PRODUCTION PROTOCOL FOR ORGANIC BHINDI

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DECLARATION

I hereby declare that this thesis entitled **"Production protocol for organic bhindi"** is a bonafied record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree,diploma,associateship,fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled **"Production protocol for organic bhindi"** is a record of research work done independently by Gayathri Karthikeyan. P (2008-11-110) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, and associateship to her.

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LIST OF ABBREVIATIONS

@	-	at the rate of
^oC	-	Degree celsius
%	-	Percent
CD	-	Critical difference
cm	-	Centimetre
DAS	-	Days After Sowing
DMP	-	Dry matter production
et al.	-	And others
Evapn.	-	Evaporation
Fig.	-	Figure
FYM	-	Farmyard manure
ha	-	Hectare
g	-	Gram
i.e.	-	That is
K	-	Potassium
K_2O	-	Potash
kg ha^{-1}	-	Kilogram per hectare
kg ha^{-1} mm^{-1}	-	Kilogram per hectare millimetre
LAI	-	Leaf Area Index
l	-	Litre
m	-	Metre
mg	-	Milligram
N	-	Nitrogen
No.	-	Number
NUE	-	Nitrogen use efficiency
NS	-	Not significant

LIST OF ABBREVIATIONS continued

P	**-**	**Phosphorus**
P_2O_5	**-**	**Phosphate**
Plant $^{-1}$	**-**	**Per plant**
POP	**-**	**Package of practice**
RH	**-**	**Relative humidity**
Rs	**-**	**Rupees**
RDF	**-**	**Recommended dose of fertilizer**
SE	**-**	**Standard error**
Sl.	**-**	**Serial**
t ha^{-1}	**-**	**Tonnes per hectare**
VC	**-**	**Vermicompost**
VAM	**-**	**Vesicular arbuscular mycorrhiza**
Viz.	**-**	**Namely**
WUE	**-**	**Water Use Efficiency**
Zn SO_4	**-**	**Zinc Sulphate**

Introduction

1. INTRODUCTION

Vegetables are integral part of a balanced diet and are considered as 'protective foods' as their consumption prevents many diseases. Role of vegetables as a source of antioxidants in prevention of new generation diseases and delaying ageing is well recognized. India is a country where majority of the population are vegetarians. Even among the non vegetarians, vegetables have a significant role in the diet, being a rich source of vitamins, minerals, dietary fibre etc. The requirement of vegetables is 300 g person^{-1} day^{-1}. The current production can supply only 250 g person^{-1} day^{-1}. But actual consumption is still lower, i.e. only 174 g person^{-1} day $^{-1}$ (Gajanana and Hegde, 2009).

India is the second largest producer of vegetables in the world; second only to China**.** Presently, India occupies 7.8 m ha of area of vegetable cultivation with an annual vegetable production of 125.89 m t. With increasing population, it is estimated that by 2020, the production has to be increased to at least 135 m t yr $^{-1}$ (Rai et al., 2009). Hence it is imperative to increase the production but without any quality deterioration.

The production technologies should be designed in such a way that it should not harm the environment and soil. As vegetables are consumed even in raw form, pesticide residue problems are likely to result in very worse health problems. Immune-suppression, hormone disruption, diminished intelligence, reproductive abnormalities, cancer etc. are some of the health hazards caused by pesticide residues in vegetables.

Among the wide variety of vegetables being cultivated in India, bhindi (*Abelmoschus esculentus* L. Moench.) is a popular one. It is a good source of vitamins A and B, protein and minerals. It is also an excellent source of iodine and is useful for the treatment of goitre. India is the largest producer of bhindi with a production of 4526 thousand t (NHM, 2009). The vegetable is very popular in Kerala and is also exported to foreign countries.

Use of organic manures as a source of nutrition is gaining importance as people are becoming more health conscious and are even ready to pay premium price for organically produced food.

Organic cultivation is not of recent origin in India. In ancient literature such as *Rig-Veda*, the use of animal dung as manure was emphasized. *Atharvaveda* indicated the importance of green manures, which was practiced before 1000 BC. Kautilya's *Arthashastra* recorded manures like oil cakes, excreta of animals etc.

To the maximum extent feasible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off farm organic wastes and aspects of biological pest control to maintain soil productivity and to supply plant nutrients and to control insects, weeds and other pests.

Among the different organic sources, farm yard manure is the traditional manure and is most readily available to the farmers. Farm yard manure is a decomposed mixture of cattle dung and urine with straw and litter used as bedding material and residues from the fodder fed to the cattle. Well rotted farm yard manure contains 0.5 % nitrogen, 0.2 % P_2O_5 and 0.5 % K_2O.

Vermicompost is one of the potential organic sources which contain almost all nutrients. The mucus associated with the cast being hygroscopic, absorbs water and prevents water logging and improves water holding capacity. It improves physical, chemical and biological properties of soil in the long run on repeated application. The organic carbon in vermicompost releases the nutrients slowly and steadily in to the system and enables the plant to absorb these nutrients.

The practice of green manuring is as old as the art of manuring crops. In addition to the improvement in productivity, green manuring may also increase the availability of several other plant nutrients and micronutrients through its favourable impact on the physical, chemical and biological properties of the soil. Green manures improve soil structure, letting more air into the soil and improving drainage. They cover the ground well and stop growing weeds beneath them.

Bio fertilizer consists of beneficial micro organisms in a definite concentration formulated for commercial use. The beneficial effect of biofertilizers enhances establishment and growth of plants; increases crop yield, replaces nitrogen and phosphorus by 25 %, increases biomass etc.

Vermiwash is a collection of excretory products and excess secretions of earthworms along with micronutrients from soil organic molecules. Cow's urine is used as a nutrient as well as a pest repellant from very ancient period in India.

Considering the challenges in vegetable production, food safety, soil fertility, ecological stability, economic viability and resource conservation, it is high time that we adopt organic nutrient source for sustainable vegetable production.

The following are the objectives of the present study:

To standardize the organic manuring schedule for bhindi and to assess the effect of different levels of organic manure combination and irrigation on growth, yield and quality of bhindi. It is intended to work out the economics of bhindi and bhindi – amaranthus sequence and also to study the residual effect of the organic manures.

Review of Literature

2. REVIEW OF LITERATURE

The presence of pesticide residues in vegetables is of great concern these days. Moreover, unscientific use of fertilizers has also resulted in pollution of air and water. As the demand for organic vegetables is increasing day by day, the effect of using different organic manures for the production of vegetables have been studied by several workers. The present study is to assess the effect of using organic nutrient sources, mulching and irrigation on the growth and yield of bhindi. The works done on this aspect and the related works are reviewed in this chapter.

2.1 EFFECT OF ORGANIC MANURES ON GROWTH CHARACTERS OF BHINDI

2.1.1 Effect of FYM on Growth Characters of bhindi

In a study conducted by Montasser (1991) on bhindi, it was revealed that the average length and fresh weight of shoot and root increased considerably in cattle, pigeon, rabbit and sheep manure amended plots.

Subbiah and Sunderarajan (1993) found that combined application of 12.5 t ha^{-1} FYM + recommended dose of macronutrients + 25 kg $ZnSO_4$ ha^{-1} in bhindi was better than FYM alone or combinations of 25 t ha^{-1} FYM with the recommended dose of fertilizers with or without micronutrients.

In an experiment conducted by Isaac (1996) at College of Agriculture, Vellayani on the yield, quality and vigour of bhindi seed as influenced by number of harvests and nutrient sources, it was found out that application of 6 t ha^{-1} of FYM + chemical fertilizers resulted in increased biometric parameters such as plant height at 60 and 90 DAS, LAI at 30 DAS and 60 DAS and root spread at final harvest.

Senthilkumar and Sekar (1998) observed that use of FYM as an organic amendment increased the dry matter production of bhindi.

Nuruzzaman et al. (2003) studied the effect of biofertilizers on vegetative growth of bhindi and found that plant height, number of leaves plant^{-1}, stem base diameter, root length, root dry weight and LAI were the highest with application of azotobacter + 5 t cow dung ha^{-1}.

Different studies reveal that FYM application helps in improving the growth of bhindi.

2.1.2 Effect of Vermicompost on Growth Characters of bhindi

Vermicompost is a potential organic manure containing nitrogen fixing, phosphorus solubilising and cellulose decomposing organisms (Bhawalkar, 1992).

In bhindi, vermicompost along with fertilizer application as per POP recommendation of Kerala enhanced the growth characters like height of plant, number of leaves and number of branches (Govindan et al., 1995).

In an experiment conducted by Raj (1999) on organic nutrition of bhindi, it was revealed that different doses of organic manures could significantly vary the growth characters *viz.* LAI, plant height, shoot dry weight etc. Maximum plant height (16.94 cm) was obtained by the highest level of nitrogen given in the form of organic manure. Shoot dry weight increased significantly with each successive increasing level of organic manuring (898.58 kg ha $^{-1}$ to 1781.29 kg ha $^{-1}$).

Manonmani and Anand (2002) at Thiruchirappalli observed that root length, number of root hairs, length and breadth of the leaf and dry weight of bhindi were maximum when nutrient application was supplemented with vermicompost.

The reviews reveal that application of vermicompost has a positive effect on the growth characters of bhindi.

2.1.3 Effect of Organic Manures on Growth Characters of other Vegetables

Arunkumar (2000) observed that highest level of FYM and vermicompost (150 %) maintained their superiority at all growth stages regarding plant height, number of leaves and number of branches in amaranthus.

The yield of green chilli and spinach were significantly increased by the application of soil conditioner and vermicompost along with organic booster as compared to recommended dose of NPK (Hangarge et al., 2002).

Sharma and Sharma (2004) found that application of FYM (10 and 20 t ha^{-1}) in tomato significantly increased the plant height and number of branches $plant^{-1}$ over no application.

According to Shakila and Anburani (2008) combined application of FYM (12.5 t ha^{-1}) + vermicompost (2.5 t ha^{-1}) + panchagavya (3 %) foliar spray resulted in improvement of growth characters in tomato. Similar improvement in growth characters was also observed by the application of pressmud (6.25 t ha^{-1}) + vermicompost (2.5 t ha^{-1}) + panchagavya (3 %) foliar spray.

From a study conducted by Sankar et al. (2009) on organic farming practices in white onion, the highest numbers of leaves (9.55 and 11.05) was noticed at treatment combination of 3 % panchagavya +100 % recommended NPK fertilizers which was on par with the organic manure application (3 % panchagavya + 50 % poultry manure +50 % FYM (9.45 and 10.85).

A field experiment conducted by Akparobi (2009) revealed that when amaranthus was treated with various farm yard manure levels of 0 t ha^{-1}, 15 t ha^{-1}, 25 t ha $^{-1}$ and 35 t ha $^{-1}$, treatment with the highest manure level of 35 t ha $^{-1}$ attained the highest plant height of 123.27 cm and those that received no manure treatment reached a maximum height of only 80.20 cm.

Different organic manures have found to be very promising in improving the growth of crops.

2.2 EFFECT OF ORGANIC MANURES ON YIELD CHARACTERS OF BHINDI

2.2.1 **Effect of FYM on Yield Characters of bhindi**

Naidu et al. (1999) found that application of NPK @ 80:60:50 kg ha^{-1} + 20 t FYM ha^{-1} in bhindi resulted in increased number of fruits plant $^{-1}$, weight of fruits plant^{-1} and maximum fruit yield.

In an experiment conducted on bhindi at College of Agriculture, Vellayani, it was revealed that plant height and LAI were highest for FYM + green leaf which also recorded minimum number of days for 50 % flowering (Raj, 1999).

An experiment conducted by Dademal and Dongale (1999) on lateritic soils to study the response of bhindi to the application of organic manures and varied levels of chemical fertilizers at Dapoli, revealed that application of FYM @ 7.5 t ha $^{-1}$ along with N P K @ 150, 75 and 75 kg ha $^{-1}$ was most useful for maximization of fruit yield (85.01 q ha $^{-1}$).

The study conducted by Patil et al. (2000) on the effect of organic manures and biofertilizers on yield and quality of bhindi revealed that application of biofertilizers (1 litre slurry) + FYM + 50 kg N ha $^{-1}$ was beneficial for obtaining higher yields of export quality fruits when compared to their individual application.

In an experiment conducted by Prabhu et al. (2003) in bhindi, it was revealed that the application of FYM and biofertilizers along with reduced dose of inorganic fertilizers i.e. 2/3 recommended dose of fertilizers + FYM + azospirillum +VAM increased the growth attributes like the number of leaves, leaf area and fresh and dry weight of plants and yield attributes like days to 50 % flowering, number of fruits plant^{-1}, fruit weight and marketable yield ha^{-1}.

In a field experiment conducted by Sekhar and Rajasree (2009) at Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore to find out the effect of different organic manures on growth, yield and quality attributes of bhindi, it was revealed that among the different organic manure treatments, application of FYM @ 20 t ha^{-1} performed better than the other treatments through improved plant characters *viz.* number of fruits plant^{-1} (19.3) and yield (10.39 t ha^{-1}) compared to the FYM manure application at lower doses; though all the organic manure treatment showed positive effect through growth and yield characters.

From the above results it was observed that FYM application helps in improving the yield of bhindi.

2.2.2 Effect of Vermicompost on Yield Characters of bhindi

From an experiment conducted at College of Agriculture, Vellayani on the efficiency of vermicompost on growth and yield of bhindi, Ushakumari et al.(1999) reported that vermicompost as a source of organic manure (12 t ha $^{-1}$) along with full recommended dose of NPK increased number of fruits plant^{-1} and yield in kg ha $^{-1}$.

An experiment conducted by Raj (1999) on organic nutrition in bhindi revealed that different doses of organic manures could significantly vary the yield attributes. Fruit weight (20.24 g to 30.8 g), fruit yield plant^{-1} (115.8 g to 341.64 g) and total fruit yield ha $^{-1}$ increased significantly with the increasing dose of organic manures.

Nishana (2005) found that aquatic vermicompost recorded higher number of leaves with maximum LAI at all growth stages compared to other sources of organic manure. Aquatic weed vermicompost applied plots recorded maximum number of flowers plant^{-1}, fruits plant^{-1}, setting % and length and girth of fruits. She has also noticed that soil + foliar application of vermiwash was found better in increasing the growth and yield attributing characters in bhindi.

Perusal of the results of above studies shows that vermicompost as a source of organic manure enhances yield of bhindi.

2.2.3 Effect of Organic Manures on Yield Characters of other Vegetables

In a study conducted by Subbiah et al. (1983), the yield of brinjal was significantly influenced by levels of FYM (0, 12.5,25 and 37.5 t ha^{-1}) but not by the levels of fertilizer (0, 50,100,150 % of recommended dose).

Rao et al. (2001) studied the effect of organic manures like vermicompost, neem cake, *Azospirillum* and *Phosphobacterium* on the growth and yield of brinjal and observed that the highest fruit yield was obtained with the treatment FYM + vermicompost followed by FYM + neem cake.

Application of vermicompost along with organic manures resulted in earliness in flowering, maximum fruit size, more number of fruits plant^{-1} and yield in tomato (Renuka and Ravishankar, 2001).

Maheshwari and Haripriya (2008) observed that application of vermicompost @ 5 t ha $^{-1}$ and groundnut cake @ 250 kg ha $^{-1}$ along with foliar application of panchagavya 3 % for 4 times recorded the maximum number of fruits, highest fruit length, maximum fruit girth and highest dry fruit yield of hot pepper which was comparable with inorganic fertilizers.

Study conducted by Singh and Mukherjee (2008) on effect of FYM, chemical and biological fertilizers on yield and quality attributes of brinjal revealed that yield (266.14 q ha^{-1}) increased with the application of FYM and chemical fertilizers at increasing level up to 100 percent of recommended dose of N and P + FYM @ 20 t ha^{-1}.

Singh et al. (2009) conducted an experiment on the effect of different combinations of organic manures on growth and yield of ginger and it was found that application of FYM @ 330 q ha^{-1} + pongamia cake @ 8.30 q ha^{-1} + neem cake @ 8.30 q ha^{-1} + sterameal @ 8.30 q ha^{-1} + rock phosphate @ 8.30q ha^{-1} + wood ash @ 8.30 q ha^{-1}gave the highest yield.

The results of the above studies indicate that different organic manures enhanced the yield and yield attributing characters of vegetables.

2.3 EFFECT OF GREEN MANURING ON GROWTH AND YIELD OF CROPS

Application of 30 kg N ha^{-1} as green manure produced maize yields comparable with that from 90 kg N ha^{-1} in fallow plots, indicating a substitution value of 60 kg N ha^{-1} from green manuring (Ogbonna and Mabbayad, 1983).

In tomato, the highest yield of 22 - 24 t ha^{-1} was obtained with the application of subabul leaves (24 t ha^{-1}). This yield was comparable with that produced by the application of inorganic fertilizers at the high rate of 210 kg N + 49.3 kg P + 74.7 kg K ha^{-1} (Deanon, 1983).

Brewbaker (1985) reported that maize responded linearly and positively to subabul green leaf manuring with 24 kg grain kg^{-1} nitrogen from incorporated leaves.

Patil and Kulkarni (1988) reported that incorporation of 5 t ha^{-1} of subabul leaves gave sorghum yield which was on par with that obtained with recommended fertilizer dose.

A study conducted by Nitant (1990) on the N contribution from subabul lopping revealed that application of 50 kg N ha^{-1} + subabul resulted in higher grain production than that obtained from 150 kg N ha^{-1} alone.

Experiment conducted by Raj (1999), revealed that green manured plants recorded 32.05 % increase in yield compared to that of POP recommendation in bhindi. Plants supplied with green leaf manure showed significant response with respect to growth, yield and quality of bhindi as compared to the plants supplied with POP recommended dose of nutrients.

The reviews indicate that green manure can be used as a source of organic nutrient and that it enhances the crop growth and yield.

2.4 EFFECT OF ORGANIC MANURES ON QUALITY ASPECTS OF CROPS

Tomati et al. (1990) observed that incorporation of vermicompost increased protein synthesis in lettuce and radish by 24 and 32 % respectively.

Joseph (1998) observed that in snake gourd, application of FYM resulted in a higher level of ascorbic acid content (4.85 mg 100 g^{-1}) in fruits and was on par with vermicompost and superior to poultry manure.

Raj (1999) reported that at highest level of organic nitrogen source, quality attributes like crude protein content and ascorbic acid were maximum and crude fibre content was minimum in bhindi.

In a study conducted on the effect of enriched vermicompost (vermicompost enriched with rock phosphate) on cowpea, Sailajakumari (1999) reported that application of enriched vermicompost resulted in highest mean value of protein content (24.94 %).

An experiment on standardization of organic and inorganic fertilizer combinations for maximizing productivity in bitter gourd by Rajasree (1999) revealed that maximum crude protein content of 23.93 % was recorded when FYM / poultry manure and chemical fertilizers was added in the ratio 2:1 to supply 300 kg N ha^{-1}.

Sharu (2000) reported that in chilli, treatment combination of 75 % N as poultry manure and 25 % N as chemical fertilizer recorded the highest ascorbic acid content.

Experiment on organic nutrition in amaranthus by Arunkumar (2000) revealed that the lowest crude fibre content was recorded by the highest level of vermicompost in amaranthus. He has also reported that protein content and ascorbic acid content increased significantly with increasing levels of organic manures and highest value of ascorbic acid content was recorded by the highest level of organic manure (65.57 mg 100 g^{-1}).

Sheeba (2004) conducted an experiment on the effect of vermicompost enriched with organic additives in amaranthus and the results revealed that highest value of beta carotene was recorded by enriched vermicompost (neem cake 1 % + bone meal 1 %) along with full dose of RDF.

The effect of organic manures on growth, yield and quality of chilli under black soils of northern transition zone of Karnataka was studied by Shashidhara et al. (2007) and the results revealed that the quality parameters like oleoresin % increased by 13.89, 6.6, 3.7 and 2.3 per cent with the application of poultry manure @ 7.5 t ha^{-1}, vermicompost 10 t ha^{-1}, FYM (50 %) + vermicompost (50 %) and FYM (50 %) + neem cake (50 %) respectively as compared to RDF alone. The ascorbic acid also increased substantially due to application of organics, FYM (50 %) + neem cake (50 %) (133.32 mg 100 g^{-1}) recorded significantly higher over rest of the treatments.

Sekhar and Rajasree (2009) reported that the lowest crude fibre content in bhindi was recorded by the treatment receiving 20 t ha^{-1} of FYM compared to the lower levels.

The results presented above reveal that organic manures impart a positive effect on the quality of vegetables.

2.5 EFFECT OF MULCHING

2.5.1 Effect of Mulching on Growth and Yield Characters of Bhindi

Sunilkumar and Jaikumaran (1998) reported that, irrespective of irrigation levels and methods of irrigation, mulched crop of bhindi recorded significantly higher levels of fruit set i.e. on an average 88.1 %. The growth characters like mean plant height, green leaves, number of fruiting branches, leaf area $plant^{-1}$ and LAI; yield attributes like number of flowers $plant^{-1}$, number of fruits, total fruit weight etc. were higher in mulched situation than in unmulched situation.

Bhadauria and Kumar (2006) reported that black plastic mulch and mulching with sugarcane trash significantly increased transpiration rate, photosynthesis, pod length and pod yield $plant^{-1}$ as compared to without mulch.

Mulching with *Mecarantha indica* is as effective as stale bed practice followed by pre emergent application of fluochloralin in suppressing the weeds and improving yield and economics of bhindi crops (Sheela et al., 2007). More over these practices were more economic than the farmer's practice of inter cultivation and weeding with spade.

In a study conducted by Bahadur et al. (2009) on irrigation scheduling and mulching in bhindi, it was revealed that in mulched plots the estimated total water applied was 278 mm and 395 mm in non mulched plots. The mulched plants exhibited remarkably higher WUE (476.56 kg ha^{-1} cm^{-1}) and water saving (29.6 %) than plants in non mulched plots.

Mohammed and Mamkagh (2009) observed that covering the soil surface with black plastic mulch significantly increased plant height of bhindi compared with bare soil under different tillage treatments. They also reported that though plastic-film mulched plots significantly increased bhindi yield (early mid, late & total yield) compared with bare plots, the highest total bhindi yield (5.42 t ha^{-1}) was produced, from plots where soil is tilled three times and covered with black plastic mulch.

The study conducted by Patel et al. (2009) on mulching of bhindi revealed that mulching with either black polythene or organic materials (paddy straw) recorded significantly higher values for all yield components compared to no mulch.

Thus, it can be concluded that mulching has a positive effect on improving the growth and yield of bhindi.

2.5.2 Effect of Mulching on Growth and Yield Characters of Vegetables

Farias et al. (1994) observed that cucumber on a clay soil in Colima, Mexico gave the yield of 63.37 t ha^{-1} with clear plastic mulching against 21.61 t $ha^{-1}$with no mulch; both white and black plastic mulches significantly increased yields.

In an experiment conducted by Hedau et al. (2001) on the effect of nitrogen and mulching in tomato, the maximum fruit yield was observed with silver black polythene mulch but it was found statistically on par with black polythene mulch.

Acharya and Kapur (2001) reported that application of pine leaf mulch @ 10 t ha^{-1} at the time of sowing of potato in a shallow depth silty clay loam soil significantly improved tuber yield and WUE, and resulted in saving of one irrigation equivalent to 40mm. Application of mulch with 60 kg N ha^{-1} registered significantly higher tuber yield and WUE than 120 kg N ha^{-1} without mulching, indicating a saving of 60 kg N ha^{-1} through the former treatment.

In a study conducted to find the effect of mulching and fertilizer management practices on the growth and yield of garlic, Islam et al. (2007) reported that plants grown under black polyethylene, water hyacinth and straw mulches produced the yields of 5.80, 5.70 and 5.48 t ha^{-1}, respectively which were 39, 36.6 and 31.41% higher than the control (4.17 t ha^{-1}).

The reviews indicate that mulching can be effective in enhancing vegetable growth and yield.

2.6 EFFECT OF IRRIGATION ON GROWTH AND YIELD CHARACTERS OF VEGETABLES

Kumar (1986) observed that bhindi responded well to frequent irrigation. The fruit yield increased with decrease in irrigation interval and daily irrigation was found essential for obtaining maximum yield.

The experiment conducted by Kar and Kumar (2007) on the effect of irrigation and straw mulch on water use and tuber yield of potato in eastern India revealed that four irrigations resulted in air-dry tuber yields of 14.9 and 11.2 t ha^{-1} for the mulched and non-mulched plots, respectively. Sankar et al. (2008) reported higher WUE in bhindi under water limited conditions.

In a study conducted by Adekalu et al. (2008), irrigation at 30 % moisture depletion produced the highest leaf area, stem diameter, and yield for plants in mulched and unmulched plots and also produced higher plant height and dry matter for mulched plots.

Bahadur et al. (2009) reported that in bhindi, significantly higher soil water content was registered with irrigation at 4 days interval coupled with pea-straw mulch.

Application of 100 % recommended dose of nitrogen through fertigation increased pod yield of bhindi (16972 kg ha^{-1}) as compared to lower dose (Patel et al. 2009).

From an on-farm irrigation trial conducted on the upland of Chitwan valley of Nepal by Tan et al. (2009), it was reported that low level of nitrogen application (30 kg N ha^{-1}) with low but daily watering had significantly resulted in higher yield (1,365 g $plot^{-1}$) of bhindi than from higher level of nitrogen application (90 kg ha^{-1}).

The reviews indicate that irrigation can positively influence the growth and yield of vegetables.

2.7 EFFECT OF ORGANIC MANURES ON NUTRIENT UPTAKE OF BHINDI AND SOIL NUTRIENT AVAILABILITY

Isaac (1996) reported that application of 12 t of FYM along with 11 t of vermicompost showed higher available N and K status significantly superior to other sources of N.

In bhindi**,** N and P uptake was highest for FYM + neem cake where as K uptake was maximum for FYM + poultry manure with 150 kg $ha^{-1}$of N and with azospirillum inoculation. The available N, P and K status of the soil were highest in FYM + neem cake, FYM + enriched compost and FYM alone treated plots respectively with 150 kg ha^{-1} of N and azospirillum inoculation **(**Raj, 1999).

The result of an experiment conducted by Barani and Anburani (2004) revealed that application of different levels of farmyard manure (12.5, 25 and 37.5 t ha^{-1}), inorganic fertilizers and vermicompost (3, 4 and 5 t ha^{-1}) significantly influenced the nutrient uptake and post harvest available soil nutrients in bhindi. Application of FYM @ 25 t ha^{-1}, along with 75 % of the recommended dose of inorganic fertilizer and vermicompost @ 5 t ha^{-1}, recorded the highest nutrient (N, P and K) uptake and post harvest available soil nutrients.

Sharma et al. (2009) reported that in bhindi, nutrient uptake increased significantly with increasing levels of vermicompost as well as farmyard manure. After completion of the experiment, the highest available NPK content (303, 28.1, 345 kg ha^{-1}, respectively) was recorded in case of the treatment consisting of vermicompost 10 t ha^{-1}.

The studies reveal that organic manuring have a positive effect on the nutrient uptake of bhindi and soil nutrient availability.

2.8 EFFECT OF ORGANIC MANURES ON NUTRIENT UPTAKE OF OTHER VEGETABLES AND SOIL NUTRIENT AVAILABILITY

In an experiment conducted by Rajeswari and Shakila (2009) at Annamalai University, application of FYM 10 t ha $^{-1}$ + vermicompost 2.5 t ha $^{-1}$ along with panchagavya 3 % as foliar spray significantly enhanced the uptake of nitrogen, phosphorus and potassium in Palak.

Sesbania green manuring and mung bean residue incorporation increased soil organic carbon over summer fallow by 0.10 % -0.14 % points, nitrogen by 0.01 % points and available P by 5 -5.5 kg ha $^{-1}$ (Sharma et al.,2001).

Organic manures show a positive effect on the nutrient uptake and availability of vegetables.

2.9 EFFECT OF DIFFERENT ORGANIC MANURES ON PESTS OF BHINDI.

Prakash et al. (2002) showed lower percentage of fruit borer infestation in bhindi when the plants were treated with FYM and vermicompost.

The overall damage caused by fruit and shoot borer revealed that significantly lowest number (2.37 %) of fruits were damaged in the plots fertilized with 75 % RDF from neem cake + 25 % RDF. Maximum (11.33 %) weight loss was evident in case of inorganic form of fertilizers applied alone (Adilakshmi et al. 2008).

2.10 EFFECT OF DIFFERENT ORGANIC MANURES ON ECONOMICS OF BHINDI.

Raj (1999) observed that application of farmyard manure along with neem cake at 150 kg ha $^{-1}$ and azospirillum recorded the highest fruit yield and profit in bhindi.

Application of poultry manure/neem cake/farm yard manure to supply 100 kg N ha $^{-1}$ (N equivalent basis) in combination with seedling dip of azospirillum and foliar application of 2 % pseudomonas combined with cow's urine spray at 5 % concentration was the best economic organic nutrient schedule for increasing the productivity of bhindi (Geethakumari , 2005).

Mulching with *Mecarantha indica* is as effective as stale bed practice followed by pre emergent application of fluochloralin in suppressing the weeds and improving yield and economics of bhindi crops (Sheela et al., 2007). More over these practices were more economic than the farmer's practice of inter cultivation and weeding with spade.

In an investigation conducted by Sekhar and Rajasree (2009), it was observed that among the treatments, application of FYM @ 20 t ha $^{-1}$ resulted in a higher benefit cost ratio in bhindi (3.56) compared to the lower levels.

2.11 EFFECT OF ORGANIC MANURES ON GROWTH AND YIELD OF RESIDUE CROP

In case of FYM, only half N, one sixth P and a little more than half K alone are readily available to plants during the first season of application (Thampan, 1993).

Yaduvanshi (2000) reported that the application of FYM to kharif crop gave significant residual effect on the grain yield of succeeding wheat crop.

Sharu (2000) observed high residual soil K in plots which received higher level of neem cake along with fertilizer.

In an experiment conducted by Sharma (2004), it was found that, for a legume – cereal rotation, wheat straw applied to the legume crop decomposed and became available to the next cereal crop. The residual effect of straw incorporation after groundnut increased the wheat grain yield by 3.9 to 36.8 %. Maximum residual effect was obtained with 10 t ha $^{-1}$ straw.

Raj (2006) has reported that combined application of organic manures showed considerable residual effect in improving available nitrogen content of soil compared to the sole application of manures.

According to Sharma et al. (2009), in a cropping sequence of bhindi – onion, substantial improvement was recorded in residual soil fertility as the contents of organic carbon, available nitrogen, phosphorus and potassium were significantly higher in case of plots which had received either FYM or vermicompost in combination with chemical fertilizers than the plots which had received chemical fertilizers only.

The experiment conducted at Shalimar by Chattoo et al. (2009) to study the residual effect of organic manures on succeeding crop pea, it was revealed that organic integration (FYM 6 t + sheep manure 4t + poultry manure 1 t + vermicompost 1 t + biofertilizer 7 kg ha $^{-1}$) recorded higher values of plant height (43.38 cm), pod number plant $^{-1}$, pod yield plant $^{-1}$, pod yield ha^{-1} and nodule number plant $^{-1}$.

Materials and Methods

3. MATERIALS AND METHODS

An Experiment was conducted at College of Agriculture, Vellayani to standardize the organic manuring schedule for bhindi and to assess the effect of different levels of organic manure combination and irrigation on growth, yield and quality of bhindi from June 2009 to November 2009. The details of the materials used and the methods adopted are presented in this chapter.

3.1. EXPERIMENTAL SITE

The experiment was carried out at the Instructional Farm attached to the College of Agriculture, Vellayani situated at 8.5 ^{0} North latitude and 76.9^{0} East longitude and at an altitude of 29 m above mean sea level.

3.1.1 Soil

The soil of the experimental site was laterite red loam belonging to the order oxisol of Vellayani series. The important chemical properties of the soil and the methods adopted for analysis are presented in Table 1.

Table 1. Chemical composition of the soil at the experimental site

Sl. No	Parameter	Content	Rating	Methods adopted
1	P^H	4.9	Acidic	P^H meter with glass electrode (Jackson,1973)
2	Available N (kg ha^{-1})	226.6 kg ha^{-1}	Medium	Alkaline potassium permanganate method (Subbiah andAsija,1956)
3	Available P (kg ha^{-1})	11.41 kg ha^{-1}	Medium	Bray colorimeter method (Jackson ,1973)
4	Available K (kg ha^{-1})	40.10 kg ha^{-1}	Low	Neutral normal ammonium acetate method(Jackson,1973)

3.1.2 Cropping History of the Field

The experimental area was kept fallow for more than 8 months before raising the crop.

3.1.3 Season

The experiment was conducted during Kharif 2009 - from June to November of 2009.

3.1.4 Weather conditions

The weekly averages of the weather parameters *viz.* maximum and minimum temperature, relative humidity and rainfall received during the cropping period collected from the observatory of College of Agriculture, Vellayani are given in Appendix 1 and illustrated in Fig.1.

3.2 MATERIALS

3.2.1 Cultivar used

The cultivar of bhindi used for the study was Varsha Uphar which was released by Chaudhary Charan Singh , Haryana Agricultural University , Hissar by inter varietal hybridization between ‘Lam Selection 1’ and ‘Parbhani Kranti’ following pedigree selection in 1996. It is an early high yielding variety, resistant to Yellow Vein Mosaic disease.

3.2.2 Seeds

Seeds of the variety Varsha Uphar were obtained from the Instructional farm, College of Agriculture, Vellayani.

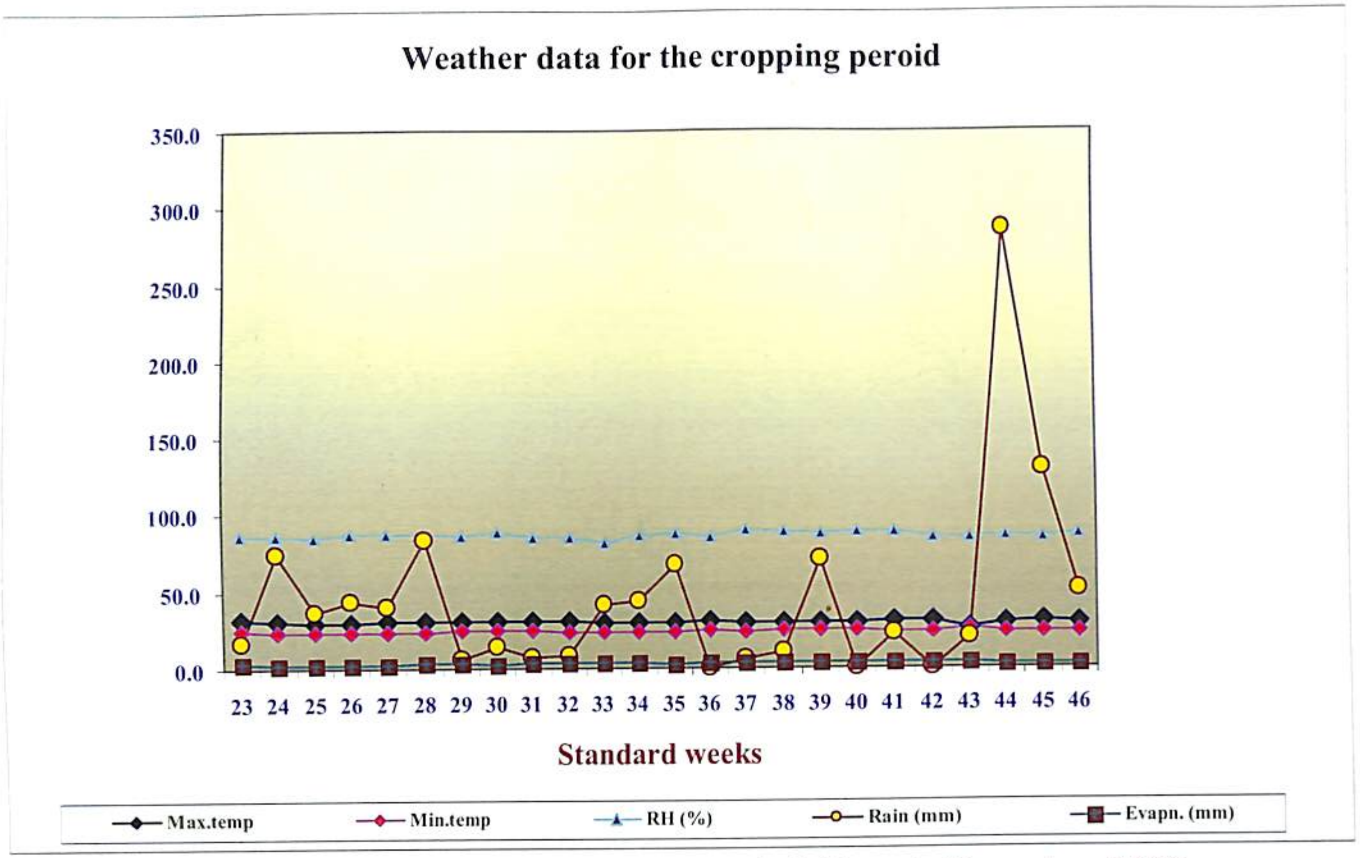
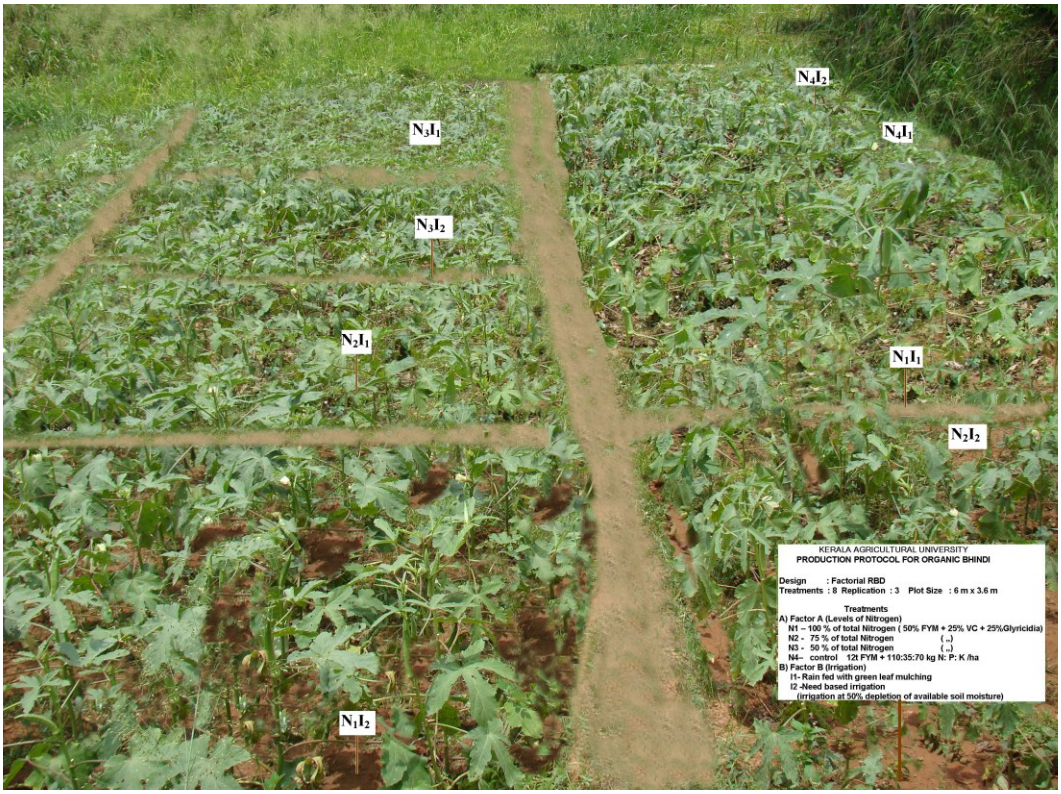


Fig.1. Weather data for the cropping period (June to November, 2009)


N4I2
N3I1
N4I1
N3I2
N2I1
N1I1
N2I2
KERALA AGRICULTURAL UNIVERSITY
PRODUCTION PROTOCOL FOR ORGANIC BHINDI
Design : Factorial RBD
Treatments : 8 Replication : 3 Plot Size : 6 m x 3.6 m
Treatments
A) Factor A (Levels of Nitrogen)
N1 – 100 % of total Nitrogen (50% FYM + 25% VC + 25%Glyricidia)
N2 - 75 % of total Nitrogen (,,)
N3 - 50 % of total Nitrogen (,,)
N4– control 12t FYM + 110:35:70 kg N: P: K /ha
B) Factor B (Irrigation)
I1- Rain fed with green leaf mulching
I2 -Need based irrigation
(irrigation at 50% depletion of available soil moisture)
N1I2

3.2.3 Azospirillum culture

Azospirillum culture was obtained from the Department of Microbiology, College of Agriculture, Vellayani.

3.2.4 Manures and Fertilizers

FYM (0.5 % N), vermicompost (1.5 % N) and glyricidia leaves (2.9 % N) were used as organic sources of nitrogen and Urea (46 % N), Rajphos (20 % P_2O_5) and MOP (60 % K) as the inorganic sources of Nitrogen, Phosphorus and Potassium respectively.

Vermiwash and cow's urine at ten times dilution was given as foliar spray at fortnightly interval.

3.3 METHODS

3.3.1 Design and Lay out

The lay out of the experiment is presented in Fig. 2
General view of the experimental field is given in Plate 1.

Design : Factorial RBD
Treatments : 8
Replication : 3
Plot Size : 6 m x 3.6 m
Spacing : 60 cm x 45 cm
Total number of plots: 24

To protect the rainfed treatments from irrigated treatments, a buffer strip of 0.5 m was provided in between these two treatments.

Fig.2. Lay out Plan of the Experiment

R1	N_4I_1	N_4I_2	N_2I_2	N_2I_1	N_1I_2	N_1I_1	N_3I_2	N_3I_1
R2	N_2I_2	N_1I_2	N_4I_2	N_3I_1	N_1I_1	N_3I_2	N_4I_1	N_2I_1
R3	N_3I_1	N_2I_2	N_4I_2	N_1I_1	N_3I_2	N_1I_2	N_4I_1	N_2I_1

N_1 - 100 % of total Nitrogen (50 % FYM + 25 % Vermicompost + 25 % Glyricidia)

N_2 - 75 % of total Nitrogen (50 % FYM + 25 % Vermicompost + 25 % Glyricidia)

N_3 - 50 % of total Nitrogen (50 % FYM + 25% Vermicompost +25 % Glyricidia)

N_4 – control 12 t FYM + 110:35:70 kg N: P: K ha^{-1}

I_1 - Rainfed with green leaf mulching (In the case of acute water shortage due to reduction in rainfall, life saving irrigation would be provided.**)**

I_2 -Need based irrigation (irrigation at 50 % depletion of available soil moisture)

3.3.2 Treatments

A) ***Factor A (Levels of Nitrogen)***

N_1 – 100 % of total Nitrogen as in POP in the form of organic manures (50 % FYM + 25 % Vermicompost + 25 % Glyricidia)

N_2 - 75 % of total Nitrogen as in POP in the form of organic manures (50 % FYM + 25 % Vermicompost + 25 % Glyricidia)

N_3 - 50 % of total Nitrogen as in POP in the form of organic manures (50 % FYM + 25 % Vermicompost +25 %Glyricidia)

N_4 – control 12 t FYM + 110:35:70 kg N: P: K ha^{-1} (POP) - Recommended dose of fertilizer.

B) ***Factor B (Irrigation)***

I_1- Rain fed with green leaf mulching **(**In the case of acute water shortage from rainfall, life saving irrigation would be provided**).**

I_2 - Need based irrigation (irrigation at 50 % depletion of available soil moisture).

Treatment Combinations: **N_1I_1, N_1I_2, N_2I_1, N_2I_2, N_3I_1, N_3I_2, N_4I_1, N_4I_2.**

The organic nutrient combination was given (ha^{-1}) as:

N_1 - 17.00 t FYM + 2.83 t vermicompost + 1.47 t glyricidia leaves.

N_2 - 12.75 t FYM + 2.13 t vermicompost + 1.10 t glyricidia leaves.

N_3 - 8.50 t FYM + 1.42 t vermicompost + 0.73 t glyricidia leaves.

The following organic practices were uniformly adopted for all treatments:

1. Seed inoculation with azospirillum.
2. Spraying of vermiwash (10 times dilution) and cow's urine (10 times dilution) at fortnightly interval.
3. Need based application of *Pseudomonas fluorescens* (2 % solution) – for disease management.
4. Need based application of neem oil garlic extract (2 %) – for pest management.

Residual experiment: To assess the residual effect of different treatments, a crop of amaranthus was raised after bhindi and the yield obtained plot^{-1} was recorded.

3.4 CROP HUSBANDRY

3.4.1 Land Preparation

The experimental area was cleared of weeds and stubbles. The field was laid out as per the design and individual plots were dug well and levelled. In the plots of 6 m x 3.6 m size, pits were taken at 60 x 45 cm spacing for sowing seeds. Individual treatments were randomly allocated for each plot.

3.4.2 Inoculation with Azospirillum

Seeds were inoculated with Azospirillum and shade dried for half an hour before sowing.

3.4.3 Application of Manures and Fertilizers

Farm yard manure, vermicompost and glyricidia leaves were applied as per the treatment as basal dose. Foliar application of vermiwash and cow's urine (ten times dilution) alternatively at fortnightly interval from 15 DAS onwards was uniformly followed in all treatments.

3.4.4 Other management practices:

Other intercultural operations were followed as per POP recommendations. Irrigation was given once in 2 days based on the soil moisture analysis. 25 kg mulch plot^{-1} was added to each rainfed plots. First weeding was done 20 DAS and there after weeding was done only in the unmulched, irrigated plots.

3.4.5 Harvest

Harvest of fruits started from 63 DAS and was repeated on alternate days. Maturity of fruits for harvest was decided by visual appearance (usually 7 days after flowering).

3.5 OBSERVATIONS

Biometric Observations

Six plants were selected as observational plants from each plot. From these six plants, biometric observations and yield attributes were recorded.

3.5.1 Growth Characters

3.5.1.1 ***Height of the plant (cm)***

The height was measured from the base to the terminal bud and the average was worked out and expressed in cm.

3.5.1.2 ***Number of leaves (No.)***

From the observational plants, the number of leaves was noted and average was calculated.

3.5.1.3 ***Leaf area index (LAI)***

LAI was worked out using the formula suggested by Watson (1952) at 30 days interval.

LAI = Leaf area /Land Area

3.5.1.4 ***Number of branches plant^{-1}(No.)***

The number of branches per plant was recorded from the observation plants at 60 DAS and the average was worked out.

3.5.2 Root Characteristics

3.5.2.2 ***Length of taproot (cm)***

Length of taproot was recorded at final harvest and expressed in cm.

3.5.2.3 ***Lateral root spread (cm)***

The length of the largest lateral root on both sides of the taproot was measured, the mean worked out and expressed in cm.

3.5.2.4 ***Root Shoot ratio***

Fresh and dry weights of the root and shoot were taken and the root shoot ratio was calculated.

3.5.3 Yield Attributes

3.5.3.1 ***Time for 50 % flowering (Days)***

Total number of plants flowered in each plot were counted from the onset of flowering everyday and the date on which half of the population flowered was taken as the days for 50% flowering.

3.5.3.2 ***Number of flowers plant^{-1}(No.)***

Total number of flowers from the six observation plants was recorded and the average was worked out.

3.5.3.3. ***Number of fruits plant^{-1}(No.)***

Total number of fruits obtained form the six observation plants of each plot were counted and the average was worked out.

3.5.3.4 ***Setting percentage (%)***

From the six observation plants of each plot, the total number of flowers opened and the number of fruits formed were recorded and the setting percentage was worked out by the formula:-

Setting Percentage = No. of fruits formed / No. of flowers opened X 100

3.5.3.5 ***Height of first bearing node (cm)***

The height of the node at which the first fruit was formed was measured from the ground level in all the six observation plants and their mean was worked out and expressed in cm.

3.5.3.6 ***Length of the fruit (cm)***

The length of the fruits harvested from the observation plants was measured and the mean worked out and expressed in cm.

3.5.3.7 ***Girth of the fruit (cm)***

The same fruits used for measuring the length were used for finding the girth. Girth was measured by winding a thread around individual fruits. The mean values were worked out and expressed in cm.

3.5.3.8 ***Fruit yield plant^{-1}(g plant^{-1})***

The weight of fruits from the observation plants was recorded. Total weight of fruits from observation plants of each plot at different harvests were worked out and expressed as the fruit yield plant^{-1}.

3.5.3.9 ***Total fruit yield (t ha^{-1})***

Weight of fruit from each plot excluding the border row at each harvest was summed up at the end of the cropping season and the yield in terms of kg plot^{-1} was calculated and converted into t ha^{-1}.

3.5.3.10 ***Dry matter production (kg ha^{-1})***

Dry matter production was recorded at the final harvest. Sample plants were cut close to the ground and oven dried at 60 ^{0} C to a constant weight and expressed in kg ha^{-1}.

3.5.4 Quality aspects of fruits

3.5.4.1 ***Ascorbic acid content of fruits (mg 100 g^{-1})***

The ascorbic acid content of the fruits was estimated by titrimetric method. (Gyorgy and Pearson, 1967).

3.5.4.2 ***Crude fibre content (%)***

The crude fibre content was determined by AOAC method (AOAC, 1960).

3.5.4.3 ***Protein content (%)***

The nitrogen content of the fruits were determined and the values were multiplied by the factor 6.25 to obtain the protein content of fruits and the values were expressed as percentage (Simpson et al., 1965).

3.5.4.4 ***Shelf life (days)***

Fresh fruits harvested from each plot were kept in open condition to find out the keeping quality.

3.5.4.5 ***Organoleptic test (Score)***

Organoleptic test was conducted to rate the appearance, aroma and taste of the cooked fruit. A panel of 5 members tested the organoleptic qualities and expressed their opinion in a score card.

3.5.5 Plant Analysis

Sample plants collected from each plot at harvest were chopped, sun dried and oven dried to a constant weight. Samples were ground to pass through a 0.5 mm mesh in a Willey Mill and the required quantity of samples were digested and used for nutrient content analysis.

3.5.5.1 ***Uptake of Nitrogen***

The nitrogen content in plant samples was estimated by the modified microkjeldhal method (Jackson, 1973) and the uptake of nitrogen was calculated by multiplying the nitrogen content of plant sample with the total dry weight of plants. The uptake values were expressed in kg ha^{-1}.

3.5.5.2 ***Uptake of Phosphorus***

The phosphorus content in the plant sample was colorimetrically determined by wet digestion of the sample and developing colour by ascorbic acid method and read in a Spectrophotometer (Bray and Kurtz 1964). The uptake of phosphorus was calculated by multiplying the phosphorus content of plant sample with the total dry weight of plants. The uptake values were expressed in kg ha^{-1}.

3.5.5.3 ***Uptake of Potassium***

The potassium content in the plant sample was determined by flame photometer method and the uptake of Potassium was calculated by multiplying the nitrogen content of plant sample with the total dry weight of plants. The uptake values were expressed in kg ha^{-1}.

3.5.6 Soil Analysis

Soil samples were taken from the experimental area before the lay out of the experiment and after. Samples were collected from each plot after the residual crop also. The air dried samples were analysed for available nitrogen by the alkaline Potassium permanganate method (Subbiah and Asiya, 1956), available phosphorus by Bray’s colorimeter method and available potassium by ammonium acetate method (Jackson, 1973).

3.5.6 Estimation of Soil Moisture

Soil moisture analysis was done to find out the days to 50 % depletion of available soil moisture, water requirement and water use efficiency.

3.5.6.1 *Irrigation interval (days)*

The range of available soil moisture was estimated by finding out the difference between field capacity and permanent wilting point. Soil moisture analysis was done in a standing crop of bhindi before the experiment to fix the irrigation interval. Based on irrigation interval, irrigation water was supplied at 50 % depletion of available soil moisture. Moisture analysis of soil from the experimental field was also done at alternate days by thermo gravimetric method.

3.5.7.3 *Crop water use efficiency (kg ha^{-1} mm^{-1})*

Water use efficiency was found out by the formula:-

WUE = Yield / Evapotranspiration.

3.5.4 Incidence of Pests and Diseases

The incidence of leaf roller and *Cercospora* leaf spot did not reach the threshold level and hence uniform score was given to all plots.

In the case of fruit and shoot borer, percentage of damaged fruits harvest^{-1} was calculated by the following method (Gupta and Yadav, 1978).

$$\text{Percentage of damaged fruits harvest}^{-1} = \frac{\text{Weight of damaged fruits plot}^{-1}}{\text{Total weight of fruits plot}^{-1}} \times 100$$

3.5.5 Residue Crop

A residual crop of amaranthus was raised in the same field after the crop of bhindi to find out the effect of different treatments on the yield of amaranthus. The residual crop was not given any nutrient supply. The crop was watered daily.

3.5.10 Economics of bhindi cultivation

The income from bhindi and amaranthus (residue crop) was calculated separately as well as together to find out the B: C ratio as per the formulae given below. Economic analysis considering the high market price of organic produce was also attempted.

$$B:C = \frac{\text{Gross Income}}{\text{Cost of cultivation}}$$

Results

4. RESULTS

The field experiment to study the effect of different nutrient levels and irrigation on growth, yield and residual effect of bhindi was conducted at Instructional Farm, College of Agriculture, Vellayani during the period from June to December, 2009. The experimental data collected were statistically analyzed and the results obtained are presented below.

4.1 GROWTH CHARACTERS OF BHINDI:-

3.5.6 **Height of the Plant (cm)**

The average height of plants recorded at 30, 60 and 90 DAS (Days After Sowing) is presented in Table 2.

Different levels of nutrients and irrigation did not cause significant variation in plant height up to 60 DAS but there was significant variation in plant height due to different levels of nutrients and irrigation (rainfed with green leaf mulching and need based irrigation) during later growth stages.

At 90 DAS, among the different nutrient levels, N_1 (organic nutrient combination given at 100 % of N equivalent) recorded significantly taller plants (78.27cm) than N_3 (organic nutrient combination given at 50 % of N equivalent) (63.99cm) and N_2 (organic nutrient combination given at 75 % of N equivalent) (63.72cm) and was on par with N_4 (RDF) (77.26cm).

The rainfed mulched (I_1) plots recorded significantly taller plants (82.43cm) compared to that in irrigated plots (I_2) (59.18cm). Interaction effect was not significant.

Table 2. Influence of nutrient levels and irrigation on plant height (cm).

Treatment Means	30 DAS	60DAS	90DAS
Nutrient levels			
N_1	16.84	56.38	78.28
N_2	16.21	48.99	63.72
N_3	16.74	48.86	63.99
N_4	16.61	54.96	77.26
F(3,14)	**0.071 ^{NS}**	**1.557 ^{NS}**	**4.963****
SE(N)	**1.433**	**3.155**	**3.610**
CD	**-**	**-**	**10.954**
Irrigation			
I_1	16.98	54.70	82.44
I_2	16.22	49.88	59.19
F(1,14)	**0.519 ^{NS}**	**2.333 ^{NS}**	**41.459****
SE(I)	**0.738**	**2.231**	**2.553**
CD	**-**	**-**	**7.745**
Interaction			
N_1I_1	16.72	60.42	86.80
N_1I_2	16.96	52.33	69.75
N_2I_1	15.93	53.63	73.75
N_2I_2	16.48	44.34	53.69
N_3I_1	17.92	46.96	74.26
N_3I_2	15.57	50.75	53.72
N_4I_1	17.33	57.80	94.94
N_4I_2	15.88	52.11	59.58
F(7,14)	**0.438 ^{NS}**	**0.883 ^{NS}**	**1.296 ^{NS}**
SE(N x I)	**1.475**	**4.463**	**5.106**
CD	**-**	**-**	**-**

**** – Significant at 1% level**
*** – Significant at 5% level**
NS – Not Significant

Number of Leaves Plant^{-1} (No.)

The data on number of leaves plant^{-1}is given in Table 3.

Different levels of nutrients did not cause any significant influence on number of leaves plant^{-1}at all growth stages. However, rainfed plots with mulching produced significant effect at later stages of plant growth (60 and 90DAS).

Significantly higher number of leaves plant^{-1}was recorded by I_1 both at 60 and 90 DAS (12.01 and 22.16 respectively) compared to irrigated plots (10.02 and 18.56 respectively).

The interaction effect between the different nutrient levels and irrigation did not show any significant variation in number of leaves plant^{-1}.

3.5.7 Number of Branches Plant^{-1}(No.)

Data on number of branches plant^{-1}is presented in Table 4.

The nutrient levels and irrigation significantly influenced the number of branches plant^{-1}. N_4 (2.77) recorded significantly higher number of branches compared to the other treatments except N_1 (2.30) which was on par.

Rainfed plots which were mulched produced significantly higher number of branches (2.59) compared to that of irrigated unmulched plots (1.98).

The interaction effect was not significant.

4.1.3 Leaf Area Index (LAI)

The leaf area index calculated at 30, 60 and 90 DAS is presented in Table 4.

Table 3. Influence of nutrient levels and irrigation on number of leaves plant^{-1} (No.)

Treatment Means	30 DAS	60DAS	90DAS
Nutrient levels			
N_1	6.67	10.80	19.92
N_2	6.65	11.25	20.25
N_3	6.28	10.28	19.47
N_4	6.32	11.72	21.83
F(3,14)	**0.518** ^{NS}	**0.867** ^{NS}	**0.898** ^{NS}
SE(N)	**0.288**	**0.665**	**1.083**
CD	**-**	**-**	**-**
Irrigation			
I_1	6.69	12.02	22.16
I_2	6.27	10.00	18.57
F(1,14)	**2.173** ^{NS}	**9.208****	**11.022****
SE(I)	**0.204**	**0.471**	**0.766**
CD	**-**	**1.426**	**2.325**
Interaction			
N_1I_1	6.97	11.24	20.33
N_1I_2	6.37	10.34	19.50
N_2I_1	6.53	13.17	20.89
N_2I_2	6.77	9.33	19.61
N_3I_1	6.63	11.72	22.33
N_3I_2	5.93	8.84	16.61
N_4I_1	6.63	11.94	25.11
N_4I_2	6.00	11.50	18.55
F(7,14)	**0.585** ^{NS}	**1.468** ^{NS}	**1.867** ^{NS}
SE(N x I)	**0.408**	**0.940**	**1.532**
CD	**-**	**-**	**-**

**** – Significant at 1% level**
*** – Significant at 5% level**
NS – Not Significant

Different nutrient levels could not significantly influence the leaf area index at all the growth stages.

At later stages of plant growth viz. 60 and 90 DAS irrigation significantly influenced the LAI and at these stages of plant growth the rainfed crops produced maximum LAI compared to the irrigated crops.

The interaction effect was significant at 60 DAS. The highest value of LAI was recorded by the interaction N_3I_1 (1.90) which was on par with N_4I_1 (1.66) and N_2I_1 (1.42) and these interactions were superior to all other interactions.

4.1.4 Dry Matter Production (kg ha^{-1})

Dry matter production recorded at harvest is presented in Table 4.

The different nutrient levels could not significantly influence the dry matter production. However, highest dry matter content was recorded by N_1 (1187.08 kg ha^{-1}).

Irrigated and rainfed treatments recorded significant variation in DMP. Rain fed plots which were mulched recorded significantly superior DMP (1156.92 kg ha^{-1}) over irrigated unmulched plots (888.48 kg ha^{-1}).

Different nutrient levels and irrigation did not significantly interact with each other in the case of DMP.

3.6 ROOT CHARACTERISTICS

Data regarding the influence of nutrient levels and irrigation on root characteristics is given in Table 5.

Table 4. Influence of nutrient levels and irrigation on number of branches plant^{-1}, leaf area index and dry matter production of bhindi.

Treatment Means	No of branches (No.)	LAI			DMP (kg ha^{-1})
Nutrient levels	60DAS	30DAS	60DAS	90DAS	at Harvest
N_1	2.30	0.39	0.92	0.59	1187.08
N_2	1.97	0.33	1.05	0.68	982.88
N_3	2.11	0.33	1.28	0.67	906.71
N_4	2.78	0.33	1.09	0.65	1014.14
F(3,14)	**3.440**	**0.281** ^{NS}	**1.745** ^{NS}	**0.437** ^{NS}	**1.442** ^{NS}
SE(N)	**0.190**	**0.054**	**0.113**	**0.057**	**98.700**
CD	**0.575**	**-**	**-**	**-**	**-**
Irrigation					
I_1	2.59	0.33	1.52	0.85	1156.92
I_2	1.98	0.36	0.65	0.44	888.48
F(1,14)	**10.360**	**0.288** ^{NS}	**58.613****	**51.130****	**7.397****
SE(I)	**0.134**	**0.038**	**0.080**	**0.041**	**69.792**
CD	**0.407**	**-**	**0.242**	**0.122**	**211.714**
Interaction					
N_1I_1	2.49	0.36	1.09	0.71	1148.79
N_1I_2	2.11	0.41	0.76	0.48	1225.36
N_2I_1	2.00	0.31	1.42	0.89	1292.00
N_2I_2	1.94	0.35	0.68	0.46	673.76
N_3I_1	2.61	0.3	1.90	0.91	1067.13
N_3I_2	1.61	0.35	0.67	0.43	746.28
N_4I_1	3.27	0.34	1.66	0.91	1119.77
N_4I_2	2.26	0.32	0.51	0.40	908.52
F(7,14)	**1.541** ^{NS}	**0.092** ^{NS}	**3.327***	**1.212** ^{NS}	**2.116** ^{NS}
SE(N x I)	**0.268**	**0.077**	**0.160**	**0.081**	**139.584**
CD	**-**	**-**	**0.484**	**-**	**-**

**** – Significant at 1% level**
*** – Significant at 5% level**
NS – Not Significant

3.6.4 Length of Taproot (cm)

The different levels of nutrients, irrigation and their interaction could not significantly influence the length of taproot.

3.6.5 Lateral Root Spread (cm)

The different nutrient levels, irrigation and their interaction did not significantly influence the lateral root spread.

3.6.6 Root Shoot Ratio

The different levels of nutrients, irrigation and their interaction could not significantly influence the root shoot ratio.

4.3 YIELD ATTRIBUTES

4.3.1 Time to 50% Flowering (days)

The mean number of days taken for 50 % flowering is given in Table 6.

The plants which received the nutrient level N_1 attained 50 % flowering in 42.16 days. This was earlier compared to the plants which received other nutrient levels, but the effect was not significant.

Plants in the rainfed and irrigated plots did not significantly differ in their duration to attain 50 % flowering, but the rainfed plants attained 50 % flowering earlier.

The interaction effect between the nutrient levels and irrigation was also not significant.

Table 5. Influence of nutrient levels and irrigation on root characteristics of bhindi.

Treatment Means	Length of taproot (cm)	Lateral root spread (cm)	Root shoot ratio
Nutrient levels			
N_1	16.75	21.24	0.37
N_2	17.60	19.70	0.38
N_3	18.15	20.22	0.41
N_4	17.32	19.64	0.34
F(3,14)	**0.799** ^{NS}	**1.688** ^{NS}	**0.552** ^{NS}
SE(N)	**0.652**	**0.570**	**0.039**
CD	**-**	**-**	**-**
Irrigation			
I_1	17.13	19.83	0.37
I_2	17.78	20.57	0.38
F(1,14)	**0.967** ^{NS}	**1.706** ^{NS}	**0.056** ^{NS}
SE(I)	**0.461**	**0.403**	**0.027**
CD	**-**	**-**	**-**
Interaction			
N_1I_1	16.70	21.53	0.31
N_1I_2	16.80	20.95	0.43
N_2I_1	15.87	19.53	0.45
N_2I_2	19.33	19.87	0.31
N_3I_1	17.90	19.57	0.34
N_3I_2	18.40	20.87	0.48
N_4I_1	18.07	18.68	0.38
N_4I_2	16.57	20.60	0.30
F(7,14)	**2.522** ^{NS}	**0.926** ^{NS}	**3.629** ^{NS}
SE(N x I)	**0.923**	**0.805**	**0.055**
CD	**-**	**-**	**-**

**** – Significant at 1% level**
*** – Significant at 5% level**
NS – Not Significant

4.3.2 Height of First Bearing Node (cm)

The height of first bearing node recorded at 40 DAS is given in Table 6.

The different nutrient levels could not significantly influence the height of first bearing node.

Rainfed plants recorded a significantly shorter height of first bearing node (22.34 cm) compared to the irrigated plants (25.70 cm).

4.3.3 Number of Flowers Plant^{-1} (No.)

The number of flowers plant^{-1} is presented in Table 6.

The different nutrient levels and irrigation did not impart any significant variation on the number of flowers plant^{-1}. The highest number of flowers plant^{-1} was recorded by N_1I_1 (26.06) which was on par with all other interactions except N_2I_1 and N_3I_2.

4.3.4 Setting Percentage (%)

The setting percentage of fruits is presented on Table 6.

Even though the different nutrient levels could not significantly vary the setting percentage, irrigation could vary them significantly. However the highest setting percentage was recorded by nutrient level N_1 (88.44 %).

The rainfed plants recorded a significantly better fruit setting percentage (88.04 %) compared to the irrigated plants (84.21 %).
The different nutrient levels and irrigation could significantly interact in the case of setting percentage. The highest fruit setting percentage was recorded by N_1I_1

Table 6. Influence of nutrient levels and irrigation on yield attributes of bhindi.

Treatment Means	Time to 50% flowering (days)	Height of first bearing node(cm)	No. of flowers Plant^{-1} (No.)	Setting percentage (%)	No. of fruits plant^{-1} (No.)
Nutrient levels					
N_1	42.17	22.45	24.40	88.44	21.60
N_2	42.50	25.06	22.51	84.05	18.85
N_3	44.33	23.17	21.67	84.67	17.85
N_4	43.83	25.46	23.75	87.36	21.03
F(3,14)	**2.528** ^{NS}	**1.704** ^{NS}	**1.697** ^{NS}	**1.444** ^{NS}	**6.496****
SE(N)	**0.654**	**1.123**	**0.940**	**1.752**	**0.983**
CD	**-**	**-**	**-**	**-**	**1.97**
Irrigation					
I_1	42.67	22.34	22.92	88.04	20.25
I_2	43.75	25.70	23.24	84.21	19.42
F(1,14)	**2.745** ^{NS}	**8.933****	**0.112** ^{NS}	**4.779***	**1.428** ^{NS}
SE(I)	**0.469**	**1.589**	**1.329**	**2.478**	**0.696**
CD	**-**	**2.410**	**-**	**3.759**	**-**
Interaction					
N_1I_1	41.67	19.78	26.06	91.18	23.73
N_1I_2	42.67	25.12	22.73	85.69	19.47
N_2I_1	42.33	23.10	19.61	85.68	16.97
N_2I_2	42.67	27.03	25.40	82.42	20.73
N_3I_1	43.00	20.65	22.39	86.61	18.63
N_3I_2	45.67	25.59	20.96	82.73	17.08
N_4I_1	43.67	25.86	23.65	88.70	21.67
N_4I_2	44.00	25.07	23.86	86.02	20.40
F(7,14)	**0.709** ^{NS}	**1.584** ^{NS}	**4.369****	**0.119** ^{NS}	**5.796****
SE(N x I)	**0.925**	**1.588**	**1.329**	**2.478**	**1.391**
CD	**-**	**-**	**4.032**	**-**	**2.796**

**** – Significant at 1% level**
*** – Significant at 5% level**
NS – Not Significant

(91.18 %) which was on par with all other interactions except N_3I_2 (82.73 %) and N_2I_2 (82.42 %).

4.3.5 Number of Fruits Plant^{-1}

The number of fruits plant^{-1} recorded is presented in Table 6.

The different levels of nutrients could significantly influence the number of fruits plant^{-1}. The highest number of fruits plant^{-1} was recorded by N_1 (21.60) and this was on par with N_4 (21.03). The lowest number of fruits plant^{-1} was recorded by N_3 and it was on par with N_2.

Though the number of fruits plant^{-1} in rainfed plots was more than that in irrigated plots, the variation was not significant.

The interaction effect of nutrient levels and irrigation on fruit number was significant .The highest number of fruits plant^{-1} was recorded by N_1I_1 (23.73) which were on par with N_4I_1 (21.67) and significantly superior to all other interactions.

4.3.6 Length of Fruit (cm)

There was no significant difference observed on length of the fruit with respect to different nutrient levels, irrigation and their interaction (Table 7).

4.3.7 Girth of Fruit (cm)

Either different nutrient levels, irrigation or their interaction did not show any significant influence on girth of the fruit (Table 7).

4.3.8 Fruit Yield Plant^{-1} (g)

The average fruit yield plant^{-1} was recorded and the data is given in Table 7. The different nutrient levels could significantly influence the fruit yield plant^{-1}.

The highest fruit yield plant^{-1} was recorded by the nutrient level N_1 (285.70 g) which was on par with N_4 (276.38 g) and significantly superior to N_2 and N_3, which was on par with each other.

Irrigation could not significantly influence the fruit yield plant^{-1}.

The interaction effect of nutrient levels and irrigation on fruit yield plant^{-1} was significant. The highest number of fruit yield plant^{-1} was recorded by N_1I_1 (312.95) which were on par with N_4I_2 (279.75) and significantly superior to all other interactions.

4.3.9 Total Fruit Yield (t ha^{-1})

The data on total fruit yield (t ha^{-1}) is given in Table 7.

The total fruit yield was significantly influenced by the different nutrient levels. The highest total fruit yield was recorded by N_1 (10.58 t ha^{-1}) which was on par with N_4 (9.82 t ha^{-1}). The lowest fruit yield was recorded by N_3 (8.54 t ha^{-1}) and this was on par with N_2 (8.39 t ha^{-1}).

The rainfed, mulched plots produced total fruit yield of 9.72 t ha^{-1} while the yield in irrigated plots was 8.95 t ha^{-1}. However the variation produced was not significant. The interaction effect between nutrient levels and irrigation was not significant.

Table 7. Influence of nutrient levels and irrigation on fruit characters and yield of bhindi

Treatment Means	Length of fruit (cm)	Girth of fruit (cm)	Fruit yield $plant^{-1}$ (g $plant^{-1}$)	Total fruit yield (t ha^{-1})
Nutrient levels				
N_1	16.90	6.05	285.71	10.58
N_2	16.15	6.21	230.98	8.54
N_3	16.22	6.19	227.58	8.39
N_4	17.12	6.18	276.38	9.82
F(3,14)	**0.568** ^{NS}	**0.218** ^{NS}	**10.922****	**7.081****
SE(N)	**0.643**	**0.159**	**12.904**	**0.395**
CD	**-**	**-**	**25.938**	**1.198**
Irrigation				
I_1	16.40	6.06	260.44	9.72
I_2	16.79	6.25	249.89	8.95
F(1,14)	**0.369** ^{NS}	**1.422** ^{NS}	**1.339** ^{NS}	**3.805** ^{NS}
SE(I)	**0.455**	**0.113**	**9.125**	**0.280**
CD	**-**	**-**	-	**-**
Interaction				
N_1I_1	16.04	5.53	258.46	11.52
N_1I_2	17.77	6.56	214.48	9.65
N_2I_1	16.84	6.07	247.48	8.56
N_2I_2	15.45	6.36	241.33	8.53
N_3I_1	16.46	6.24	213.83	8.88
N_3I_2	15.99	6.13	273.00	7.90
N_4I_1	16.27	6.40	279.75	**9.92**
N_4I_2	17.97	5.96	258.46	9.72
F(7,14)	**1.496** ^{NS}	**3.959***	**4.417****	**1.129** ^{NS}
SE(N x I)	**0.909**	**0.226**	**18.249**	**0.559**
CD	**-**	**0.683**	**36.681**	**-**

**** – Significant at 1% level**
*** – Significant at 5% level**
NS – Not Significant

4.4 QUALITY ASPECTS OF BHINDI

4.4.1 Ascorbic acid content (mg 100gm^{-1})

The data on ascorbic acid content of fruits is presented in Table 8.

The different levels of nutrients did not impart any significant variation in the ascorbic acid content. However, the highest value of ascorbic acid content was recorded by N_1 (24.23 mg 100 gm^{-1}).

The rainfed and irrigated plants did not show any variation in the ascorbic acid content of fruits. The interaction effect was also not significant.

4.4.2 Crude Fibre content (%)

The crude fibre content of fruits is presented in Table 8.

The different nutrient levels showed significant variation in crude fibre content but the variation was not significant between rainfed and irrigated plots.

The highest value of crude fibre content was recorded by N_3 (9.17 %) which showed significant difference from all other treatments. This was followed by N_4 (7.02 %), N_2 (7 %) and N_1 (6.73 %).

The interaction between different levels of nutrients and irrigation significantly influenced the crude fibre content. The highest value of crude fibre content was recorded by N_3I_2 (9.33%) which was on par with all other treatments except N_2I_2, N_4I_2 and N_1I_1.

Table 8. Influence of nutrient levels and irrigation on quality attributes of bhindi

Treatment Means	Ascorbic acid content (mg100 g $^{-1}$)	Crude fibre content (%)	Crude protein content (%)	Shelf life (days)	Organoleptic (Score-1 to 5)
Nutrient levels					
N_1	24.23	6.73	29.63	5.72	3.96
N_2	18.91	7.00	23.66	5.61	3.58
N_3	18.32	9.17	23.62	5.72	3.17
N_4	20.09	7.02	27.45	5.78	3.50
F(3,14)	**2.380 ^{NS}**	**4.743***	**3.737***	**0.085 ^{NS}**	**2.132 ^{NS}**
SE(N)	**1.727**	**0.520**	**1.533**	**0.241**	**0.223**
CD	**-**	**1.577**	**4.653**	**-**	**-**
Irrigation					
I_1	20.39	7.71	25.66	5.91	3.60
I_2	20.39	7.25	26.56	5.50	3.50
F(1,14)	**0 ^{NS}**	**0.777 ^{NS}**	**0.313 ^{NS}**	**2.987 ^{NS}**	**0.219 ^{NS}**
SE(I)	**1.221**	**0.368**	**1.084**	**0.170**	**0.158**
CD	**-**	**-**	**-**	**-**	**-**
Interaction					
N_1I_1	24.82	4.80	31.73	5.77	3.92
N_1I_2	23.64	8.67	27.52	5.67	4.00
N_2I_1	17.73	8.50	22.70	5.78	4.00
N_2I_2	20.09	5.50	24.62	5.44	3.17
N_3I_1	17.73	9.00	23.50	6.00	3.00
N_3I_2	18.91	9.33	23.73	5.44	3.3
N_4I_1	21.27	8.53	24.70	6.12	3.50
N_4I_2	18.91	5.50	30.20	5.44	3.50
F(7,14)	**0.390 ^{NS}**	**9.992****	**1.729 ^{NS}**	**0.263 ^{NS}**	**1.292 ^{NS}**
SE(N x I)	**2.441**	**0.735**	**2.169**	**0.340**	**0.315**
CD	**-**	**2.231**	**-**	**-**	**-**

**** – Significant at 1% level**
*** – Significant at 5% level**
NS – Not Significant

4.4.3 Crude Protein content (%)

The data on crude protein content of fresh fruits is presented in Table 8.

The different nutrient levels could significantly vary the crude protein content. The highest value was recorded by N_1 (29.63 %) which was on par with N_4 (27.45 %) and significantly superior to N_2 and N_3.

Crude protein content did not vary significantly among irrigated and rainfed plots.

The interaction effect was not significant.

4.4.4 Shelf Life of Fruits (days)

The data presented in table 8 reveals that either the different nutrient levels or irrigation could not significantly vary the shelf life of fruits.

4.4.5 Organoleptic test (score: 1 to 5)

The data on organoleptic test is presented in Table 8.

The different nutrient levels, irrigation and their interaction could not significantly influence the organoleptic characters of fruit.

4.5 PLANT ANALYSIS OF BHINDI

4.5.1 Nitrogen Uptake (kg ha^{-1})

The plant samples were analysed for nitrogen, phosphorus and potassium content and the uptake was worked out. The data is presented in Table 9.

Nitrogen uptake was significantly influenced by the different nitrogen levels as well as irrigation. The highest value of nitrogen uptake was recorded by N_1 (48.97 kg ha^{-1}) which was on par with N_4 (41.02 kg ha^{-1}) and significantly superior to N_3 and N_2.

Rainfed, mulched plots recorded a significantly better nitrogen uptake (42.33 kg ha^{-1}) compared to the irrigated plots (34.41 kg ha^{-1}).

There was also significant interaction between the nutrient levels and irrigation. The highest value of nitrogen uptake was recorded by N_1I_1 (61.37 kg ha^{-1}) which was significantly superior to all other interactions.

4.5.2 Phosphorus Uptake (kg ha^{-1})

The different nutrient levels significantly varied the phosphorus uptake. N_1 (10.45 kg ha^{-1}) recorded the highest uptake and was on par with N_4 (10.05 kg ha^{-1}) and N_2 (8.71 kg ha^{-1}) and significantly superior to N_3.

The phosphorus content did not vary significantly among the rainfed and irrigated plots.

The interaction effect between the nutrient levels and irrigation was significant. The highest value was recorded by N_1I_1 (11.69 kg ha^{-1}) which was on par with N_4I_2, N_2I_1 and N_1I_2.

4.5.3 Potassium Uptake (kg ha^{-1})

The different nutrient levels could not significantly influence the potassium uptake though potassium uptake was maximum recorded by plants receiving N_1.

Table 9. Influence of nutrient levels and irrigation on nutrient uptake of bhindi.

Nutrient Uptake / Treatment Means	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
Nutrient levels			
N_1	48.97	10.45	23.92
N_2	24.93	8.71	21.70
N_3	38.55	6.90	22.71
N_4	41.02	10.05	23.15
F(3,14)	**9.757****	**7.190****	**0.581 ^{NS}**
SE(N)	**3.201**	**0.597**	**1.215**
CD	**9.711**	**1.811**	**-**
Irrigation			
I_1	42.33	9.60	26.56
I_2	34.41	8.46	19.18
F(1,14)	**6.124****	**3.677 ^{NS}**	**36.896****
SE(I)	**2.263**	**0.422**	**0.859**
CD	**6.866**	**-**	**2.605**
Interaction			
N_1I_1	61.37	11.69	37.74
N_1I_2	36.57	9.21	10.11
N_2I_1	25.15	10.36	20.19
N_2I_2	24.72	7.06	23.21
N_3I_1	37.33	7.37	23.17
N_3I_2	39.76	6.42	22.25
N_4I_1	45.47	8.98	25.14
N_4I_2	36.57	11.12	21.15
F(7,14)	**3.649***	**4.027***	**32.259****
SE(N x I)	**4.527**	**0.844**	**1.718**
CD	**13.733**	**2.561**	**5.211**

**** – Significant at 1% level**
*** – Significant at 5% level**
NS – Not Significant

Rainfed mulched treatment registered significantly higher potassium uptake (26.56 kg ha^{-1}) compared to the irrigated plants (19.18 kg ha^{-1}).

The interaction between the factors could significantly influence the potassium uptake. The highest potassium uptake was recorded by N_1I_1 (37.74 kg ha^{-1}) which was significantly superior to all other interactions.

4.6 SOIL ANALYSIS AFTER BHINDI

4.6.1 Available Nitrogen (kg ha^{-1})

N_1 recorded significantly higher available nitrogen content (404.40 kg ha^{-1}) and the lowest available nitrogen content was recorded by N_3 (306.54 kg ha^{-1}).

The available nitrogen content in the soil was not significantly influenced by irrigation and its interaction with nutrient levels.

4.6.2 Available Phosphorus (kg ha^{-1})

Significantly higher available phosphorus content was recorded by N_1 (26.27 kg ha^{-1}). N_3 recorded the lowest available phosphorus content (21.19 kg ha^{-1}).

Neither irrigation nor its interaction with nutrient levels significantly influenced the available phosphorus content.

4.6.3 Available Potassium (kg ha^{-1})

The available potassium content was significantly higher for N_1 (188.63 kg ha^{-1}) and it was on par with N_2 (174.72 kg ha^{-1}). The lowest available potassium content was recorded by N_3 (119.55 kg ha^{-1}).

The available potassium content in the soil was not significantly influenced by irrigation and its interaction with nutrient levels.

4.7 SCORING OF PESTS AND DISEASES

4.7.1 Incidence of Fruit and shoot borer (%)

Scoring of fruit and shoot borer incident was done in the field and the extent of it's occurrence is expressed in Table 11.

The incidence of fruit and shoot borer was not significantly influenced by the different nutrient levels but highest incidence was observed in N_4 (14.83 %). Irrigation as well as the interaction effect between nutrient levels and irrigation did not have significant influence on the incidence of fruit and shoot borer.

4.8 SOIL MOISTURE ANALYSIS

Soil moisture analysis was done to find out the irrigation interval, irrigation requirement in mulched and unmulched plots and water use efficiency.

4.8.1 Estimation of irrigation interval

The data on irrigation interval is given in Table 12.

The results revealed that during the initial growth stages i.e. up to 2 months, the soil moisture attained 50 % depletion in 3 to3.5 days. Towards the later stages (fruiting stage), the same was attained earlier (2.5 to 3 days).

Table 10. Influence of nutrient levels and irrigation on available N, P and K after the crop of bhindi.

Treatment Means	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
Nutrient levels			
N_1	404.40	26.27	188.63
N_2	380.33	24.48	174.72
N_3	306.54	21.19	119.55
N_4	340.63	24.15	147.92
F(3,14)	**3.776***	**3.896***	**3.506***
SE(N)	**31.526**	**1.507**	**23.062**
CD	**63.37**	**3.03**	**46.35**
Irrigation			
I_1	372.37	24.29	155.07
I_2	343.90	23.76	160.34
F(1,14)	**1.631 ^{NS}**	**0.244**	**0.104 ^{NS}**
SE(I)	**22.292**	**1.066**	**16.307**
CD	**-**	**4.633**	**-**
Interaction			
N_1I_1	297.62	20.19	118.08
N_1I_2	315.46	22.19	121.03
N_2I_1	364.59	26.12	173.97
N_2I_2	397.31	22.84	175.47
N_3I_1	433.52	25.57	167.81
N_3I_2	375.29	26.97	209.45
N_4I_1	393.74	25.26	160.43
N_4I_2	287.52	23.04	135.42
F(7,14)	**2.149 ^{NS}**	**1.502 ^{NS}**	**0.589 ^{NS}**
SE(N x I)	**44.582**	**2.132**	**32.615**
CD	**-**	**-**	**-**

**** – Significant at 1% level**
*** – Significant at 5% level**
NS – Not Significant

Table 11. Influence of nutrient levels and irrigation on incidence of fruit and shoot borer and crop water use efficiency.

Treatment Means	Incidence of fruit and shoot borer (%)	Crop WUE (kg $ha^{-1}mm^{-1}$)
Nutrient levels		
N_1	8.3833	43.37
N_2	13.4917	35.78
N_3	11.2233	34.38
N_4	14.8367	40.10
F(3,14)	**2.0063** ^{NS}	**5.623****
SE(N)	**1.9949**	**1.735**
CD	**-**	**5.253**
Irrigation		
I_1	13.9700	40.13
I_2	9.9975	36.68
F(1,14)	**3.9652** ^{NS}	**3.977**
SE(I)	**1.4106**	**1.224**
CD	**-**	**-**
Interaction		
N_1I_1	10.3167	47.19
N_1I_2	6.4500	39.54
N_2I_1	14.5733	36.60
N_2I_2	12.4100	34.95
N_3I_1	12.3833	36.39
N_3I_2	10.0633	32.38
N_4I_1	18.6067	40.35
N_4I_2	11.0667	39.84
F(7,14)	**0.3924** ^{NS}	**0.830** ^{NS}
SE(N x I)	**2.8213**	**2.449**
CD	**-**	**-**

**** – Significant at 1% level**
*** – Significant at 5% level**
NS – Not Significant

Table 12.* Time taken for 50% depletion of available soil moisture (days)

Samples	1	2	3	4	**Mean**
Week 1	3	3.5	3.5	3.25	**3.31**
Week 2	3.5	3.25	3.25	3.25	**3.31**
Week 3	3.5	3.5	3.5	3.5	**3.5**
Week 4	2.75	2.5	3	2.75	**2.75**
Week 5	2.5	3	2.5	2.5	**2.63**
Week 6	2.5	2.75	3	2.5	**2.69**
Week 7	3	2.75	2.75	3	**2.89**
Week 8	2.5	2.75	2.5	2.5	**2.66**
Week 9	2.75	2.5	2.75	3	**2.75**

*The table was not statistically analyzed.

4.8.2 Irrigation Requirement

Irrigated plots received a total of 845 l and the rainfed plots received a total of 130 l of water for the entire crop period exclusive of rainfall, thus saving about 84.62 % of water by mulching.

4.8.3 Crop Water Use Efficiency (kg $ha^{-1}mm^{-1}$)

Water use efficiency was calculated and the data is presented in Table 11.

The different nutrient levels could significantly influence the WUE. The highest value was recorded by the highest nutrient level N_1 (43.37 kg $ha^{-1}mm^{-1}$) which was on par with N_4 (40.10 kg $ha^{-1}mm^{-1}$).

Though not significant, the mulched plots recorded a superior value for WUE (40.13 kg $ha^{-1}mm^{-1}$) compared to the irrigated, unmulched plots (36.68 kg $ha^{-1}mm^{-1}$). The interaction effect was also not significant.

4.9 ANALYSIS AFTER THE RESIDUE CROP (AMARANTHUS)

After the crop of bhindi, a crop of amaranthus was raised to find out the residual effect of organic manures. The crop yield and the available N, P, K content of the soil were recorded.

4.9.1 Yield of Residue crop

The data on the yield of residue crop is given in Table 13.

The yield of amaranthus was significantly influenced by the different levels of organic nutrients. The highest yield of 18.92 t ha^{-1} was recorded by N_1 which was significantly superior to all other treatments. The lowest yield was recorded by N_3 which was significantly inferior to all other treatments.

Table 13. Influence of nutrient levels and irrigation on yield of residue crop (amaranthus).

Treatment Means	Yield (t ha^{-1})
Nutrient levels	
N_1	18.92
N_2	13.61
N_3	10.48
N_4	14.10
F(3,14)	**16.890****
SE(N)	**0.852**
CD	**2.584**
Irrigation	
I_1	19.91
I_2	9.09
F(1,14)	**161.432****
SE(I)	**0.602**
CD	**1.827**
Interaction	
N_1I_1	25.23
N_1I_2	12.61
N_2I_1	19.19
N_2I_2	8.03
N_3I_1	14.65
N_3I_2	6.30
N_4I_1	20.58
N_4I_2	9.41
F(7,14)	**1.098** ^{NS}
SE(N x I)	**1.205**
CD	**-**

**** – Significant at 1% level**
*** – Significant at 5% level**
NS – Not Significant

The rainfed mulched plots recorded a significantly higher yield (19.91 t ha^{-1}) compared to that from irrigated plots (9.09 t ha^{-1}) which were not mulched.

The interaction effect was not significant on the yield of residue crop.

4.9.2 Soil Analysis after the residue crop

The available N, P, K content of the soil after the crop of amaranthus was analyzed and the data is presented in Table 14.

4.9.2.1 Available Nitrogen (kg ha^{-1})

The different nutrient levels, irrigation and their interaction could not significantly influence the soil available nitrogen content after amaranthus.

4.9.2.2 Available Phosphorus (kg ha^{-1})

Neither the nutrient levels nor the irrigation significantly influenced the soil P content after amaranthus. The interaction effect was also not significant.

4.9.2.3 Available Potassium (kg ha^{-1})

The different nutrient levels, irrigation and their interaction could not significantly influence the soil available potash content after amaranthus.

4.10 ECONOMICS OF BHINDI CULTIVATION

The economics was calculated for bhindi alone and for bhindi - amaranthus sequence with (Table 15a) and without (Table 15b) considering the high market price of organic produce.

Table 14. Influence of nutrient levels and irrigation on available N, P and K after the residue crop (amaranthus).

Treatment Means	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
Nutrient levels			
N_1	294.45	16.53	103.93
N_2	299.19	17.60	102.69
N_3	279.13	18.11	107.55
N_4	292.87	16.75	100.68
F(3,14)	**0.388** ^{NS}	**0.830** ^{NS}	**0.589** ^{NS}
SE(N)	**19.577**	**1.144**	**5.324**
CD	**-**	**-**	**-**
Irrigation			
I_1	300.85	16.58	103.84
I_2	281.97	17.92	103.58
F(1,14)	**1.860** ^{NS}	**2.749** ^{NS}	**0.005** ^{NS}
SE(I)	**13.843**	**0.809**	**3.764**
CD	**-**	**-**	**-**
Interaction			
N_1I_1	292.86	17.06	101.47
N_1I_2	296.04	15.99	106.40
N_2I_1	298.97	16.69	106.44
N_2I_2	299.41	18.51	98.90
N_3I_1	292.81	16.65	108.88
N_3I_2	265.45	19.56	106.21
N_4I_1	318.76	15.89	98.58
N_4I_2	266.98	17.60	102.77
F(7,14)	**0.876** ^{NS}	**1.093** ^{NS}	**0.618** ^{NS}
SE(N x I)	**27.686**	**1.618**	**7.527**
CD	**-**	**-**	**-**

**** – Significant at 1% level**
*** – Significant at 5% level**
NS – Not Significant

Considering the high market price of organic bhindi and amaranthus, the different nutrient levels and irrigation showed significant variation in B: C ratio of bhindi and bhindi – amaranthus sequence.

The highest B:C ratio for bhindi cultivation and the sequence was recorded by the nutrient level N_1 (2.03 and 3.88 respectively) which was significantly superior to all other treatments and the lowest B:C ratio was recorded by N_4 (1.48 and 2.46 respectively).

The returns from rainfed, mulched plots were significantly better than that from irrigated plots in both cases. The B:C ratio recorded were 2.01 (I_1) and 1.44 (I_2) for bhindi and 3.97 (I_1) and 2.16 (I_2) for the bhindi - amaranthus sequence respectively.

For bhindi and for the sequence, there was significant interaction between the nutrient levels and irrigation. For bhindi, the highest B:C ratio was recorded by N_1I_1 (2.42) which was significantly superior to all other interactions. The lowest B: C ratio was recorded by N_4I_2 (1.22). For the sequence, the highest B:C ratio was recorded by N_1I_1 (5.07) which was significantly superior to all other interactions. N_4I_2 (1.77) recorded the lowest B:C ratio.

Considering the local price for both bhindi and amaranthus, the different nutrient levels and irrigation showed significant variation in B: C ratio of bhindi and bhindi – amaranthus sequence.

The highest B:C ratio for bhindi cultivation and the sequence was recorded by the nutrient level N_1 (1.47 and 2.59 respectively) which was significantly superior to all other treatments except N_4 which was on par and the lowest B:C ratio was recorded by N_3 (1.26 and 1.91 respectively).

Table 15a. Influence of nutrient levels and irrigation on B:C ratio (based on market price)

Treatment Means	Bhindi	Bhindi + Amaranthus (sequence)
Nutrient levels		
N_1	2.03	3.88
N_2	1.68	3.09
N_3	1.73	2.84
N_4	1.48	2.46
F(3,14)	**20.790***	**32.000***
SE(N)	**0.050**	**0.106**
CD	**0.150**	**0.323**
Irrigation		
I_1	2.01	3.97
I_2	1.44	2.16
F(1,14)	**132.564****	**287.826****
SE(I)	**0.053**	**0.075**
CD	**0.106**	**0.228**
Interaction		
N_1I_1	2.42	5.07
N_1I_2	1.64	2.69
N_2I_1	1.87	3.97
N_2I_2	1.49	2.20
N_3I_1	2.02	3.69
N_3I_2	1.43	1.99
N_4I_1	1.74	3.14
N_4I_2	1.22	1.77
F(7,14)	**2.793***	**3.882***
SE(N x I)	**0.070**	**0.150**
CD	**0.212**	**0.456**

Cost of bhindi (inorganic)-Rs.20kg^{-1} Cost of amaranthus (inorganic)–Rs.10kg^{-1}
Cost of bhindi (organic)-Rs.30kg^{-1} Cost of amaranthus (organic)–Rs.15kg^{-1}

**** – Significant at 1% level**
*** – Significant at 5% level**
NS – Not Significant

Table 15b. Influence of nutrient levels and irrigation on B:C ratio (based on local price).

Treatment Means	Bhindi	Bhindi + Amaranthus (sequence)
Nutrient levels		
N_1	1.47	2.59
N_2	1.30	2.05
N_3	1.26	1.91
N_4	1.47	2.46
F(3,14)	**9.393****	**16.954****
SE(N)	**0.050**	**0.106**
CD	**0.164**	**0.323**
Irrigation		
I_1	1.56	2.91
I_2	1.19	1.58
F(1,14)	**4.080****	**287.798****
SE(I)	**0.053**	**0.075**
CD	**0.116**	**0.228**
Interaction		
N_1I_1	1.75	3.38
N_1I_2	1.37	2.65
N_2I_1	1.48	2.49
N_2I_2	1.62	3.14
N_3I_1	1.18	1.79
N_3I_2	1.23	1.46
N_4I_1	1.04	1.32
N_4I_2	1.31	1.77
F(7,14)	**45.143****	**1.588***
SE(N x I)	**0.070**	**0.150**
CD	**0.233**	**0.456**

Cost of bhindi – Rs. 20kg^{-1} Cost of amaranthus – Rs. 10kg^{-1}

**** – Significant at 1% level**
*** – Significant at 5% level**
NS – Not Significant

The returns from rainfed, mulched plots were significantly better than that from irrigated plots in both cases. The B:C ratio recorded were 1.56 (I_1) and 1.19 (I_2) for bhindi and 2.94 (I_1) and 1.58 (I_2) for the bhindi - amaranthus sequence respectively.

In the case of bhindi, B:C ratio was influenced by the significant interaction between the nutrient levels and irrigation. The highest B:C was recorded by N_1I_1 (1.75) which was on par with N_2I_2(1.63) and significantly superior to all other interactions. The lowest B:C ratio was recorded by N_4I_1 (1.04) and was on par with N_3I_1 and N_3I_2. Similar interaction effect was followed in the case of B:C ratio of bhindi – amaranthus sequence. The highest B:C ratio was recorded by N_1I_1 (3.58) which was on par with N_2I_2 (3.14) and significantly superior to all other interactions. The lowest B: C ratio was recorded by N_4I_1 (1.32).

Discussion

5. DISCUSSION

An experiment was conducted to find out the effect of different nutrient levels and irrigation on growth, yield and quality of bhindi and also to find out the residual effect of different levels of organic manures. The results obtained are discussed below.

5.1 EFFECT OF NUTRIENT LEVELS, IRRIGATION AND THEIR INTERACTION ON GROWTH, YIELD ATTRIBUTING CHARACTERS AND YIELD OF BHINDI

5.1.1 Growth Characters

The crop growth parameters such as plant height (90 DAS), number of leaves plant^{-1}and number of branches plant^{-1} responded positively to the different nutrient levels.

The effect of nutrient levels and irrigation was significant in varying the plant height towards the later growth stages (90 DAS). Among the different nutrient levels, N_1 recorded significantly taller plants (78.27cm) and was on par with N_4 (77.26 cm) (Fig.3.). Taller plants were observed in the highest nutrient level i. e. organic nutrient combination given at 100 % of N equivalent. The increased availability of nutrients through vermicompost, FYM and green leaf manure might have resulted in increased nitrogen uptake (Table 9). The increased uptake of nitrogen might have contributed to rapid meristematic activity (Crowther, 1935), higher rate of metabolic activity coupled with rapid cell division brought about by phosphorus (Bear, 1965) and by increased growth of meristamatic tissue (Tisdale and Nelson, 1985). These might have led to increased plant height towards later stage. Similar increase in plant height due to vermicompost application in bhindi was reported by Govindan et al. (1995), Ushakumari et al. (1999) and Shanthi and Vijayakumari (2002). Increase in plant

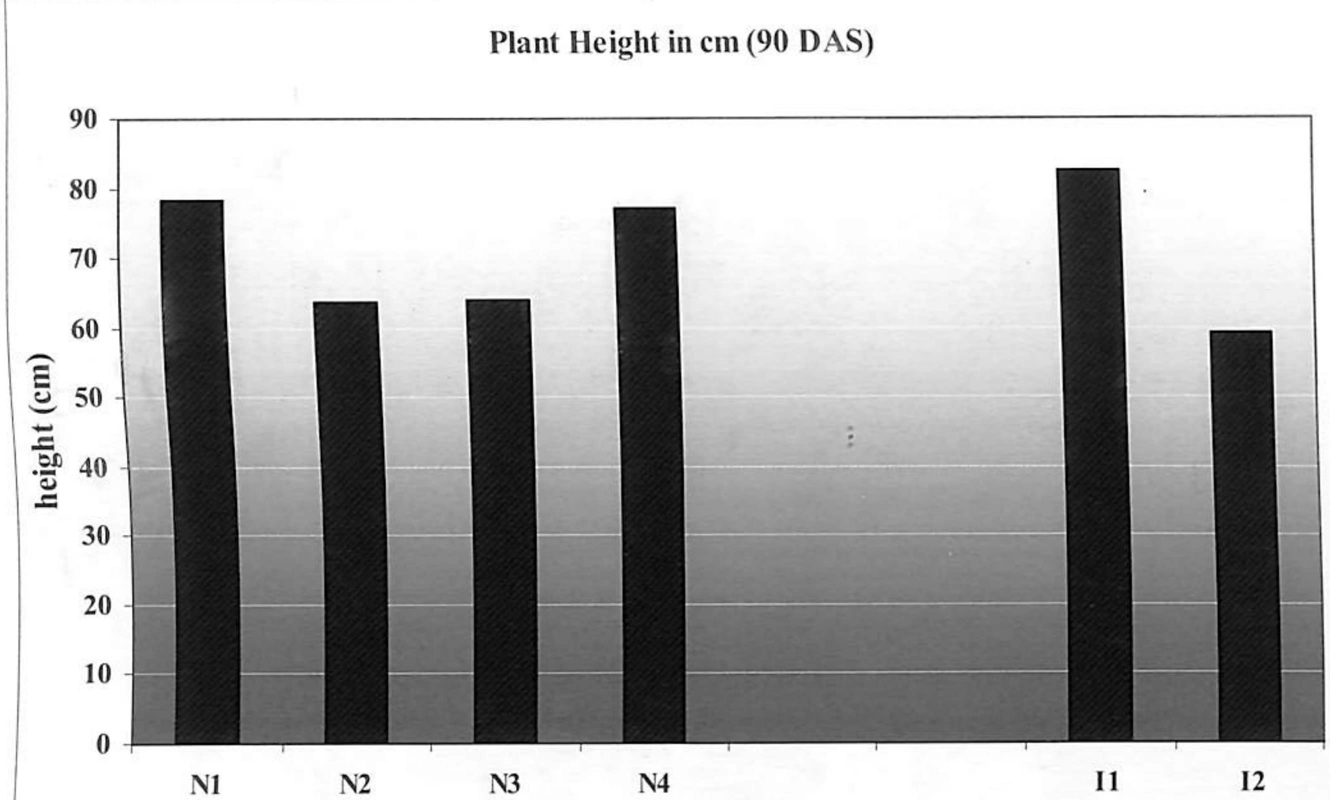


Fig.3. Effect of different nutrient levels and irrigation on plant height of bhindi

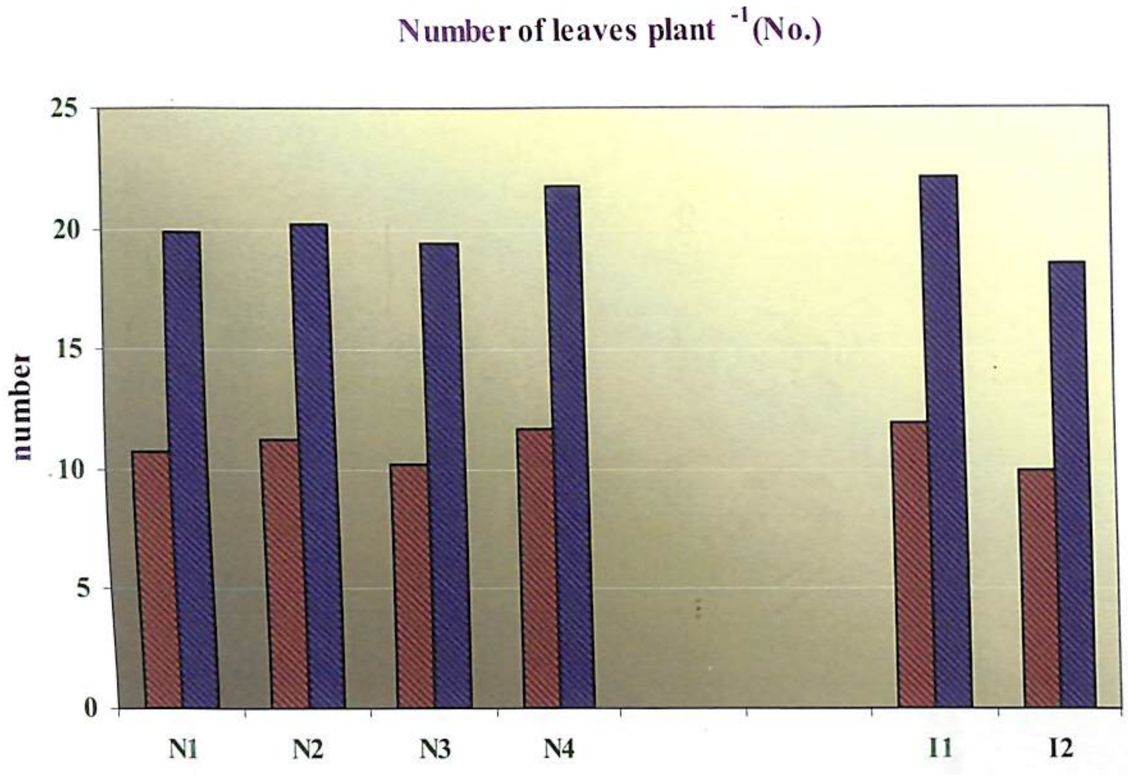


Fig.4.Effect of different nutrient levels and irrigation on no. of leaves plant^{-1} of bhindi

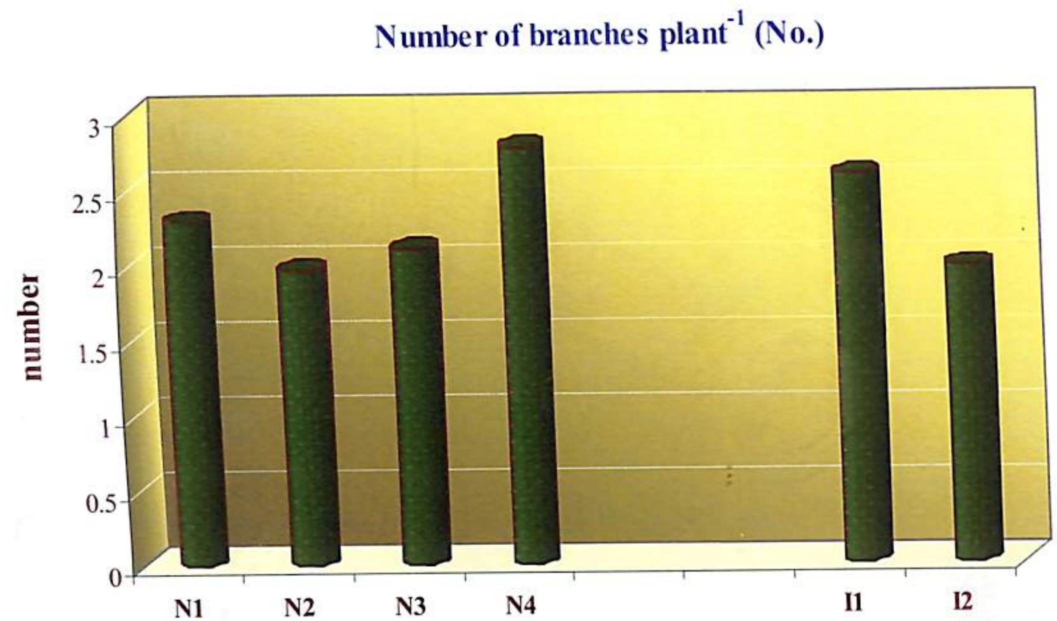


Fig.5.Effect of different nutrient levels and irrigation on number of branches plant^{-1} of bhindi

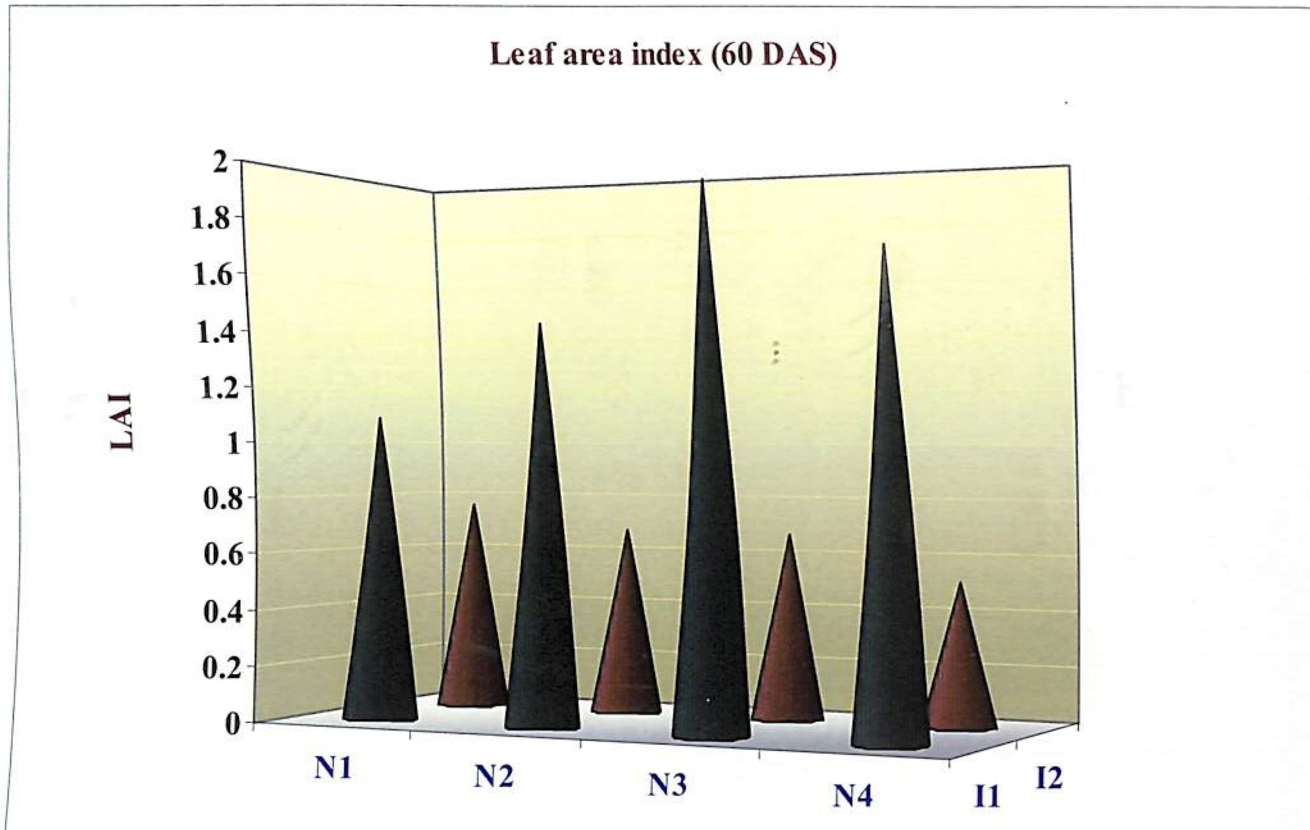


Fig.6. Effect of different nutrient levels and irrigation on LAI of bhindi (60 DAS)

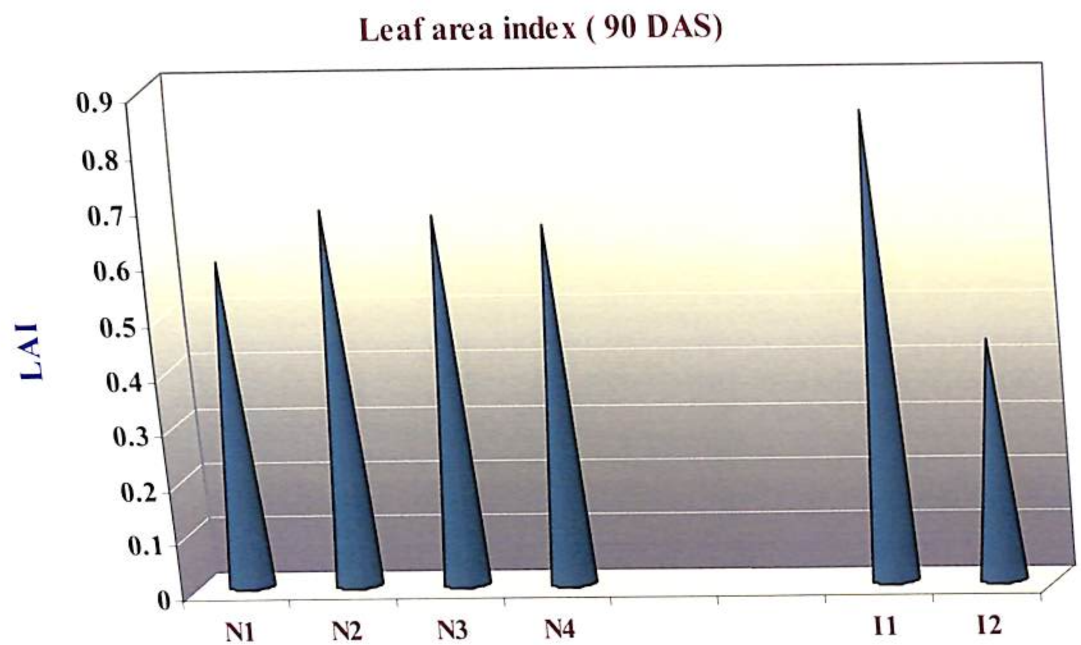


Fig.7.Effect of different nutrient levels and irrigation on leaf area index of bhindi (90DAS)

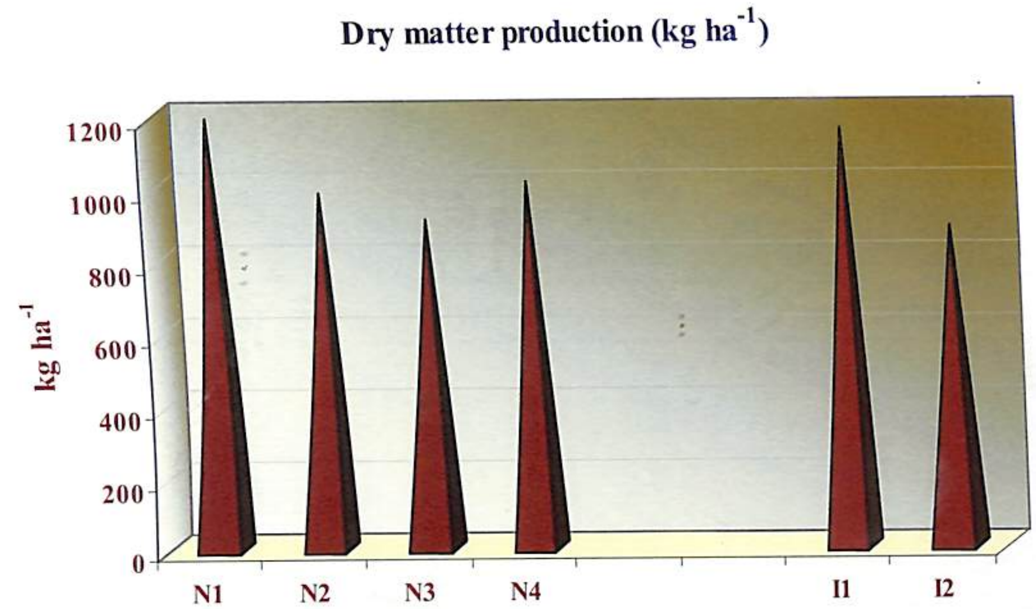


Fig.8. Effect of different nutrient levels and irrigation on dry matter production of bhindi

height due to vermicompost and FYM application has also been reported by Raj (1999). Number of branches plant^{-1} (Fig.5.) was the highest in plants which received RDF (2.77) and this was significantly superior to all other treatments except the highest dose of organic nutrition. Increased N availability and its uptake (Table 9.) might have increased the production, translocation and assimilation of photosynthates to growing points there by stimulating the plants to produce more number of branches (Arunkumar, 2000). Similar results of increased number of branches due to increased nitrogen levels have been reported by Dar et al. (2009).

Taller plants in the rainfed mulched plots might be due to reduced nutrient loss and improved soil micro life leading to better availability and uptake of nutrients. Enhancement in plant height of bhindi by mulching have been reported by Mohammed and Mamkagh (2009). Number of branches plant^{-1} was significantly high in mulched plots compared to that of unmulched plots. Mulching influences the NUE of crops by affecting the hydrothermal regime of soil, which might have enhanced shoot growth (Acharya, 2008) leading to more number of branches plant^{-1} in the rainfed mulched plots compared to that of irrigated ones. During later growth stages (60 and 90 DAS) , the plants in the rainfed mulched plots have recorded significantly more number of leaves (Fig.4), better LAI (Fig 6. and Fig. 7) and DMP (Fig.8.) (Table 3 and 4). Mulching greatly retards loss of moisture from soil. Higher and uniform soil moisture regime in mulched plots (Ramakrishna et al., 2006) along with rainfall which might have resulted in improved growth characters. The increased plant height, number of branches plant^{-1}, number of leaves plant^{-1} and better LAI might have resulted in increased DMP. Similar results of enhancement in growth characters like plant height, LAI, etc. in bhindi due to mulching was reported by Sunilkumar and Jaikumaran (1998). Higher availability of water for a prolonged period and higher nutrient availability might have resulted in enhancement of growth parameters. Interaction effect between the nutrient levels and irrigation was significant in the case of LAI at 60 DAS.

5.1.2 Yield Attributing Characters and Yield

Perusal of results in table 6 and 7 revealed that the number of fruits plant^{-1}, fruit yield plant^{-1} and total fruit yield ha^{-1} was significantly influenced by the different nutrient levels.

The highest dose of organic manures (100 % of N equivalent) recorded the highest number of fruits plant^{-1}. The higher availability and uptake of nutrients might have enabled the plant to produce more number of flower buds which in turn increased the number of fruits. The highest dose of organic manures (100 % of N equivalent) recorded the highest fruit yield plant^{-1}. Increased fruit yield plant^{-1}may be due to improved vegetative growth, better availability of nutrients, greater synthesis of carbohydrates and their proper translocation (Dar et al. 2009). It is well known that photosynthetic activity of the plant is modified by the nutritional status of the plant, since the nitrogen content in the plants increased with increasing levels of nutrients in the soil. More over application of nutrients in organic form reduced the loss of nutrients leading to more uptake. The cumulative effect of increased growth attributes like plant height, LAI, DMP (Table 2 and 4) and yield attributes like number of fruits plant^{-1}, setting percentage etc. (Table 6) reflected in the increased fruit yield plant^{-1} with increased levels of nitrogen. The positive direct effect of growth and yield attributing characters due to increased dose of organic manure have resulted in significantly better total fruit yield ha^{-1}. Similar results of increased fruit yield plant^{-1}due to increased nutrient levels have been reported by Raj (1999) and Hedau et al. (2001) in bhindi. The highest total fruit yield ha^{-1} was recorded by the treatment in which 100 % nitrogen was applied as organic (10.58 t ha^{-1}) which was on par with RDF (9.82 t ha^{-1}).

Rainfed mulched plots recorded significantly higher fruit setting % (Fig.10.) as well as shorter height of first bearing node (Fig.9). Similar results of increased setting % due to mulching were reported by Sunilkumar and Jaikumaran (1998).

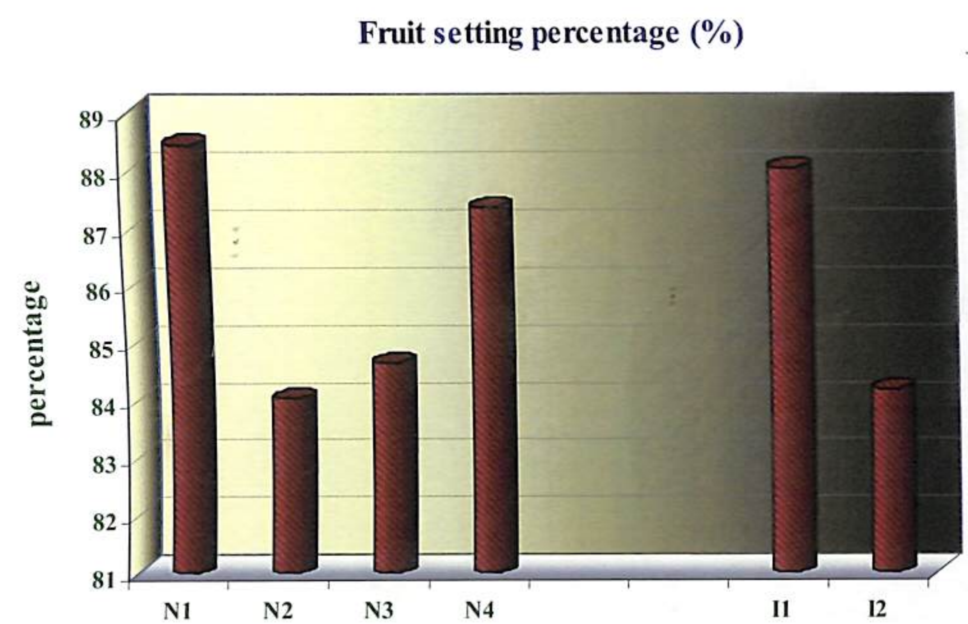


Fig.10.Effect of different nutrient levels and irrigation on fruit setting percentage of bhindi

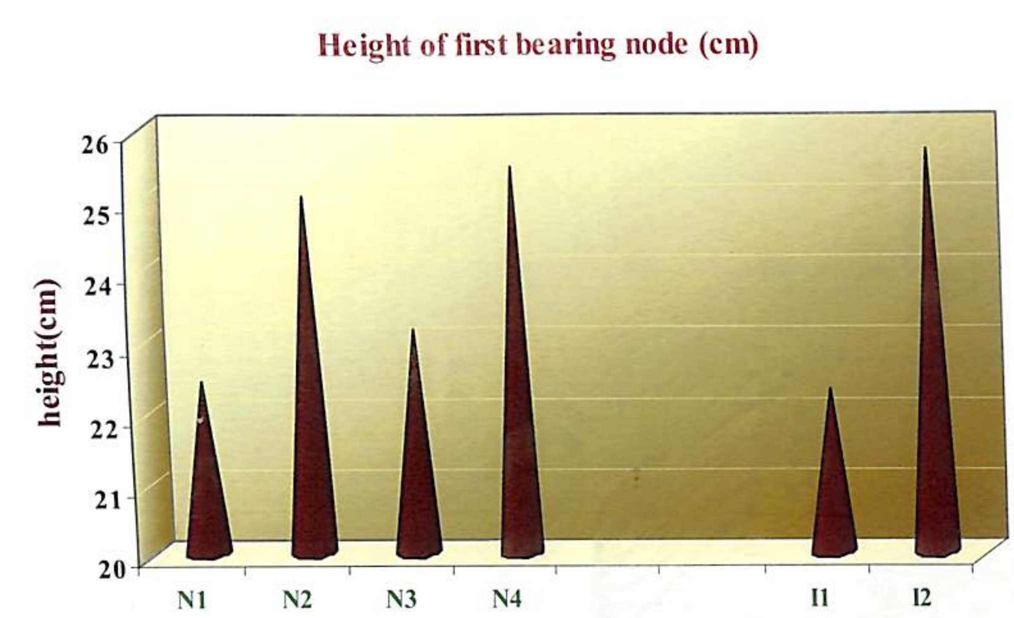


Fig.9.Effect of different nutrient levels and irrigation on height of first bearing node of bhindi

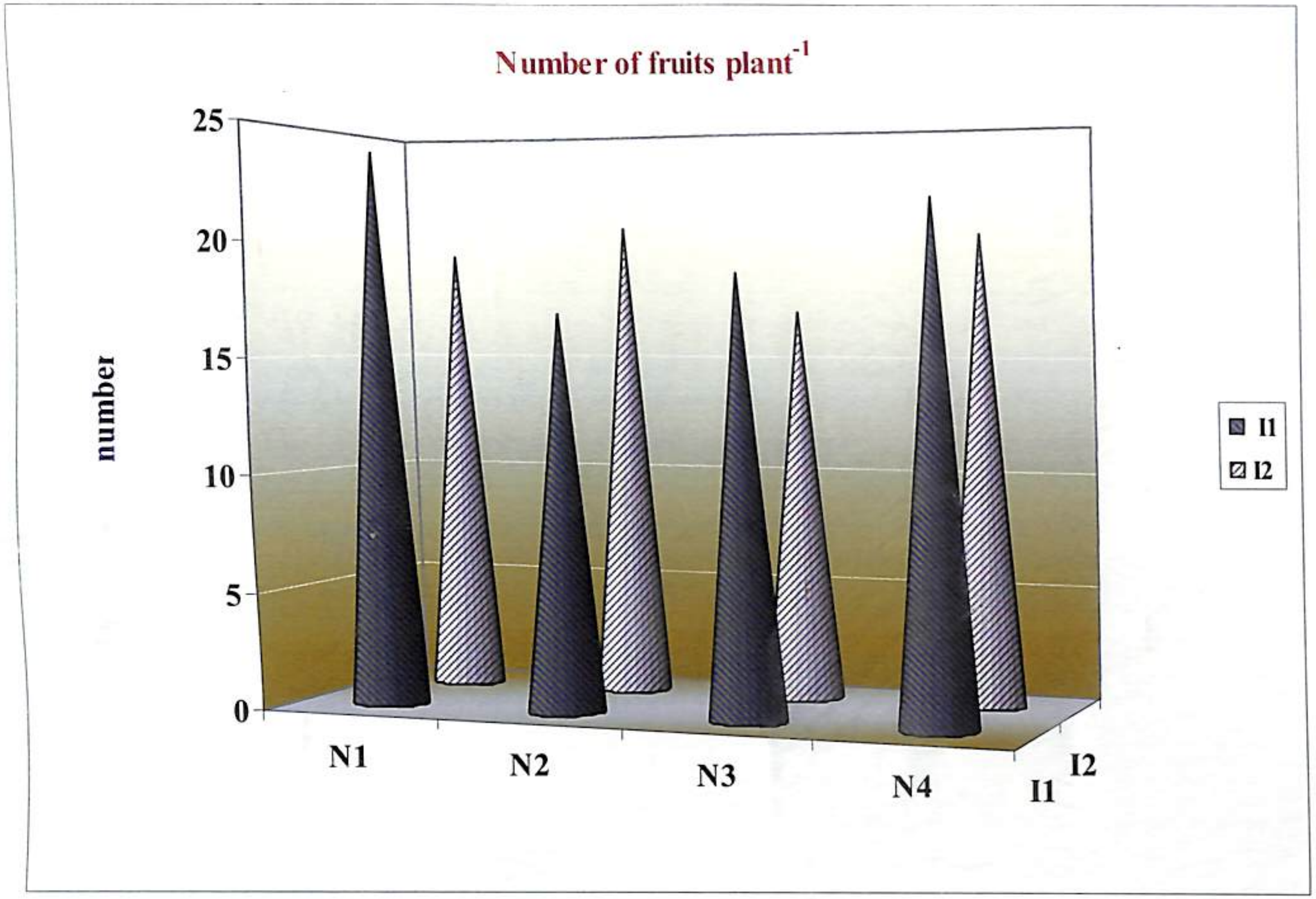


Fig.11. Effect of different nutrient levels and irrigation on number of fruits plant^{-1} of bhindi

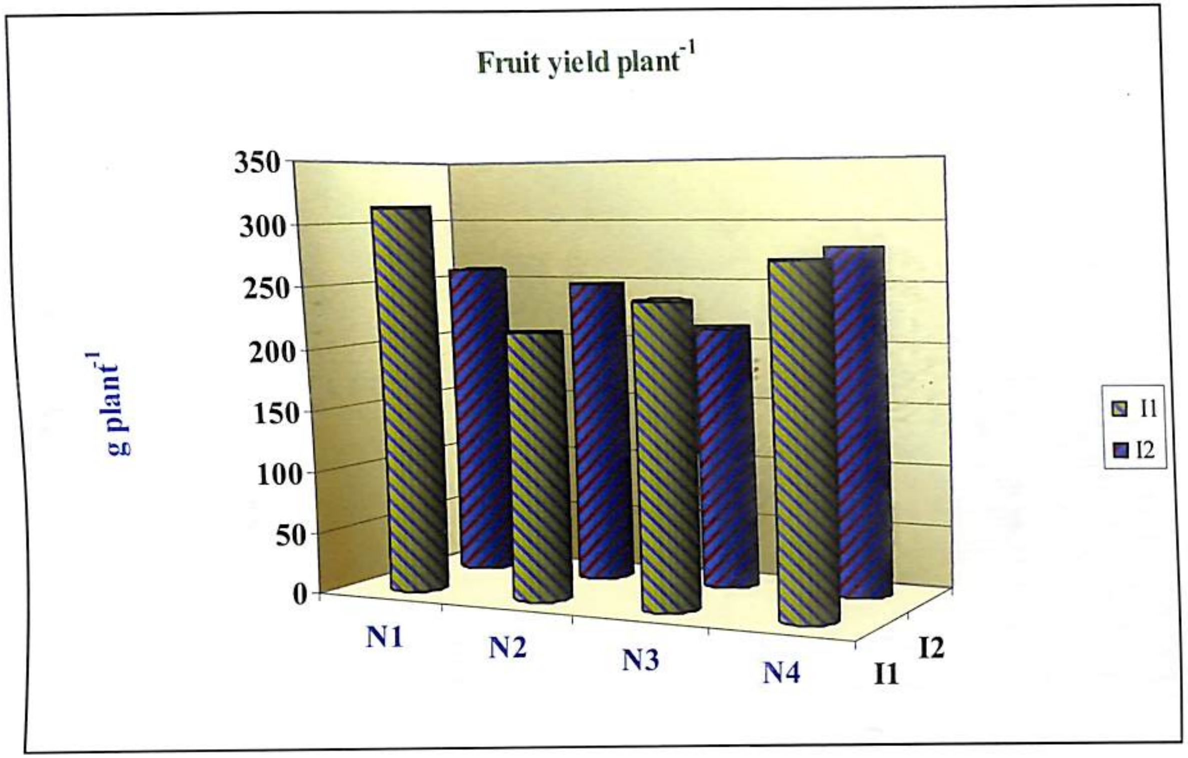


Fig.12. Effect of different nutrient levels and irrigation on fruit yield plant^{-1} of bhindi

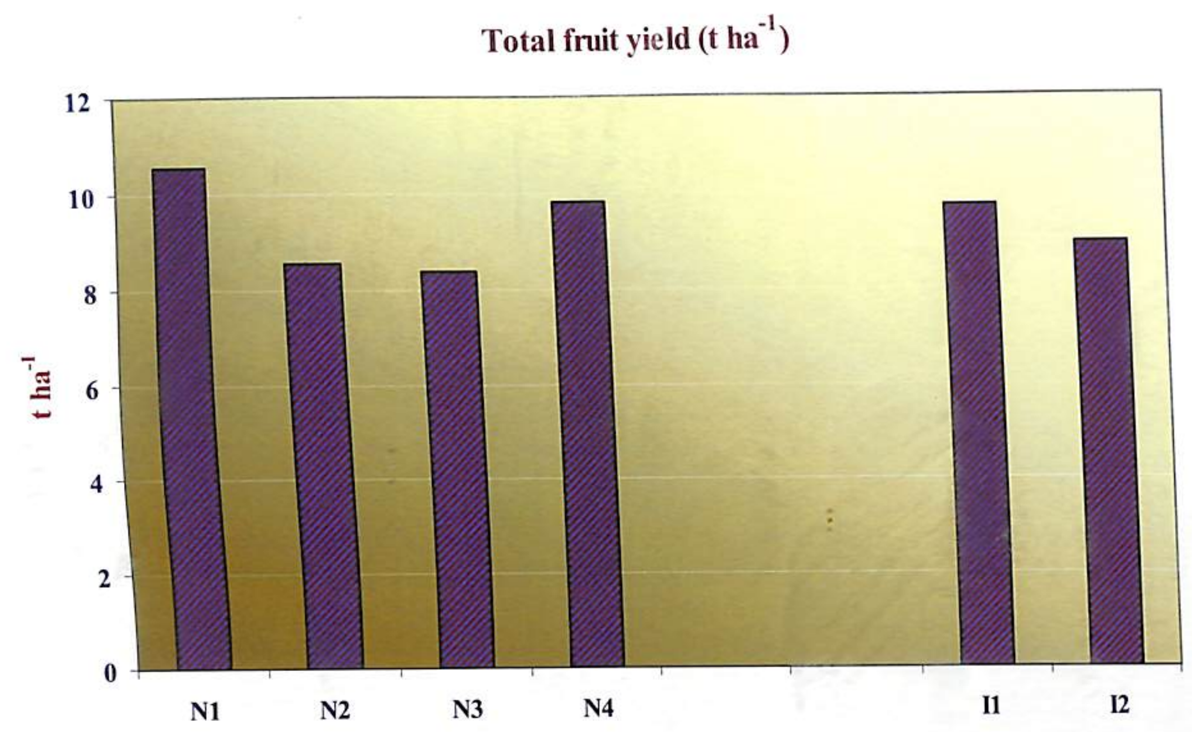


Fig.13.Effect of different nutrient levels and irrigation on total fruit yield of bhindi

Even though not significant, rainfed mulched plots produced a total fruit yield of 9.71 t ha^{-1} compared to 8.94 t ha^{-1} from the irrigated unmulched plots. Higher setting % and higher fruit yield $plant^{-1}$ led to increased total fruit yield. Sheela et al. (2007) also observed yield increase in bhindi due to mulching.

5.1.3 Quality Attributes of bhindi

The quality attributes like crude fibre content and crude protein content were significantly influenced by the different nutrient levels (Fig.14. and Fig.15.). The crude fibre content was inversely related to the increased levels of organic manures. The highest value of crude fibre content was recorded by the lowest dose of organic manure combination (50 % of N equivalent). The increased nitrogen level might have resulted in more juice content and succulence of plants which might have resulted in reduced crude fibred content. Similar results of decreased crude fiber content in bhindi due to increased nitrogen levels were reported by (Sekhar and Rajasree, 2009).

The crude protein content was significantly highest in plots receiving the highest level of nutrient (organic manure combination of 100 % N equivalent) and was on par with the RDF. The higher protein content in line with higher nitrogen levels could be attributed to the enhanced absorption of added nitrogen from soil and its direct participation in protein synthesis (Sujan and Ruban, 2007). During decomposition, bulky organic manures produce many organic compounds as well as antibiotic substances as intermediate products. These products on absorption by plants improve the quality of harvested produce (Thampan, 1993). Increase in protein synthesis at higher nitrogen levels was also reported by Singh and Mukherjee (2008).

Increased levels of nitrogen and mulching showed significant interaction in varying the crude fiber content. The lowest crude fibre content was observed in

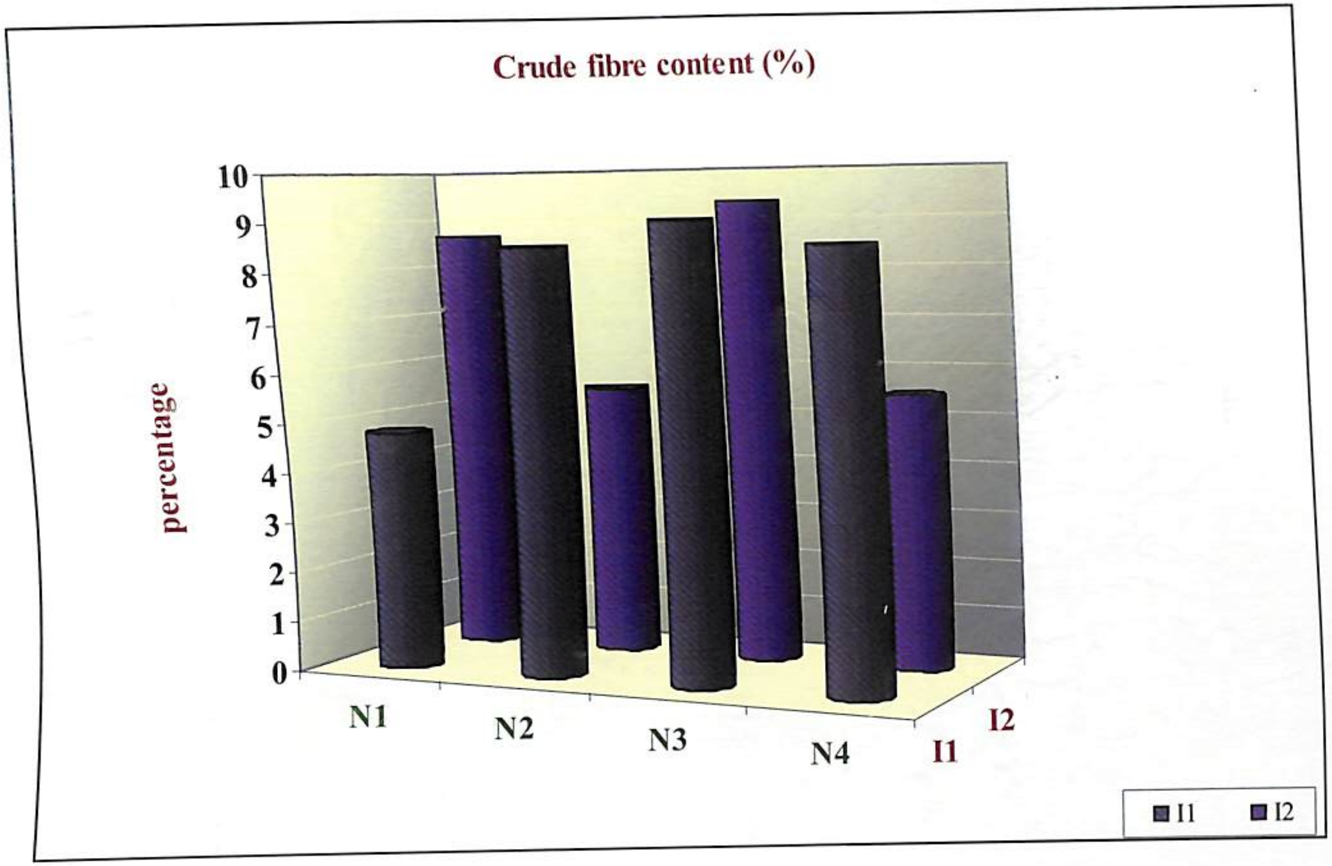


Fig.14. Effect of different nutrient levels and irrigation on crude fibre content of bhindi

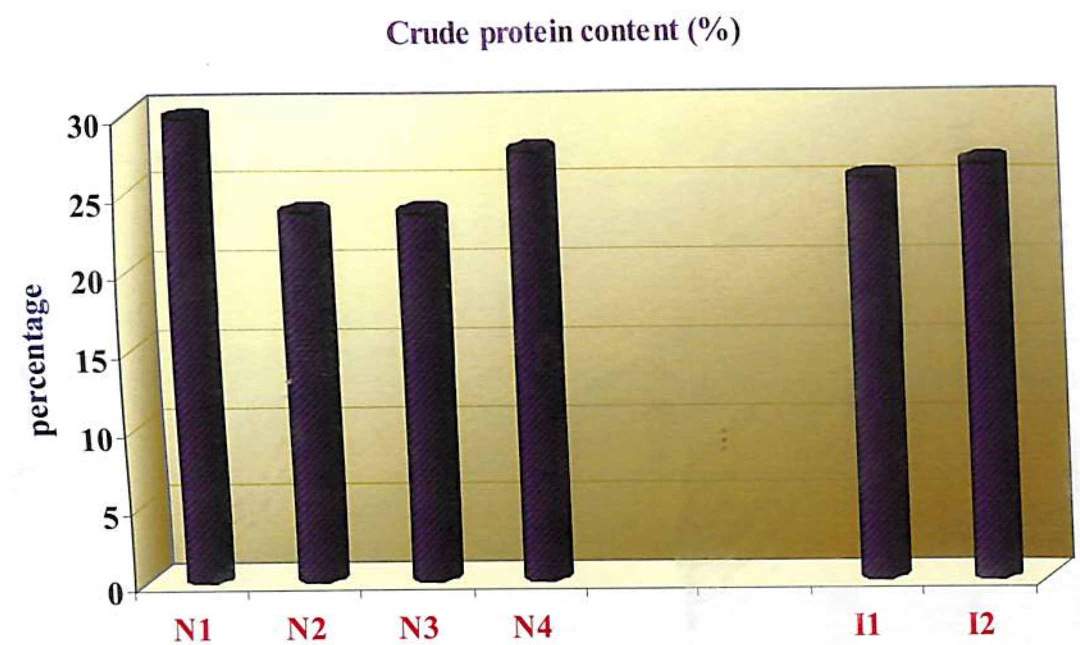


Fig.15.Effect of different nutrient levels and irrigation on crude protein content of bhindi

plants treated with organic manure combination of 100 % N equivalent with rainfed mulched condition.

5.2 EFFECT OF DIFFERENT NUTRIENT LEVELS, IRRIGATION AND THEIR INTERACTION ON NUTRIENT UPTAKE OF BHINDI

Nitrogen, phosphorus and potassium uptake were significantly influenced by different nutrient levels. The highest value of nitrogen and phosphorus uptake was recorded in plants treated with organic manure combination of 100 % N equivalent and was on par with the RDF. An increased uptake of around 16.24 % of nitrogen compared to RDF was recorded by 100 % N equivalent. Compared to RDF, nutrient levels @ 75 % N equivalent and 50 % N equivalent recorded decreased uptake of about 39.23 % and 6.33 % respectively (Fig.16a.). With regard to the uptake of phosphorus an increased uptake of around 3.83 % compared to RDF was recorded by 100 % N equivalent. Compared to RDF, nutrient levels @ 75 % N equivalent and 50 % N equivalent recorded decreased phosphorus uptake of about 13.34 % and 31.35 % respectively (Fig.16b.). Same trend was noticed in the case of potassium also. An increased uptake of around 3.30 % compared to RDF was recorded by 100 % N equivalent. Compared to RDF, nutrient levels @ 75 % N equivalent and 50 % N equivalent recorded decreased phosphorus uptake of about 6.27 % and 1.91 % respectively (Fig.16c.).

The increase in nutrient uptake due to the application of organic manures might be due to the fact that organic manures like FYM when applied to soil results in the breakdown of complex nitrogenous compounds by the action of micro organisms (slow mineralization) and its availability to the soil in the form of nitrate nitrogen (Rajeswari and Shakila, 2009). Increase in available P content of soil due to organic manure application may be due to the solubilization of native P through release of various organic acids (Sharma et al., 2009) which might be the reason for increased uptake. Similar results of increased nutrient uptake due to the application of organic manures were reported by Barani and

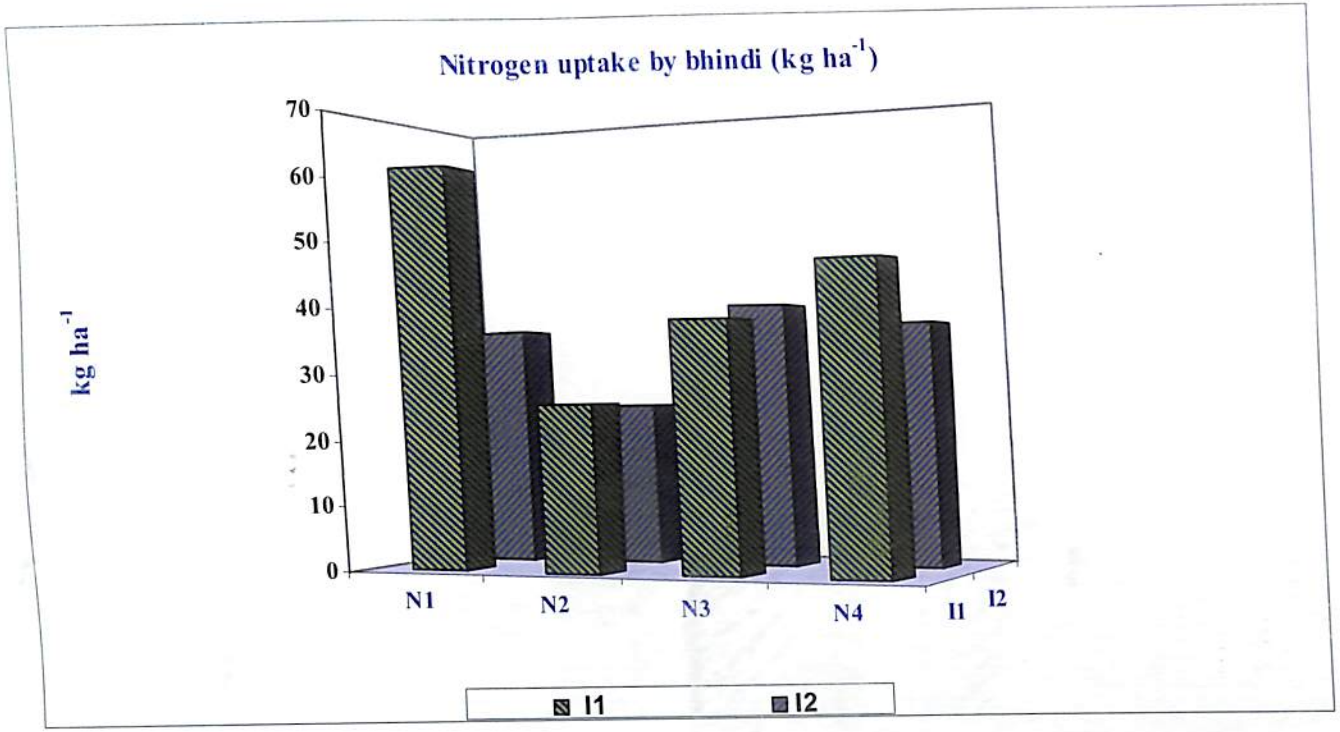


Fig. 16a.Effect of different nutrient levels and irrigation on nitrogen uptake of bhindi

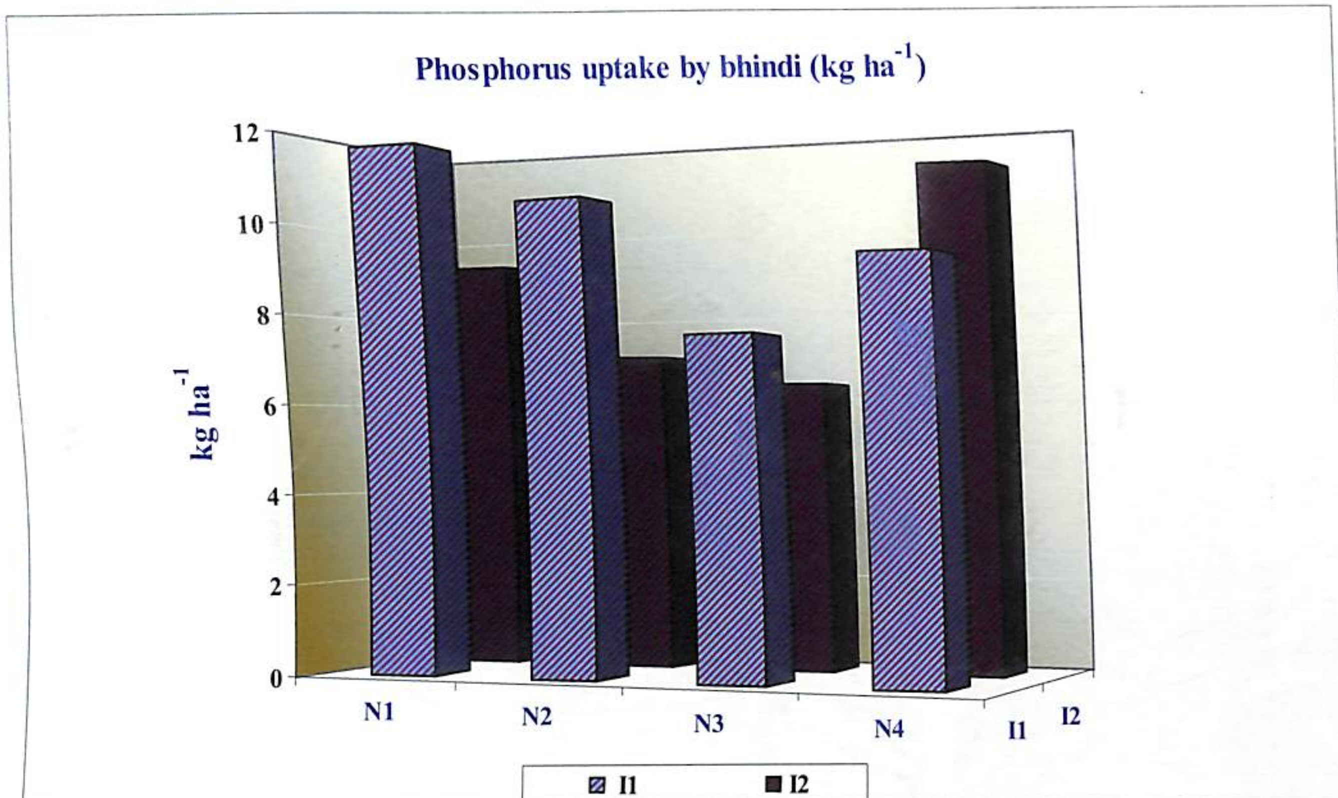


Fig. 16b.Effect of different nutrient levels and irrigation on phosphorus uptake of bhindi

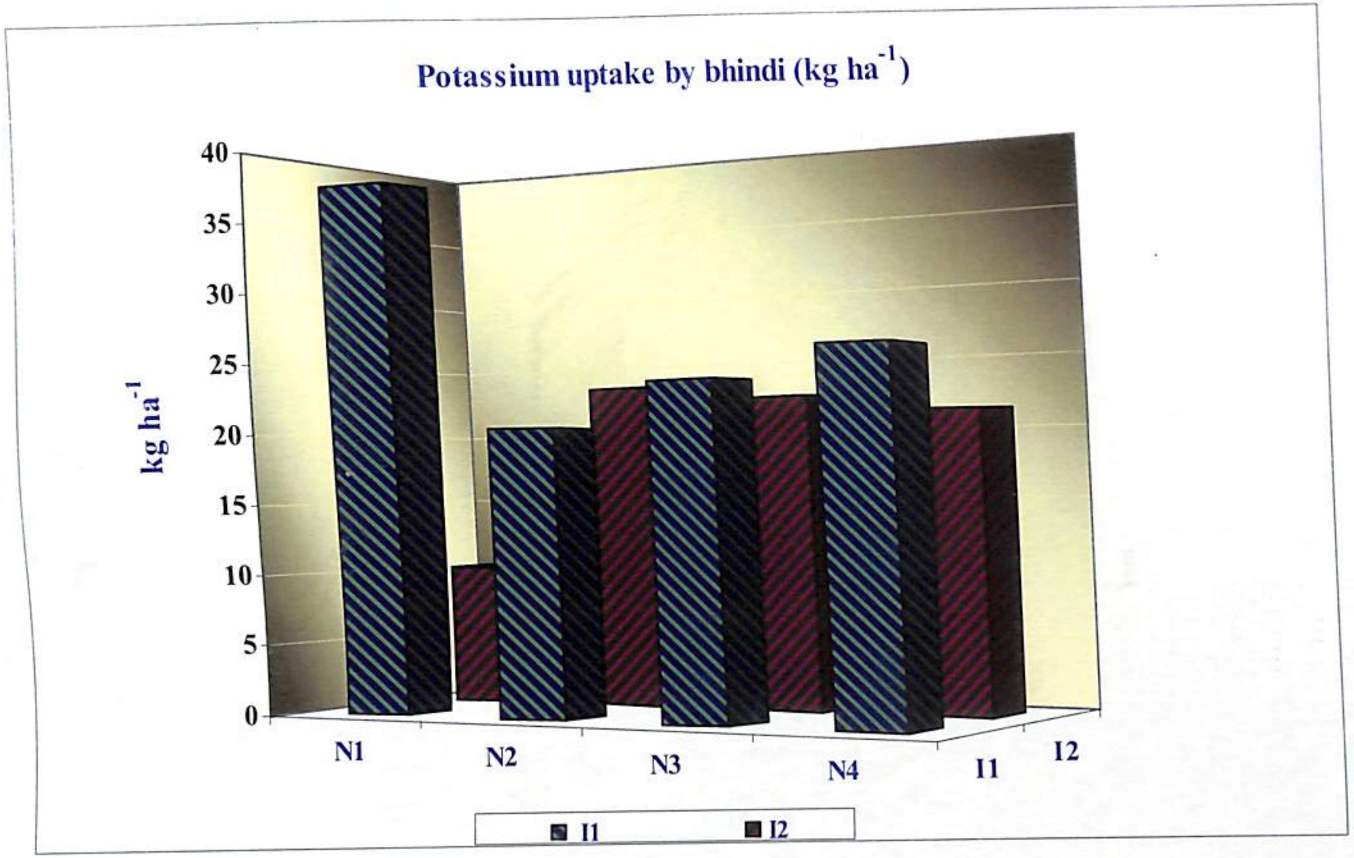


Fig. 16c.Effect of different nutrient levels and irrigation on Potassium uptake of bhindi

Anburani (2004) and Raj (1999). Significant increase in nutrient uptake due to increased levels of FYM and vermicompost in bhindi was also reported by Sharma et al. (2009).

The increase in nutrient uptake viz. N and K was significantly more in rainfed mulched plots compared to that in irrigated unmulched plots. Mulching helps in better soil moisture conservation which greatly influences nutrient transformation and release from organic forms, their uptake by roots and subsequent translocation and utilization by plants (Acharya, 2008). The better microbial activity in mulched plots also might have contributed to better nutrient uptake by the plants. More over the decayed green leaves used for mulching might have added the nutrient supply to the soil in mulched plots.

The interaction between the different levels of nutrients and irrigation significantly influenced the N P K uptake of bhindi. The highest level of organic nutrient combination along with mulched condition resulted in highest uptake values for N, P and K.

5.3 SOIL ANALYSIS AFTER BHINDI

Different levels of nutrients significantly influenced the residual nutrient status of the soil. The maximum value for available nitrogen, phosphorus and potassium was given by organic manure combination of 100 % N equivalent and least value for the organic manure combination of 50 % N equivalent (Fig 17a,17b and17c.). The higher value of available nitrogen for highest level of nutrient organic manure combination might be due to the higher level given to the crop.

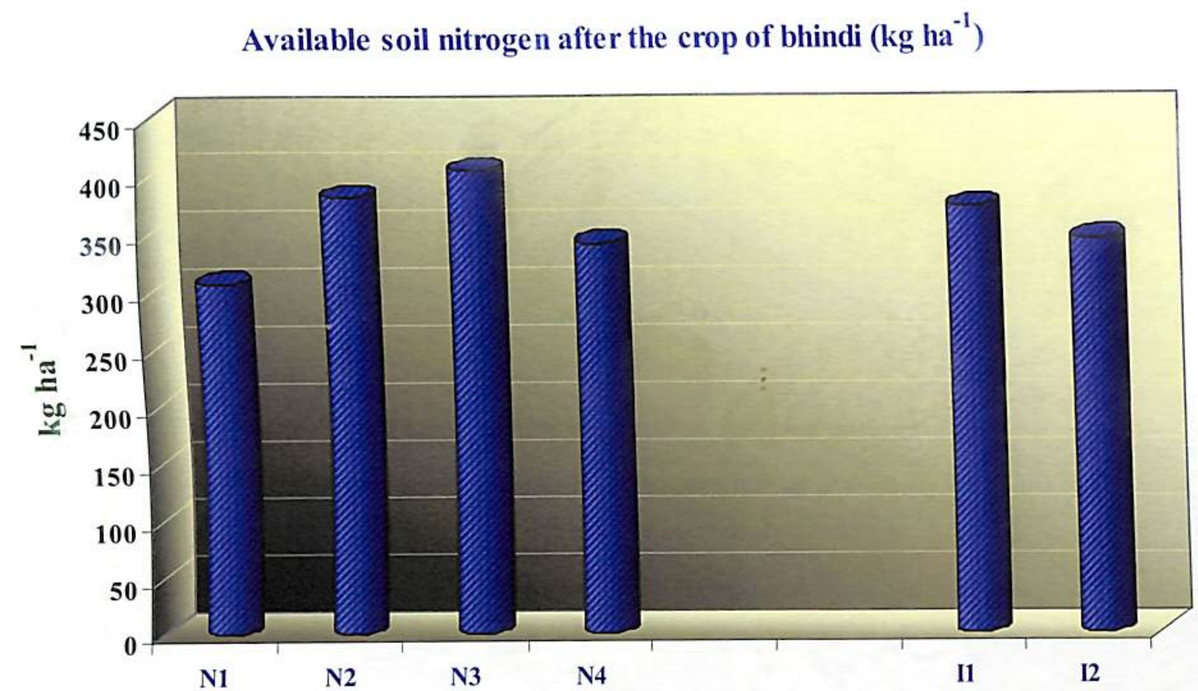


Fig.17a.Effect of different nutrient levels and irrigation on available soil nitrogen after bhindi

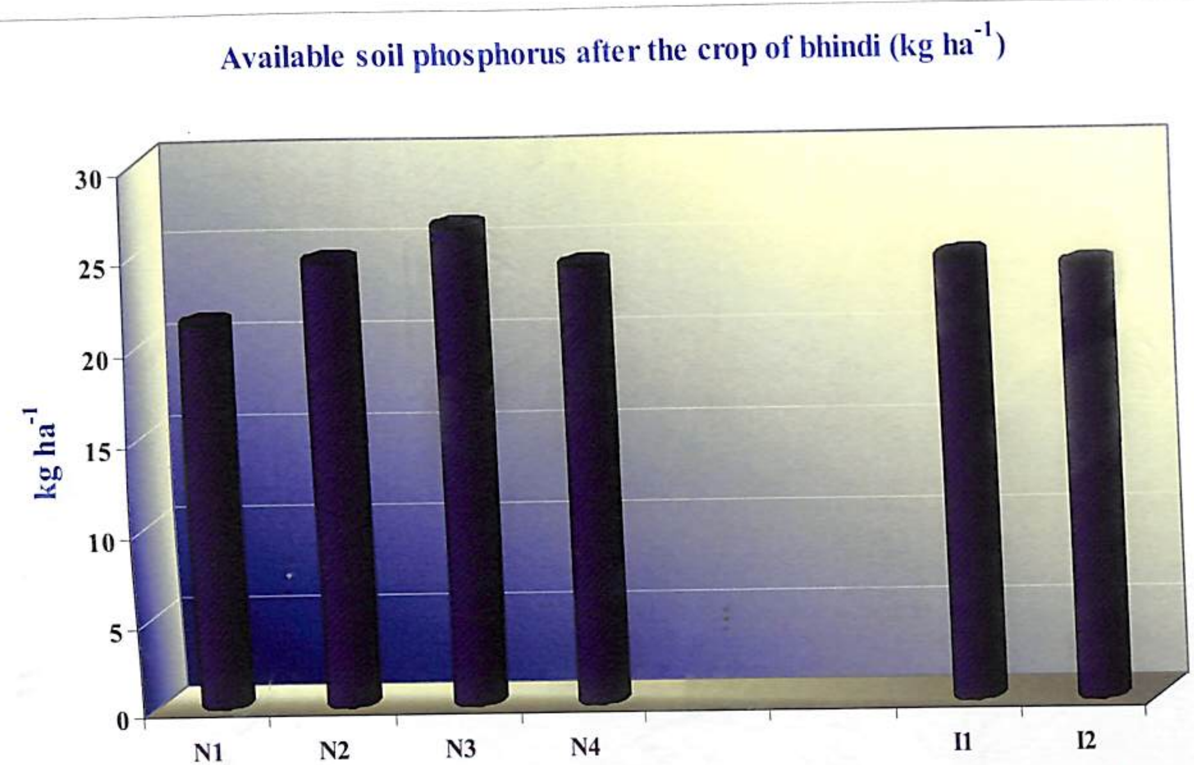


Fig.17b.Effect of different nutrient levels and irrigation on available soil phosphorus after bhindi

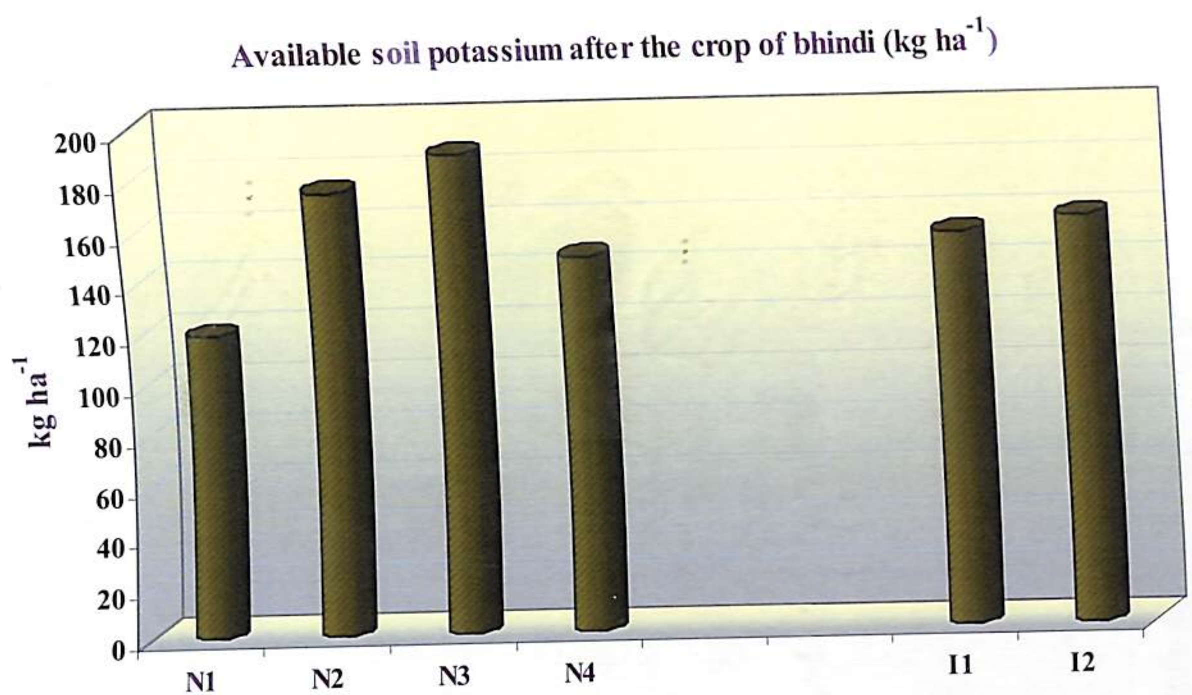


Fig.17c.Effect of differnt nutrient levels and irrigation on available soil potassium after bhindi

5.4 ESTIMATION OF IRRIGATION INTERVAL AND CROP WUE

For those treatments receiving irrigation, irrigation was provided at 50 % depletion of available soil moisture. During cropping period it was observed that during the initial growth period, (almost up to 60 DAS), 50 % depletion of available soil moisture was reached in 3 to 3.5 days. But after that, due to the increased water requirement for enhanced photosynthetic activity and increased evaporation rate (3.6 mm) during the 32^{nd} standard week (Appendix 1), 50 % depletion of available soil moisture was reached earlier i.e. in 2 to 2.5 days.

The irrigated plots required 845 litres of water for the entire crop duration, while the rainfed mulched plots required only 130 litres of water for the entire crop duration; thus saving about 84.62 % of water. During the crop period a total of about 2694 l has been received as rainfall which also has contributed to the water needs of the crop. Water requirement could be reduced in bhindi by mulching. This might be due to reduced evaporation rate from the mulched plots resulting in moisture conservation. Similar results of water saving due to mulching in bhindi were reported by Sunilkumar and Jaikumaran (1998) and Bahadur et al. (2009).

The different nutrient levels significantly influenced the crop WUE (Fig.18.). Organic manure treatment with 100 % N equivalent recorded the highest WUE of 43.36 kg ha^{-1} mm^{-1} which was on par with that of RDF (40.09 kg ha^{-1} mm^{-1}). Water use efficiency increased with increased levels of nitrogen application mainly because of increased yield levels. Similar findings of yield increase due to increased nitrogen application were observed by Acharya and Kapur (2001). Even though not significant, mulched plots showed a better WUE compared to the irrigated plots. This is in conformity with the findings of Sankar et al. (2008) who reported higher WUE in bhindi under water limited conditions. This indicates that, in irrigated plots photosynthesis was increased at the cost of water loss resulting in lower WUE (Bahadur et al. 2009).

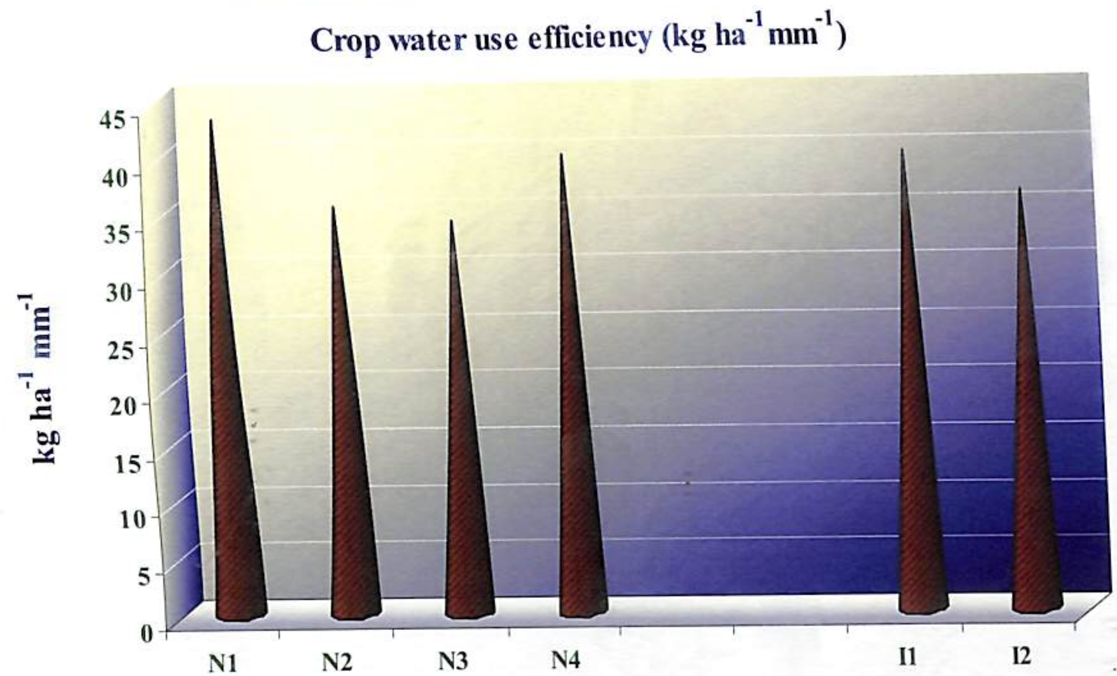


Fig.18.Effect of different nutrient levels and irrigation on crop water use efficiency of bhindi

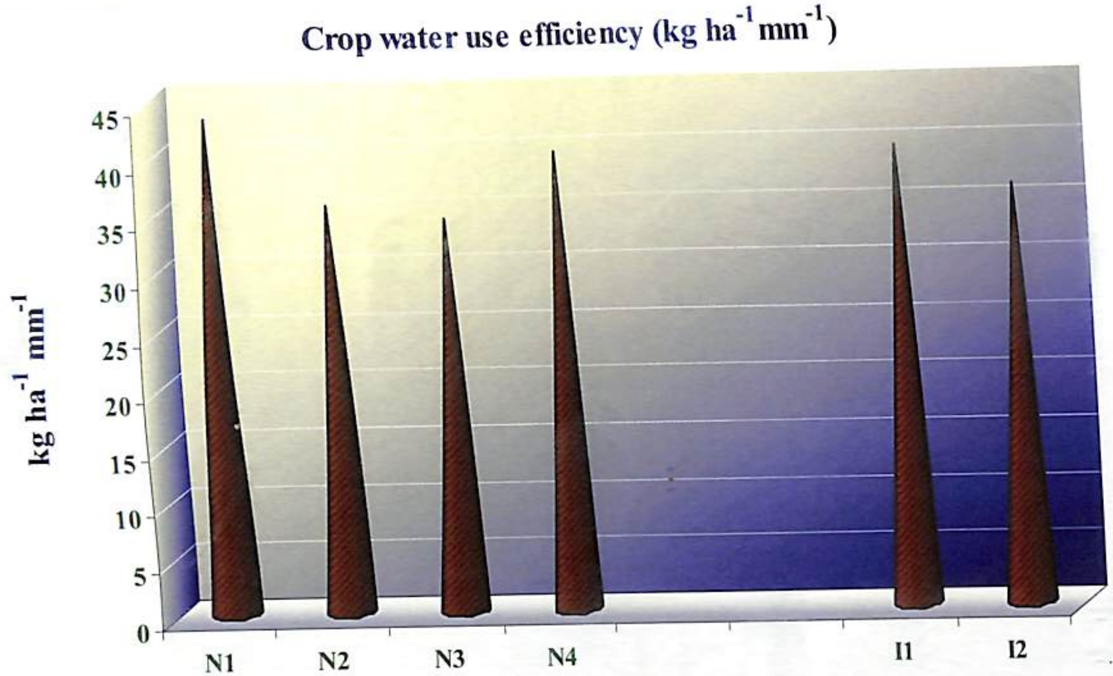


Fig.18.Effect of different nutrient levels and irrigation on crop water use efficiency of bhindi

5.5 EFFECT OF DIFFERENT NUTRIENT LEVELS AND IRRIGATION ON THE INCIDENCE OF FRUIT AND SHOOT BORER OF BHINDI

Though not significant, the incidence was lowest in plots receiving the highest level of organic manuring (100 % of N equivalent). Similar results of reduced pest attack due to organic manure application were reported by Prakash et al. (2000). Availability of micronutrients from organic manures is more than 10 % compared to only 2 to 10 % from inorganic sources (Sahu and Samant, 2006). This helps in balanced nutrition of plants resulting in better resistance to pest and diseases (Mohan et al., 2007). Maximum incidence was observed in plots treated with inorganic form of fertilizers. Similar results were reported by Adilekshmi et al. (2008).

5.6 EFFECT OF ORGANIC NUTRIENT LEVELS AND IRRIGATION ON THE YIELD OF RESIDUE CROP (AMARANTHUS)

In contrast to the chemical fertilizers, the availability of nutrients present in the bulky organic manures such as FYM is quite slow during the current season. In case of FYM, reports reveal that only half nitrogen, one sixth P and a little greater than half of K alone are readily available to plant during the first season of application (Thampan, 1993). Their availability is spread over more than one season. Thus raising a residue crop after the first season would help in better utilization of available nutrients.

The different nutrient levels could significantly influence the yield of subsequent crop – amaranthus (Fig.19.). The highest yield was recorded by the highest dose of nutrient which was significantly superior to all other treatments. This could be attributed to the increased availability of nutrients from organic manures for a longer time resulting in higher yield of residue crop.

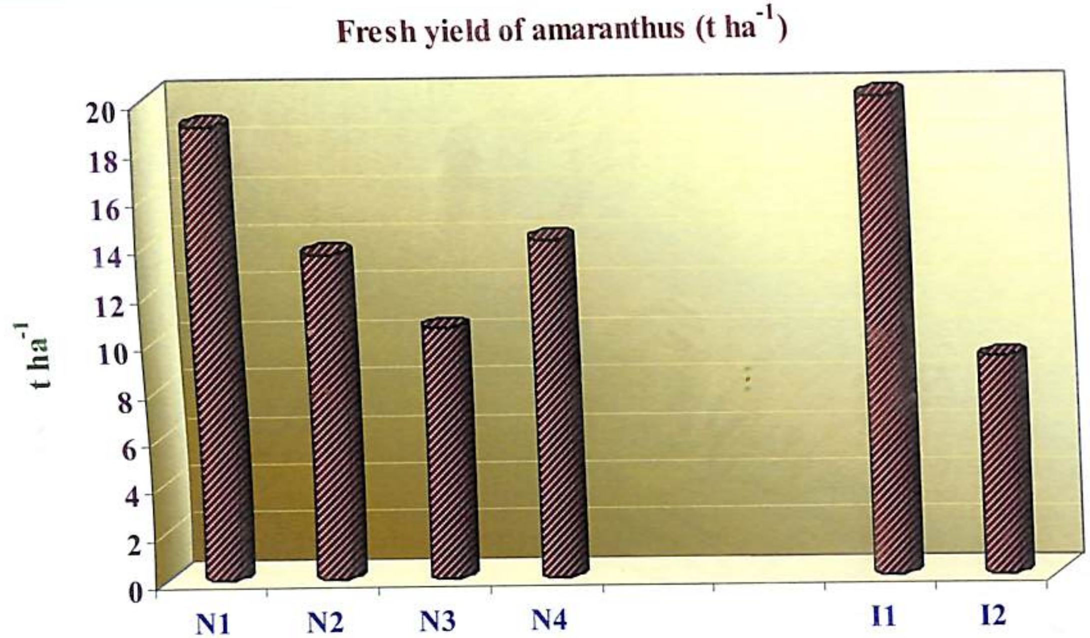


Fig.19. Effect of different nutrient levels and irrigation on fresh yield of amaranthus

Amaranthus yield in rainfed mulched plots was significantly higher due to the extended influence of conserved nutrients due to mulching and the nutrient release during the course of decomposition of mulch material. Similar results of increase in yield of residue crop due to mulching were reported by Sharma et al. (2004).

5.7 EFFECT OF ORGANIC NUTRIENT LEVELS AND IRRIGATION ON AVAILABLE SOIL N P K CONTENT AFTER THE RESIDUE CROP

The different nutrient levels, irrigation and their interaction could not significantly influence the soil available nitrogen, phosphorus and potassium content of soil after the residue crop of amaranthus.

5.7 ECONOMICS OF BHINDI CULTIVATION

The different levels of nutrients and irrigation had significant influence on the B:C ratio of bhindi as well as the cumulative B:C ratio of bhindi – amaranthus sequence with and without considering the high market price for organic produce

While considering the high market price for organic produce, the plots which received highest level of organic manuring (100 % of N equivalent) recorded maximum B:C ratio of 2.03 for bhindi and 3.88 for the sequence. For bhindi highest level of organic manuring (100 % of N equivalent) registered 17.25 % more returns than that of RDF. Organic nutrient levels at 75 % and 50 % of N equivalent recorded increased returns of about 11.91 % and 14.96 % respectively compared to the RDF. For the sequence, highest level of organic manuring (100 % of N equivalent) registered 36.6 % more returns than that of RDF. Organic nutrient levels at 75 % and 50 % of N equivalent recorded increased returns of about 20.39 % and 13.84 % respectively compared to the RDF. The high yield produced by the highest level of organic nutrition resulted in higher B:C ratio for these plots. The high price fetched by the organic bhindi along with high yield

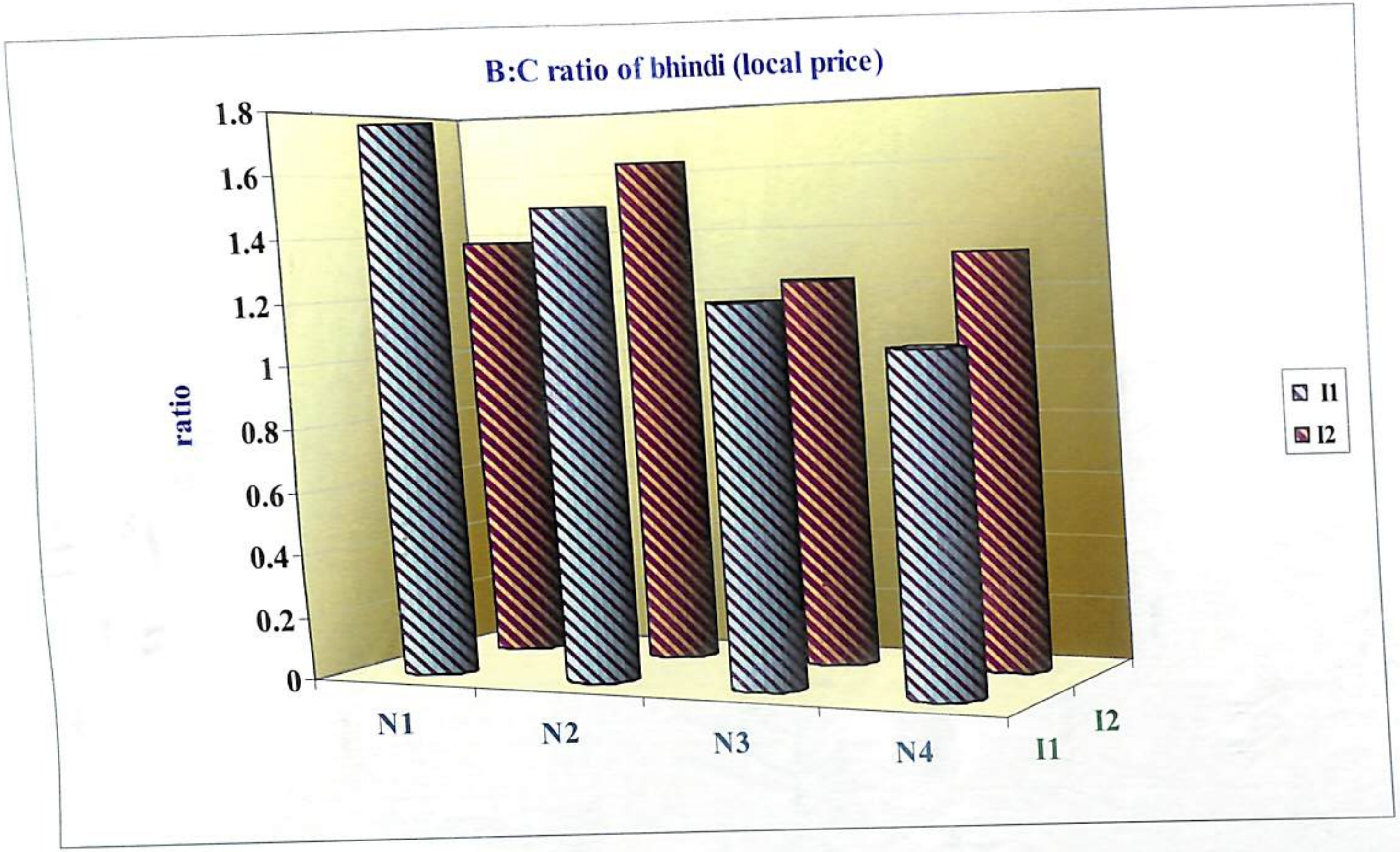


Fig. 20. Effect of different nutrient levels and irrigation on the B:C ratio of bhindi (based on local price)

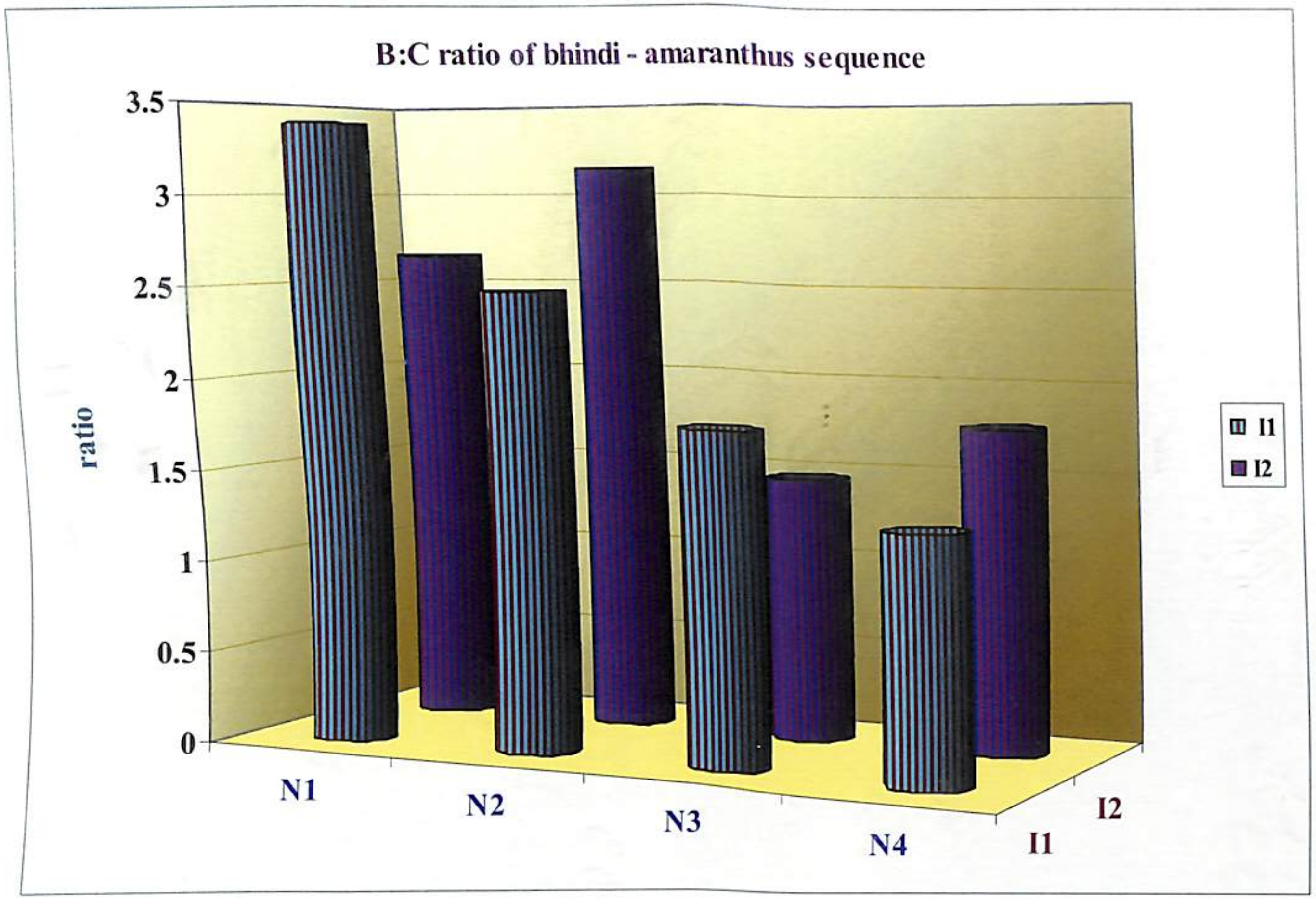


Fig. 21. Effect of different nutrient levels and irrigation on the B:C ratio of bhindi – amaranthus sequence(based on local price)

compared to the RDF resulted in highest B:C ratio. A similar result of increased profit was reported by Raj (1999) in bhindi with organic nutrition.

While considering the local price for organic produce, the plots which received highest level of organic manuring (100 % of N equivalent) and RDF recorded maximum B:C ratio of 1.47 for bhindi. For the sequence, N_1 recorded highest B: C ratio of 2.59 which was on par with RDF. For bhindi, highest level of organic manuring (100 % of N equivalent) and RDF registered 11.6 % more returns than that from 75 % of N equivalent and 14.29 % more returns than that from 50 % of N equivalent. For the sequence, highest level of organic manuring (100 % of N equivalent) registered 5.02 % more returns than that of RDF. Organic nutrient levels at 75 % and 50 % of N equivalent recorded decreased returns of about 20 % and 28 % respectively compared to the RDF. Even though highest yield was produced by the highest level of organic nutrition, the high cost of inputs incurred for the organic cultivation resulted in same B:C ratio as that of RDF.

For both bhindi and bhindi – amaranthus sequence, higher B:C ratio was recorded for mulched rainfed plots with and without considering the high market price of organic produce. Considering the high market price for organic produce mulched rainfed plot recorded 23.72 % more B:C ratio compared to that of irrigated plots in bhindi and 45.6 % for the sequence. Considering the local price for all produce, mulched rainfed plot recorded 28.36 % more B:C ratio compared to that of irrigated plots in bhindi and 45.71 % for the sequence. The higher B:C ratio for rainfed mulched plots may be due to the reduced cost of cultivation for these plots considering the cost incurred for irrigation for irrigated plots.

With and without considering the high market price for organic produce, highest level of organic manuring (100 % of N equivalent) with mulching recorded maximum B:C ratio and this may be due to the highest yield produced along with low cost of cultivation incurred for these plots. The continuous supply

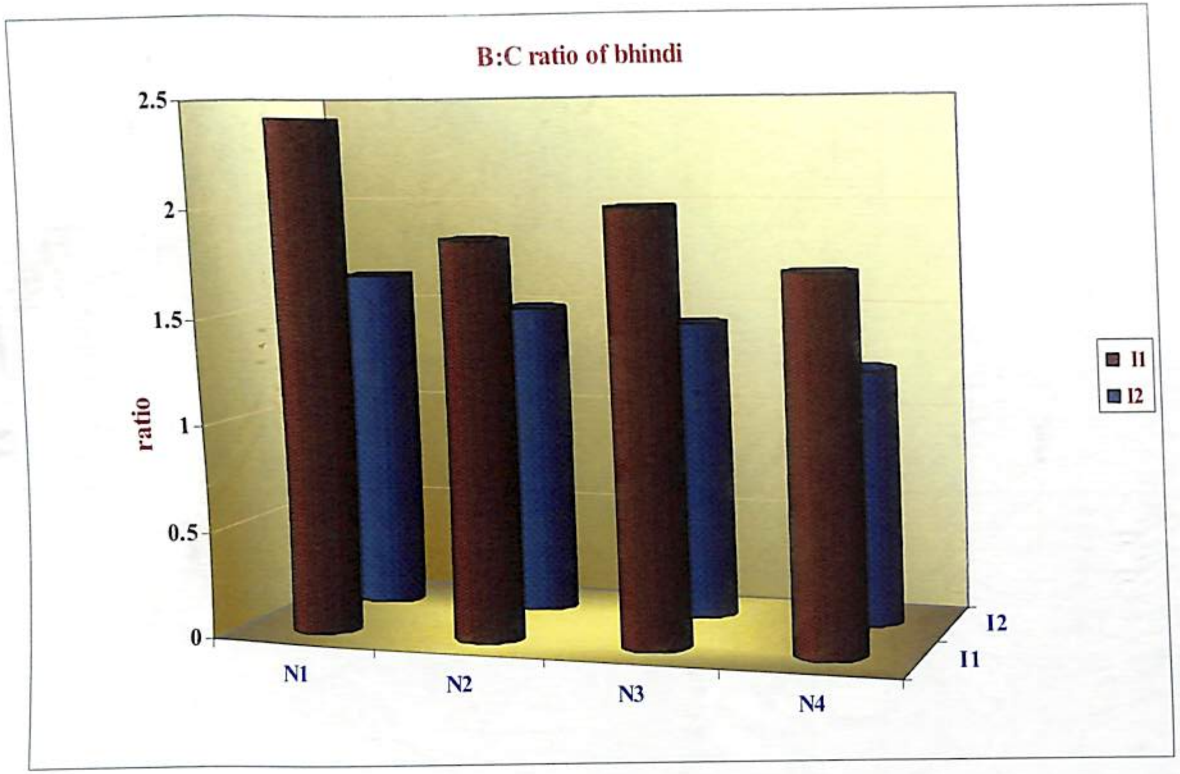


Fig.22. Effect of different nutrient levels and irrigation on the B:C ratio of bhindi (based on market price)

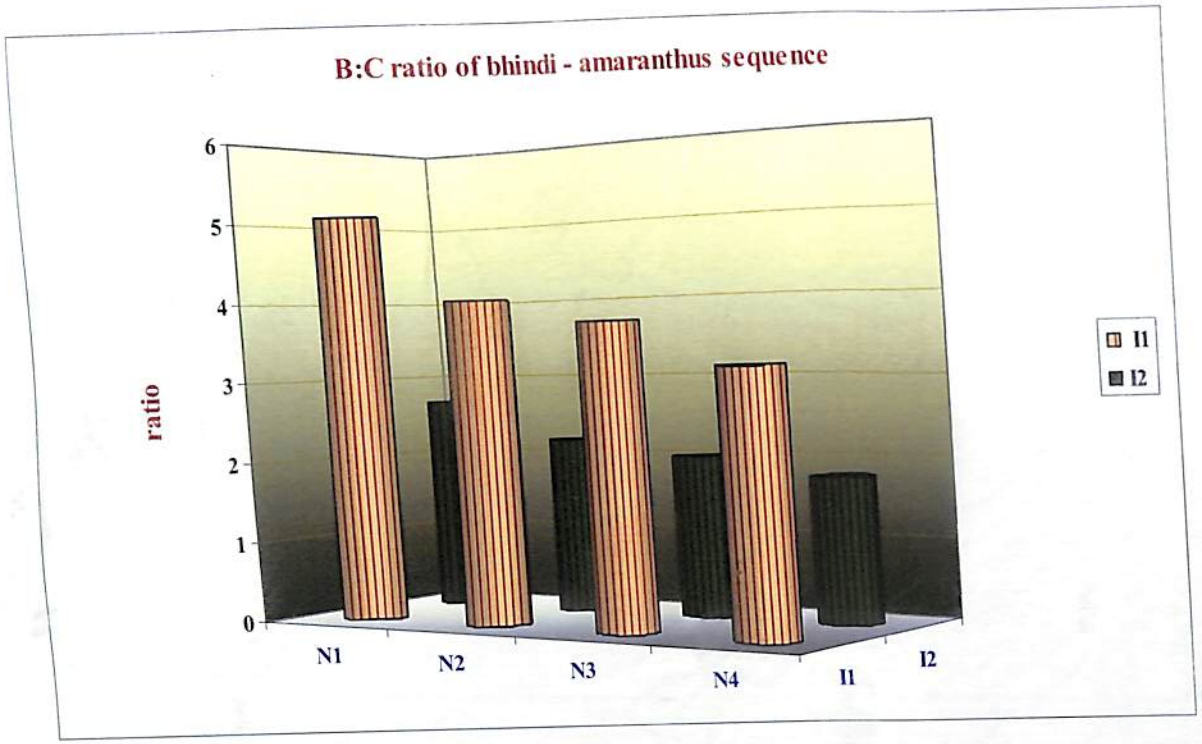


Fig.23. Effect of different nutrient levels and irrigation on the B:C ratio of bhindi – amaranthus sequence (based on market price)

of nutrition for a prolonged period due to organic manuring might have resulted in higher yield in these plots (Thampan, 1993). The higher yield along with high price for the organically produced vegetables has resulted in high B:C ratio.

Summary

6. SUMMARY

An experiment was conducted at College of Agriculture, Vellayani to standardize the organic manuring schedule for bhindi and to assess the effect of different levels of organic manure combination and irrigation on growth, yield and quality of bhindi from June 2009 to November 2009. The findings of the experiment are given below.

Maximum plant height was recorded during later growth stage (90 DAS) by the highest nutrient level, i.e. organic nutrient combination (FYM 50 % + vermicompost 25 % + glyricidia leaf manure 25 %) given at 100 % of nitrogen equivalent -17 t FYM + 2.83 t vermicompost + 1.47 t glyricidia leaves. Plots which were rainfed and mulched recorded taller plants compared to those in irrigated plots.

Number of branches plant^{-1} was highest in plants which received RDF and this was significantly superior to all other treatments. Also, rainfed mulched plots recorded significantly more number of branches plant^{-1} compared to that of irrigated unmulched plots.

During later growth stages (60 and 90 DAS), the plants in the rainfed mulched plots have recorded significantly more number of leaves, better LAI and DMP (at harvest).

Highest number of fruits was recorded by the highest level of organic nutrient combination.

Fruit yield plant^{-1} (285.69 g) and total fruit yield ha^{-1} (10.58 t) were highest for the highest dose of organic nutrient combination which was on par with RDF (276.38 g and 9.82 t ha^{-1} respectively).

The crude protein content was significantly highest in plots receiving the highest level of organic manure combination and was on par with the RDF. The lowest value of crude fibre content was recorded by the highest dose of organic nutrient combination (100 % of N equivalent).

The maximum value for available nitrogen, phosphorus and potassium was given by organic manure combination of 100 %N equivalent and least value for highest level of nutrient organic manure combination 50 % of N equivalent. The increase in nitrogen and potassium uptake was significantly more in rainfed mulched plots compared to that in irrigated unmulched plots.

The irrigated plots required 845 litres of water for the entire crop duration, while the rainfed mulched plots required only 130 litres of water for the entire crop duration as irrigation water; thus saving about 84.62 % of water.

Organic nutrient combination with 100 % nitrogen equivalent recorded the highest WUE of 43.36 kg ha^{-1} mm^{-1} which was on par with the RDF (40.09 kg ha^{-1} mm^{-1}).

The highest yield of amaranthus (residue crop) was recorded by the highest dose of organic nutrient combination which was significantly superior to all other treatments. Also, the rainfed mulched plots recorded a significantly higher yield compared to that of irrigated unmulched plots.

The highest B:C ratio was recorded by the highest dose of organic manure both in the case of bhindi as well as for the sequence. The highest nutrient level (100 % N equivalent -17 t ha^{-1} FYM + 2.83 t ha^{-1} vermicompost + 1.47 t ha^{-1} glyricidia leaves) along with mulched condition resulted in the highest net income of Rs. 3, 40,001 for the cropping sequence when local price was assumed for the produce (bhindi - Rs 20 kg $^{-1}$ and amaranthus - Rs. 10 kg $^{-1}$) and when high market price was assumed for the organic produce (bhindi - Rs 30 kg $^{-1}$ and amaranthus - Rs. 15 kg $^{-1}$), a net income of Rs. 5, 81,301 could be obtained.

When bhindi (var. Varsha Uphar) with 110 days duration was cultivated at a spacing of 60 x 45 cm during Kharif season (June to October, 2009), in the red loam soils of Vellayani, Kerala, the organic nutrient combination (17 t ha^{-1} FYM + 2.83 t ha^{-1} vermicompost + 1.47 t ha^{-1} glyricidia leaves) gave the highest fruit yield plant^{-1} (285.71 g) and total fruit yield (10.58 t ha^{-1}). When amaranthus (var. Arun) was raised after bhindi as a residue crop, the plots with the same dose of nutrient combination also recorded the maximum fresh yield of amaranthus (18.92 t ha^{-1}) when harvested at 45 DAS. Along with mulching the same nutrient dose of 17 t ha^{-1} FYM + 2.83 t ha^{-1} vermicompost + 1.47 t ha^{-1} glyricidia leaves resulted in highest B:C ratio for bhindi as well as for bhindi – amaranthus sequence.

Future Line of Work:

Organic production protocol for other export oriented summer season vegetables along with mulching and irrigation needs further investigation. Mineralisation studies on different organic nutrient sources has to be carried out to assess the exact period of availability of nutrients from organic manures so that the time of application of these manures could be standardized.

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PRODUCTION PROTOCOL FOR ORGANIC BHINDI

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ABSTRACT

An experiment was conducted at College of Agriculture, Vellayani to standardize the nutrient schedule for organic bhindi from June 2009 to November 2009. The experiment was laid out in factorial RBD with three replications. The treatments consist of graded levels of nitrogen supplied in the form of organic manure combination and one control (RDF), and irrigation (rainfed with green leaf mulching and need based irrigation). The objectives of the study were to standardize the organic manuring schedule for bhindi and to assess the effect of different levels of organic manure combination and irrigation on growth, yield and quality of bhindi. It was intended to work out the economics of bhindi and bhindi – amaranthus sequence and also to study the residual effect of the different levels of organic manures.

The highest level of organic nutrient combination (100 % of nitrogen equivalent - 17 t FYM + 2.83 t vermicompost + 1.47 t glyricidia leaves ha^{-1}) recorded maximum plant height (90 DAS), highest number of fruits plant $^{-1}$, highest fruit yield plant $^{-1}$, highest total fruit yield ha^{-1}, highest crop WUE of 43.36 kg $ha^{-1}mm^{-1}$ and highest yield of amaranthus (residue crop) compared to the lower levels of organic nutrition. Maximum number of branches was recorded by the RDF. Quality attributes like crude protein content was significantly highest and crude fibre content was lowest in plots receiving the highest nutrient level. Nutrient uptake (N and P) was also significantly more in plots receiving highest level of organic nutrition. The highest B:C ratio for bhindi as well as bhindi – amaranthus sequence was recorded by the highest dose of organic nutrient combination.

Plants which were rainfed and mulched recorded significantly more number of branches, leaves, better LAI (60 and 90 DAS) and DMP (at harvest). The rainfed plots also recorded a significantly better fruit setting %, higher fruit yield $plant^{-1}$ and higher yield of residue crop compared to that of irrigated plots.

Compared to the irrigated plots which required 845 l of water for the entire crop duration, the rainfed mulched plots required only 130 l of water as irrigation water for the entire crop duration, thus saving about 84.62 % of water. Uptake of N and K was more in rainfed mulched plots compared to that of irrigated plots. B:C ratio of bhindi and bhindi – amaranthus was also significantly influenced by irrigation.

Organic nutrient combination at 50 % of nitrogen equivalent with rainfed mulched plots recorded highest LAI at 60 DAS. Organic nutrient combination at 100 % of nitrogen equivalent with rainfed mulched plots recorded highest number of fruits plant^{-1}, lowest crude fibre content, highest N P K uptake and B:C ratio of bhindi and bhindi – amaranthus sequence.

Appendix

Appendix 1

Weather data for the cropping period
(15th June – 15th November, 2009) – Weekly averages

Standard Week	Temperature (° C)		Relative humidity (%)	Rain fall (mm)	Evaporation (mm)
	Max. temp	Min. temp			
23	31.6	24.5	86.5	16.8	3.4
24	30.4	23.7	86.0	74.8	2.3
25	30.0	23.9	85.4	36.4	2.5
26	29.0	23.9	87.1	44.2	2.5
27	30.4	24.1	87.0	40.6	2.7
28	30.2	23.4	87.9	83.8	3.0
29	30.8	24.4	86.4	5.4	3.2
30	30.4	24.5	88.2	13.9	2.9
31	30.6	24.5	84.8	7.6	3.3
32	30.4	23.7	84.9	7.8	3.6
33	29.7	23.9	81.6	41.2	3.3
34	29.7	24.2	86.3	43.6	3.3
35	29.2	23.9	87.9	67.0	2.9
36	30.3	24.5	85.7	0.0	3.5
37	29.5	24.0	89.3	6.0	3.4
38	29.8	24.3	88.3	10.6	3.3
39	29.6	24.3	87.6	70.8	3.2
40	29.9	24.4	88.6	0.0	3.5
41	30.3	24.1	88.9	22.1	3.5
42	31.2	23.9	85.7	0.0	3.7
43	25.7	26.6	85.1	20.1	3.3
44	29.3	23.5	86.3	285.8	2.7
45	30.8	23.9	85.4	130.6	2.9
46	29.2	23.5	87.8	50.9	2.9