (MBC) contents at 0-15 cm soil layer. Application of mineral fertilizer at recommended dose recorded lower MBC content compared to organic added plots. However, at 15-30 cm soil depth fertilizer or manure application did not affect MBC of soil. Puddling significantly increased the MBC of soil in rice crop and maximum MBC was found in FYM treated plots followed by green manure treated plots in both puddled and non-puddled soils. Soil MBC was on peak at flowering stage of the rice and wheat crops. Thus integrated application of organic manures and chemical fertilizer and reduced tillage resulted in enhancement of MBC in rice-wheat cropping system.

Key words: carbon sequestration, microbial biomass carbon, organic carbon, organic amendments, rice-wheat system

INTRODUCTION

The rice wheat cropping system (RWCS) of the Indo-Gangetic Plains (IGP) in South Asia is vital for food security and livelihood for millions of people. This system is practiced on more than 13.5 million hectares (m ha) in South Asia. In India, the RWCS is spread over five states in the IGP namely, Punjab, Haryana, UP, Bihar and West Bengal covering an area of about 10 m ha(Prasad, 2007). In the IGP, the increased adoption of rice-wheat has resulted in a heavy usage of irrigation, fertilizer, electricity and diesel. Long-term experiments conducted in Indian IGP showed that there is a stagnating or declining trend in productivity at several locations even with application of N, P, and K fertilizers under modern intensive farming (Sinha *et al.*, 1998). Over time more nutrients are removed than the amount externally added through fertilizers and manures. Farmers, therefore, have to apply more fertilizers to get the yield as they were getting with less fertilizer 20-30 years ago. Although there are reports indicating declining organic carbon in these systems (Swarup *et al.*, 2000) much work needs to be done to clearly understand the soil carbon dynamics. Judicious nutrient management is crucial to soil organic carbon (SOC) sequestration in tropical soils (Bhattacharyya *et al.*, 2007; Mandal *et al.*, 2007). Adequate supply of nutrients in soil can enhance biomass production and SOC content (Van Kessel and Hartley, 2000). Use of organic manure and compost enhances the soil microbial biomass carbon (MBC) pool more than application of the same amount of nutrients as mineral fertilizers (Gregorich *et al.*, 2001). It is, however,

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argued that SOC sequestration in tropics is a major challenge in soils of the tropics and sub-tropics, where climate is harsh and the rate of C mineralization is high because of high temperature and the humification efficiency is low (Ladha *et al.*, 2003). Therefore, we need to identify such carbon management strategies that may be needed for sustainable development of agriculture. Enhancing organic matter content of our soils will ensure better soil fertility as well as assist in sequestering atmospheric carbon. Enhanced soil MBC levels could possibly also be used for carbon trading to sell these credits to carbon deficit nations. With this background a field experiment was conducted to estimate the productivity and MBC of soils amended with different organic manures in rice-wheat system of Indo-Gangetic region.

MATERIALS AND METHODS

The experiments growing rice and wheat for *kharif* and *rabi* seasons for two years(2006-2008) were conducted at the farm of Indian Agricultural Research Institute (IARI), New Delhi situated at a latitude of 28°40' N and longitude of 77°12' E, altitude of 228.6 meters above the mean sea level (Arabian Sea). The climate of Delhi is sub-tropical semi-arid with hot and dry summers and cold winters under average climatic conditions. The area receives 750 mm annual rainfall, about 80% of which occurs from June to September. The mean annual maximum temperature is 35°C while the mean annual minimum temperature is 18°C. The soils are well drained with the ground water table at 6.6 and 10 m depth during the rainy and summer seasons, respectively. The alluvial soil of experimental site had 7.82 pH and sandy clay loam texture. At the beginning of experiment, composite soil sample had 250.0 kg ha^{-1} total N, 13.2 mg kg^{-1} NH_4-N, 31.0 mg kg^{-1} NO_3-N, 56.5 kg^{-1} available P and 406.0 kg^{-1} available K.

Field experiments were conducted with rice (*Oryza sativa* L.) variety *'Pusa Sugandh-5'* during *kharif* seasons of 2006 and 2007. The experiments were laid out in a split plot design. The main plots comprised two tillage treatment viz. puddled and non-puddled. The sub-plots included seven treatments each with 3 replications in plots of 7.5 m long and 7.00 m wide. In puddling treatments, cross ploughing was done with disc plough and then water was filled 12 hours before puddling. Transplanting was done 8 hours after puddling. In non-puddled treatments water was filled after cross ploughing of field and then transplanting was done. The C, N, P and K content of the applied organic manures is provided in Table 1. In the year 2006 and 2007 transplanting was carried out on 22 and 18 July, respectively and a row to row spacing of 20 cm and plant to plant spacing of 15 cm was maintained. Details of the treatments are given in Table 2. Urea was used as a source of mineral nitrogen and applied in 3 equal splits as per the

Table 1. Composition of different organic amendments (dry weight basis)

Organic sources	C (g kg^{-1})	N (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})
FYM	318	9.6	2.9	4.8
GM (*Sesbania aculeata*)	410	20.7	1.9	18.5
Compost (MSW)	35	2.5	4.0	1.56

Table 2. Effect of different nutrition and tillage practices on grain yield of rice and wheat under different tillage conditions during 2006 and 2007

Treatment	Rice				Wheat			
	Puddled		Non-puddled		Conventional tilled		No- tillage	
	2006	2007	2006	2007	2006-07	2007-08	2006-07	2007-08
T_1	5.18	5.3	4.21	4.10	5.11	5.59	4.19	3.97
T_2	5.96	5.89	4.76	4.8	5.87	5.59	4.92	4.59
T_3	4.95	4.9	4.08	4.2	4.42	4.67	3.75	3.86
T_4	5.58	5.7	4.85	4.8	5.62	5.78	4.56	4.40
T_5	4.78	4.8	4.23	4.07	4.73	4.86	4.03	3.97
T_6	5.65	5.8	4.62	4.55	5.37	5.47	5.02	4.38
T_7	4.60	4.95	3.91	3.85	4.63	4.63	3.98	3.82
LSD (<0.05)	0.35	0.26	0.35	0.26	0.26	1.16	0.26	1.16

T_1: 120 kg mineral N ha^{-1}(control); T_2: 120 kg mineral N ha^{-1} + 6000 kg FYM ha^{-1}; T_3: 60 kg mineral N ha^{-1} + 6000 kg FYM ha^{-1}; T_4:120 kg mineral N ha^{-1} + 3000 kg GM ha^{-1}; T_5:60 kg mineral N ha^{-1}+ 3000 kg GM ha^{-1}; T_6:120 kg mineral N ha^{-1}+ 60 kg N ha^{-1} (MSW Compost); T_7: 60 kg mineral N ha^{-1}+ 60 kg N ha^{-1} (MSW Compost) treatment. Phosphorus (60 kg P ha^{-1}) and potassium (50 kg N ha^{-1}) were applied as basal. Irrigations were provided at every two days throughout the cropping period to maintain the saturation moisture regime. Farmyard manure (FYM) was incorporated in soil two weeks before transplanting at the rate 6 t ha^{-1}. On dry weight basis it contained 0.96% N, 0.29% P and 0.48% K. Green manuring crop *(Sesbania aculeata)* was incorporated (3 t ha^{-1}) in soil before transplanting. Municipal Solid wastes (MSW) compost was incorporated at the rate of 60 kg N ha^{-1} two weeks before transplanting. Wheat (*Triticum aestivum*) variety 'PBW-343' was sown on last week of November at a row spacing of 22.5 cm. Urea was applied as per the treatment in three splits, half at 24 days after sowing(DAS) and the remaining half in two equal splits at 40 and 90 DAS. Phosphorus (60 kg P ha^{-1}) and potassium (50 kg N ha^{-1}) were applied basally. Five irrigations were applied at 20, 41, 63, 83 and 107 DAS. FYM, green manure and MSW compost were applied in the same way as in rice. The experiments were laid out in a split plot design. The main plots included two tillage treatment viz. conventional tillage (CT) and no-tillage. In conventional tillage treatments, two times cross ploughing was done with disc plough and once by cultivator and then sowing was done. In no-tillage treatments sowing was done with no-tillage seed drill. The sub-plots included seven treatments as done in rice crop. Each treatment was replicated thrice. Plots size in rice as well as wheat was 7.5 m x 7.00 m and same layout was used for two years in both the crops. Wheat crop was harvested in third week of April.

Soil samples from 0-15 cm and 15-30 cm depth were collected in 3 locations from each plot at different crop growth stages like sowing, tillering, flowering and harvesting. The soil samples was analysed for microbial biomass carbon (MBC) at different stages of crops. The entire volume of soil was mixed thoroughly and subsamples were used for analysis. Fresh soil was used for determining MBC. Soil was air-dried for 7 days, sieved through 0.2 mm screen, mixed and stored in sealed plastic jars for further analysis. The MBC content in soil was determined by fumigation extraction method (Witt *et al.* 2000). Observations on yield of rice and wheat were recorded at 14% moisture and expressed in tonnes ha^{-1}. The data were analyzed statistically using MSTAT-C (version 1.41), developed by Crop and Soil Science Division, Michigan State University, USA.

RESULTS AND DISCUSSION

Grain yield of rice and wheat

Grain yield of rice as well as wheat were significantly affected by integrated application of organic amendments in both the tillage conditions. In puddled conditions, grain yields of rice ranged from 4.60 to 5.96 t ha^{-1} and 4.8 to 5.89 t ha^{-1} and in non-puddled conditions from3.91 to 4.85 t ha^{-1} and 3.85 to 4.80 t ha^{-1} in wet seasons of 2006 and 2007, respectively (Table 2). In conventionally tilled conditions, grain yield of wheat ranged from 4.42 to 5.87 t ha^{-1} and 4.63 to 5.78 t ha^{-1} and in no tillage condition from 3.75 to 5.02 t ha^{-1} and 3.82 to 4.95 t ha^{-1} in dry seasons of 2006-07 and 2007-08, respectively. Grain yield of rice and wheat were increased when FYM, GM and MSW compost were added with recommended dose of mineral nitrogen. However, yield of rice and wheat declined when 50% of mineral nitrogen was substituted with organic sources i.e., FYM, GM and MSW. Treatments with addition of organic manures along with mineral N (urea) gave higher yield in both rice and wheat due to rapid and higher nutrient availability as compared with the mineral fertilizer treatment. Treatments with addition of organic manures along with urea gave higher yields in both rice and wheat because of higher and balanced nutrient availability as compared with the mineral fertilizer treatment (Singh *et al.* 1997). Goyal *et al.* (1997) observed higher crop yields and N uptake with the addition of *Sesbania* GM. The yields in the MSW compost treatments were at par with the farm yard manure and green manure treatments in both rice and wheat. The yield data obtained clearly demonstrate the superiority of the integrated use of FYM, GM, compost and chemical fertilizers, which provided greater stability in crop production in comparison to mineral N treatment. The beneficial effect of integrated use of N with organic amendments was more pronounced and effective in enhancing the productivity. This could be associated with other benefits of organics apart from N, supply, such as improvements in microbial activities; better supply of macro- and micronutrients such as S, Zn, Cu, and B, which are not supplied by mineral fertilizers and less losses of nutrients from the soil (Abrol *et al. 1997;* Yadav *et al. 2000*). The higher wheat yields obtained on FYM, GM and compost amended plots in both conventionally tilled and no-tilled wheat were possibly caused by the better supply pattern of N, P, and K and improved soil physical conditions (Yadvinder-Singh *et al. 2004).* Increase in rice yield and residual effects in the next wheat crop due to FYM application has been reported (Kundu *et al.* 2007; Singh *et al.* 2011).

Dynamics of soil microbial biomass carbon (MBC)

MBC in rice plots

MBC of rice plots at 0-15 cm depth was significantly affected by nutrient application practices and tillage treatments during both the years (Table 3). Non-puddled plot with application of mineral N at recommended rate (T_1) recorded significantly lower MBC than other integrated applied organic amendments. Maximum value of MBC was recorded with GM (212 mg kg^{-1}) at flowering stage followed by FYM (203 mg kg^{-1}) at sowing time and harvesting in puddled soil. At tillering stage FYM treatment (T_2) showed highest MBC (191.2 mg kg^{-1}) followed by green manure treatment in puddled soil. MSW compost applications also affected soil MBC at all the crop growth stages. In puddled soil application of FYM and green manure led to 10% and 20% higher MBC as compared to other organic amendment treatment, respectively however, in non-puddled such trend was not recorded. In non-puddled soils MBC was found to be the highest in green manure treated plots at flowering stage.

At 0-15 cm soil layer MBC was found to increase gradually during the plant growth period and it was maximum at the flowering stage. MBC decreased sharply at harvesting stage except in the FYM applied plots. Mineral fertilizer application did not have any significant effect on MBC of soil at 15-30 cm layer. However, puddling significantly increased the MBC of soil at both 0-15 and 15-30 cm soil layers (Tables 3 and 4). In 15-30 cm soil layer MBC value of GM treatment during sowing was 102 mg kg^{-1} while in non-puddled soil it is 76.5 mg kg^{-1}.

MBC in wheat plots

In wheat plots at 0-15 cm depth, MBC of wheat soil organic fertilization with mineral fertilizer was significantly higher than sole mineral fertilized (control) plots under CT and no-tillage conditions (Table 5). Higher values were observed in integrated applied FYM (T_2), GM (T_4) and MSW compost (T_6) plots. Maximum value was recorded in FYM treatment (209.5 mg kg^{-1}) at flowering stage followed by FYM treatment at tillering stage (213.4 mg kg^{-1}) in wheat field. Similar to rice in wheat also soil MBC was found to be maximum at flowering stage and declined thereafter. In the second soil layer (15-30 cm) MBC was not at all affected by the fertilization treatments (Table 6) and MBC values were lower at this depth than 0-15 cm.

Tillage operations significantly affected the soil MBC at 15-30 cm soil layer in rice and wheat crop. At both the stages puddled/ tilled soils showed significantly higher MBC as compared to non-puddled/ tilled soils. Tilled soil recorded maximum soil MBC (209.5 mg kg^{-1}) at flowering stage of the crop. Non-tilled soil showed highest values of soil MBC (197.5 mg kg^{-1}) at tillering stage. At the flowering stage puddled soils were found to have more MBC than non puddled soils in all the organically treated plots.

Use of organic matter through FYM, GM and MSW compost resulted in higher microbial activity leading to increased MBC content of soils. Since biological activity is concentrated near the surface, in the first year MBC of lower soil layer (15-30 cm) did not show much change in both the years. Similar observations were also made by Gunapala

Table 3. Influence of different nutrition and tillage practices on MBC content (mg kg^{-1}) of rice soil (0-15 cm) at different stages in 2006 and 2007

Treatment	Puddled						Non-puddled					
	Before transplanting		Flowering stage		At harvest		Before transplanting		Flowering stage		At harvest	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
T_1	160.2	159.0	161	162	160.2	173.0	137.3	146.2	131	169	136.6	162.0
T_2	203.2	213.0	191	233	203.2	213.0	144.2	198.2	152	216	137.1	181.1
T_3	171.4	180.0	171	195	171.4	183.0	153.7	176.2	144	183	153.0	172.2
T_4	178.1	202.0	212	214	178.2	207.1	157.2	177.0	153	199	158.0	169.2
T_5	169.3	176.0	170	181	169.5	173.4	129.2	173.0	140	174	129.2	174.5
T_6	178.5	182.0	185	213	178.2	181.2	151.8	157.0	143	182	152.3	167.2
T_7	168.2	165.2	178	170	168.2	164.5	133.5	167.0	139	171	134.1	163.2
LSD(<0.05)	12.43	16.23	13.6	9.65	10.79	14.64	12.43	16.23	13.6	9.7	10.8	14.64

Table 4. Influence of different nutrition and tillage practices on microbial biomass carbon (mg kg^{-1}) of rice soil (15-30 cm) at different stages in 2006 and 2007

Treatment	Puddled						Non-puddled					
	Before transplanting		Flowering stage		At harvest		Before transplanting		Flowering stage		At harvest	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
T_1	67.2	93.1	73.2	95.4	73.2	78.4	72.3	88.3	77.5	78.7	74.2	88.3
T_2	101.2	98.7	79.7	96.3	76.4	91.8	75.4	89.5	79.9	95.5	73.6	73.1
T_3	75.2	95.6	82.9	93.3	65.1	99.2	71.1	87.5	80.3	92.3	69.9	86.9
T_4	102	96.2	81.3	97.2	79.7	93.4	76.5	97.8	81.2	76.3	68.4	71.8
T_5	90.2	95.4	71.6	84.1	71.6	90.8	75.8	92.1	68.7	82.4	76.2	77.0
T_6	80.1	96.1	66.7	89.7	71.6	87.4	71.2	79.3	74.3	84.5	82.4	71.0
T_7	80.2	90.3	81.3	82.0	66.7	86.1	76.8	78.6	70.1	74.8	79.5	84.7
LSD (<0.05)	6.68	5.21	7.42	6.57	10.43	11.41	6.68	5.21	7.42	6.57	10.23	11.41

Table 5. Influence of different nutrition and tillage practices on MBC (mg kg^{-1}) of wheat soil (0-15 cm) at different stages in 2006-07 and 2007-08

Treatment	Conventional village						No tillage					
	Before sowing		Flowering stage		At harvest		Before sowing		Flowering stage		At harvest	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
T_1	153.8	148.2	157.2	156.2	151.2	152.0	164.5	156.0	175.1	159.0	162.5	153.0
T_2	204.2	184.6	209.5	191.2	179.6	179.1	189.5	180.0	201.5	188.2	188.0	171.0
T_3	169.0	167.5	176.5	173.0	177.9	162.0	176.2	171.2	185.2	175.0	185.4	168.2
T_4	182.0	180.0	192.5	191.2	182.9	170.0	185.2	174.2	190.5	184.0	179.2	166.0
T_5	170.0	167.0	175.1	169.2	167.3	161.2	170.0	165.1	179.2	164.0	169.5	157.0
T_6	200.0	184.0	202.5	193.2	170.3	175.2	180.1	182.2	176.7	178.0	175.5	171.0
T_7	163.0	159.2	168.0	153.5	155.1	145.2	170.2	159.2	173.5	157.0	167.2	151.0
LSD (<0.05)	9.81	6.10	5.99	6.40	5.07	5.90	9.81	6.10	5.99	6.40	5.07	5.90

Table 6. Influence of different nutrition and tillage practices on MBC (mg kg^{-1}) of wheat soil (15-30 cm) at different stages in 2006-07 and 2007-08

Treatment	Conventional village						No tillage					
	Before sowing		Flowering stage		At harvest		Before sowing		Flowering stage		At harvest	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
T_1	81.1	73.9	73.7	71.6	73.7	84.5	71.5	69.9	71.6	73.7	71.6	79.6
T_2	87.9	88.3	98.7	81.5	80.5	75.2	80.4	71.8	79.1	79.3	79.1	75.0
T_3	72.0	80.0	83.5	77.0	74.0	72.0	74,7	70.0	76.6	73.0	76.6	74.0
T_4	84.7	66.4	89.9	80.6	78.5	75.2	82.2	70.6	81.0	82.2	81.0	72.8
T_5	86.0	74.3	84.6	79.2	76.4	82.1	73.7	75.2	75.4	84.4	75.4	78.3
T_6	85.0	71.9	79.2	77.4	73.7	83.2	79.5	82.7	80.2	78.4	80.2	72.5
T_7	79.6	71.6	92.4	73.5	71.7	81.5	76.3	79.2	75.2	77.6	75.2	66.7
LSD (<0.05)	NS*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Non significant

and Scow (1998). Hossain *et al.* (1995) also observed that fertilizer application has significant effect on MBC of surface soil. According to Gupta *et al.* (1994) microbial biomass, the living portion of soil organic matter, responds rapidly to changes in soil and crop management practices. They showed that cultivation resulted in smaller increases in MBC at 0-5 cm, but this was offset by larger increases at 5-10 cm depth, particularly in the stubble incorporated treatment. During the crop growing season the microbial activity was probably highest during flowering stage of the crop and therefore microbes tended to assimilate more carbon for their energy requirement. Besides this at flowering stage maximum translocation of nutrients occur from soil to plant. So activity of microbes in rhizosphere is highest at this stage, which might have caused high values of microbial biomass carbon. The decrease in MBC thereafter may be due to a shift in the composition of the micro flora of the soil (Acquaye *et al.*, 2000). Higher MBC in puddled soil might be due to the fact that standing water in the puddled rice fields gave rise to anaerobic condition which resulted in greater microbial activity near the root zone and ultimately higher microbial biomass. Application of carbon through FYM resulted in higher microbial biomass than sole mineral fertilized plots (control), which may be due to the fact that it had a high C: N ratio as compared to green manure and MSW compost, which slows down the mineralization process. Microbes take longer time to decompose these organic manures and bring the nutrients in available form and so these are available for a longer duration. Besides this most of the manures remain in the soil surface where biological activity is less (Stewart, 1993). So MBC content of soil became somewhat less in this treatment in wheat. Since microbes are mostly active in the rhizosphere so at greater soil depth MBC did not get significantly affected by fertilizer application. Puddling i.e. the repeated tillage of saturated (submerged) soil, has considerable effects on the physical, chemical and biological properties of soil that influences microbial growth. It softens soil, promotes root growth and reduces water and nutrient losses by leaching, thereby increases nutrient and organic carbon availability (Sharma *et al.*, 2003). Availability of organic carbon may also be increased by the mechanical breakdown of organic matter due to repeated tillage of the inundated soil. Puddled and the subsequent submerged condition in rice thus provides a favorable environment for the growth of microbes, particularly soil bacteria (Roger, 1996) resulting in higher MBC in soil. Moreover, spontaneous growth of photo dependent free-living blue green algae (BGA) is a basic feature in wetland rice fields. The growth of these microbes and the subsequent decomposition of their biomass contribute towards the higher MBC in puddled rice soils compared to the non puddled soils. A favorable temperature in the puddled soil compared to the aerobic soils (Gajri and Majumdar, 2002) may also contribute towards enhanced microbial activity and higher MBC in soil.

Overall trends during rice-wheat cropping

In rice-wheat cropping system, soil MBC of 0-15 cm soil layer was also found to be higher during the growth of the second rice crop in puddled soil and the maximum value were recorded with FYM application with recommended dose of mineral N (Table 3 and 5). Two years of rice-wheat cropping resulted in decrease in MBC in puddled / tilled and non- puddled / no-tilled crops of rice / wheat. During the first rice crop highest MBC value was seen in green manure applied plots (212 mg kg^{-1}) while in second rice it is in FYM treatment (233 mg kg^{-1}). In both the wheat crops MBC was found to be slightly higher in tilled site but the difference was not significant. In non-puddled soils there was a slight increase in MBC values from the initial ones (137.3 to 153 mg kg^{-1}). But highest value (233 mg kg^{-1}) was recorded during the second rice crop in FYM treatment (Table 3). In non-puddled soils initially MBC was much lower than puddled one. After two years of rice-wheat cropping MBC of non-puddled soil increased. Less water application in non-puddled soil might have resulted in slower activity of microbes, which ultimately lowered the MBC of soil. Numerous studies have reported decrease in microbial biomass due to drying of the soil (Van Gestel *et al*., 1992). In puddled soils MBC of 15-30 cm soil layer was also found high during second rice crop. At 15-30 cm soil layer MBC was low (71-82 mg kg^{-1}) at the time of transplanting in non-puddled soil and no significant change was observed in the MBC value after the harvesting of second year rice crop.

It was concluded that 100% replacement of mineral N with FYM, GM or MSW compost showed good potential in increasing grain yield and MBC in soils of rice-wheat system. Increasing MBC in soil indicated for higher soil productivity leading to increased crop yield under rice- wheat cropping system. Integrated nutrient management including manure and chemical fertilizer was an appropriate technology for increasing soil microbial biomass carbon and crop productivity.

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Effect of coloured plastic mulches on earliness, water productivity and production economics of summer squash under high hills of North-West Himalayas

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ABSTRACT

A field experiment was conducted during 2009 and 2010 to assess the effect of plastic mulch colours on vegetative characters, earliness, water requirement and production economics of summer squash in Uttarakhnad state. Four coloured plastic mulches, viz. black, blue, green and transparent along with unmulched control were tested for summer squash production with four replications in a randomized block design. The results indicated that all the growth parameters, *viz.* plant height, collar diameter, plant spread, number of leaves/plant and root length were found maximum in black mulched followed by blue mulched plants. Similarly, black plastic gave the maximum fruit yield (64.70 t ha^{-1}), which being 63.54 % higher over control (39.56 t ha^{-1}), was statistically at par with blue mulch (61.55 t ha^{-1}). Data pertaining to water requirement reveals that least water utilized to produce per kg of fruit i.e. water productivity (37.56 liter kg^{-1}) was observed with black plastic mulch and also registered net profit (Rs. 2,12,072.00) and benefit cost ratio (2.48).

Key words: Plastic mulch, production economics, summer squash, vegetative characters, water productivity

INTRODUCTION

The State Uttarakhand is endowed with diverse agro-climatic conditions suitable for year round production of vegetables especially off-season vegetables in hills. Off-season vegetables fetch relatively higher returns for the producer as well as have high market growth prospects. Summer squash (*Cucurbita pepo* L.), a member of Cucurbitaceae family, is also an important off-season vegetable of Uttarakhand hills. Being a short duration crop the produce comes early in the market during summer and fetches handsome returns to the growers. In rainfed high hills, spring-summer (February to July) has been observed to be the best time for its cultivation. The production is constrained by low temperature during initial growth period followed by its fluctuations in latter part of the growth, moisture stress, less and erratic precipitation, depletion in available soil moisture and high wind velocity (Bhatt *et al.*, 2011). This dependency on natural factors restricts its early as well as quality production and limits the scope of its profitable cultivation. Thus, protection against abiotic stresses is a key to successful cultivation. The working group on horticulture constituted by the Planning Commission, Government Of India had recommended deployment of Hi-tech horticulture and precision farming for achieving vertical growth in horticulture. One of the Hi-tech interventions in horticulture crop is *in-situ* moisture conservation through plastic mulching (Samuel and Singh, 2004). Mulches are the growers' first line of defense in providing ideal conditions for plants and are easy and cost effective. Mulching, i.e. covering of soil surface around the plant, is an age old practice and can be done by using various materials such as organic materials (dry leaf, paddy straw, dry leaves/twigs/grass, paddy husk, dry coconut leaves/husk etc.) as well as inorganic materials (plastic films). The non availability in adequate quantity for commercial application and difficulty in application in cropped area are the major limiting factors in commercial use of organic mulches. In contrast, the plastic films are easily

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available, easy to handle, transport and lay. A linear low density polyethylene (LLDPE) film has been proved better mulch because of its puncture resistance quality, thinness and lower cost (Panda, 2004). This leads to use of plastic films as most preferred material for mulches. A wide variety of vegetables can be successfully grown by using mulches. Cucumbers, squashes, capsicums, melons, tomatoes, cole crops and okra have shown significant increase in earliness, yield and quality (Singh *et al.*, 2005). Government of India is also providing subsidy @ 50% with a ceiling of Rs. 10,000.00 ha^{-1} per farmer under National Horticulture Mission. In addition to soil and moisture conservation, improved yield and quality, suppression of weed growth, mulches can improve the water and nutrient use efficiency with the reduction in labour requirement and drudgery (Singh *et al.*, 2012). Now various colours are available in the market for selecting as mulch. Further, by proper selection of mulch colour, the soil micro-climate could precisely be controlled as per the target plant. Very little work has been done so far on the effect of mulch colour on yield and water use efficiency of summer squash in Uttarakhand hills, therefore, the experiment was conducted to study the effect of different available coloured mulches on earliness, water productivity and production economics.

MATERIALS AND METHODS

The study was conducted at Horticultural Farm of Krishi Vigyan Kendra, Gwaldam of G.B. Pant University of Agriculture and Technology, Pantnagar, in Chamoli district of Uttarakhand during the spring-summer season of 2009 and 2010 to find out the effect of different colour plastic mulches on growth, yield and water use efficiency of open field summer squash against without mulch. The experimental site is situated in mid-high hill zone of Garhwal Himalayas and lies at 30^0 1' North latitude and 79^0 34' East longitudes at an altitude of 1950 m above mean sea level. Four coloured plastic mulches *viz.*, black, blue, green and transparent were used in summer squash crop along with control (no mulch) treatment. The experimental site has sandy loam soil (19% clay, 18% silt and 63% sand) having pH – 5.80, EC – 0.60 dSm^{-1}, organic carbon- 0.85% with bulk density- 1.52 mg m^{-2}. The available N, P_2O_5 and K_2O contents were 275 kg ha^{-1}, 32.5 kg $ha^{-1}$and 410 kg ha^{-1}. The fertilizers were applied @ 180 kg N, 100 kg P_2O_5 and 150 kg K_2O per hectare. The seeds of summer squash variety Ducato were sown in polybags on 10 February during both the years under plastic low-tunnel. Thirty days old seedlings were transplanted on raised beds of plot size 9m x 3m at row spacing of 90 cm and plant to plant spacing of 75 cm. The different colour mulches of 25-micron thickness were cut as per the size of the plots and laid on the raised beds four days after transplanting when the seedlings got established. Recommended cultural practices were followed in raising the crop. The observations were recorded on plant height, collar diameter, plant spread, number of leaves / plant, root length, days to 50% flowering (male as well as female), days to first harvest and total marketable yield with partitioning in early and late yields as per standard techniques. These investigations carried out using five treatments *viz.*, black, blue, green and transparent plastic film along with unmulched control were tested under completely randomized block design replicated four times. Data were statistically analyzed as per statistical methods suggested by Panse and Sukhatme (1989) and pooled data were presented.

The seasonal water use, water conserved as well as water productivity (WP) were also calculated as irrigation water is a scarce natural resource in Uttarakhand hills particularly in summers. The water requirement was measured using standard procedures. The average daily pan evaporation (PE) value and mean daily depletion (MD) values for each treatment were also worked out. Benefit-cost ratio was calculated to determine the economic feasibility of using plastic mulches. The cost of summer squash production includes cost of all inputs, wages of labour (including family labour also) incurred since seed sowing for nursery raising to final picking / harvesting and expenditure on transportation and marketing. The gross and net returns were worked out accordingly by taking the prevailing average market price of the early and late yields of the crop during the periods of harvesting which were 700.00 q^{-1} and 400.00 q^{-1} respectively.

RESULTS AND DISCUSSION

The data presented on growth parameters (Table 1) indicated that all the vegetative traits were positively and significantly influenced by the plastic mulches irrespective of the mulch colour. All the growth parameters *viz.*, plant height (39.75 cm), collar diameter (21.24 mm), plant spread (143.26 cm), number of leaves / plant (41.90) and

Table 1. Effect of mulch colour on vegetative characters of summer squash cv. Ducato (pooled)

Treatment	Plant height (cm)	Collar diameter (mm)	Plant spread (cm)	No. of leaves $plant^{-1}$	Root length (cm)
Black mulch	39.75	21.24	143.36	41.90	37.48
Blue mulch	38.52	20.79	137.31	39.19	36.81
Green mulch	29.47	17.71	115.62	32.85	33.05
Transparent mulch	35.90	18.93	129.07	36.19	35.58
Control	25.14	17.58	104.45	26.82	30.02
CD at 5%	1.87	1.57	5.40	1.74	1.58

Table 2. Effect of plastic mulch colour on earliness and yield of summer squash cv. Ducato (pooled)

Treatment	Days to 50% flowering (female)	Days to 50% flowering (male)	Days to first harvest	Early yield (t ha^{-1})	Late yield (t ha^{-1})	Total marketable yield (t ha^{-1})	Yield increase over control (%)
Black mulch	28.00	33.67	42.00	32.23	32.47	64.70	63.54
Blue mulch	27.67	33.83	43.33	28.32	33.23	61.55	55.59
Green mulch	29.00	36.17	47.67	20.14	25.59	45.73	15.60
Transparent mulch	26.33	32.33	40.33	29.89	23.96	53.85	36.12
Control (no mulch)	32.17	37.67	52.00	16.75	22.81	39.56	-
CD at 5%	1.50	1.50	2.33	2.14	2.81	4.90	-

root length (37.48 cm) were found maximum in black colour which was closely followed by blue colour film in all the respective characters. These characters were also significantly superior in transparent and green plastic films over control as the same character values were obtained lowest in unmulched plots. Improvement in growth characters as a result of mulches might be due to enhanced photosynthetic rates and other metabolic activities. Mulching enhances early growth as it can positively affect the soil plant system, soil temperature, reducing evaporative humidity with good weed control (Hatt *et al.*, 1994).

Compared to the unmulched control, the plastic mulches significantly advanced the flowering in summer squash plants (Table 2). In cultivar Ducato female flowers appeared first and in transparent plastic mulched plants it was the earliest (26.33 days) followed by blue mulch (27.67 days) and black mulch (28.00 days), however, without any significant difference among these three treatments with respect to the trait. Almost similar trend was seen in respect of days to 50% male flowering as black, blue and transparent mulched plots exhibited no significant difference for the trait with the transparent film showed the earliest flowering. The earliest marketable maturity was also observed in transparent (40.33 days) followed by black (42.00 days) plastics with no significant difference between these two values. This crop advancement (10-12 days) can fetch a premium price early in the season. Green mulched plants were the inferior among the mulch treatments in respect of earliness in flowering and yield while unmulched control being the poorest in respect of the traits under investigation. Plastic mulches had also shown significant influence on early and total yields. It was black plastic which produced the maximum early and total yields (64.70 t ha^{-1}) which was 63.54% higher over control. The blue mulched plots yielded 61.55 t ha^{-1} fruits with 55.59% increase over control and had no significant difference with black film in respect of yield. The transparent and green mulched plants also showed highly significant yield increase over control but both are also significantly inferior to black and blue films as far as total yield is concerned. Earliness in flowering and fruiting with significantly higher yields in plastic mulches owed to the direct effect of plastic mulch on the micro-climate around the plant as it modifies the radiation budget (absorbitivity vs. reflectivity) of the surface and decreasing the nutrient leaching as well as compaction of the soil which provides better environment for root growth (Orzolek *et al.*, 2003). Besides improved plant micro-climate plastic mulch films have an effect in higher yields as they are nearly impervious to carbon-di-oxide. ‘Chimney effect’ might have been created, resulting in abundant CO_2 for the plants which might have added higher plant growth and fruit yield grown under plastic mulches (Singh *et al.*, 2005). Similar results with early growth, flowering and fruiting with plastic mulches in cucumber, summer squash, cucumber and tomato were also observed by Farias-Larios *et al.* (1994), Orzolek *et al*. (2003) and Singh *et al*. (2005), respectively. Earlier reports also confirmed the present findings of positive response of summer squash to dark blue (Orzolek and Lamont, 2002) and black coloured mulches (Singh *et al.*, 2011) with respect to early growth and higher yields.

The seasonal water requirements for the crop in black, blue, green and transparent plastic mulch along with control plots were 24.3, 26.9, 27.1, 30.0 and 35.8 cm, respectively (Table 3). It is clear from the data that the black, blue, green and transparent mulches saved 32.12, 24.86, 24.30 and 16.20 per cent of irrigation water respectively over control. The PE / MD ratio for the black, blue, green, transparent and control plots were 1.55, 1.39, 1.38, 1.24 and 1.03 respectively. PE / MD ratio was recorded to be maximum (1.55) with highest water conserved over control (32.12) in black mulched plot which may be due to the fact that the losses through evapo-transpiration was minimum in this treatment. The similar trend was also found in water productivity (WP) as least water is required to produce one kilogram summer squash fruit in black film (37.56 litre kg^{-1}) followed by blue film (43.70 litre kg^{-1}), transparent (55.71 litre kg^{-1}), green film (59.26 litre kg^{-1}) with the maximum water requirement in control (90.50 litre kg^{-1}) to produce one kilogram of fruit. The seasonal water use, total yield and WP of all the treatments also depicted in Fig. 1. Mulching reduces the water evaporation by interfering the radiation falling on the soil surface and thus delays the drying of the soil and increases WP. The highest WP in black mulched plot was due to absence of light which did not allow photosynthesis under the film and therefore weed growth was depressed. On the contrary with transparent film, the presence of light with the improved condition for growth encouraged weed growth (Manutention, 1984). Further, adequate presence of moisture to the plants due to increased WP in plastic mulch treatments results in full cell turgidity and eventually higher meristematic activity leading to more foliage development, greater photosynthetic rate and consequently better plant growth with higher yields.

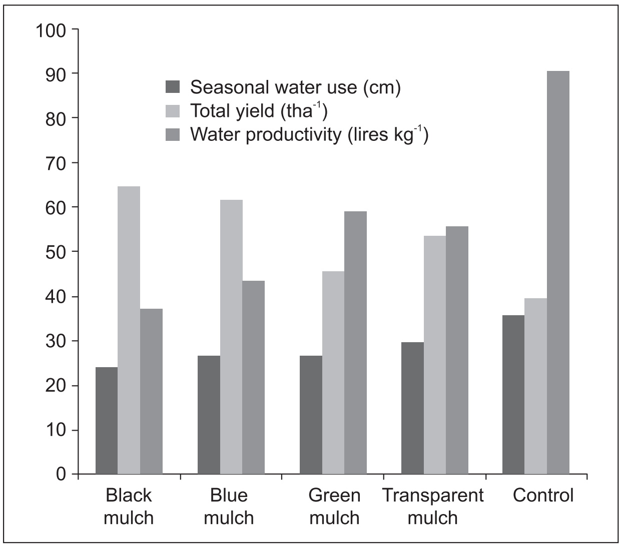

Fig.1. Effect of coloured plastic mulches on seasonal water use, total yield and water productivity of summer squash

Table 3. Effect of mulch colour on water conserved and water productivity (pooled)

Treatment	Seasonal water use (cm)	Water conserved (%) over control	Mean daily depletion (MD) cm day^{-1}	PE / MD ratio	Water productivity (litre kg^{-1})
Black mulch	24.3	32.12	0.397	1.55	37.56
Blue mulch	26.9	24.86	0.442	1.39	43.70
Green mulch	27.1	24.30	0.445	1.38	59.26
Transparent mulch	30.0	16.20	0.495	1.24	55.71
Control (no mulch)	35.8	-	0.596	1.03	90.50

Mean daily pan evaporation (PE)= 0.614 cm day^{-1}

Table 4. Production economics of summer squash under different mulch colours (pooled)

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	BCR
Black mulch	143558.00	355630.00	212072.00	2.48
Blue mulch	141873.00	331160.00	189287.00	2.33
Green mulch	138876.00	243340.00	104464.00	1.75
Transparent mulch	140352.00	305070.00	164718.00	2.17
Control	118500.00	208490.00	89990.00	1.76

The economic analysis of the summer squash cultivation under plastic mulches was also carried out with the objective to realize the economic feasibility of this technology (Table 4). The economic analysis revealed that black plastic mulch is most profitable, giving highest gross return (355630.00 ha^{-1}), net return (212072.00 ha^{-1}) and BCR (2.48) followed by blue and transparent plastic film in respect of economic gain as clear from the BCR values.

CONCLUSION

Initial cost on purchase and installation of plastic mulches are the few constraints in large scale adoption of this technology by the farming community. The available subsidy of 50% may be made use for adoption of this technology by large number of farmers.

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Irrigation scheduling and submergence studies for effective water management in farmers' fields

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ABSTRACT

Efficiency of water use in canal command areas in Chhattisgarh is often quite low around 30%. Although appropriate interventions with new water management technologies have been developed through several on-farm water management studies they are yet to be executed to command areas of distributaries and water courses. Farmers' Participatory Action Research Programme was implemented in 4 villages of Chhattisgarh in the years 2007-08 to 2009-10, to improve upon water management. The major objective of the study was Irrigation scheduling as per the ET requirement of crops and at critical crop growth stages and demo trial on full submergence, partial submergence and intermittent submergence at critical crop growth stages. Irrigation scheduling as per ET requirement of crops helped satisfactorily to develop seasonal irrigation plan / schedule. Though theoretically, the rains at flowering and late reproductive phase were higher than ET requirement, either due to various water losses or the location of field at disadvantage position (tail enders), two irrigations each 50 mm at these stages are required to realize full potential of rice, particularly to late duration photosensitive rice varieties. Three levels of submergence of rice fields were attempted in the study. Higher yield of rice main product was achieved in deep submergence 56.2-59.7 q ha^{-1} as compared to intermittent submergence and partial submergence, however, higher water use efficiency was observed in intermittent submergence (0.72-0.75 kg ha^{-1} m^{-3}). The relative saving of water ranged from 1000 to 1500 m^3 ha^{-1} (12.3% to 16.1%) in intermittent submergence over deep submergence.

Key words: Evapotranspiration, partial submergence, intermittent submergence, paddy, critical growth stages, Chhattisgarh

INTRODUCTION

Water, the unique resource on the planet earth is the elixir for sustaining all forms of life. Agriculture sector is the major user (78% water use) of water. It contributes 17% of the National GDP and sustains livelihood of about two thirds of population. India has total water resources of 400 M ha-m which is almost 4.2% of worlds' fresh water resources with 16% of world's population, 15% of world's livestock and 2.4% of world's geographical area. Indian agriculture has 66.7% rainfed areas, contributing 42% of total food production whereas 33.3% irrigated areas have 58% share in food production.

Canal irrigation is an age old and major source of irrigation in Chhattisgarh. Inspite of being a major source of irrigation, the irrigation efficiency in most canal command areas is very low, often 30% or less (Tanwar, 1998; Pandey and Reddy, 1988). The uncertainty of availability of water at the time of sowing forces farmers to go in for *broadcast biasi* system in irrigated areas. The water flows from field to field resulting in to deep submergence in the head reach and moisture stress in the tail-end areas. This also results in growing of tall late duration photo-sensitive rice varieties (145 days).

Farmer's Participatory Action Research Programme, funded by Central Water Commission, Ministry of Water Resources, Government of India, New Delhi was implemented in the Faculty of Agricultural Engineering, IGKV, Raipur in the year 2007-09. The major objective was to demonstrate the Irrigation scheduling as per the ET requirement

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of crops & at critical crop growth stages in order to develop seasonal plan / schedule and demo trial on full submergence, partial submergence & intermittent submergence at critical crop growth stages of rice crop. The study conducted at IIT Kharagpur (Ghildyal and Jana, 1968) showed that rice yield progressively decreased with the increase in soil moisture tension. Constant flooding gave highest yield over all other treatments. In this study 3 water regimes were used i.e. 0-3 cm, 3-6 cm and 6-9 cm standing water. This water regime was maintained at a definite growth stage and soil was kept saturated at other growth stages. Frequent and light irrigation so as to maintain the soil moisture at field capacity recorded the highest grain yield.

MATERIALS AND METHODS

Study area

The study was undertaken in 4 villages – two each in the districts of Dhamtari and Durg. The study area represents Chhattisgarh plains agro-climatic zone (NARP classification) and it comes under Pt. Ravishankar Shukla Reservoir (Gangrel dam) command area under Mahanadi basin. The normal rainfall of the project area is 1169.9 mm distributed over 64 rainy days. Agricultural characteristics of the study area lead to better performance of growth indicators in Dhamtari district as compared to Durg district. It is reflected in higher rice productivity under both rainfed and irrigated conditions in Dhamtari district (10.4 q ha^{-1} and 20.4 q ha^{-1}) as compared to Durg district (6.7 q ha^{-1} and 11.4 q ha^{-1}). The soils of the study area at Dhamtari and Durg represent black soil. Historical meteorological data of study site regarding estimation of rice ET were collected for the period 1971-2009, documented, analyzed and investigated SMW - wise regarding various weather parameters used for calculation of ET requirement of rice.

Technology demonstration

Irrigation scheduling as per crop ET

Knowledge of consumptive use is necessary in planning and operating water resources. ET data are essential for estimating water requirements for

Table 1. Water Requirement of Rice at Different Crop Growth Stages

Year	Establishment			Vegetative stage			Reproductive stage			Maturity stages		
	ET	E_O	ET/ E_O	ET	E_O	ET/ E_O	ET	E_O	ET/ E_O	ET	E_O	ET/ E_O
1981	30.2	31.1	1.00	297.0	178.5	1.66	241.8	143.5	1.68	140.8	98.0	1.43
1982	36.9	37.8	0.97	259.7	146.3	1.77	288.2	147.7	1.95	110.0	76.3	1.44
1983	38.0	29.4	1.20	177.6	151.2	1.17	176.5	123.2	1.43	80.7	72.8	1.10
1984	28.3	22.8	1.25	287.0	150.5	1.90	246.4	132.3	1.86	165.5	105.7	1.56
1985	22.5	29.4	0.76	174.3	137.9	1.26	170.8	126.7	1.34	89.6	93.1	0.96
1986	26.5	27.3	0.97	240.3	149.1	1.61	258.1	130.9	1.97	124.2	86.8	1.43
1987	30.2	32.9	0.91	298.7	144.9	2.06	275.4	132.3	2.08	131.3	81.2	1.61
1988	26.1	19.6	1.39	284.0	139.3	2.03	214.4	133.7	1.60	142.4	107.1	1.32
1989	30.0	31.5	0.95	217.6	130.9	1.66	218.5	226.7	1.72	142.1	94.5	1.50
1990	22.1	23.1	0.99	250.2	140.2	1.78	216.3	113.4	1.90	141.0	84.0	1.67
1991	29.5	27.3	1.08	151.0	99.4	1.51	152.1	135.8	1.12	109.7	99.4	1.10
1992	25.3	25.9	0.97	266.5	139.3	1.91	237.8	148.4	1.60	146.7	94.7	1.54
1993	31.1	27.3	1.10	140.3	136.6	1.76	246.4	139.3	1.76	140.0	94.5	1.48
1994	27.1	28.0	0.96	194.4	144.2	1.34	175.0	123.2	1.42	115.5	96.1	1.20
1995	25.6	26.6	0.96	196.3	153.6	1.27	194.3	136.5	1.42	121.6	102.2	1.18
1996	18.5	16.8	1.10	193.4	148.4	1.30	191.8	137.2	1.39	90.8	92.4	0.98
1997	31.4	25.2	1.24	294.9	151.9	1.94	225.4	124.6	1.80	97.0	84.7	1.14
1998	31.5	28.0	1.12	199.4	149.1	1.33	204.2	123.9	1.64	97.5	78.4	1.24
1999	25.4	21.0	1.20	202.4	126.0	1.60	261.9	132.3	1.97	117.9	96.3	1.22
2000	28.8	28.2	1.02	212.4	148.4	1.43	231.3	137.5	1.69	134.5	109.2	1.23
2001	26.3	23.8	1.10	215.5	163.1	1.32	191.7	156.1	1.22	107.9	114.8	0.93
2002	33.5	30.1	1.11	220.0	150.5	1.46	264.7	145.6	1.81	123.3	98.0	1.25
2003	41.6	49.3	0.84	282.3	200.0	1.41	312.0	169.6	1.84	89.3	74.1	1.21
2006	77.0	77.1	1.00	280.6	192.1	1.46	206.9	153.4	1.35	53.2	39.1	1.36
Avg.	24.1	23.1	1.04	190.9	123.2	1.55	186.3	116.3	1.60	97.0	74.9	1.29

irrigation. Actual measurements of ET, under each of the various physical and climatic conditions, are not possible but reliable methods (Penman-Montieth) are available for estimating ET of crops based on past historical meteorological data. ET requirement of various duration rice varieties are essential to know how much and when to irrigate. The lysimeter data are available at IGKV, Raipur and the same were used to determine the ET requirement of rice at different crop growth stages (Table 1). On an average 24.1 mm water is required at establishment stage of rice, followed by 190.9 mm at vegetative stage, 186.3 mm at reproductive phase, and 97.0 mm at maturity stage, with a total of 498.3 mm covering all growth stages. The seasonal crop coefficient was found to be 1.48. The analysis of the pattern of weekly ET, EP and crop coefficient of 3 different duration rice varieties indicated that the early duration rice (100-110 days) needs 460.9 mm, medium duration rice (120-125 days) needs 626.8 mm and late duration rice (150-160 days) require 750 mm water to realize full potential of crop. The seasonal crop coefficients were found to be 1.23, 1.49 and 1.50 for early, medium and late duration rice varieties respectively (Patel, G. 2010).

Submergence studies

Presently flood irrigation is practiced in both the seasons (*kharif and rabi*), through canal supply. The canal supply is available at the early crop growth period (i.e. during *biasi* operation- the local method of sowing cum interculture of rice) for one month. The second canal supply is available at the late crop growth stages. This is again for about one month period. It is evident from the present water use pattern that canal water supply is not available as per the critical crop growth stages. It is also to note that some mid season crop growth stages (such as primordial phase and early flowering stages) miss the canal water supply and experience water shortage. In view these situations of water scarcity, it was decided to make three levels of assured water in selected farmer's field. Full submergence, partial submergence and intermittent submergence at critical crop growth stages of rice crop were maintained in farmer's field (Fig. 1). Full submergence was made with 5±2 cm through out

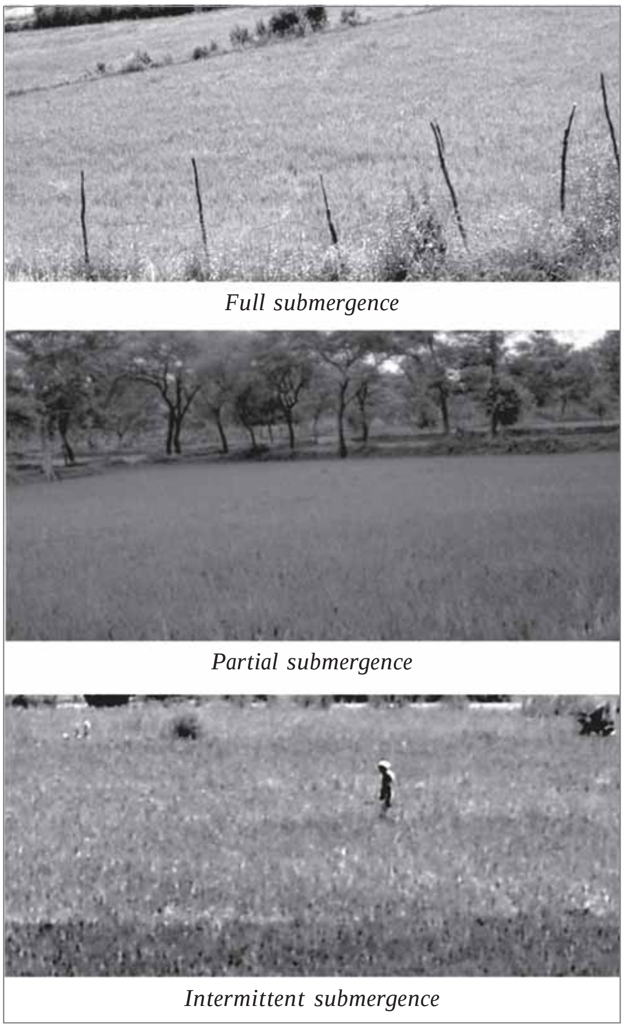

Fig. 1. View of full submergence, partial submergence and intermittent submergence in farmer's field

Table 2. Probability of Occurrence of Dry Spells (in days) in the Study Area

Periods/ Growth stages	SMW days	Parameters of distribution	Expected length of dry spell ≥ at probability of exceedance					
			25%	40%	50%	60%	75%	80%
Transplanting	27+28	α=2.693 β=1.780	6.32	4.99	4.22	3.57	2.65	2.34
Flowering	37+38	α=6.828 β=1.227	10.28	8.8	7.98	7.22	6.06	5.64
Reproductive phase	37to40	α=5.372 β=2.634	17.68	14.84	13.3	11.86	9.71	8.94
Monsoon season	23to42	α=6.670 β=3.632	29.73	25.5	23.03	20.80	17.43	16.2

the growth period of rice crop. The partial submergence was made with water level just above the saturation to 3 cm. The water level in intermittent submergence is maintained 5±2 cm at all the critical stages of crop growth, besides maintaining shallow water level at other stages with a provision of draining the rice fields from time to time viz. 45 and 75 days after transplanting.

RESULTS AND DISCUSSION

Length of dry spell, ET and water supply requirement

The length of dry spell in different probability of exceedance, its number of days and crop growth stage at project site is given in Table 2 (Patel, G. 2010). It is clear from the table that the length / number of days of dry spell increased with lower probability of exceedance. During flowering stage which coincides with 37 and 38 SMW the length of dry spell / number of continuous dry days are 6, 8, 9, 11 at 75 and 80, 50 and 60, 40 and 25 per cent of probability of exceedance. During this period 55 mm water is required to meet out the crop ET requirement, which can be fulfilled with the available rains of 88.7 mm. However, late duration rice varieties particularly those grown at the tail end require one-irrigation of 50 mm to meet out various water losses. In absence of supplemental irrigation, drastic reduction in rice yield destabilized the productivity in the command area. Similarly during reproductive stage (37 and 40 SMW) taken together, including flowering stage, the length of dry spell / number of continuous dry days was 9, 10, 12, 13, 15 and 18 days at 80, 75, 60, 50, 40 and 25 per cent probability of exceedance respectively (Table 2). During this period 111.6 mm water is required to meet out the crop ET demand (Table 3), the rainfall of 132.1 mm received during this period is higher (Table 4) than ET, hence theoretically the ET demand is fulfilled. However, to meet out various water losses such as percolation and seepage and conveyance losses etc. particularly to the late duration rice grown at the tail end requires one-irrigation (50 mm), to realize full potential of the crop. The canal supply availability, at this stage is either inadequate or absent due to shortage of water in reservoirs. It was observed that the monsoon withdraws in the second fortnight of September and therefore it is very much urgent to provide supplemental irrigation to rice at this stage,

Table 3. Weekly ET, EP & Crop Coefficient (ET / EP) of different duration Rice

SMW	Week from Sowing	Early duration Rice			Medium duration Rice			Late duration Rice		
		ET	EP	ET / EP	ET	EP	ET / EP	ET	EP	ET / EP
23	1	18.2	21.2	0.86	22.4	17.6	1.27	16.9	23.2	0.73
24	2	25.7	26.8	0.96	36.7	28.6	1.28	41.7	27.3	1.53
25	3	32.5	30.9	1.05	31.4	22.6	1.39	41.7	24.0	1.74
26	4	28.5	20.8	1.37	36.7	24.8	1.48	43.4	22.1	1.96
27	5	33.6	21.6	1.56	38	24.9	1.53	36.4	21.9	1.66
28	6	43.2	28.2	1.53	40.6	26.5	1.53	30.7	21.2	1.45
29	7	41.1	28.6	1.44	44.9	24.9	1.8	39.4	24.7	1.6
30	8	44.7	31.7	1.41	45.7	26.4	1.73	36.0	22.0	1.64
31	9	43.3	31.4	1.38	43.3	26.5	1.63	36.0	26.7	1.35
32	10	37.8	26.6	1.42	44.3	25.9	1.71	42.6	26.5	1.61
33	11	38.5	27.9	1.38	45.3	27	1.68	36.3	28.2	1.29
34	12	25.9	26.4	0.98	42.9	26.3	1.63	45.3	24.3	1.86
35	13	24.3	25.5	0.95	40.5	26.3	1.54	44.5	25.2	1.77
36	14	23.6	25.3	0.93	36.4	24.3	1.5	43.3	26.2	1.65
37	15	-	-	-	30.6	22.3	1.37	45.3	22.1	2.05
38	16	-	-	-	26.5	20.1	1.32	35.8	22.9	1.56
39	17	-	-	-	20.6	21.8	0.94	34.2	20.5	1.67
40	18	-	-	-	-	-	-	25.3	20.2	1.25
41	19	-	-	-	-	-	-	24.2	22.2	1.09
42	20	-	-	-	-	-	-	26.2	25.8	1.02
43	21	-	-	-	-	-	-	24.8	22.5	1.1
	Total	460.9	372.9	1.23	626.8	416.8	1.49	750.0	499.7	1.5

Table 4. Expected Rainfall Amount at Different Probability Levels

Period	Rainfall at probabilities of exceedance		
	50%	60%	80%
Annual (1-52 SMW)	1169.5	1081.0	875.3
Monsoon (22-43 SMW)	1109.2	1022.2	820.2
22 SMW	6.1	4.5	2.0
23 SMW	9.8	7.2	3.2
24 SMW	39.0	28.7	12.6
25 SMW	49.6	36.6	16.0
26 SMW	40.3	29.7	13.0
27 SMW	45.1	33.2	14.5
28 SMW	53.1	39.1	17.1
29 SMW	92.5	73.4	29.0
30 SMW	68.8	53.8	19.2
31 SMW	78.6	62.6	25.4
32 SMW	80.6	66.8	35.0
33 SMW	79.3	66.6	36.9
34 SMW	70.7	55.5	23.3
35 SMW	68.7	52.8	15.9
36 SMW	55.4	41.6	19.4
37 SMW	45.5	33.5	14.7
38 SMW	21.0	15.5	6.8
39 SMW	14.4	10.6	4.6
40 SMW	11.8	8.7	3.8
41 SMW	9.4	6.9	3.0
42 SMW	5.8	4.3	1.9
43 SMW	5.9	4.4	1.9

particularly at the tail end with late duration photo sensitive varieties, to realize full production potential of the crop. In absence of supplemental irrigation, drastic reduction in rice yield destabilized the productivity in the command area.

Submergence studies

Yield of Main and by Product: The intermittent submergence resulted in rice yields ranged from 51.2 to 58.3 q ha^{-1} with yield advance ranged from 8.7 to 9.0 q ha^{-1} over the conventional method. The conventional method resulted in rice yields ranged from 42.2 to 49.6 q ha^{-1}. Similarly the yield advantage of by product of rice ranged from 14.3 to 15.0 q ha^{-1} over the conventional method (Table 5).

Deep submergence (5 $\pm$ 2 cm) resulted in 2.4% to 9.8% higher yields over the intermittent submergence in farmer's field. The relative yield benefit over conventional method was found to be 7.0 - 8.5 q ha^{-1} and to that of intermittent submergence was 1.4 - 5.0 q ha^{-1}. By intermittent drying and watering the field every third day, the crop yields were of the same order as by maintaining continuously a 7.5 cm depth of water in the field.

In partial submergence the water was kept from field capacity / saturation to 3 cm standing in rice fields. This practice, though good for aeration of plant roots, but scarcity of water to some extent was felt at some critical crop growth stages. Therefore it resulted in lowest yield of main and by product of rice in farmer's field. The relative yield disadvantage over intermittent submergence ranged from 1.6 to 4.7 q ha^{-1} that was 3.1% to 8.1% of intermittent submergence. On covering the partial submergence to deep submergence, it was found the relative yield disadvantage further aggravated in the ranged 6.1 to 6.6 q ha^{-1} that forms 1.2 to 11.7 per cent of the yields under deep submergence. Partial submergence when compared with equivalent conventional practices, it was found that it resulted in yield advantage: 5.1 - 5.8 q ha^{-1} that forms 11.5-12.1% of yields under conventional practices.

Water Use: Intermittent submergence required water ranged from 7100 to 7800 m^3 ha^{-1}, with saving of water ranged from 1100 to 1500 m^3 ha^{-1}, over that spent in equivalent conventional practices. Similarly deep submergences saved water ranged from 1100 to 1400 m^3 ha^{-1} over that used in equivalent conventional practice. In a like manner the partial submergence saved water in the range of 1200 to 1400 m^3 ha^{-1} over the conventional equivalent practices. If the comparison is made among various treatments, it can be found that intermittent submergence required lowest

amount of water; it ranged from 7100 to 7800 m^3 ha^{-1}. The highest amount of water was required in deep submergence: ranged from 8100 to 9300 m^3 ha^{-1}, while that used in the intermittent submergence various from 7700 to 8800 m^3 ha^{-1}. The relative saving of water ranged from 1000 to 1500 m^3 ha^{-1} in intermittent submergence over deep submergence and from 600 to 1000 m^3 ha^{-1} in partial submergence. It forms 12.3% to 16.1% saving is water in intermittent submergence as compared to deep submergence. In a similar manner, the saving in water in intermittent submergence forms 7.8% to 11.4% as compared to partial submergence.

Water Use Efficiency: The water use efficiency was found highest in case of intermittent submergence ranged from 0.72 to 0.75 kg ha / m^3. It was lowest in case of partial submergence wherein it ranged from 0.60 kg / ha / m^3 to 0.64 kg / ha / m^3. Deep submergence showed medium level

Table 5. Impact of Technology: Levels of Submergence of Rice Fields

S. No.	Item	Conventional method	Using technologies	Benefits
1.	Yield of rice (quintals/ha) A. Intermittent Submergence Main product By-product	 42.2 – 49.6 69.5 – 81.8	 51.2 – 58.3 84.5 – 96.1	 9.0 – 8.7 15.0 – 14.3
	B. Deep Submergence Main product By-product	 49.2 – 51.2 81.2 – 84.5	 56.2 – 59.7 92.7 – 98.5	 7.0 – 8.5 11.5 – 14.0
	C. Partial Submergence Main product By-product	44.5 – 47.8 73.4 – 78.9	49.6 – 53.6 81.8 – 88.4	5.1 – 5.8 8.4 – 9.5
2.	Water used (m^3/ha) A. Intermittent Submergence B. Deep Submergence C. Partial Submergence	 8200 – 9300 9500 – 10400 9100 – 10000	 7100 – 7800 8100 – 9300 7700 – 8800	 1100 – 1500 1400 – 1100 1400 - 1200
3.	Water saving (m3/ha) A. Intermittent Submergence B. Deep Submergence C. Partial Submergence	 - - -	 1100 – 1500 1400 – 1100 1400 – 1200	 1100 – 1500 1400 – 1100 1400 – 1200
4.	Water use efficiency (kg/ha/m^3) A. Intermittent Submergence B. Deep Submergence C. Partial Submergence	 0.51 – 0.53 0.52 – 0.49 0.49 – 0.48	 0.72 – 0.75 0.69 – 0.64 0.64 – 0.60	 0.21 – 0.22 0.17 – 0.1 50.15 – 0.12
5.	Inputs Fertilizers(kg/ha) - Nitrogen - Phosphorus - Potash - Zinc Sulphate - Spray of Sulphur	 90 – 130 55 – 70 36 – 48 - -	 120 60 40 25 0.50	 Use of DAP reduced the amount of Nitrogen application
	Seed	80-90	80	5-10 kg
	Pesticide	Delayed application	Timely application	Reduced cost of application
6.	Other benefits e.g. ecological gains etc., if any (insects and pests)	Higher incidences	Reduced intensity	Reduced cost of insecticides/ pesticides

of water use efficiency. Based on these facts it can be concluded that intermittent submergence is beneficial to rice in command areas where intermittent water supply from canal is available. The only question is regarding its timing. The timing of canal supply and critical crop growth stages of rice usually do not match. This is the fact based on which we should think of transient storage in SFR to avoid this mismatch and recycle the stored water in SFR to the rice crop in canal command area.

Parihar and Sadhu (1989) observed that excessive depth of water on the land did not influence the ratio of weight of water transpired by a crop during the growth to the weight of dry matter produced. On the other hand, the proper growth the rice plant requires a certain optimum soil moisture status and this is adequately provided at the soil moisture saturation level (field capacity). Slightly better yields with irrigation at field capacity may be attributed to better soil aeration under this treatment was compared with the two submergence treatments. There is no doubt that soil aeration is a vital factor for the good growth and resultant high yield in the rice crop.

Alternate wetting and drying practices resulted in both water savings and rice yield losses of 0-70 per cent compared with the continuous flooding treatment, depending on the irrigation intervals and existing soil conditions. It has been found that rice yield losses are generally smaller than the reduction in water inputs and therefore water productivities are increased. There is a trade-off between land productivity and water productivity. Field experiments under 4 different management treatments (continuous submergence, irrigation supplied 1, 2 and 4 days after subsidence of standing water) at Balipatna block in Khurda district, Orissa, showed that irrigation applied 4 days after subsidence of standing water in fields saved 42 to 45% water without significant reduction in rice yields. Also the mean water use efficiency increased from 28.7 kg cm^{-1} water under continuous submergence to 47.5 kg cm^{-1} water under treatment where irrigation applied 4 days after subsidence of standing water (Singh *et al.*, 2008).

CONCLUSION

The farmer's participatory irrigation management can lead to enhancement in the water use efficiency. The farmer's participatory cooperative movement should be encouraged. The operation and maintenance of irrigation minors and sub minors must be entrusted to the farmer's cooperatives. This will help in synchronizing the water delivery as per the need. Cultivation in view of the ET requirement and submergence studies will help the farmers to get return from their efforts.

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Evaluation of storage capacity of ponds and water quality analysis of tubewell and stream in small watershed

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ABSTRACT

This study deals with determination of various topographic parameters, storage capacity of ponds and water quality analysis of water bodies existing in *Sandhari nala* watershed. Water storage capacity of 34 ponds was determined. Maximum storage capacity of the farm pond is determined on the basis of overall shape, surface area and depth of the pond. Water samples collected from the open streams and tube wells at different locations in the watershed were analyzed for their physicochemical characteristics including pH, TDS, TH, Ca^{++}, Mg^{++}, Na^{+}, K^{+} and Cl^{-} etc. Total storage capacity of ponds existing in the watershed was estimated to be 49, 37,000 m^3. The water is used for different purposes such as domestic, irrigation, fish production etc. and farmers are being benefited in terms of crop production during both *rabi* and *kharif* seasons. Water samples of tube wells and open streams showed acidic nature. However, some other parameters available in the water samples taken from the tube well showed higher values than the open stream. As per the standard specifications the water flowing in the streams and available in the tube wells found to be suitable for Domestic and Irrigation purpose.

Key words: pond, storage capacity, water quality, watershed, topography survey

INTRODUCTION

Water is the essential for the survival of all living beings i.e. humans, animals and plants. Water is an essential resource upon which our ecosystem and agricultural production depend. India is facing a serious problem of natural resource scarcity, especially that of water in view of population growth and economic development (Garg *et al.*, 2009). Most of fresh water bodies all over the world are getting polluted, thus decreasing the potability of water (Gupta *et al.*, 2005). Ground water quality is mainly affected due to drastic pollution activities that are taking place on surface waters (Rao *et al.*, 2012). Water resources can be classified into two categories of water body, Surface water and Ground water. Changes in the water quality affect the biotic community of the aquatic ecosystem which ultimately reduces the primary productivity (Rossiter, *et al.*, 2010). The water quality depends on various physico-chemical characteristics and their concentration. The water quality degradation is almost increases due to human activities. Due to natural process of weathering of rocks, leaching of soils and mining processing etc. which contaminates the natural water. It is necessary that the quality of drinking water should be checked at regular time interval, because due to use of contaminated drinking water, human population suffers from varied of water borne diseases (Patil *et al., 2012*). Natural events such as torrential rainfall and hurricanes lead to excessive erosion and landsides in affected rivers and lakes (Balek, 1977). The nature and concentration of chemical elements and compounds in a fresh water system are subject to change by various types of natural processes, that is, physical, chemical, hydrological and biological (Balek, 1977). Permanent natural conditions in some areas may make water unfit for drinking or for specific uses such as irrigation (Peavy *et al.*, 1986). The natural aquatic resources are causing heavy and varied pollution in aquatic environment leading to water quality and depletion of aquatic biota. It is therefore necessary that the quality of drinking water and irrigation water should be checked at regular time interval because due to use of contaminated water for drinking, human population suffers from a variety

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of water borne diseases and for irrigation, affect agricultural productivity and change the soil characteristics also. The world health organization (WHO) estimates that 88% of diarrheal disease is caused by unsafe water, inadequate sanitation and poor hygiene. The physicochemical characteristics like pH, dissolved oxygen, total alkalinity, total hardness, chloride contents etc. in one way or another has significant influence on aquatic life. Aquatic organisms are influenced by changing in water quality (Chatterjee and Raziuddin, 2002).

The growth of urban settlements and growing industrial production, combined with rapidly measuring demand for water are causing water quality problems. Water quality assessment operations are undertaken as preliminary survey, multipurpose monitoring, background monitoring, modeling survey, early warning surveillance etc. (UNESCO / WHO / UNEP / UNEP, 1992, Sanders *et al.*, 1983). Good quality water is essential for living organisms. The indiscriminate use may cause secondary salinization and sodification of soil resulting in serious effect on crop growth. But in emergency these waters can be used with special management practice depending upon the rainfall, crop to be grown and soil type (Sharma *et al.*, 2013).

The quality of irrigation water is concern to its effects on the management of soils and crops. High quality crops can be produced only by using good and safe qualitatively parameter of irrigation water. Characteristics of irrigation water that define its quality vary with the source of the water. Water used for irrigation can also vary greatly in quality depending upon quantity of dissolved salts. Water quality concerns have often been neglected because good quality water supplies have been plentiful and readily available (Shamsad and Islam, 2005; Islam *et al.*, 1999). Poor quality irrigation water becomes more concern as the climate changes from humid to arid conditions. Salts are originated from dissolution or weathering of rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. These substances are carried with the water to wherever it is used (UCCC, 1974; Tanji, 1990). The evaluation of irrigation water quality to be identifying their acceptable levels of concentrations that are important for plant growth and.

A pond is an earthen container for storing water. The surface area of the stored water will normally vary from a fraction of an acre to tens of acres. Ponds have traditionally been used as an economical and efficient way to retain water for livestock and irrigation.

The main objective of this present work is to be indentified physicochemical characteristic of surface and ground water in watershed. Assessment of water quality for irrigation is to be identifying the characteristics that are important for plant growth, and their acceptable levels of concentrations.

MATERIALS AND METHODS

Study Area: Sanghari nala watershed has been considered for this study, which is in Arang block of Raipur district (fig. 1). The watershed comprises of several villages namely Rasni, Khamtarai, Kalai, Jaraud, Chhatauna, Ghumrabhata and Bodra. The watershed is located within $81^0 54'$ to $82^0 0'$ E longitude and $21^0 12'$ to $21^0 16''$ N latitude at an altitude ranged from 270 to 300 m above mean sea level (MSL) covering an area of 54.50 km^2. The average slope of the watershed is 1.5%.

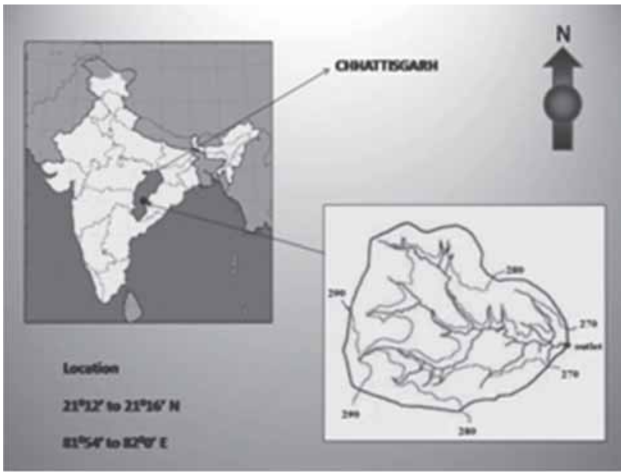

Fig. 1. Location map of the study area

The watershed receives an average annual rainfall of 1420 mm. About 80-90% of total rainfall occurs between June to September as monsoon rains. The daily mean temperature ranges from a maximum of 45^0C to a minimum of 10^0C. Clay, sandy clay loam and sandy loam soils were found in the watershed area.

Since the Global Positioning System (GPS) was used to determine the specific location of various ponds, tube wells and open wells situated at different villages of watershed. The topographic datasets were originally stored as point measurement. Each point had northing, easting, and elevation values.

Storage Capacity of Farm Pond: In general for calculation of volume of a pond the basic information which require includes the overall shape, as well as pond surface area and depth. The estimated capacity or volume of the pond can be determined by multiplying the surface area of the pond with the average water depth measured at the farm pond.

Analytical details of Water Sample: Quality of water directly affects quality of life of inhabited population. It is very essential and important to test the water before it is used for drinking, domestic, agricultural or industrial purpose. Water must be tested with different physico-chemical parameters. Selection of parameters for testing of water is solely depends upon for what purpose we are going to use that water and to what extent we need its quality and purity. Water may contain different types of floating, dissolved, suspended and microbiological as well as bacteriological impurities. Water samples were collected from the surface water and ground water. The water samples collected from the open water body (AM-P1) and tube wells (BD-W3) (Table 2). The samples were collected in polystyrene bottles having 1000 ml capacities as per requirement of the test. The method adopted for the determination of the physic-chemical characteristics of water was given in Table 1. The bottles were kept air tight and labeled properly for identification. These samples were brought to the laboratory for the analysis of different physicochemical characteristics like pH, total alkalinity, boron, calcium, chloride, colour, fluoride, total hardness, Iron, manganese, nitrate, calcium, turbidity, SAR, RSC, SSP and Magnesium hazard for drinking and irrigation purpose and results were compared with IS: 10500 of drinking and irrigation.

Table 1. Experimental methods used for analysis of water quality of drinking and irrigation

Particulars	Method/Instruments used
pH	Potentiometeric
Electrical conductivity (EC) and TDS	Conductivity Cell Potentiometer
Total hardness and Calcium (Ca^{++})	EDTA Titrimetric
Magnesium (Mg^{++})	Calculation from Total hardness and Calcium
Sodium (Na^{+}) and Potassium (K^{+})	Flame Emission Photometric
Chloride (Cl^{-})	Argentometric Titration
Primary alkalinity	Titrimetric to pH=8.3 (Phenolphthalein)
Total alkalinity	EDTA Titrimetric to pH=4.5 (Methyl Orenge)
Carbonate and Bicarbonate	Calculation from pH and Alkalinity
Sodium Adsorption Ratio (SAR)	Richards, 1954
Soluble Sodium Percentage (SSP)	Todd, 1980
Residual Sodium Carbonate (RSC)	Eaton, 1950
Magnesium Hazards	Szabolcs and Darab (1964)

RESULTS AND DISCUSSION

The storage capacities of farm ponds were calculated 49, 37,000 m^3 of water was stored in all the ponds which come under the watershed area (Table 3). This water is used for different purposes such as domestic, ag-ricultural landscapes, fish production, irrigation etc. The volume of water in ponds decrease during summer but negligible effect was seen in different water sources like open well, tube well, bore well etc.

Physico-chemical characteristics of water

pH: pH is the important parameter for determining the corrosiveness nature of water. Lower the pH value higher is the corrosive nature of water. pH was positively correlated with electrical conductance and total alkalinity (Gupta 2009). As evident from Fig. 2 pH value of tube well and open stream water were found to be 6.7 and 6.8 respectively. Both samples showed the slightly acidic nature. As per IS: 10500 the tube well water and open stream water both samples were found to be under desirable limit. The higher pH values observed suggests that carbon dioxide, carbonate-bicarbonate equilibrium is affected more due to change in physico-chemical condition (Karanth 1987).

Table 2. Water samples details of different water bodies

Village Name	Sample Code	Location		
		N	E	Elevation (m)
Amethi	AM-P1	21°13.455'	81°59.523'	274
Bodra	BD-W3	21°13.600'	81°55.885'	291

Table 3. Water storage capacity of farm pond

Village Name	Name of Pond	Average Depth (m)	Area of Pond (ha)	Area of Pond (m^2)	Water Storage Capacity (m^3)
Rasni	Dogiha pond	6.5	2.91	29,100	1,89,150
	Bandhwa pond	7.5	2.86	28,600	2,14,500
	Dumrahi pond	6.5	2.14	21,400	1,39,100
	Banjariya pond	6.5	2.2	22,000	1,43,000
	New pond	6.5	1.96	19,600	1,27,400
Jaraud	Dhobani pond	5.5	1.89	18,900	1,03,950
	Bandhuwa pond	7.5	7.30	73,000	5,47,500
	New pond	6.5	1.36	13,600	88,400
	Sendhwara pond	5.5	1.95	19,500	1,07,250
	Balar pond	5.5	1.40	14,000	77,000
	Hajariya pond	7.5	2.65	26,500	1,98,750
	Chudeline pond	7	5.49	54,900	3,84,300
Bodra	Lawan pond	6.5	2.98	29,800	1,93,700
	Chepta pond	6.5	1.07	10,700	69,550
	Banjariya pond	6.5	1.81	18,100	1,17,650
	Darry pond	5.5	0.75	7,500	41,250
	New pond	6.5	1.60	16,000	1,04,000
	Ganwa pond	7.5	2.80	28,000	2,10,000
	Dubey pond	7.5	2.80	28,000	2,10,000
	Raja pond	5.5	0.78	7,800	42,900
	Dogi pond	5.5	0.77	7,700	42,350
Chhatauna	Sargodwa pond	7.5	1.19	11,900	89,250
	Charkhutiya pond	6.5	1.19	11,900	77,350
	Dogiha pond	6.5	2.26	22,600	1,46,900
	Chakoli pond	5.5	0.63	6,300	34,650
	Baramdeya pond	6.5	1.51	15,100	98,150
Khamtarai	New pond	7.5	2.14	21,400	1,60,500
	Bandha pond	7.5	5.89	58,900	4,41,750
Kalai	Gaura pond	5.5	1.55	15,500	85,250
	Ganesh pond	6.5	1.08	10,800	70,200
	Ganganiya pond	6.5	1.39	13,900	90,350
	Nawa pond	6.5	1.47	14,700	95,550
Ghumarabhata	Bade pond	7.5	2.12	21,200	1,59,000
	Niji pond	6.5	0.56	5,600	36,400
Total Water Storage Capacity		49,37,000			

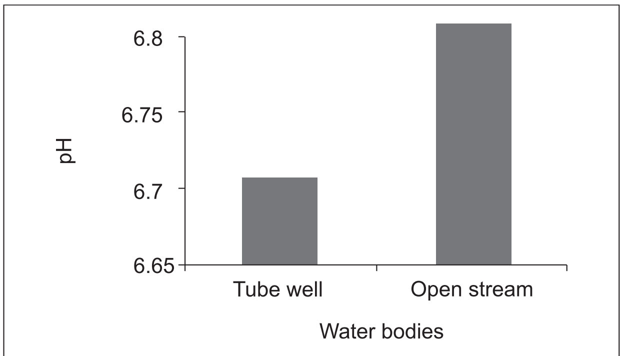

Fig 2. pH values of water samples

Electrical Conductivity: EC is the measure of the ability of an aqueous solution to convey an electric current. The EC value of tube well and open stream water was found to be 3035.20 micromhos cm^{-1} and 463.37 micromhos cm^{-1} respectively. Fig. 3 shows the high EC values of tube well indicating the presence of high amount of dissolved inorganic substances in ionized form as compare to open stream water.

Total Dissolved Solids: Total dissolved solids indicate the salinity behavior of groundwater. In the present study the total dissolved solids 1942.53 ppm and 296.56 ppm was recorded in the water sample of tube well and open stream water respectively. The results indicated that the open stream water comes under desirable limit and tube well water crossed the desirable limit but showed under the permissible limit as per IS: 10500.

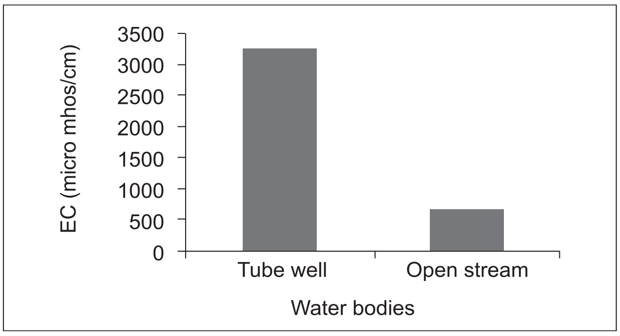

Fig 3. EC values of water samples

Hardness: Hardness in water is a concentration of multivalent cations. These cations include Ca^{2+} and Mg^{2+}. These ions enter a water supply by leaching from minerals within an aquifer. The calcium and magnesium hardness is the concentration of calcium and magnesium ions expressed as equivalent of calcium carbonate. There are two types of water hardness one of the temporary and next is permanent hardness. The total hardness was found to be 598 ppm and 192 ppm in the water sample of tube well and open stream water, respectively (Fig. 4). The results indicated that the open stream water comes under desirable limit and tube well water crossed the desirable limit but showed under the permissible limit as per IS: 10500. Hard water affects cleaning ability of soap. When hard water is used for washing, large amount of soap is consumed. Hard water can cause scaling inside the pipes. Hard water when used for drinking for long period can lead to stomach disorders. Especially hard water contains magnesium sulphate can weaken the stomach permanently.

Calcium: Calcium and magnesium are directly related to hardness. The calcium was found to be 218.01ppm and 44.88 ppm of the water sample of tube well and open stream water, respectively (Fig. 4). As per IS: 10500 results indicated that the open stream water comes under desirable limit and tube well water crossed the desirable limit but showed under the permissible limit.

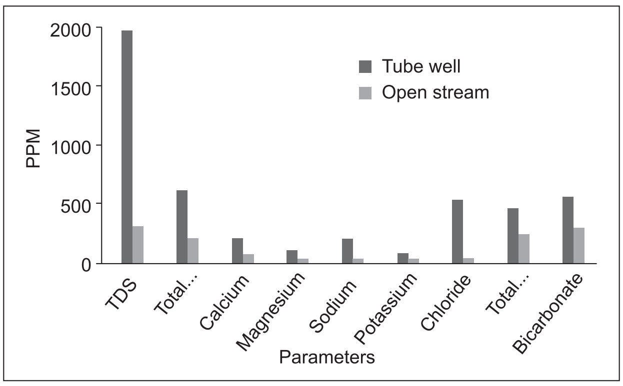

Fig. 4. Variation of different parameter value of water samples

Magnesium: Magnesium is often associated with calcium in all kinds of water, but its concentration remains generally lower than the calcium. Magnesium is essential for chlorophyll growth and acts as a limiting factor for the growth of phytoplankton (Dagaonkar and Saksena, 1992). The value of magnesium was found to be low 19.39 ppm of the open stream water which indicated that under the desirable limit. The water sample of tube well was found to be 112.5 ppm (Fig. 4) which indicated that crossed the desirable limit but showed under the permissible limit as per IS: 10500.

Sodium: Sodium concentration was recorded as 187.2 ppm and 15.4 ppm in the water sample of tube well and open stream water. As per IS: 10500 results indicated that the open stream water comes under desirable limit and tube well water crossed the desirable limit but showed under the permissible limit.

Potassium: The value of potassium 64.2 ppm and 2.8 ppm was recorded in the water sample of tube well and open stream water, respectively. The sample of tube well showed higher potassium values than the open stream water.

Chloride: Chlorides may get into surface water from several sources such as rocks agricultural runoff, wastewater from industries, oil well wastes, effluent wastewater from wastewater treatment plants, and road salting etc. Excess of chloride in inland water is usually taken as index of pollution. The salts of sodium, potassium and calcium contribute chlorides in water. Large contents of chloride in freshwater is an indicator of pollution (Venkatasubramani and Meenamba, 2007). Chloride plays a very important role in the water quality determination. The chloride concentration was found to be 510.48 ppm and 19.85 ppm in the water sample of tube well and open stream, respectively. The sample of open stream water shows under desirable limit whereas tube well crossed desirable limit but showed under the permissible limit as per IS: 10500.

Alkalinity: The Alkalinity refers to the capability of water to neutralize the acid. Alkali substances in water include hydroxides or bases. They can be detected by their acid taste. Alkalinity of water may be due to the presence of one or more number of hydroxides, carbonates and bicarbonates ions. Total alkalinity of 448 ppm and 228 ppm has been recorded in the water sample of tube well and open stream water, respectively. The sample of open stream water shows under desirable limit whereas tube well crossed desirable limit but showed under the permissible limit as per IS: 10500.

Bicarbonate: The value of Bicarbonate concentration of 546.56 ppm and 278.16 ppm was found in the water sample of tube well and open stream water, respectively. The sample of open stream water shows the lower value of bicarbonate than the tube well.

Salinity Hazard: Electrical conductivity (EC) is the most important parameter in determining the suitability of water for irrigation use and it is a good measurement of salinity hazard to crop as it reflects the TDS in water. The effect of salts on crop growth is largely of osmotic in nature. The osmotic potential of the soil-water solution at root zone relates directly to the electrical conductivity of irrigation water. Saline soils are the soil with high level of total salinity. The most important negative effect on the environment caused by agricultural wastewater is the increases in soil salinity, which if not controlled, can decrease productivity in long Term (Oster *et al.*, 1994). The salinity of water is mainly measured by the electric conductivity or total dissolved solids. In the present study tube well water was showed bad and open stream showed good for irrigation as per IS: 10500.

Sodium Hazard: Sodium is an important factor for irrigation water quality evaluation. Excess of sodium in water shows it unsuitable for irrigation on soil containing exchangeable calcium and magnesium ions. Excessive sodium leads to development of an alkaline soil that can cause soil physical problems and reducing soil permeability (Kelley *et al.*, 1951). Hence, for the suitability for irrigation, assessment of sodium concentration is necessary. The Soluble Sodium Percentage (SSP) was estimated by using the equation suggested by (Todd, 1980):

$$SSP = (Na^{+}) \times 100 \;/\; (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}) \quad \dots (1)$$

Where: Na^+, Ca^{2+}, K^+ and Mg^{2+} are in meq/l. The calculated values of SSP were 29.8% and 14.62% of the tube well and of open stream respectively (Fig. 5). The tube well water fall good and open stream water was excellent classes for the use of irrigation as per IS: 10500 (Table 4).

Sodium hazard is usually expressed in terms of Sodium Adsorption Ratio (SAR) and it can be calculated from the ratio of sodium to calcium and magnesium. SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard (Todd *et al.*, 1980). The use of water having a high SAR leads to a breakdown in the physical structure of the soil. SAR is an important parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard (Nagarajah *et al.*, 1988). The sodium adsorption ratio (SAR) was estimated by using the equation suggested by (Richards, 1954):

$$SAR = \frac{Na^{+}}{\sqrt{\dfrac{Ca^{2+} + Mg^{2+}}{2}}} \quad \dots (2)$$

where: Na^+, Ca^{2+} and Mg^{2+} are in meq/l. The SAR value was found to be 2.74 meq/l of tube well and 0.48 meq/l of open stream (Fig. 6). Both the samples were showing excellent class for the use

Table 4. Drinking water quality parameters of tub well and open stream water

S. No	Parameter	Tube well	Open Stream	IS: 10500 for Drinking	
				Requirement Desirable limit	Permissible limit
1.	pH	6.7	6.8	6.5 - 8.5	8.5
2.	Electrical conductivity, micromhos cm^{-1}	3035.20	463.37	-	-
3.	TDS, ppm	1942.53	296.56	500	2000
4.	Total hardness, ppm	598.00	192	300	600
5.	Calcium hardness, ppm	545.02	112.21	-	-
6.	Calcium, ppm	198.01	44.88	75	200
7.	Magnesium, ppm	92.5	19.39	30	100
8.	Sodium, ppm	187.2	15.4	180	-
9.	Potassium, ppm	64.2	2.8	-	-
10.	Chloride, ppm	510.48	19.85	250	1000
11.	Primary alkalinity, ppm	0.0	0.0	200	-
12.	Total alkalinity, ppm	448	228	200	600
13.	Carbonate, ppm	0.0	0.0	-	-
14.	Bicarbonate, ppm	546.56	278.16	-	-

of irrigation as per IS: 10500 (Table 5).

Residual Sodium Carbonate (RSC): A major factor in affecting the final SAR value of soil water is the change in calcium and magnesium concentration due to precipitation or dissolution of alkaline earth carbonate. In irrigation water containing high concentration of HCO_3 ions, there is tendency for calcium and to a lesser extent, magnesium to precipitate in the form of carbonate. When total carbonate levels exceed the total amount of calcium and magnesium, the water quality may be decreased. When the excess carbonate (residual) concentration becomes too high, the carbonates combine with calcium and magnesium to form a solid material (scale) which settles out of the water. To quantify the effect an empirical parameter was devised by Eaton (1950) on the assumption that all calcium and magnesium will precipitate. The parameter is termed as Residual Sodium Carbonate. The end result is an increase in both the sodium percentage and SAR. The residual sodium carbonate (RSC) was determined by the equation using the values obtained for $CO^{2-}{}_3$, HCO_3 in me/l (Eaton, 1950):

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+}) \quad ... (3)$$

Where all ions are in meq/l. The RSC value < 1.25 meq/l is safe for irrigation, a value between 1.25 to 2.5 meq/l is of permissible quality and a value more than 2.5 meq/l is unsuitable for irrigation (USSL, 1954). The RSC value of tube well and open stream was found to be -8.53 meq/l and 0.76 meq/l respectively (Fig. 5). Both the samples were showing excellent class for the use of irrigation as per IS: 10500 (Table 5).

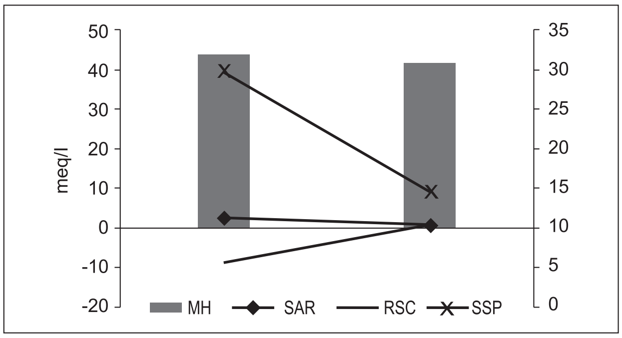

Fig 5. Variation of different irrigation parameter of water samples

Magnesium Hazards: The Ca^{2+} and Mg^{2+} ions are associated soil aggregation and friability, but they are also essential plant nutrients. High concentration of Ca^{2+} and Mg^{2+} ions in irrigation water can increase soil pH, resulting in reducing of the availability of phosphorous (Al-Shammiri *et al.*, 2005). When water containing Ca^{2+} and Mg^{2+} > than 10 meq/l cannot be used in agriculture (Khodapanah *et al.*, 2009). Magnesium hazards were proposed by Szabolcs and Darab (1964) for irrigation water.

$$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \quad MH = \quad .... (4)$$

Table 5. Irrigation water quality parameters of tub well and open stream water

S. No.	Parameters	Tube well	Open stream	IS : 10500, for Irrigation		Remark: Tube well	Remark: Open stream
1.	Salinity /EC (micromhos)	3035.20	463.37	< 250 250 – 750 750 – 2250 2250 – 4000 >4000	Excellent Good Medium Bad Very bad	Bad	Good
2.	Sodicity/SAR, meq/l	2.74	0.48	< 10 10 – 18 18 – 26 > 26 > 26	Excellent Good Medium Bad Very bad	Excellent	Excellent
3.	RSC, meq/l	-8.53	0.76	< 1.25 1.25 – 2.0 2.0 – 2.5 > 2.5	Excellent Good Medium Very bad	Excellent	Excellent
4.	SSP, %	29.80	14.62	< 20 20 – 40 40 – 60 60 – 80 >80	Excellent Good Medium Bad Very bad	Good	Excellent
5.	Magnesium hazard, meq/l	43.51	41.51	-	-		

Where all ionic concentrations are in meq / l. The value magnesium hazard for tube well and open stream was found to be 43.51 meq / l and 41.51 meq / l respectively (Fig. 6). Both the samples were showing safe for the use of irrigation as suggested by Khodapanah, 2009, if the value of MH is less than 50, then the water is safe and suitable for irrigation.

CONCLUSION

Storage capacity, 4937000 m^3 water was found in all the ponds of the watershed. This quantity of water is not sufficient for assured irrigation in the watershed but sufficient for supplemental irrigation and protected irrigation. The ponds also meet out the domestic requirement in summer. Different physico-chemical properties of drinking and irrigation water were compared with the water quality standards set for drinking and irrigation. As per the standard specifications both source of water viz. the open stream water and tube well water is found to be slightly acidic nature and suitable for Domestic and Irrigation purpose.

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Study on nutrient uptake and soil fertility as influenced by pigeonpea (*Cajanus cajan* L.) + soybean (*Glycine max* Merrill.) cropping system, sources and levels of phosphorus in the succeeding wheat crop

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ABSTRACT

A field investigation was conducted at Agronomy research farm A.S. (P.G) College, Lakhaoti, Bulandshahr during *kharif* & *rab*i seasons of 2008-09 and 2009-10 to study 'Nutrient uptake and soil fertility as influenced by pigeonpea (*Cajanus cajan* L.) + soybean (*Glycine max* Merrill.) cropping system, sources and levels of phosphorus in the succeeding wheat crop'. The treatments consisted of combination of four cropping systems viz. pigeonpea sole (M1), soybean sole (M2), pigeonpea+ soybean 1:1 ratio (M3) and pigeonpea 50/100 + 2 rows of soybean (M4) in main plots; two sources of phosphorous viz. single super phosphate (SSP) (S1) and rock phosphate (RP) (S2) in sub plots and three levels of phosphorous viz. control (L1), 40 kg P_2O_5/ha (L2) and 80 kg P_2O_5/ha (L3) in sub-sub plots in split plots design replicated thrice during the *kharif* seasons. Succeeding wheat crop was sown in the undisturbed layout with recommended N and K only during the *rabi* season. The pigeonpea variety Pusa 992 and soybean variety PK 1042 were used in the cropping systems during *kharif* season and wheat variety HD-2824 was used in the succeeding crop during *rabi* season. The soil of the experiment site was sandy loam in texture, medium in fertility and slightly alkaline in reaction. The weather during the both years of the experiment was by and large normal and devoid of any extreme conditions. It was observed that N uptakes in succeeding wheat crop was superior when preceding cropping systems was sole pigeonpea which received rock phosphate at 80 kg P_2O_5/ha. However the P and K uptakes in succeeding wheat crop were superior when the cropping systems of the preceding crop was sole soybean which received rock phosphate at 80 kg P_2O_5/ha. The rock phosphate as source of phosphorous when applied at 80 kg P_2O_5/ha, would be superior as it is the cheaper source of phosphorous suitable to the farmers and when applied in either pigeon or soybean sole cropping systems, enhances the soil fertility status, thus helping sustained crop growth and yield.

Key words: Cropping Systems, Sources and Levels of phosphorous, Nutrient (N,P and K) uptake, Residual effects

INTRODUCTION

Pigeonpea and soybean being two important *kharif* crops, their cultivation in sole as well as in mixed stand, because of their diverse morphology, growth rhythm and similar climate requirement is well explored. Pigeonpea and soybean is a popular mixture in north and north-western India, particularly in the rainfed conditions. However its real advantage can be obtained by choosing proper combination of crops, adopting well worked out proportion and optimum phosphorus fertilization, as both the crops are exhaustive phosphorus requiring crops. Chemical fertilizers are seldom applied to pigeonpea and soybean in traditional systems, perhaps due to the false belief that they do not respond to fertilizers. Phosphorus fertilizer has tremendous influence in increasing the production and productivity in both pigeonpea and soybean. Since phosphorus is a costly input, there is a need for exploitation of cheaper sources of phosphorus like rock phosphate. The role of sources and levels of phosphorus in pigeonpea and

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soybean cropping system thus needs special attention. Often the wheat is grown in cropping sequence after rice, pigeonpea, maize, soybean etc. Low soil fertility has now been recognized as one of the most important problems causing low yields.

Beneficial residual effects of crops on the yields of subsequent crops are very well known from earlier times. In India pigeonpea has been reported to fix 58 to 88 kg N/ha in sole crop systems and may provide 30 to 50 kg N/ha in intercropping systems. Similarly soybean can fix 125-150 kg N/ha (Chandel *et al*., 1989). Residual N has beneficial effects on the yields of subsequent wheat crops. Residual P has also beneficial effects on the growth and yields of subsequent wheat crops. The role of residual effects of sources and levels of phosphorus in cropping system on the succeeding wheat crops also thus needs special attention. Keeping in view the above points the present experiment was conducted to study nutrient uptake and soil fertility status as influenced by pigeonpea (*Cajanus cajan* L.) + soybean (*Glycine max* Merrill.) cropping system, sources and levels of phosphorus in the succeeding wheat crop.

MATERIALS AND METHODS

A field investigation on "Nutrient uptake and soil fertility as influenced by pigeonpea (*Cajanus cajan* L.) + soybean (*Glycine max* Merrill.) cropping system, sources and levels of phosphorus in the succeeding wheat crop" was conducted at Agronomy research farm A.S. (P.G.) College, Lakhaoti during *kharif* & *rabi* seasons of 2008-09 and 2009-10. The treatments consisted of combination of four cropping systems viz. pigeonpea sole (M1), soybean sole (M2), pigeonpea+ soybean 1:1 ratio (M3) and pigeonpea 50/100 + 2 rows of soybean (M4) in main plots; two sources of phosphorous viz. single super phosphate (SSP) (S1) and rock phosphate (RP) (S2) in sub plots and three levels of phosphorous viz. control (L1), 40 kg P_2O_5/ha (L2) and 80 kg P_2O_5/ha (L3) in sub-sub plots in split plots design replicated thrice during the *kharif* seasons. Succeeding wheat crop was sown in the undisturbed layout with recommended N and K only during the *rabi* seasons. The pigeonpea variety Pusa 992 and soybean variety PK 1042 were used in the cropping systems during *kharif* season and wheat variety HD-2824 was used in the succeeding crop during *rabi* season. The soil of the experiment site was sandy loam in texture, medium in fertility and slightly alkaline in reaction. The weather during the both years of the experiment was by and large normal and devoid of any extreme conditions. The experiment was conducted as per the standard procedures and all the pre and post harvest observations were recorded and analyzed as per the prescribed statistical procedures. The experimental data pertaining to each character were subjected to statistical analysis by using the technique of analysis of variance (ANOVA) and their significance was tested by "F" test (Cochran and Cox, 1957). Standard error of means (SEm+) and least significant difference (LSD) at 0.05 probabilities were worked out for each character studied to evaluate differences between treatment means.

RESULTS AND DISCUSSION

Nutrient uptakes of pigeonpea

Data on N, P and K uptakes of pigeonpea are given at table-1. The N, P and K uptakes of pigeonpea were significantly influenced by the cropping systems in both the years of the experimentation. Higher uptakes of N (46.47, 47.54 kg/ha), P (14.58, 14.42 kg/ha) and K (6.99, 6.83 kg/ha) were recorded in pigeonpea sole cropping system as compared to intercropping system in both years of the experiment. Similar finding were recorded by Jat *et al.* (2004) who observed that sole pigeonpea recorded higher nutrient uptakes.

The N, P and K uptakes of pigeonpea were significantly influenced by the sources of phosphorous in both the years of the experimentation. Higher uptakes of N (41.27, 41.26 kg/ha), P (13.20, 12.61 kg/ha) and K (6.42, 6.07 kg/ha) were recorded with rock phosphate (RP) source of phosphorous as compared to single super phosphate (SSP) source of phosphorous. The rock phosphate (RP) as source of phosphorous may have facilitated better availability of plant nutrients and growth parameters which resulted in higher yield. Mathan *et al.* (1994) also recorded highest uptakes of N, P and K with rock phosphate as source of phosphorous. The findings of Meena *et al.* (2005) and Ravi *et al.* (2001) observed similar results.

The N, P and K uptakes of pigeonpea were significantly influenced by the levels of phosphorous in both the years of the experimentation. Application of phosphorous at 80 kg P_2O_5/ha level recorded higher uptakes of N (47.55, 46.02 kg/ha), P (15.18, 13.88 kg/ha) and K (7.43, 6.74 kg/ha). Modak *et al.* (1994) observed that uptakes of N and P increased with P application rate. Pawar *et al.* (1998) observed that in pigeonpea,

Table 1. N, P and K uptakes in pig eonpea as influenced by cropping systems, sources and levels of phosphorus

Treatment	N (kg/ha)		P (kg/ha)		K (kg/ha)	
	2008	2009	2008	2009	2008	2009
Cropping systems						
M_1	46.47	47.54	14.58	14.42	6.99	6.83
M_3	34.24	34.85	11.48	11.13	5.59	5.37
M_4	37.27	38.35	12.17	12.04	5.97	5.87
SEm±	0.34	0.67	0.13	0.15	0.07	0.06
CD (P=0.05)	0.94	1.85	0.36	0.42	0.20	0.15
Sources of phosphorus						
S_1	37.39	39.23	12.29	12.45	5.95	5.99
S_2	41.27	41.26	13.20	12.61	6.42	6.07
SEm±	0.26	0.36	0.11	0.08	0.08	0.04
CD (P=0.05)	0.62	0.88	0.26	NS	0.20	NS
Levels of phosphorus(kg/ha)						
L_1	31.37	33.90	10.43	11.05	5.02	5.27
L_2	39.08	40.81	12.63	12.67	6.11	6.07
L_3	47.55	46.02	15.18	13.88	7.43	6.74
SEm±	0.36	0.35	0.09	0.07	0.04	0.04
CD (P=0.05)	0.74	0.72	0.18	0.15	0.09	0.07

M_1: Pigeonpea sole
M_3: Pigeonpea+ soybean 1:1 ratio (Additive series)
M_4: Pigeonpea 50/100 + 2 rows of soybean
S_1: Single super phosphate (SSP)
S_2: Rock phosphate (RP)
L_1: Control
L_2: 40 kg. P_2O_5/ha
L_3: 80 kg. P_2O_5/ha

P uptakes increased with increasing P rate. Higher N, P and K uptakes of pigeonpea was recorded in the treatment with the interaction effects among pigeonpea sole cropping system, rock phosphate (RP) source of phosphorous and 80 kg P_2O_5/ha level of phosphorous.

Nutrient uptakes of soybean

Data on N, P and K uptakes of soybean are given at table-2. The N, P and K uptakes of soybean were significantly influenced by the cropping systems in both the years of the experimentation. Higher uptakes of N (122.4, 119.2 kg/ha), P (6.8, 6.4 kg/ha) and K (61.1, 59.2 kg/ha) ware observed in soybean sole cropping system as compared to intercropping system. However in contradiction, Nimje *et al.* (1996) observed that the N and P contents of seed and straw, and total N and P uptakes, were higher with the pigeonpea and soybean 1:3 intercropping system.

The N, P and K uptakes of soybean were significantly influenced by the sources of phosphorous in both the years of the experimentation. Higher uptakes of N (98.87, 94.65 kg/ha), P (5.66, 5.25 kg/ha) and K (50.35, 47.61 kg/ha) uptakes were observed in rock phosphate (RP) as source of phosphorous as compared to single super phosphate (SSP). The rock phosphate (RP) may have facilitated better availability of plant nutrients and growth parameters which resulted in higher uptakes. Agarwal *et al.* (2004) reported that compacted rock phosphate (RP) as source of P was at par with SSP for uptake of Ca, S and P by crops. Rana *et al.* (2004) reported that single large application of rock phosphates in acid P deficient soil results in a significant build up of soil available P which helps in increasing crop yields and P uptake by crops.

The N, P and K uptakes of soybean were significantly influenced by the levels of phosphorous in both the years of the experimentation. Application of phosphorous at 80 kg P_2O_5/ha level recorded higher uptakes of N (111.4, 105.9 kg/ha), P (6.3, 5.7 kg/ha) and K (58.2, 54.7 kg/ha). Bhakare *et al.* (2000) recorded higher P uptake in grain and straw from the 100 kg P_2O_5/ha treatment. The results showed that inorganic forms of P contributed to increased availability, uptake and yield in soybean. Ghosh *et al.* (2005) reported that the highest P uptake was obtained with 75 kg P_2O_5 /ha application. The effects of combined application of N, P and S increased yield, uptake and utilization of fertilizer P. Majumdar *et al.* (2001) reported that all the P levels significantly increased the N, P and S uptake by soybean. Prasad *et al.* (2006) reported that P uptake of soybean increased with increased level of P application in soils of both medium and high fertility status.

Table 2. N, P and K uptakes in soybean as influenced by cropping systems, sources and levels of phosphorus

Treatment	N (kg/ha)		P (kg/ha)		K (kg/ha)	
	2008	2009	2008	2009	2008	2009
Cropping systems						
M_2	122.4	119.2	6.8	6.4	61.1	59.2
M_3	76.9	72.7	4.3	3.9	40.1	37.8
M_4	90.8	88.0	4.9	4.6	47.0	44.8
SEm±	2.31	1.61	0.14	0.07	4.13	1.18
CD (P=0.05)	6.93	4.83	0.42	0.21	12.39	3.54
Sources of phosphorus						
S_1	94.49	91.98	4.96	4.67	48.43	46.91
S_2	98.87	94.65	5.66	5.25	50.35	47.61
SEm±	0.83	0.81	0.06	0.03	1.63	1.39
CD (P=0.05)	2.49	2.43	0.18	0.09	NS	NS
Levels of phosphorus (kg/ha)						
L_1	81.7	79.2	4.4	4.1	41.2	39.9
L_2	97.0	94.9	5.3	5.1	48.8	47.2
L_3	111.4	105.9	6.3	5.7	58.2	54.7
SEm±	0.58	0.89	0.07	0.07	0.85	0.72
CD (P=0.05)	1.2	1.83	0.15	0.15	1.74	1.48

M_2: Soybean sole
M_3: Pigeonpea+ soybean 1:1 ratio (Additive series)
M_4: Pigeonpea 50/100 + 2 rows of soybean
S_1: Single super phosphate (SSP)
S_2: Rock phosphate (RP)
L_1: Control
L_2: 40 kg. P_2O_5/ha
L_3: 80 kg. P_2O_5/ha

Reddy *et al.* (2006) reported that P uptake by soybean increased with increasing P rate under all the P supply strategies.

Nutrient Uptakes of succeeding wheat crop

Data on N, P and K uptakes of succeeding wheat are given at table-3. The cropping systems had significant residual effects on the uptakes of the succeeding wheat crop in both years of the experimentation. Higher N, P and K uptakes were recorded in the succeeding wheat crop due to the residual effects of pigeonpea/soybean sole cropping systems in both years of the experimentation. This may be attributed to better nutrients availability in sole cropping systems.

The sources of phosphorous had significant residual effects on N, P and K uptakes of the succeeding wheat crop in both the years of the experimentation. Higher uptakes of N (49.64, 51.01 kg/ha), P (16.93. 17.10 kg/ha) and K (65.67, 65.90 kg/ha) in the succeeding wheat crop were recorded due to residual effects of rock phosphate (RP) as source of phosphorous as compared to single super phosphate (SSP). Qureshi *et al.* (2005) also reported that residual effects of phosphate rocks applied to soybean significantly improved the uptake of P in wheat crops over no-P control.

The levels of phosphorous had significant residual effects on N, P and K uptakes of the succeeding wheat crop in both the years of the experimentation. Application of Phosphorous at 80 kg P_2O_5/ha recorded higher uptakes of N (56.52, 57.71 kg/ha), P (17.77, 17.93 kg/ha) and K (69.59, 70.02 kg/ha) in the succeeding wheat crop as compared to control. Ghosh *et al.* (2003) observed that total P uptake by residual wheat crop showed wide variation among different treatments. Lal *et al.* (1997) observed that the total P uptakes by wheat were enhanced significantly by the residual effects of P fertilizer. Ummed Singh *et al.* (2006) observed that application of 34.4 kg P/ha to pigeonpea recorded higher N and P uptakes in succeeding wheat.

Soil fertility status after harvest of the pigeonpea & soybean crops

Data on soil fertility status are given at table-4. The cropping systems had significant residual effects on the N, P and K contents of the soil after harvest of intercrops in both years of the experimentation. Higher N and P contents of the soil, due to the residual effects of pigeonpea sole cropping systems and higher K content of the soil, due to the residual effects of cropping systems of pigeonpea 50/100 + 2 rows of soybean were recorded in both years of the experimentation. This may be attributed to better nutrients availability in the cropping systems. Kantwa *et al.* (2006)

Table 3. N, P and K uptakes in wheat as influenced by residual effects of cropping systems, sources and levels of phosphorus in the previous season

Treatment	N (kg/ha)		P (kg/ha)		K (kg/ha)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Cropping systems						
M_1	54.45	56.72	16.92	17.29	64.45	65.15
M_2	50.74	53.38	17.06	17.66	65.57	67.51
M_3	44.99	45.07	16.51	16.34	65.36	64.80
M_4	45.10	45.25	16.23	15.98	64.19	63.10
SEm±	0.60	1.00	0.09	0.18	0.51	0.51
CD (P=0.05)	1.80	3.00	0.27	0.54	1.53	1.53
Sources of phosphorus						
S_1	48.00	49.20	16.43	16.54	64.11	64.38
S_2	49.64	51.01	16.93	17.10	65.67	65.90
SEm±	0.21	0.45	0.05	0.06	0.27	0.26
CD (P=0.05)	0.63	1.35	0.15	0.18	0.81	0.78
Levels of phosphorus (kg/ha)						
L_1	40.35	41.45	15.42	15.58	59.77	60.07
L_2	49.59	51.15	16.85	16.95	65.32	65.32
L_3	56.52	57.71	17.77	17.93	69.59	70.02
SEm±	0.33	0.41	0.06	0.06	0.39	0.36
CD (P=0.05)	0.99	1.23	0.18	0.18	1.17	1.08

M_1: Pigeonpea sole
M_2: Soybean sole
M_3: Pigeonpea+ soybean 1:1 ratio (Additive series)
M_4: Pigeonpea 50/100 + 2 rows of soybean

S_1: Single super phosphate (SSP)
S_2: Rock phosphate (RP)

L_1: Control
L_2: 40 kg. P_2O_5/ha
L_3: 80 kg. P_2O_5/ha

Table 4. N, P and K status of soil at the end of each cropping cycle as influenced by cropping systems, sources and levels of phosphorus

Treatment	After *kharif* season crops						After *rabi* season crop					
	N (kg/ha)		P (kg/ha)		K (kg/ha)		N (kg/ha)		P (kg/ha)		K (kg/ha)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Cropping systems												
M_1	368.2	376.2	48.9	35.0	227.6	190.1	353.8	359.5	32.0	17.8	180.4	130.2
M_2	357.9	348.0	47.8	41.9	228.7	137.9	347.2	234.6	30.8	24.2	180.5	136.2
M_3	320.2	311.5	46.8	40.2	226.8	173.5	315.3	306.4	30.3	23.9	178.4	134.0
M_4	321.4	302.9	46.1	39.0	232.5	226.4	316.3	297.7	29.9	23.1	185.5	136.2
SEm±	3.54	3.18	1.02	1.02	0.71	0.86	3.18	3.11	1.02	1.09	1.00	0.72
CD (P=0.05)	10.62	9.54	3.06	3.06	2.13	2.58	9.54	9.33	NS	3.27	3.00	2.16
Sources of phosphorus												
S_1	343.3	313.0	46.9	39.0	227.7	181.7	335.3	303.8	30.5	22.5	180.8	134.5
S_2	340.6	306.3	47.9	39.1	230.1	182.3	331.0	295.3	31.0	22.0	181.6	133.6
SEm±	2.68	2.64	0.31	0.32	0.43	0.51	2.64	2.82	0.32	0.29	0.43	0.45
CD (P=0.05)	NS	NS	0.93	NS	1.29	NS	7.92	NS	NS	NS	NS	NS
Levels of phosphorus (kg/ha)												
L_1	332.3	318.9	45.5	22.1	222.9	182.8	332.0	317.5	30.1	36.5	180.3	139.9
L_2	340.3	306.2	47.2	38.6	228.9	181.6	330.7	295.1	30.4	31.6	180.8	133.5
L_3	353.3	303.8	49.5	56.5	234.9	181.5	336.7	286.1	31.8	38.5	182.5	128.7
SEm±	3.48	3.33	0.34	0.35	0.49	0.5	3.33	3.30	0.35	0.35	0.47	0.58
CD (P=0.05)	10.44	9.99	1.02	1.05	1.47	1.5	NS	9.91	NS	NS	1.41	1.74

M_1: Pigeonpea sole
M_2: Soybean sole
M_3: Pigeonpea+ soybean 1:1 ratio (Additive series)
M_4: Pigeonpea 50/100 + 2 rows of soybean

S_1: Single super phosphate (SSP)
S_2: Rock phosphate (RP)

L_1: Control
L_2: 40 kg. P_2O_5/ha
L_3: 80 kg. P_2O_5/ha

observed that the soil had lower available P status at harvest after intercropping as compared with sole pigeonpea. Prasad *et al.* (1997) observed that soybean + pigeonpea in 4:1 rows intercropping system also added maximum nitrogen to the soil through leaf litter of soybean and pigeonpea. The available N status in soil after harvest of soybean, pigeonpea and soybean + pigeonpea intercropping systems was higher than other intercropping systems, while organic carbon and available P and K under treatments did not show appreciable variations. Nimje (2003) observed that the available N and P contents of soil were highest under soybean-gram and pigeonpea-wheat systems.

The sources of phosphorous had significant residual effects on N, P and K contents of the soil after harvest of intercrops in both the years of the experimentation. Higher N content of the soil after harvest of intercrops were recorded due to the residual effects of single super phosphate (SSP) as source of phosphorous compared to rock phosphate (RP) in both the years of the experimentation, whereas higher P and K contents of the soil after harvest of intercrops were recorded due to the residual effects of rock phosphate (RP) as source of phosphorous compared to single super phosphate (SSP) in the first year of the experimentation only. Dutta (2007) reported that the integrated use of the indigenous source of P (RP), SSP, FYM and PSB increased P availability in soil. Mathan *et al.* (1994) observed that with application of 50 kg P_2O_5/ha as rock phosphate, the available nutrient status of the soil after harvesting increased significantly. The levels of phosphorous had significant residual effects on N, P and K contents of the soil after harvest of intercrops in both the years of the experimentation. Phosphorous at 80 kg P_2O_5/ha recorded higher nutrient (N P & K) status of the soil as compared to control. Bhakare *et al.* (2000) reported that an increase in applied P increased soil available P. Mathan *et al.* (1994) observed that with application of 50 kg P_2O_5/ha as rock phosphate, the available nutrient status of the soil after harvesting increased significantly.

Soil fertility status after harvest of the succeeding wheat crops

Data on soil fertility status are given at table-4. The cropping systems had significant residual effects on the nutrient contents of the soil after harvest of the succeeding wheat crop in both years of the experimentation. Higher N content of the soil after harvest was recorded in the succeeding wheat crop due to the residual effects of pigeonpea sole cropping systems in both years of the experimentation. Higher P content of the soil after harvest was recorded in the succeeding wheat crop due to the residual effects of cropping systems of pigeonpea+ soybean 1:1 ratio in the second year of the experimentation. Higher K content of the soil after harvest was recorded in the succeeding wheat crop due to the residual effects of cropping systems of pigeonpea 50/100 + 2 rows of soybean, in both years of the experimentation. This may be attributed to better nutrients uptake and availability in different cropping systems.

The sources of phosphorous had significant residual effects on N content of the soil after harvest of the succeeding wheat crop. Higher nutrient N content of the soil after harvest of the succeeding wheat crop were recorded due to the residual effects of single super phosphate (SSP) as source of phosphorous compared to rock phosphate (RP) in the second year of the experiment only. The sources of phosphorous had no significant residual effects on P and K contents of the soil after harvest of the succeeding wheat crop in both the years of the experiment.

The levels of phosphorous had significant residual effects on N content of the soil after harvest of the succeeding wheat crop in the second year of the experimentation only. The levels of phosphorous had no significant residual effects on P content of the soil after harvest of the succeeding wheat crop in both years of the experimentation. The levels of phosphorous had significant residual effects on K content of the soil after harvest of the succeeding wheat crop. Phosphorous at 80 kg P_2O_5/ha recorded higher K content of the soil after harvest of the succeeding wheat crop in the first year of the experiment, however phosphorous at control recorded higher K content of the soil after harvest of the succeeding wheat crop in the second year of the experiment. This may be attributed to dynamics of nutrients in cropping systems, nutrient management practices and nutrient recycling on introduction of legume crops in the system.

CONCLUSION

The N uptakes in succeeding wheat crop was superior when preceding cropping system was sole pigeonpea which received rock phosphate at 80 kg P_2O_5/ha. However the P and K uptakes in succeeding wheat crop were superior when the cropping system of the preceding crop was sole soybean which received rock phosphate at 80 kg P_2O_5/ha. The rock phosphate as source of phosphorous when applied at 80 kg P_2O_5/ha, would be superior as it is the cheaper source of phosphorous suitable to the farmers and when applied in either pigeon or soybean sole cropping system, enhances the soil fertility status, thus helping sustained crop growth and yield.

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Crop growth indices of wheat-Japanese mint intercropping as influenced by land configurations and nutrition levels

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ABSTRACT

A field experiment was conducted during winter to summer seasons of 2006-07 and 2007-08 at Gurdaspur (Punjab) on silty clay loam soil to study the crop growth rate (CGR) and relative growth rate (RGR) of wheat-Japanese mint (J. mint) intercropping system under different planting methods and nitrogen levels. The experiment was laid out in randomized block design having two planting methods viz. two rows of wheat (November sown) with 20 cm row spacing and two rows of J. mint (intercropping in February) on outer sides of wheat rows under flat and bed (37.5 cm top + 30 cm furrow) methods covering a total width of 67.5 cm and five levels of nitrogen i.e. 0+0 (control), 90+75, 120+75, 150+75 and 180+75 kg N ha^{-1} to wheat and J. mint, respectively. In wheat, the bed method gave significantly higher CGR over flat and it was higher by 8.9, 12.4 and 24.4 per cent during 2006-07 and 11.9, 16.6 and 40.4 per cent during 2007-08 at 60-90 DAS, 90-120 DAS and 120 DAS-harvest stage, respectively. In J. mint, during both the years from 60-90 DAS, the flat recorded significantly higher CGR than the bed. However, at 120 DAS-harvest stage during 2007-08, the bed produced significantly higher CGR than the flat, possibly due to variable rainfall pattern between the years. Between 120 DAS-harvest stage, the CGR of wheat decreased from 0 to 90 kg ha^{-1} and then increased upto 150 kg N ha^{-1} during 2006-07 and it enhanced upto 180 kg ha^{-1} during 2007-08. The impact of higher rate of N application to wheat remained effective for wheat only and it was not shifted on the CGR of J. mint. During both the years at all the stages, the RGR of wheat did not differ significantly due to both the planting methods except at 120 DAS-harvest stage during 2007-08. In J. mint, at almost all the crop growth intervals, both the planting methods differed significantly in RGR. The RGR of wheat at N_{120} over control showed an increment of 71 and 39 per cent at 60-90 DAS and 9 and 35 per cent at 90-120 DAS during 2006-07 and 2007-08, respectively but, reversely, at 120 DAS-harvest stage, the respective increase in control over N_{120} was 109 and 276 per cent. Interactive impact of planting method and nitrogen levels on CGR of wheat was significant between 120 DAS-harvest stage during 2007-08.

Key words: Wheat, mint, intercropping, crop growth rate, relative growth rate, planting method, nitrogen

INTRODUCTION

In the present scenario, increase in the productivity of wheat per unit area per unit time is a challenging task under Punjab conditions. However, the possibility of higher productivity can be explored by adopting better alternative techniques like intercropping of a high value crop J. mint in standing wheat and altering the management practices especially land configurations and nitrogen application. Common characteristics of different forms of intercropping are that they have the advantage of exploiting environmental resources more efficiently (Francis, 1989; Li et al., 2003; Zhang and Li, 2003; Li et al., 2006), improving soil fertility (Shen and Chu, 2004; Dahmardeh et al., 2010) and increasing crop yield and quality (Javanmard et al., 2009; Dahmardeh et al., 2010). In an intercropping situation where two or more crops are associated, their fertilizer requirement may vary widely and hence, fertilization becomes more complex (Singh et al, 1996).

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Growth analysis is an important tool in the prediction of yield and to assess the events that occurs during plant growth. It is a suitable method for plant response to different environmental conditions during plant life (Teaser, 1984). Crop growth rate and relative growth rate are the most important traits in plant growth analysis and are useful for interpreting plant reaction to environmental factors. Crop growth rate indicates the rate at which a crop is growing and expressed as kg ha^{-1} day^{-1}. Relative growth rate indicates the rate of growth per unit dry matter. It is expressed as milligram of dry matter produced by a gram of existing dry matter in a day.

As per the packages of practices of Punjab, the sowing of wheat is recommended on flat as well as bed planting with the help of seed-cum-fertilizer drill and bed planter, respectively. Reports from India and Pakistan revealed many advantages of bed planting in rice-wheat systems (Hobbs and Gupta, 2003; Connor *et al.*, 2003). Bed planting may improve the resource use efficiency and increase the yield potential of wheat. Bed planting offers many benefits like opportunity for mechanical weed control, reduced crop lodging, lowering of the seeding rates and reduced water logging (Humpreys *et al.*, 2005). Beds also provide additional advantages like reduced germination of *Phalaris minor*, reduced irrigation water requirement (by 30-50%), reduced water logging (Sharma and Swarup, 1988; Gill *et al.*, 1993) and reduced seed rate requirement by 25-30% (Dhillon *et al.*, 2004). Owing to its positive results, it has also been recommended and included in the package of practices of Punjab Agricultural University, Ludhiana in 2002-03 (PAU, 2002). Therefore, studies of wheat-mint intercropping under flat and bed planting methods is very significant.

In wheat-mint intercropping system, whole of nitrogen to wheat was applied within one month of sowing and to J. mint, half nitrogen was applied at the time of planting in the mid season of wheat and the remaining half nitrogen was top dressed after harvesting of wheat crop. The possibility was there that J. mint crop might use the residual nitrogen applied to wheat. Therefore, suitable rate of nitrogen application under different planting methods for the growth of both the component crops in an intercropping system needs to be evaluated.

Considering these facts, a two year study was conducted to study the crop growth rate and relative growth rate of wheat-mint intercropping system under flat and bed planting methods with various rates of nitrogen application.

MATERIALS AND METHODS

A field experiment was conducted during winter (*rabi*) to summer seasons of 2006-07 and 2007-08 at Village Dalla in the Gurdaspur district of Punjab. Chemical analysis of the experimental soil indicated that it was normal in reaction and non-saline, high in organic carbon, low in available nitrogen, high in available phosphorous and potassium at 0-15 cm depth whereas it was low in available nitrogen and medium in organic carbon, available phosphorus and potassium at 15-30 cm depth.

The treatments comprising of two planting methods and five levels of nitrogen were tested in randomized block design with three replications. Two rows of wheat (W) with 20 cm spacing and planting of two rows of J. mint (M) in close vicinity on outer sides of wheat rows (2:2) were sown under flat (FP) and bed planting (BP) covering a total width of 67.5 cm and designated as FP-W+M (2:2) 67.5 cm (Fig. 1) and BP-W+M (2:2) 67.5 cm (Fig. 2), respectively. Five levels of nitrogen i.e. 0+0

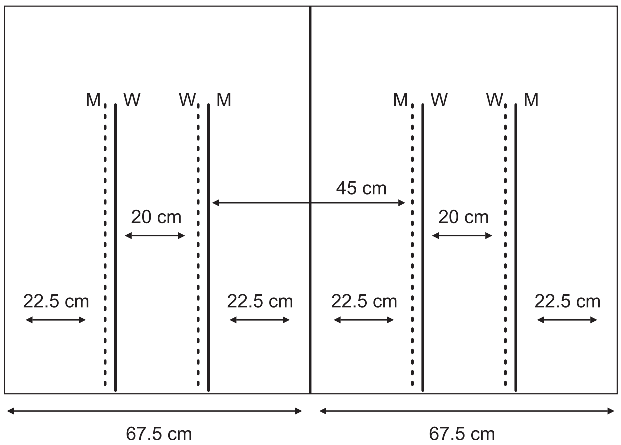

Fig. 1. Flat method: FP-W+M (2:2) 67.5 cm

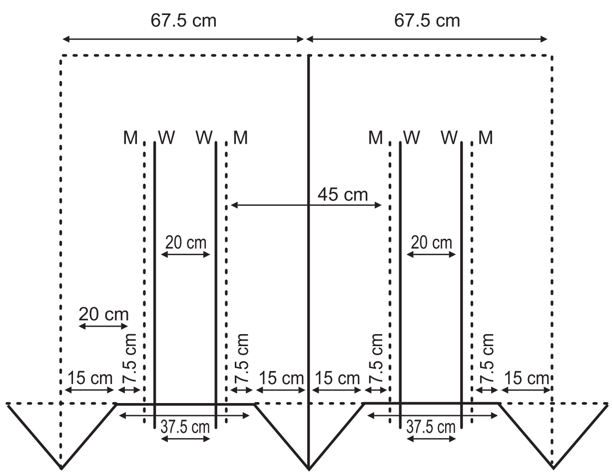

Fig. 2. Bed planting: BP-W+M (2:2) 67.5 cm

(control), 90+75, 120+75, 150+75 and 180+75 kg N ha^{-1} to wheat and J. mint, respectively, were abbreviated as WN_0+MN_0, $WN_{90}+MN_{75}$, $WN_{120}+MN_{75}$, $WN_{150}+MN_{75}$, $WN_{180}+MN_{75}$ in similar order.

The wheat variety 'PBW 502' was sown on November 3 and 5 during 2006-07 and 2007-08, respectively, using 75 kg seed ha^{-1}. In a single operation, with the help of bed maker-cum-planter, the raised beds of 67.5 cm were prepared by keeping 37.5 cm as the top of the bed with furrows of 30 cm and two rows of wheat were drilled at 20 cm spacing on the top of the 37.5 cm raised beds. Irrigation water was applied in the furrows between the beds and water was not allowed to reach at the top of the bed by applying 5 cm irrigation on the plot area basis. Bed sown row arrangements were exactly followed in the flat situation and crop was sown in solid rows with the help of seed drill and irrigated with 7.5 cm of depth. In Punjab, the row to row spacing of wheat has been recommended as 20 cm on bed top and it is 20-22 cm for flat. To make the uniformity of treatments, the row spacing in both the methods was kept 20 cm.

Planting of J. mint was done in the standing wheat on February, 7 and 10 during 2006-07 and 2007-08, respectively. In bed planting, two rows of J. mint were planted on the bed-top on outer sides of wheat rows. In flat situation, similar row pattern was followed. The wheat and J. mint were harvested manually on April 13 and June 26 during 2006-07 and on April 19 and July 10 during 2007-08, respectively.

Nitrogen fertilizer was applied through urea to wheat and J. mint as per treatment. In wheat, half dose of N was broadcast just before sowing of wheat and the remaining N was top dressed after first irrigation. In J. mint crop, half of the N was applied along the J. mint rows at the time of planting and remaining half N applied as top dressing after harvesting of wheat crop. In flat, fertilizer was broadcast uniformly but in bed treatment it was applied carefully on the top 37.5 cm width for both wheat and J. mint crops. Recommended dose of phosphorus i.e. 61.8 kg P_2O_5 ha^{-1} was applied to wheat at sowing through diammonium phosphate but it was skipped at the time of planting of J. mint. All the recommended cultural operations were followed as per packages of practices for *rabi* and *kharif* crops of Punjab (PAU, 2006 and PAU, 2007).

Crop growth indices i.e. crop growth rate and relative growth rate of wheat and J. mint were calculated at 60-90 DAS, 90-120 DAS and 120 DAS-harvest stages by using the following formulae and expressed in kg ha^{-1} day^{-1} and mg g^{-1} day^{-1}, respectively.

$$CGR = \frac{(W_2-W_1)}{(t_2-t_1)}$$

$$RGR = \frac{(Log_eW_2-Log_eW_1)}{(t_2-t_1)}$$

where, W_1 and W_2 referred to dry matter weight of plants at time t_1 and t_2, respectively.

RESULTS AND DISCUSSION

Crop growth rate of wheat and J. mint

Planting method

The crop growth rate of wheat and J. mint indicated that as both the crops progressed from 60 DAS-120 DAS, it showed an increasing trend under flat and bed planting methods during 2006-07 and 2007-08 (Table 1). In the subsequent stage i.e. 120 DAS-harvest, the CGR of wheat during both the years and J. mint during 2006-07 decreased under both the planting methods. However, in the year 2007-08, the CGR of J. mint under flat planting decreased marginally but it increased in bed planting. In wheat, the 'Bed Planted Wheat + J. mint (2:2 rows) on 67.5 cm width' gave significantly higher crop growth rate of wheat over 'Flat Planted Wheat + J. mint (2:2 rows) on 67.5 cm width' and it was higher by 8.9, 12.4 and 24.4 per cent during 2006-07 and 11.9, 16.6 and 40.4 per cent during 2007-08 at 60-90 DAS, 90-120 DAS and 120 DAS-harvest stage, respectively. Favourable environment of the bed which contained loose soil and better aeration (West and Black, 1969), possibly enhanced the mineralization of nutrients which increased root growth and consequently the higher CGR. Rasheed *et al*. (2003) reported that crop growth rate of hybrid maize at 30-75 DAS was significantly higher in the crop planted on 70 cm spaced ridges (31.1 g m^{-2} day^{-1}) than 70 cm spaced single-rows (28.0 g m^{-2} day^{-1}). In J. mint, during both the years from 60-90 DAS, the flat method recorded significantly higher crop growth rate than the bed planting. At 90-120 DAS during both the years and 120 DAS-harvest stage during 2006-07, both the planting methods were on par. However, at 120 DAS-harvest stage during 2007-08, the bed produced significantly higher CGR than the flat. The possible reason for variation in CGR of J. mint between the planting methods was related to

Table 1. Effect of planting methods and nitrogen levels on the crop growth rate of wheat and J. mint

Treatment	Crop growth rate (kg $ha^{-1}day^{-1}$)											
	60-90 DAS				90-120 DAS				120 DAS-harvest			
	Wheat		J. Mint		Wheat		J. Mint		Wheat		J. Mint	
	06-07	07-08	06-07	07-08	06-07	07-08	06-07	07-08	06-07	07-08	06-07	07-08
Planting Methods (P)												
FP-W+M (2:2) 67.5 cm	107.3	99.2	24.0	28.8	146.2	141.5	71.7	73.7	44.3	44.6	66.1	72.7
BP-W+M (2:2) 67.5 cm	116.8	111.1	19.8	25.1	164.4	165.0	68.0	70.9	55.1	62.6	67.5	90.8
CD (5%)	4.58	5.20	1.70	1.85	9.44	9.49	NS	NS	7.12	3.09	NS	5.25
Nitrogen (Kg ha^{-1})												
WN_0+MN_0	36.9	44.7	17.9	22.3	61.9	53.2	54.2	53.8	49.2	73.9	43.7	55.5
$WN_{90}+MN_{75}$	124.6	115.0	22.8	28.1	169.6	163.8	74.4	75.9	28.1	33.1	74.2	89.9
$WN_{120}+MN_{75}$	131.4	120.7	22.8	28.0	176.9	178.0	72.9	76.5	60.0	44.5	71.9	87.2
$WN_{150}+MN_{75}$	133.8	122.0	23.3	27.8	184.0	185.4	73.6	77.5	69.0	56.7	71.5	89.4
$WN_{180}+MN_{75}$	133.7	123.4	22.7	28.6	184.3	186.0	74.2	77.7	42.2	60.1	72.6	86.6
CD (5%)	7.24	8.22	2.69	2.93	14.93	15.01	6.33	8.17	12.92	4.89	9.34	8.31

variable rainfall pattern between the two years. During first year, due to comparatively low rainfall (70.4 mm) between 120 DAS-harvest stage, the crop on beds came under water stress which affected the crop growth. In the second year, higher rainfall (314.7 mm) during this period caused excess moisture content and poor aeration under flat planting owing to heavy texture of the soil which suppressed the plant growth. While, the bed sown J. mint escaped from submergence / water logged like situation and, infact, the rainfall favoured the crop growth rate due to optimization of soil moisture under the bed. Sweeney and Sisson (1988) reported improved drainage in root zone in case of poorly drained soil.

At 90-120 DAS, the CGR of J. mint on beds was less than flat whereas in case of wheat it was opposite. It is mentioned that all the growth stages of both the crops were observed at different times, and environmental conditions were also not similar in the same number of days after sowing. Because, wheat was sown in the month of November and J. Mint was planted in the month of February. In J. mint, the crop on beds came under water stress due to high temperature of 36.1^0 C and 33.4^0 C during 2006-07 and 2007-08, respectively, prevailing at that stage and it resulted into less accumulation of dry matter on the beds. Moreover, irrigation water was applied in the furrows only and it could reach to mint plants owing to seepage. Further, Yadav *et al.* (2002) reported rapid drying of soil surface in bed planting. This might be the reason for low CGR in mint at this stage. On the contrary, wheat recorded maximum temperature of 17.7^0 C during 2006-07 and 17.0^0 C during 2007-08 at 90-120 DAS and it remained favourable for more accumulation of dry matter accumulation in wheat and consequently higher CGR on beds. West and Black (1969) also confirmed that favourable environment of the bed which contained loose soil and better aeration, possibly enhanced the mineralization of nutrients which increased the root growth and finally the higher CGR.

Nitrogen

During both the years, between 60-120 DAS, CGR of wheat was generally enhanced as the N application increased from 0 to 180 kg ha^{-1}. Between 120 DAS-harvest stage, it decreased from 0 to 90 kg ha^{-1} and then increased upto 150 kg N ha^{-1} during 2006-07 and enhanced upto 180 kg ha^{-1} during 2007-08. When comparison was made between no application and highest rate of N application to wheat (N_{180}), it was observed that N_{180} recorded an increase of 262 and 176 per cent at 60-90 DAS and 198 and 250 per cent at 90-120 DAS during first and second year, respectively but reversely, at 120 DAS-harvest stage, the respective increase in control was 17 and 23 per cent over N_{180}. Higher CGR was also observed at 160 kg N ha^{-1} in wheat (Kakar, 2003) and at 250 kg N ha^{-1} in hybrid maize (Rasheed *et al.*, 2003) than unfertilized crop. Bennett *et al.* (1989), Ahmad *et al.* (1993) and Mohsan (1999) also reported an increase in CGR of maize with the application of N over control. No application of nitrogen (control) recorded significantly less CGR of wheat than all the N fertilized treatments between 60-120 DAS during both the years. During 2006-07, between 120 DAS-harvest stage, the crop growth rate under control was maximum and on par with N_{120} and N_{180}. Interestingly, during 2007-08 between 120 DAS-harvest stage, the control recorded significantly higher crop growth rate over all the N fertilized treatments indicating that crop mechanism tried to accumulate maximum dry matter at the last phase even with no application of fertilizer.

At all the growth stages, N application to wheat at all the levels had no visible impact on the CGR of J. mint but application of N at 75 kg ha^{-1} to J. mint gave significantly higher increase in crop growth rate than the control (N_0). Therefore, it indicated that the impact of higher rate of N application to wheat remained effective for wheat only and it was not shifted on the growth of J. mint.

Relative growth rate of wheat and J. mint

Irrespective of planting methods and nitrogen levels, the trend in Table 2 revealed that the relative growth rate of wheat and J. mint was decreased as the crop advanced from 60 DAS-harvest stage.

Planting method

During both the years at all the stages, the RGR of wheat did not differ significantly due to both the planting methods except at 120 DAS-harvest stage during 2007-08 where the bed sown wheat recorded 16 per cent higher RGR than flat method and the differences were significant (Table 2). In J. mint, at almost all the crop growth intervals, both the planting methods differed significantly with respect to RGR. At the initial growth stage i.e. 60-90 DAS during both the years, flat recorded higher RGR than bed. At 90-120 DAS and 120 DAS-harvest, bed produced significantly higher RGR than the flat method and it was higher by 7.9 and 8.3 per cent in 2006-07 and 5.4 and 24.3 per cent in 2007-08 per cent, respectively.

Nitrogen

The two year experiment on the RGR of wheat portrayed that the impact of N application was significant except at 90-120 DAS during 2006-07. While comparing N_{120} with no application of N, it was noticed that N_{120} gave an increment of 71 and 39 per cent at 60-90 DAS and 9 and 35 per cent at 90-120 DAS during 2006-07 and 2007-08, respectively but reversely, at 120 DAS-harvest stage, in similar order, the control was higher by 109 and 276 per cent over N_{120}. In the initial stages of crop growth, no application of nitrogen (control) recorded low RGR but at 120 DAS-harvest stage, it was significantly higher than all the N levels. It clearly indicated that in the late phase, the plant mechanism tried to recover the initial set back in RGR under no application of N. In J. mint, at 60-90 DAS and 120 DAS-harvest stage during 2006-07 and 90-120 DAS during both the years, all the N levels (N_{75} to J. mint) recorded significantly higher RGR than the control. During both the years, at all the growth intervals, the RGR of J. mint was on par irrespective of variable N levels except WN_0+MN_0 to accompanied wheat crop, showing thereby, that applied level of N_{75} to J. mint was sufficient enough to meet the N requirement of the crop under the wheat+mint intercropping system at these configurations of planting.

Table 2. Effect of planting methods and nitrogen levels on the relative growth rate of wheat and Japanese mint

Treatment	Relative growth rate (mg $ha^{-1}day^{-1}$)											
	60-90 DAS				90-120 DAS				120 DAS-harvest			
	Wheat		J. Mint		Wheat		J. Mint		Wheat		J. Mint	
	06-07	07-08	06-07	07-08	06-07	07-08	06-07	07-08	06-07	07-08	06-07	07-08
Planting Methods (P)												
FP-W+M (2:2) 67.5 cm	16.6	15.4	23.7	26.6	9.5	9.4	17.7	16.6	2.4	2.5	7.2	7.4
BP-W+M (2:2) 67.5 cm	16.4	15.2	23.2	26.2	9.9	9.6	19.1	17.5	2.4	2.9	7.8	9.2
CD (5%)	NS	NS	0.45	NS	NS	NS	0.39	0.30	NS	0.14	0.48	0.65
Nitrogen (Kg ha^{-1})												
WN_0+MN_0	10.6	11.7	22.5	25.8	9.0	7.4	17.7	15.9	4.6	6.4	6.5	7.7
$WN_{90}+MN_{75}$	18.5	16.3	23.6	26.4	9.8	9.8	18.7	17.2	1.1	1.3	7.9	8.7
$WN_{120}+MN_{75}$	18.1	16.3	23.6	26.6	9.8	10.0	18.5	17.3	2.2	1.7	7.8	8.5
$WN_{150}+MN_{75}$	17.9	16.1	24.0	26.5	9.9	10.2	18.4	17.5	2.5	2.1	7.7	8.6
$WN_{180}+MN_{75}$	17.6	16.1	23.6	26.7	9.8	10.1	18.7	17.2	1.5	2.2	7.8	8.3
CD (5%)	1.00	0.62	0.72	NS	NS	0.61	0.61	0.47	0.79	0.23	0.76	NS

Planting method x Nitrogen

Interactive impact of planting method and nitrogen levels on CGR of wheat was significant at 120 DAS-harvest stage during 2007-08. At the same level of N, bed recorded significantly higher CGR than flat planting (Table 3). In both the methods, as the N application increased from 0 to 90 kg ha^{-1}, the CGR of wheat decreased significantly and thereafter, it increased significantly upto 150 N kg ha^{-1}. The interaction occurred due to variation in magnitude of increase or decrease with N levels under both the planting methods.

The Interaction between planting methods and nitrogen levels was also significant on the RGR of wheat at 90-120 DAS during 2006-07 and at 120 DAS-harvest stage during 2007-08 (Table 3). During 2006-07 at 90 to 120 DAS, bed sown wheat recorded significantly higher RGR over the flat when no N was applied. In the remaining N levels, both the planting methods did not differ significantly. In flat method, increasing levels of nitrogen enhanced the RGR of wheat significantly upto N_{90} but in the bed, all the N levels did not differ significantly. During 2007-08 at 120 DAS-harvest stage, both the planting methods were on par at the same levels of N i.e. N_0 and N_{180}, whereas, in the remaining N levels, the bed system was significantly higher than the flat. No application of N (control) to wheat under both the methods was significantly higher than all the combinations of N levels and planting methods. The RGR in both the planting methods was decreased as the N application to wheat increased from control to N_{90}, and thereafter enhanced significantly upto N_{150}.

Irrigation water used

During both the years, the bed system showed a saving of irrigation water applied from the sowing of wheat in November till harvesting of J. mint in the month of June / July (Fig. 3). It was observed that bed planting saved 33.3% irrigation water than the flat. In the bed system, as the irrigation water was applied only in the furrows and it covered less area than flat which resulted into less amount of irrigation water applied.

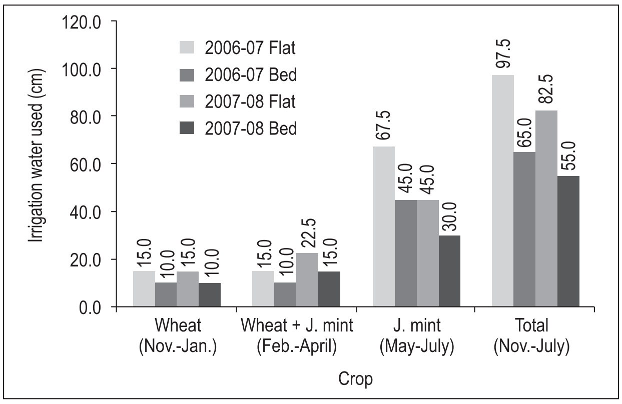

Fig. 1. Irrigation water used in wheat-J.mint intercropping during the season

Table 3. Interactive impact of planting methods and nitrogen levels on crop growth rate (CGR) and relative growth rate (RGR) of wheat

Treatment	Nitrogen (Kg ha^{-1})					
	WN_0+ MN_0	WN_{90}+ MN_{75}	WN_{120}+ MN_{75}	WN_{150}+ MN_{75}	WN_{180}+ MN_{75}	Mean
CGR (kg $ha^{-1}day^{-1}$), 2007-08 at 120 DAS to harvest						
Planting Methods (P)						
FP-W+M (2:2) 67.5 cm	69.9	21.1	32.0	47.2	53.0	44.6
BP-W+M (2:2) 67.5 cm	77.8	45.1	57.0	66.2	67.1	62.6
Mean	73.9	33.1	44.5	56.7	60.1	
CD (5%) : P= 3.09, N= 4.89, P x N= 6.91						
RGR (mg g^{-1} day^{-1}), 2006-07 at 90-120 DAS						
FP-W+M (2:2) 67.5 cm	8.2	9.4	9.7	10.1	10.0	9.5
BP-W+M (2:2) 67.5 cm	9.8	10.3	9.8	9.7	9.7	9.9
Mean	9.0	9.8	9.8	9.9	9.8	
CD (5%) : P= NS , N= NS, P x N= 1.01						
RGR (mg g^{-1} day^{-1}), 2007-08 at 120 DAS-harvest stage						
FP-W+M (2:2) 67.5 cm	6.5	0.9	1.3	1.9	2.1	2.5
BP-W+M (2:2) 67.5 cm	6.3	1.7	2.0	2.3	2.3	2.9
Mean	6.4	1.3	1.7	2.1	2.2	
CD (5%) : P= 0.14, N= 0.23, P x N= 0.32						

CONCLUSION

Considering the CGR and RGR of both wheat and J. mint, the promising option was to adopt the intercropping on beds alongwith application of 120 and 75 kg N / ha to the crops, respectively.

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Performance of aonla based agri-horticulture land use system under integrated nutrient management in Bundelkhand region

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ABSTRACT

A field experiment was conducted to evaluate an aonla based agri-horticulture land use system for red soils with low organic carbon, under integrated nutrient management practices for rainfed Bundelkhand region during 2005-06 to 2007-08 at Central Soil and Water Conservation Research and Training Institute, Research Centre, Datia, Madhya Pradesh. Five treatment combinations viz. T_1 : Control (no nutrient supplement); T_2 : Recommended doses of NPK through chemical fertilizers; T_3 : T_2 + FYM @ 10 t ha^{-1}; T_4 : T_2 + NADEP manure @ 5 t ha^{-1} and T_5 : T_2 + vermi-compost @ 2 t ha^{-1}, were studied and statistically analyzed using RBD. Observations recorded during 3 years of study reveal that the integrated nutrient management has significantly improved physico-chemical properties the soil, plant height of aonla and yield of intercrops, in comparison to control. Highest plant height of aonla (1.44m), grain yield of green gram (560 kg ha^{-1}) and seed yield of Indian mustard (627 kg ha^{-1}) was recorded in treatment combination T_5 (recommended dose of NPK + Vermicompost @ 2 t ha^{-1}) hence found superior over rest of the treatments. Furthermore, highest buildup in organic carbon and available N, P and K in soil profile was also recorded in treatment T_5.

Key words: Aonla, FYM, green gram, Indian mustard, NADEP, red soils, vermi – compost

INTRODUCTION

Bundelkhand region is located between 23° 10' - 26° 30' N and 78° 20' - 81° 40' E with a geographical area of 7.04 M ha, out of which nearly 70 per cent is subjected to varying degree of erosion hazards. The annual rainfall of the region varies from 800 to 1100 mm with very high coefficient of variation. The distribution of rainfall is erratic with long dry spells which formed water stressed soil profile during most part of the year, and confined the agriculture for one crop per year only. Red soils of the region are shallow, with characteristics of very low water holding capacity and excessive permeability. Due to adverse edapho-climatic conditions, these soils are low in organic matter, and deficient in nitrogen and phosphorus hence, are poor in crop productivity. The farmers of this region are generally take one crop in a year during *rabi* season, and are totally dependent on the conserved soil moisture. However, it has been reported in some studies that it is possible to take up two and even three crops in a year through careful selection of crop and efficient management of limited irrigation water (Narayan *et al.*, 2006). Crops like green gram (*Phaseolus radiata* L.) and Indian mustard [*Brassica juncea* (L.) Czernj. & Cosson] have been found to perform well on red soils with supplemental irrigations at critical stages (Narayan *et al.*, 2001). Incorporation of organic nutrient supplements like FYM and green manure in red soil has also proved yield booster through improvement in soil properties. However, the performance of widely promoted composts in the region, such as NADEP and vermi-compost, has not been evaluated in the prevalent cropping systems of the region.

Alternate land use systems, particularly agri-horti systems with the inclusion of *aonla* (*Emblica officinalis*) on marginal and less productive soils, have a tremendous potential in the region (Pathak and Bhatt, 2001). Besides having a nutritional and medicinal value, cultivation of *aonla* is also highly remunerative for small and marginal farmers (Singh and Mishra, 2007). All the above aspects

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were combined into one study, with hypothesis that the application of NADEP and vermi-compost along with the traditionally applied fertilizers could sustain an aonla - based green gram – Indian mustard cropping sequence on rapidly permeable and nutritionally poor red soils.

MATERIALS AND METHODS

A field experiment was conducted during 2005-06 to 2007-08 at Central Soil and Water Conservation Research and Training Institute, Research Centre, Datia (Madhya Pradesh) located at 25^0 40' N, 78^0 28' E and 342.42 m above mean sea level. An *aonla* based agri-horti land use system, with crop rotation of green gram (variety PDM-54) - Indian mustard (variety JM 1) conducted on a Lithic Ustorthent. The experimental soil was sandy loam in texture, with pH (1:2.5) 7.23 and EC 0.13 dS m^{-1} and organic carbon content 0.34 per cent. Available nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) in beginning of the experiment was 212, 14.6 and 234 kg ha^{-1} respectively. The soil was low in organic carbon and available nitrogen whereas, available phosphorus and potassium were at medium range (Table 1). Micronutrients

Table 1. Initial physico-chemical characteristics of the experiment soil

Soil parameter	Value
Soil texture	Sandy loam
Bulk density (Mg m^{-3})	1.53
Available N (kg ha^{-1})	212.0
Available P (kg ha^{-1})	14.6
Available K (kg ha^{-1})	234.0

in the soil were in adequate range. There were five treatments (T_1: control (no nutrient treatment); T_2: NPK (recommended dose through chemical fertilizers); T_3: T_2 + FYM (@10 t ha^{-1}); T_4: T_2 + NADEP manure (@ 5 t ha^{-1}), and T_5: T_2 + vermi-compost (@2 t ha^{-1}) which were tested in randomized block design in four replications. The crops were grown on 21 x 14 m plots following recommended package of practices. Planting pits measuring 1m x 1m x 1m (length x breadth x height) were dug out at each planting points and the soil was sun exposed for 15 days before re-filling the pits with mixture of sieved soil, FYM and Chloropyriphos. A*onla* (variety NA-7) were planted during June, 2005 at a spacing of 7 m x 7 m, accommodating six plants per plot. Green gram was sown during the first week of July every year and Indian mustard, during the last week of October to first week of November. The NADEP manure was prepared at the Research Farm from FYM-soil slurry and organic residue such as twigs, plant litter and stovers. Vermi-compost was also prepared at Research Farm with help of earthworm species *Eisenia foetida*. The nutrient contents of the organic manures are given in Table 2. Soil samples

Table 2. Major nutrients available in organic manures at the time of application

Organic manure	Nitrogen	Phosphorus	Potassium
	% fresh weight basis		
Farmyard manure	0.54	0.31	0.51
NADEP	0.93	0.52	1.15
Vermi-compost	1.36	0.48	0.65

(0-60 cm) were collected every year after harvest of *rabi* crop for analyzing the physico-chemical properties. Mechanical analysis was carried out by Bouyoucos hydrometer method (Day, 1965). The pH and EC were measured by Combined Electrode and Conductivity Bridge, respectively, according to the method outlined by Jackson (1973). Soil organic carbon, available nitrogen, available phosphorus and available potassium were determined by the procedures outlined by Walkley and Black (1934), Subbiah and Asija (1956), Olsen *et al*. (1954), and Hanway and Heidel (1952), respectively. Growth parameters of aonla were recorder in the month of October i.e. after the harvest of green gram. Statistical analysis of the data was carried out using analysis of variance (ANOVA) to compare the efficacy of nutrient treatment combinations applied. The significance of variation among the treatments was observed by employing Least Squire Differences at 5percent level of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect on crop yield

The yields of green gram and Indian mustard over three years (2005-06 to 2007-08) have been depicted in figures 1 and 2. The low yields of both the crops in 2006 and 2007 as compared to 2005 could be attributed to the low rainfall (drought) in the former two years. Application of organic manures in conjunction with inorganic fertilizers boosted the yields of both the crops as could be seen from the figures 1 and 2.

Green gram: The yield of green gram increased by 13, 14, 39 and 28 per cent during 2005; 25, 32, 58 and 69 per cent during 2006 and 36, 73, 89 and 102 per cent during 2007 under T_2 , T_3 , T_4 and T_5

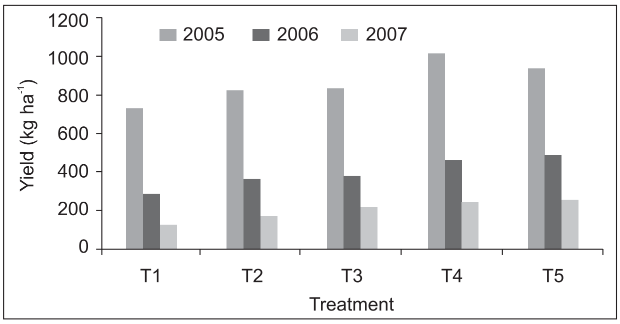

Fig. 1. Effect of INM on the yield of green gram (2005-06 to 2007-08)

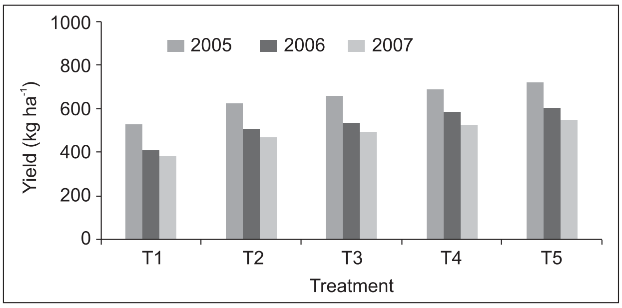

Fig. 2 Effect of INM on the yield of Indian mustard (2005-06 to 2007-08)

treatment, respectively, over T_1 control (no nutrient application). The mean yield of three years also followed the similar trend as it increased by 19, 25, 50 and 47 per cent under T_2, T_3, T_4 and T_5 treatment, respectively, over T_1 control (no nutrient application). The highest mean grain yield (560 kg ha $^{-1}$) was obtained under T_5 (recommended dose of N P K + vermi- compost @ 2 t ha $^{-1}$) and lowest (382 kg ha $^{-1}$) under T_1 (control) where no fertilizer was applied.

Indian mustard: The seed yield of Indian mustard increased by 18, 25, 31 and 36 per cent during 2005-06; 22, 29, 41 and 46 per cent during 2006-07 and 22, 30, 37 and 44 per cent during 2007-08 under T_2, T_3, T_4 and T_5 treatment, respectively, over T_1 control (no nutrient application). The mean seed yield of three years also followed the similar trend as it increased by 21, 27, 36 and 42 per cent under T_2, T_3, T_4 and T_5 treatment respectively, over T_1 control (no nutrient application). The highest mean seed yield (627 kg ha $^{-1}$) was obtained under T_5 (recommended dose of N P K + vermi - compost @ 2 t ha $^{-1}$) and lowest (442 kg ha $^{-1}$) under T_1 (control) where no fertilizer was applied. The low yield of both the crop in 2006 and 2007 as compared to 2005 could be attributed to the low rainfall (drought) in the former two years. Application of vermi-compost had a positive effect on moisture retention (data not shown) and on the soil properties, ultimately enhancing productivity of green gram and Indian mustard. This is in conformation with the findings of Rajkhowa *et al*. (2000), Nagavallemma *et al*. (2004) and Nanwal and Pawan Kumar (2007).

Effect on growth of aonla plants

Similarly, integration of organic manures with inorganic chemical fertilizers boosted *aonla* growth during all the years (Table 3). The maximum plant height was recorded under T_5 (recommended dose of N P K + vermi-compost @ 2 t ha $^{-1}$) and minimum under T_1 control (no nutrient application) during all the three years. Mean plant height also followed the similar trend. The plant height of aonla increased by 41, 76, 88 and 98 per cent during 2006; 22, 47, 60 and 67 per cent during 2007 and 29, 43, 51 and 62 per cent during 2008 under treatment T_2, T_3, T_4 and T_5, respectively, over T_1 control (no nutrient application). The mean plant height of aonla increased by 29, 52, 63 and 72 per cent under treatment, T_2, T_3, T_4 and T_5 respectively, over T_1 control. The plant height ranged from 1.6 to 2.6 m being attained by 75 per cent of the plants under the treatment T_5 after three years of planting. The height of about 88 per cent of the plants under control ranged between 0.8 and 1.2 m.

Table 3. Effect of nutrient treatments on the plant height (m) of a*onla*

Treatment	Year		
	2006	2007	2008
T_1 (Control)	0.58	0.85	1.08
T_2 (Recommended NPK)	0.82	1.04	1.39
T_3 (T_2 + FYM)	1.02	1.25	1.54
T_4 (T_2 + NADEP)	1.09	1.36	1.63
T_5 (T_2 + vermi-compost)	1.15	1.42	1.75
CD (*P = 0.05*)	NS	NS	0.33

Effect on physico–chemical properties of soil

The influence of different treatments on soil physico-chemical characteristics after three years of experimentation has been presented in Table 4. There were no significant differences among the treatments with respect to pH. The electrical conductivity of the soil increased with the application of chemical fertilizer and organic manures; however, the changes were statistically non-significant. The soil organic carbon content increased significantly with the application of organic manures under the treatment T_3, T_4 and T_5 where FYM, NADEP and vermi-compost was applied, respectively. The available N content of the soil was increased by 20, 22, 23 and 36 per cent, the available P content by 12, 35, 44 and 53 per cent

Table 4. Soil characteristics of surface layer (0-15 cm) as influenced by different treatments after three years of experimentation

Soil parameter	T_1 (Control)	T_2) (NPK)	T_3 (FYM)	T_4 (NADEP)	T_5 (vermin-compost)	CD *(P = 0.05)*
pH	7.25	7.29	7.14	7.05	7.08	NS
EC (dS m^{-1})	0.14	0.25	0.33	0.23	0.28	NS
Organic C (%)	0.33	0.34	0.35	0.36	0.36	0.02
Available N (kg ha^{-1})	197.0	237.0	240.0	256.0	267.0	30.0
Available P (kg ha^{-1})	12.4	13.9	16.7	17.8	19.0	4.1
Available K (kg ha^{-1})	192.0	214.0	220.0	236	243.0	NS

and available K content by 11, 15, 23 and 27 percent over control (T_1) under treatments T_2 , T_3 , T_4 and T_5, respectively. Maximum increase in organic carbon, available N, P and K content was recorded under treatment T_5 (application of vermi – compost alongwith recommended dose of inorganic fertilizers). The integration of organic manures along with inorganic chemical fertilizers also improved the available N and P content of the soil as compared to inorganic fertilizers alone. Enhancement of N and P availability through integrated nutrient management has been well documented by Swaroop and Rao (1999), Vats *et al.*(2001) and Narayan and Lal (2006).

CONCLUSION

Aonla based agri-horticulture land use system with green gram – Indian mustard cropping sequence under integrated nutrient management could sustain rainfed agriculture in red soils of Bundelkhand region. Application of organic manures (vermi-compost and NADEP manures) in an integrated manner with inorganic chemical fertilizers can boost productivity of red soils by improving physico-chemical properties of the soil.

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Effective management of Intellectual Property Rights for agricultural knowledge dissemination

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ABSTRACT

Intellectual Property Rights are important not only because India as a member is required to accede to the conditions of an international agreement but also because they offer possible mechanisms stimulating research, enabling access to technology and promoting enterprise growth, all for the ultimate benefit of the farming community. One of the objective of IP management is to protect the intellectual wealth generated in the Indian Counci of Agricultural Research. In today's context, it has become necessary to do so, for unprotected research results in the public domain can lead to unacknowledged use / exploitation of such research for commercial gains by other agencies both within the country and abroad. Moreover, protection of IP creates incentives for more knowledge and technology generation as scientists / innovators are recognized and rewarded. Although income generation is not the primary motive for Intellectual Property protection in Indian Counci of Agricultural Research, since only a handful of patents earn significant revenues, nevertheless, resources generated through commercialization of technologies is useful for important gap filling requirements for research and development purposes.

Key words: copyright, patents, geographical indications, trademarks, industrial designs, ICT

INTRODUCTION

Intellectual property (IP) refers to creations of the mind, such as inventions; literary and artistic works; designs; and symbols, names and images used in commerce. Intellectual property is protected in law by, for example, patents, copyright and trademarks, which enable people to earn recognition or financial benefit from what they invent or create. By striking the right balance between the interests of innovators and the wider public interest, the Intellectual property system aims to foster an environment in which creativity and innovation can flourish. Copyright, Patents, Geographical indications, Trademarks and Industrial designs are comes under the umbrella of Intellectual Property Rights (IPRs).

Copyright: Copyright is a legal term used to describe the rights that creators have over their literary and artistic works. Works covered by copyright range from books, music, paintings, sculpture and films, to computer programs, databases, advertisements, maps and technical drawings.

Patents: A patent is an exclusive right granted for an invention. Generally speaking, a patent provides the patent owner with the right to decide how - or whether - the invention can be used by others. In exchange for this right, the patent owner makes technical information about the invention publicly available in the published patent document.

Industrial designs: An industrial design constitutes the ornamental or aesthetic aspect of an article. A design may consist of three-dimensional features, such as the shape or surface of an article, or of two-dimensional features, such as patterns, lines or color.

Geographical indications: Geographical indications and appellations of origin are signs used on goods that have a specific geographical origin and possess qualities, a reputation or characteristics that are essentially attributable to that place of origin. Most commonly, a geographical indication includes the name of the place of origin of the goods.

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Trademarks: A trademark is a sign capable of distinguishing the goods or services of one enterprise from those of other enterprises. Trademarks date back to ancient times when craftsmen used to put their signature or "mark" on their products.

Indian Council of Agricultural Research is the apex body for planning promoting, coordinating, undertaking research and its application in agriculture and allied sciences in the country. ICAR is a nodal agency for the National Agricultural Research System in the country having Central and State Agricultural Universities, and affiliated colleges of agriculture where research / technologies is being generated by the scientists / innovators.

India as a member of the World Trade Organization (WTO) is obliged to comply with the agreement of Trade Related Aspects of Intellectual Property Rights (TRIPS Agreement). This requires that member countries provides for Intellectual Property Rights (IPRs) in one form or the other in all fields of technology, including agriculture. ICAR recognizes that research in frontier sciences, such as agro-biotechnology will require intellectual property (IP) protection through patents, plant variety protection and other forms of IPR. The transfer of IPR enabled agricultural technologies through commercial route will gain greater importance in the future. The ICAR has developed a policy framework that will guide the management of IP created by its scientists / innovators in the country.

IPR are important not only because India as a member is required to accede to the conditions of an international agreement but also because they offer possible mechanisms stimulating research, enabling access to technology and promoting enterprise growth, all for the ultimate benefit of the farming community. One of the objective of IP management is to protect the intellectual wealth generated in the ICAR. In today's context, it has become necessary to do so, for unprotected research results in the public domain can lead to unacknowledged use / exploitation of such research for commercial gains by other agencies both within the country and abroad. Moreover, protection of IP creates incentives for more knowledge and technology generation as scientists / innovators are recognized and rewarded. Although income generation is not the primary motive for IP protection in ICAR, since only a handful of patents earn significant revenues, nevertheless, resources generated through commercialization of technologies is useful for important gap filling requirements for research and development purposes.

Management of Intellectual Property Rights (IPRs):

The Intellectual Property Rights (IPRs) available in various forms of the following Indian Acts and amended from time to time:

- *The Copyright Act*, 1957 as amended in 1983,1984, 1992, 1994 and 1999 along with rules 1958 and the international copyright order, 1999, 2000 (Copyright Act)
- *The Patent Act*, 1970 as amended in 1999, 2002, 2004 (ordinance0, 2005 and 2006 along with rules 2005 (Patent Act)
- *The Trade Mark Act*, 1999
- *The Design Act*, 2000
- *The Geographical Indications of Goods (Registration and Protection) Act*, 1999 along with rules 2002 (GI Act)
- *The Semiconductor Integrated Circuits Layout-Design Act*, 2001
- *The Protection of Plant Varieties and Farmers Rights Act*, 2001 along with the rules 2003 (PPV&FR Act)

The Biological Diversity Act, 2002 along with rules 2004 (Biodiversity Act) specifies procedures for access to biology / genetic material for agricultural research and their IPR protection.

The PPV&FR Act is in harmony with the provisions of the Article 27.3(b) of the TRIPS Agreement. All extent varieties of ICAR that were notified under section 5 of the Seed Act, 1966 that have not completed 15 years from their notification date are registerable and can be protected as Intellectual Property under PPV&FR Act.

Intellectual Property Rights in ICAR

The technological assets of ICAR include a number of high yielding and resilient crop varieties, animal and poultry breed and fish strains, packages of improved crops and animal husbandry practices, natural resource management technologies, improved tools, equipment and farm machinery, improved dairy, poultry and fisheries technologies, post-harvest technology, computer software and data sets and several other processes and products of agriculture and allied sectors. Agricultural science has been the engine of growth and led to quantum jumps in productivity in the past. Application of ICAR technologies in farmers' fields and backyards has increased agricultural inputs and farm incomes. These technology packages have been the major contributors to the green, white and blue revolutions that brought out spectacular gains in Indian agriculture.

Protecting or patenting research output in agriculture was not customary in India and other developing countries prior to the establishment of WTO in 1995. The TRIPS Agreement has led to the evolution of IPR regimes in WTO member countries. The Indian IPR laws are also made TRIPS compliant. ICAR recognizes that TRIPS compatible IPR laws in India and in other member countries are important for management of agricultural research results. Once protected, these IPR enabled ICAR technologies, by way of licensing, could be transferred to end users through private, cooperative, non-governmental and public channels. Licensing could be for commercial use or for research or both.

Indian Council of Agricultural Research has developed guideline for Intellectual Property Management and Technology Transfer/ Commercialization. In line with Indian Council of Agricultural Research, an Institute Technology Management Unit for management of its IP/and transfer/commercialization of technologies has been constituted for pursuing IP protection, maintenance and transfer/commercialization related matters at the institute level. Institute Technology Management Unit is an integral unit of Indian Council of Agricultural Research institute involved in protection, management and commercialization of innovative technologies. The diversity of task performed by Institute Technology Management Unit include IPR management, technology licensing, developing public-private partnership, organising Industry-Institute meet to expand and establish good economic-ties. The Intellectual Property Management and Technology Transfer/ Commercialization initiative of the Indian Council of Agricultural Research had the convergence with the Business Planning and Development component of the National Agricultural Innovation Project.

The three tier IP management mechanism implemented in Indian Council of Agricultural Research provided a mechanism for bringing commercial ethos in transfer of skills and products. While the individual institutes were empowered to achieve the desired goals, the middle tier of five Zonal Technology Management & Business Planning and Development units were assigned the responsibility to cater to the individual and collective needs of various Indian Council of Agricultural Research institutes in its catchment. The zonal institutes were thus entrusted the task of working out the best fit strategies on issues related to technology prioritization, license, agreement drafting, valuation, marketing and commercialization. Business Planning and Development Units incubated many innovative ideas to develop into prototypes and generate interest among investors which supports the venture and manufacture commercially.

The Business Planning and Development Units have commercialized 331 agro- technologies and incubation support to 1,218 entrepreneurs/agri-based start-ups out of which 91 ventures were successfully graduated from the incubator. Technology transfer through the extension machinery has now found an alternative channel with the Business Planning and Development Units. Compared to the supply-driven mode of the machinery, the incubator focused more on market-oriented technology commercialization. The Business Planning and Development units have proved their potential as effective technology transfer conduits. The increasing number of technologies being commercialized through the units indicated that the National Agricultural Research System is becoming more adapted to the concept of business incubators for technology commercialization.

BPDUs successfully demonstrated scaling-up of technology commercialization and market intervention. The landmark accomplishment was the commercialization of about 50 technologies generated under National Agricultural Innovation Project and licensed to 80 companies in an Agri-tech Investor's Meet in 2013 and generated revenue also. The Business Planning and Development Units have been able to open up new revenue resources to National Agricultural Research Systemby way of membership fees, incubation service package, business development fees, technology transfer, royalty fee, consultancy assignments and training programme. These Business Planning and Development units have shown a significant business orientation by generating revenue worth ₹2,413.77 lakh on an overall investment of ₹5,000.00 lakh in less than five years. The main source of the revenue has been from the technology commercialization (40%) and consultancy work (41%) undertaken by the Business Planning and Development Units.

Formulation of policies and guidelines for technology commercialization

Many platform under Indian Council of Agricultural Research has created innovative approaches for cross learning. Many units incorporated some of the best strategies of other institutes including designing of the various forms, policies and guidelines e.g., invention disclosure form, technology transfer document, client information form, quality assurance from startups, certificates, agreements, memorandum of understanding etc. This led to a well-established technology transfer process, client satisfaction and the confidence to find solution to new challenges which keep cropping due to the evolving IP culture that has now encompassed the biodiversity issues. The following prescribed rules were followed to seek IP protection in ICAR while executing the IPR strategy under National Agricultural Research System:

- All inventors / innovators / breeders / authors were assigned the IP rights in their research results to Indian Counci of Agricultural Research.
- All applications were made in the name of "Indian Council of Agricultural Research".
- Patent / PVP / IPR applications filed by Indian Counci of Agricultural Research, had the names of all concerned scientists / innovators as True and First Inventors / Innovators.
- Patent / PVP / IPR applications were duly signed by the Authorized Signatory (Director of the concerned institution / zonal institute).
- Processing of all patent / PVP / copyright / other IPR applications and maintenance of IPR titles were undertaken as per the respective IPR laws.

Protection of plant varieties and farmers' rights

In order to provide for the establishment of an effective system for the protection of plant varieties, the rights of farmers and plant breeders and to encourage the development of new varieties of plants it has been considered necessary to recognize and to protect the rights of the farmers in respect of their contributions made at any time in conserving, improving and making available plant genetic resources for the development of new plant varieties. The Govt. of India enacted "The Protection of Plant Varieties and Farmers' Rights (PPV&FR) Act, 2001" adopting sui generis system. Indian legislation is not only in conformity with International Union for the Protection of New Varieties of Plants (UPOV), 1978, but also

have sufficient provisions to protect the interests of public/ private sector breeding institutions and the farmers. The legislation recognizes the contributions of both commercial plant breeders and farmers in plant breeding activity and also provides to implement TRIPs in a way that supports the specific socio-economic interests of all the stakeholders including private, public sectors and research institutions, as well as resource-constrained farmers.

Study on Intellectual Property Management:

Studies for promoting research and innovation through capacity building in relation to intellectual property management issues - patents, PVP, copyrights, rural innovations, Agro-biodiversity, and geographical indications were made under learning capacity building sub-project at NAARM, Hyderabad.

Institutionalization of IP Policy in ICAR System:

A review of the relevant legal and policy documents was done to understand the background of the obligations of IP protection at national and international levels. This role and functions of some statutory agencies in India that are actively involved in IP facilitation was also reviewed. The provisions and governance model of the new IP policy of the ICAR were analysed. Two constituent institutes namely Project Directorate on Poultry and Directorate of Rice Research, were studied from the IP policy and institutionalization perspectives. The study documented the implementation of guidelines, structural adjustments in decision making activities and other specific issues related to IP management at these institutes.

Capacity Building for Intellectual Property and Technology Management:

The research and capacity building initiatives of the project in IP management have led to capacity building and facilitation of ITMUs in institutions of ICAR, Business Planning and Development units set up under National Agricultural Innovation Project, and of rural innovators: Two rural innovations assessed by National Academy of Agricultural Research Management and NIF were awarded second and third provided to all Business Planning and Development units. It also included, sample agreements, application forms, technology profile templates etc. A critical area of support that was provided to the BPD Unit so as to benefit their incubatees was that of Mentors Booklet and Funding Directory. The mentor's booklet was prepared after shortlisting and interviewing many applicants from the field of agribusiness.

During mid-term implementation support review, many issues that plagued the incubator's operations and in facilitating their entry and operating domain within the parent institute's activities were discussed and sorted out. This has helped in better performance and results from the incubators. In terms of monitoring and evaluation, a monthly report template, so as to keep track of the monthly activities was provided to the incubators. The performance indicators collected every six months by NAIP also provided insights to the performance of the incubators on different metrics. Along with regular visits to Units, these assessments were scored on different parameters and the progress of the incubator was observed.

Capacity development for GIS applications in agricultural research and management

GIS user community in agricultural research is relatively small. The project reached nearly all institutes of ICAR and many SAUs. Use of open source GIS software and solutions was introduced. A range of prototype products for applications and training including Geospatial library, village knowledge system, DSS for livelihoods vulnerability assessments; DSS for experimental farm management, and DSS for agri-food retail management.

Communication management

Communication management has been improved leading to wider dissemination of events and achievements of the National Agricultural Research System by both print and electronic media. A standard web-based, user-friendly e-publishing portal has been implemented for ICAR Journals and this facility is being offered to other agricultural research societies publishing their research journals. The dream of any Indian extension professional to provide the right information at the right time and context and even many local languages to the ever "Information-Hungry" farmers is realized through Agropedia (portal for crop information) and Rice Knowledge Management Portal.

Knowledge for sharing information

Knowledge creation and management through ICT platforms like Agropedia, Rice Knowledge Management Portal, e-Courses, e-Granth, mKrishi, CeRA and introduction of open access policy has brought out global visibility and recognition. The viewership of ICAR journals has created new records. The impact factors of the journals of both ICAR and the professional societies have improved. Article processing time has reduced from 2 years to 2-4 months for many journals.

Infrastructure creation

The creation of several infrastructure facilities has given a boost to the Indian NARS. The first Advanced Super-computing Hub was established at IASRI, New Delhi. The frontier Research and matching infrastructures have provided new opportunities for collaboration, cross-learning and co-innovation across the country. Prominent infrastructures created and some of them are:

- National Agricultural Bioinformatics Grid at 6 locations - Online examination facility for ARS / NET for ASRB Examination at 23 locations - Rice Knowledge Management Labs at 8 places
- e-Course Creation Centres at 12 locations- Statistical Data Analysis Labs at 9 centres
- Consortium on E-resources in Agriculture (CeRA)
- e-Publishing Network System for Indian Agricultural Journals
- Digital repositories - e-granth, Krishikosh and Krishiprabha
- Knowledge Management Portals -Agropedia, TNAU's AgriTech Portal, e-learning Portal of the education Division of ICAR and RKMP, Management Information System & Finance Management (MIS & FMS) system
- Agri-Incubation Facilities under Business Planning Development at 22 locations - State of art Referral Laboratory on Milk quality
- Fifteen Pilot plants for value added products,and- Media Centres at 10 locations and Market Intelligence Centres at 12 locations

Application of appropriate ICT tools for the management and dissemination of agricultural technologies has transform the overall delivery of information to public. Information and communication technologies (ICTs), are re shaping many aspects of the economies, governments and societies. Now, it is right time to harnessing the transformative power of ICTs to make public services more efficient, to grow agri-businesses, and to strengthen agricultural research and extension for development. ICT has facilitated the much needed community empowerment and development by meeting their information needs. ICT is also an important enabler in research activities to accomplish tasks at faster rate with higher efficiency. It holds as much potential for development of agriculture sector as contributing in other sectors in India.

CONCLUSION

An effective Intellectual Property Rights and its management would have in-built incentive for scientists / innovators to engage in knowledge creation. This would led to greater professional recognition for them. Through licensing fees and royalties, a proportion of the monetary gains would flow to the researchers. By sharing the monetary incentives with its staff and institutions, ICAR will encourage greater creativity in the research system. Commercialization of IPR enabled technologies and other know how through public private partnership would led to their accelerated and efficient transfer. Improvement in the rate of adoption of technologies by producers will in turn lead to increase in productivity, production, farmer's income and employment. The process of technology transfer through commercialization will be rational and selective. Protection of public sector research can be used as defence mechanism to keep innovation in the public domain. IPR enabled ICAR technologies could be utilized to negotiate/bargain access to strategic research tools and technology from the private sector.

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Comparative performance of mechanical transplanting for rice in South Asia

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ABSTRACT

In India and Nepal, manual transplanting of rice is a common practice. Attempts had been made in past to introduce mechanical transplanting but no fruitful results reaped which may be because of lack of training regarding mat type nursery growing, frequent sprinkler irrigation etc. Secondly, rising labour scarcity is also an emerging problem in the way towards sustainable rice-wheat cropping systems. The problem becomes more severe due to narrow window period and legal binding to transplant paddy after 10^{th} of June which needs to be addressed for the sustainability and profitability of the RW cropping system in the region. Conventional practice is the time consuming and laborious which require huge labour which leads to late transplanting of the rice nursery which further resulted in the late sowing of subsequent wheat crop and finally a significant decrement in yields. Thus timely sowing of rice crop in the emerging scenario of labour shortage is a challenging task. Rice transplanting with mechanical transplanter is a promising technology which helps us in timely transplanting of rice nursery. This compiled review confirmed that mechanical transplanting of rice is really effective, economical in timely transplanting of rice in texturally divergent soils which ultimately leads to higher productivity, profitability and sustainability of the rice-wheat cropping system as a whole.

Key words: Rice, mechanical transplanter, rice-wheat cropping system, labour scarcity

INTRODUCTION

The rice–wheat (RW) cropping systems of India and Nepal are the backbones of these countries and to their food securities (Timsina and Connor, 2001; Paudel, 2011). More than 90 percent of the main RW areas in north-west India (Punjab, Haryana, western Uttar Pradesh) is irrigated using groundwater, and the rapid decline in groundwater levels is probably the biggest challenge to the sustainability of the RW system (Humphreys *et al*., 2010).

Nepal is located in South Asia in coordinates of 28^0N and 84^0E and it is situated in between China in the north and India in other sides. Rice in Nepal is number one crop both in area (1.481 million ha) and production (4.023 million ton) with a productivity of 2.716 ton/ha (MoAC, 2010).

In 2009-10, share of agriculture and forestry for national Gross Domestic Product (GDP) was 33.03% of which the share of rice was 20.75% whereas contribution of rice at current price of NRs 30, 000/ton alone becomes NRs 1, 20,690 million which is 10.2% of total GDP. Likewise, out of the total cultivated area of 3.091 million ha, rice cultivation occupies 47.91% in Nepal. Therefore, rice holds very important position both in agriculture and economy of Nepal (Paudel, 2011). Geographically, Nepal is divided into five main regions; the Himalayas, high hills, mid-hills, Siwalik and Terai. However, agro-ecologically, Nepal is divided into three domains *viz*. hills (both mid and high hills), Siwalik and Terai and climate vary from cool summer to severe winter that serves as micro museum of the world (Paudel, 2009). Hoever, rice cultivated in Nepal under extreme altitude ranging from 60 m of eastern Terai, Kechanakal of Jhapa to 3,050 m of temperate region, Chhumchour of Jumla, the highest elevation in the world In recent years. However, the sustainability of RW systems both in India and Nepal has been questioned, faced with yield stagnation (Ladha *et al*., 2003), declining ground

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water tables (Hira *et al.* 2004), soil degradation and atmospheric pollution (Bijay-Singh *et al*., 2008). Furthermore, intensive RW system causes severe soil degradation, declining underground water table (Central Punjab), increased incidence of pests and diseases, increasing labour scarcity, salinity, and water logging in some regions (SW Punjab) (Chhokar and Sharma, 2008; Sharma *et al*., 2004, Humphreys *et al*., 2010). In order to take care of the above-said issues of declining soil health, ground water, labour availability and residue management in RW cropping system in the region, various resource conservation technologies (RCTs) *viz*. Tensiometers (Bhatt and Sharma, 2010), leaf colour charts (Bhatt *et al.*, 2011), soil test based fertilization (Bhatt, 2013; Bhatt and Sharma, 2014) and neem coated fertilizers (Bhatt, 2012) are some of the technologies already advocated for increasing the productivity, sustainability and profitability of this system. But the performance and efficiency of these RCTs are location specific (Bhatt *et al.*, 2013). Further, there is a need to evaluate and refine especially for water management so as to be really water efficient. Some of these technologies viz. direct-seeding of rice, direct drilling of wheat and mechanical transplanting of rice are being pushed to be potential irrigation water-saving technologies apart from being labour-saving as well. The following review of literature aims to evaluate the impact of mechanical transplanting on crop performance and water productivities in different regions so as to highlight the need of refining these with respect to water management.

Mechanical transplanting to face emerging labour shortage

Labour shortage is an emerging issue in the prevailing RW cropping system due to narrow window period and legal binding to transplant paddy after 10^{th} of June which needs to be addressed for the sustainability and profitability of the RW cropping system in the region. The labour scarcity has been increasing over the last few years due to assured work under MANREGA scheme of Govt. of India (GOI, 2005). Thus, to solve the labour shortage during the peak transplanting period, mechanical transplanting is one option (Prasad *et al*., 2001; Garg *et al*., 1997, Kamboj *et al*., 2013) as manual transplanting is laborious and time-consuming requiring about 300-350 man-h / ha. A delay in transplanting of paddy by one month can reduce the yield by 25 percent whereas delay of two months may reduce it by 70 percent (Rao and Pradhan, 1973). Mohanty *et al*. (2010) concluded that labour requirement in case of self-propelled rice transplanter was 40 man-h ha^{-1} and in case of manual random transplanting it was 224 man-h ha^{-1}. However, MT under zero tillage scenarios faces higher weed biomass which further required huge labour to uproot them. (Fig. 3 & 4).

Mechanical transplanting and crop performance

Sharma *et al.* (2002) observed that mechanical transplanting by self-propelled transplanter produced similar grain yields as with the manual transplanting but produced significantly higher grain yield than that through direct sowing both under dry and wet conditions. This was attributed to the higher number of seedlings / hill planted through mechanical transplanter that produced significantly higher number of effective tillers / m^2, higher test weight and the grain yield. The MT preferred over manual transplanting even though yields in later are somewhat higher (4.87 t ha^{-1}) (though statistically at par) than former (4.85 t ha^{-1}) (Pandirajan *et al*., 2006).

The MT of rice with self propelled rice transplanter helps in getting highest grain yields as compared to manual transplanting and direct seeding of rice (Singh *et al* 2005a) as early establishment, uniform growth owing to uniform placement of seedlings at a uniform depth and spacing with equal number of seedlings per hill under MT significantly influence the plant height, total panicles / m^2, effective panicles / m^2, grains per panicle and 1000 grain weight which ultimately resulted in higher grain yield.

Compared with conventionally puddle transplanted rice (CPTR), non-puddled MT rice produced 3 to 11 percent higher grain yield as reported by Kamboj *et al* (2013). Further, Chauhan (2013) stated that even in the case of similar yield between CPTR and MTR, the MTR may help in reducing labor requirement and ultimately, increase overall profit to the farmers.

Crop performance of MT plots had an edge over the DSR plots (Table 1) while chlorophyll index was reported to be significantly at par within MT (P), Mt(ZT) and PTR while they were found to significantly better over the DSR treatments (Kukal *et al.*, 2014). However, fertility percentage found to be significantly better for PTR and MT treatments over the DSR treatments while similar was the story for the 1000 grain wt which ultimately contribute to the grain yields.

They reported that in the sandy loam soil mechanically transplanted rice in puddle system perform similarly to conventional transplanting (Table 1 & 2). However, the crop yield decreased when rice seedlings were mechanically transplanted in zero-tilled soil.

However, it wasreported that irrigation water productivity (WP_I) of MT plots was significantly higher than the DSR plots but similar to the PTR plots (Fig.1), being lower in MT-ZT plots. The higher WP_I of MT-P than MT-ZT plots was due to

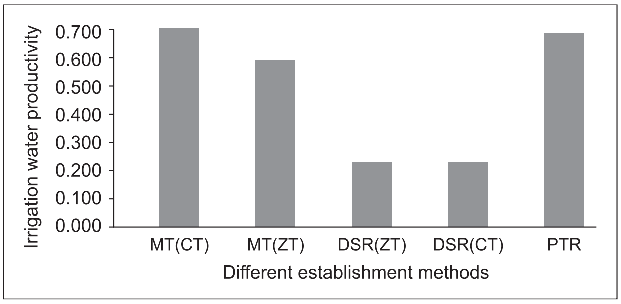

Fig 1. Water productivity (g kg^{-1}) of rice as affected by different establishment methods in a sandy loam soil

lower grain yield in MT-ZT plots (Bhatt and Kukal, 2014). The WP_I of DSR-CT was higher than that in DSR-ZT plots, which was due to lower grain yield in DSR-ZT plots (Fig.1). This led to higher irrigation water consumption in DSR plots than in PTR. This resulted in lower WP_I in zero-tilled plots compared to the conventional-tilled plots. Thus, in sandy loam soil mechanically transplanted rice in puddle system performs similarly to conventional transplanting. However, the crop yield decreased when rice seedlings were mechanically transplanted in zero-tilled soil. Sharma *et al.* (2004) observed that mechanical transplanting was at par with manual transplanting as far as grain and straw yield were concerned but statistically higher over the DSR.

In Orissa, India, self propelled transplanter and manual random transplanting and reported significantly higher number of effective tillers m^{-2} and grain yield under self propelled transplanter as compared to the manual transplanting in shallow fields (Tripathi *et al.*, 2004). Din *et al.* (2008) from Port Blair compared six-row manual transplanter with line transplanting at 20×20 cm spacing and found significantly higher number of hills m^{-2} resulting in higher grain yield in line spacing. However, Kasaby *et al.* (2002) observed higher number of panicles m^{-2}, grains $panicle^{-1}$, grain yield and straw yield under mechanical transplanting as compared to the manual transplanting.

In eastern India, from Bihar it was reported that mechanical transplanting of rice with self propelled rice transplanter (5.95 t ha^{-1}) and manual transplanting (5.98 t ha^{-1}) were at par to each other but produced significantly higher grain yield than direct seeding of rice (Sharma *et al.*, 2007). While Singh *et al.* (2006) in Uttar Pradesh found that mechanical transplanting of rice significantly increased the grain yield by 20, 24 and 39 percent

Table 1. Effect of different establishment methods on the different agronomic parameters

Treatments	Panicle length (cm)	Filled spikelets / panicle	Unfilled spikelets / panicle	Fertility %age	1000 grain weight (g)	Plant height (cm)	Chlorophyll index
MT (P)	23.0	124.8	13.1	91.4	23.9	82.4	43.9
MT (ZT)	22.3	115.9	18.3	86.6	20.8	72.8	42.6
DSR (ZT)	20.9	69.7	25.6	72.7	20.8	66.3	39.9
DSR(CT)	21.6	75.3	19.4	79.7	22.2	65.2	39.0
PTR	25.6	115.8	37.4	76.4	22.9	91.7	45.2
LSD (0.05)	2.2	16.8	10.5	6.2	1.6	5.4	2.25

(Kukal *et al.*, 2014)

Table 2. Effect of different establishment methods on leaf area index, crop yield and irrigation water productivity

Treatments	Leaf Area Index		Straw yield(t ha^{-1}), 0% moisture content	Grain yield(t ha^{-1}), 14% moisture content
	60 days	90 days		
MT (P)	2.7	3.9	10.4	5.6
MT (ZT)	2.4	2.2	11.9	4.2
DSR (ZT)	3.0	1.5	11.2	3.2
DSR (CT)	3.2	4.2	8.2	3.6
PTR	2.7	3.2	8.5	5.3
LSD (0.05)	NS	0.65	2.72	1.1

(Kukal *et al.*, 2014)

over manual transplanting, direct dry sowing and direct sowing of sprouted seeds in the puddle conditions, respectively.

Table 3 clearly depicts that mechanical transplanting of rice not only decreases the cost of cultivation but also increases the grain yields in texturally divergent soils. In a four year study conducted at Modipuram to access the effect of rice establishment methods *viz*. MT in puddled, unpuddled and manual transplanting, Gangwar and Singh (2010) observed that dry matter accumulation and leaf area index were significantly higher under MT (P) than manual transplanting of rice. It was further observed that number of panicles m^{-2} and number of grains $panicle^{-1}$ were significantly higher in MT (P) than manual transplanting of rice but differences with respect to 1000 grain weight were non-significant. Further, mechanically transplanted fields yielded 5.5 q ha^{-1} higher as compared to the manually transplanted fields at similar inputs use level (Farooq *et al.*, 2001). Mat type nursery has to feed as when tray got emptied and transplanting was done using Japanese's assemble on mechanical transplanter (Fig 2). Singh *et al.* (2005) reported that mechanical

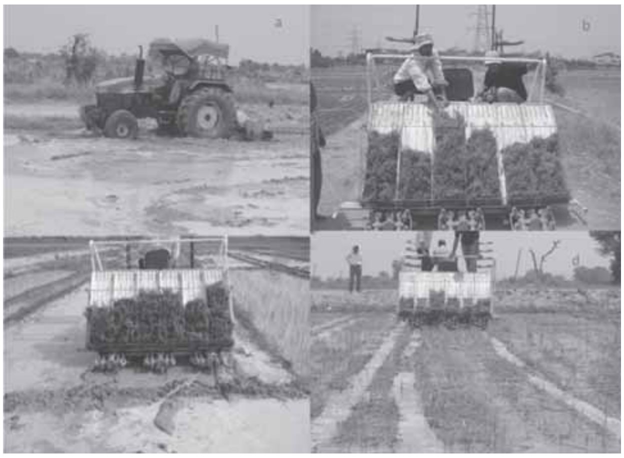

Fig. 2. Field preparation (a), filling of mat type nursery in trays (b) and performance of mechanical transplanter (c & d) (Experimental field)

transplanting of rice with self-propelled rice transplanter resulted in highest grain yield when compared with manual transplanting and direct seeding of rice. Early establishment, uniform growth owing to uniform spacing with equal number of seedlings per hill under mechanical transplanting significantly resulted in higher grain yield. In Haryana, mechanized transplanting of all type of rice cultivars has been successful in nonpuddled and no-till situations with long-term sustainability in the double no-till rice-wheat system (Kamboj *et al.*, 2013).

Weed problem become more serious when transplanting of rice seedlings shifted from Puddled to zero till plots which further demanding more labour for weed removal and secondly yield potential of these plots was low because of high weed pressure.

Compared with zero tillage, normal transplanting, drum seeder and mechanical transplanting and there was non-significant effect of crop establishment on the plant height, total tillers m^{-2}, effective tillers m^{-2} and finally grain yield at Bangalore (Hugar *et al.*, 2009). The results were further confirmed by Singh *et al.* (2005) at Modipuram, U.P with non-significant effect of crop establishment *viz*. manual and mechanical transplanting on plant height, plant dry matter, panicle m^{-2}, panicle length, grains $panicle^{-1}$ and grain yield. Kim (1993) at Korea in his field study reported that MT gave similar yields as obtained in the direct seeding and high ridged drying seeding of rice.

Mechanical transplanting and cost of cultivation

Cost of machine transplanting was found to be only Rs. 1310 ha^{-1} in comparison to Rs. 2463 ha^{-1} for manual transplanting. Mohanty *et al.* (2010) observed that the average cost of transplanting was Rs 1554 ha^{-1} in case of self-propelled rice transplanter and Rs 2675 ha^{-1} in case of traditional method.

Table 3. Comparative performance of manual transplanting and mechanical transplanting

Transplanting methods	Labour requirement			Grain yield				Cost of trans-planting (Rs/ha)	
Manual transplanting	300-350 man-h / day	224 man-h ha^{-1}	-	-	5.95 t ha^{-1}	-	-	2675	2463
Mechanical transplanting	-	40 man-h ha^{-1}	Saves 20 man-h ha^{-1}	3-11% higher	5.98 t ha^{-1}	20 % incre-ment	5.5 q ha^{-1} higher	1554	1310
Scientists involved		Mohanty et al., 2010	Malik et al., 2011	Kamboj et al., 2013	Sharma et al. 2007	Singh et al., 2006	Farooq et al., 2001	Mohanty et al., 2010	Burah et al., 2001

Table 4. Partial costs and returns analysis of mechanical rice transplanting

Costs / Returns Items Values	Rupees
Yield premium over manually transplanted fields (kg acre^{-1})	220
Basmati paddy price (Rs. / 40 Kg)	400.00
Total returns premium (Rs / acre)	2200.00
Extra costs of nursery raising and transplantation (rice transplanter rental charges included)	494.00
Partial net-benefits of mechanical transplantation (Rs / acre)	1706.00

(Farooq *et al.*, 2001)

The cost of growing mat type nursery for mechanical transplanting was about 40 percent whereas the cost for raising conventional nursery was only 25 percent of the cost of transplanting (Burah *et al.*, 2001). Fig. 1 demonstrating the cutoff on the labour for paddy transplanting if we adopt mechanical transplanting. They further reported that the energy requirements for mechanical and manual methods of transplanting were found to be 1074 and 757 MJ ha^{-1}, respectively where forty percent of the total energy requirement in mechanical transplanting was required in mat nursery preparation while energy share for traditional nursery under manual transplanting was only 11 percent. Cultivation of rice with mechanical transplanting could be done under puddle system, conventionally tilled and zero tilled soils (Fig. 3) and it was reported that ZT system suffered with significantly higher weed pressure the other two alternative methods which further demanding more labour for their uprooting (Fig. 4).

Seedling throwing and mechanical transplanting along with Arbuscular Mycorrhizhal Fungi (AMF) inoculation of seedling may be recommended wherever the labour is scarce and costlier for getting higher yield and net income (Rani and Jayakiran, 2010). Further, it was found that MT of rice helps in efficient use of resources by saving on labour (20 person day ha^{-1}), cost saving (Rs 1500 ha^{-1}), higher productivity of 0.5 t0 0.7 t ha^{-1} as compared to traditional method of rice transplanting.

Mechanical transplanting was most cost-effective and energy-efficient requiring lowest specific energy (Sharma *et al.*, 2004). On the other hand some workers (Gangwar *et al.*, 2008) found DSR to be better in comparison to the mechanical transplanting as unpuddled conditions had more plant population per unit area due to better dry / wet tillage in unpuddled conditions over the puddled conditions. The performance of rice transplanters under non-puddled (after cultivation in dry soil conditions) and no-till situations has been reported better than conventional puddle systems earlier as well (Yadav *et al*., 2010).

Problem recognized in proper adoption of mechanical transplanting of rice:

Inspite of observed large number of benefits including more grain yields, lesser required labour and a number of running schemes by policy makers, it seems that the adoption of mechanical transplanting is not upto mark. A few important reasons for non-adoption of mechanical transplanting of rice are

a) Raising of mat type nursery is technical, labour intensive and cumbersome job because special levelled place, soil preparation and regular irrigation by sprinkling are needed.

Fig.3. Comparative performance of mechanical transplanting under puddle (a), zero tilled (b) and conventionally tilled (c) plots during Kharif 2014 (Source: Rajan Bhatt, Ph.D Experiment)

Fig. 4. 4-6 weeding operations of weeding required in mechanically transplanted rice under zero tilled conditions during Kharif 2014

b) Cutting nursery according to the size of feeding trays and its transportation is a tough job.
c) Raising nursery for a very large paddy area is very costly.
d) Laser land levelling of paddy fields is an additional cost to the farmer.
e) In Chinese transplanter, damage of outer rows due to slipping out of earth is a common problem.
f) Generally, the machine does not transplant seedlings at the corners of the paddy fields which later needs to be planted manually,
g) Before transplanting, the extra water need to be drained out from the field which is not the case with manual transplanting . Therefore, mechanically transplanted fields require more irrigation water as compared to manually transplanted paddy fields.
h) The nursery raised for rice transplanters could not be used for manual transplantation because the roots of this nursery are very delicate, compactly interwoven and shorter as compared with the nursery raised in fields,
i) There is also 20-25% missing transplantation with mechanical transplanters but the higher plant population compensates it during tillering,
j) Farmers generally hesitate to adopt mechanical transplanter for transplanting his rice seedlings because of lack of his technical knowledge regarding mat type nursery growing, daily irrigation through sprinkler, monitoring iron deficiency and it's timely check.

CONCLUSION

The reviewed literature showed that mechanical transplanting helps in sustainable rice production as it is labour and energy saving but technical training regarding growing of mat-type nursery, feeding of nursery in trays, running of mechanical transplanter at uniform speed in texturally divergent soils need to be arranged well in advance from paddy transplanting in different location. Moreover, demonstration plots comparing performance of manually transplanted and mechanically transplanted plots proved to be a encouragement for the farmers who used to stick to the old lines. Further, studies especially on performance of MT in dry cultivated and untilled soils need to be studied in the region. Moreover, such studies need detailed comparisons of water balance parameters between MTR both in dry tilled and untilled soils.

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