EFFECT OF IRRIGATION SYSTEMS AND INTEGRATED NUTRIENT MANAGEMENT ON GROWTH, YIELD AND QUALITY OF GINGER (*Zingiber officinale* Rosc.)

By

SONAWANE DATTATRAYA ARJUN
(Reg. No. 04 / 03)

A Thesis Submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI-413722
DIST. AHMEDNAGAR, MAHARASHTRA, INDIA
in partial fulfillment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY (AGRICULTURE)

in

AGRONOMY

DEPARTMENT OF AGRONOMY,
POST GRADUATE INSTITUTE,

MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI-413722
DIST. AHMEDNAGAR, MAHARASHTRA, INDIA
2009

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DOCTOR OF PHILOSOPHY (AGRICULTURE)

in

AGRONOMY

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2009

CANDIDATE'S DECLARATION

I hereby declare that the thesis or part
there of has not been submitted
by me or any other person
to any other University
or Institute for
a Degree or
Diploma

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Place : M.P.K.V, Rahuri
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ABBREVATIONS

/	per
%	Per cent
@	At the rate of
^{o}C	Degree Celsius
cm	Centimeter (s)
CPE	Cumulative Pan Evaporation
cv	Cultivar
DAP	Days after planting
DASM	Depletion of available soil moisture
dm	decimeter
dsm^{-1}	Deci Siemen
EC	Electric conductivity
et al.	*et alli* (And others)
etc	et cetra (and so on)
Even	Evening
FC	Field Capacity
Fig	Figure
g	gram
ha	Hectare
i.e.	id est (that is)
IW	Irrigation Water
K	Potassium
K_2O	Potassium oxide
kg	kilogram
Km	Kilometer
Kpa	Kilo Pascal
LAI	Leaf Area Index
LER	Land Equivalent Rtio
m	meter
max.	Maximum
Mg	Mega gram
min.	Minimum
mm	millimeter
Morn	Morning
MW	Meteorological week
N	Nitrogen
No.	Number
P	Phosphorus
P_2O_5	Phosphorus pentaoxide
ppm	Parts per million
RH	Relative humidity
Rs	Rupees
SE $\pm$	Standard Error
Sig	Significant
t	Tonne(s)
temp	Temperature
Viz.	*Vide licet* (Namely)
WUE	Water Use Efficiency

ABSTRACT

"Effect of irrigation systems and integrated nutrient management on growth, yield and quality of ginger (*Zingiber officinale* Rosc.)"

by

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A candidate for the degree
of
DOCTOR OF PHILOSOPHY
2009

Research Guide	:	Dr. A. S. Jadhav
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The agronomic investigation entitled, "Effect of irrigation systems and integrated nutrient management on growth, yield and quality of ginger (*Zingiber officinale* Rosc.)" was undertaken during 2005-06 and 2006-07 on sandy clay loam soil at Instructional farm of Inter Faculty Department of Irrigation Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.). The experiment was laid out in strip plot design with three replications and twenty treatment combinations comprising of four irrigation systems viz., surface, drip, floppy sprinkler and overhead sprinkler and five integrated nutrient management practices

Abstract Contd…….

viz., 100 % RDN through organic source, 75 % RDN through organic source + 25 % RDN through inorganic fertilizer, 50 % RDN through organic source + 50 % RDN through inorganic fertilizer, 25 % RDN through organic sources + 75 % RDN through inorganic fertilizer and 100 % general recommended dose of fertilizer.

The important growth and yield attributes viz., plant height, number of tillers, number of leaves, leaf area, dry straw, dry rhizome, total dry matter per plant and green ginger yield per plant were significantly higher under floppy sprinkler system than other irrigation systems. The application of irrigation through overhead sprinkler was found second best irrigation system than surface and drip irrigation systems for all growth and yield attributes. The application of irrigation through surface throughout crop growth period recorded significantly the lowest values of these attributes.

The fresh rhizome yield, dry straw, dry rhizome and total dry matter yield (t ha^{-1}) were significantly more under floppy sprinkler system than other irrigation systems. The application of irrigation through overhead sprinkler also recorded significantly more fresh and dry rhizome and dry straw and total matter yields than surface irrigation system.

All quality parameters viz., pH, volatile oil, crude fat,

Abstract Contd…….

oleoresin, crude fibre, starch and ash percentage were not differed significantly under all irrigation systems but were numerically more under floppy sprinkler than other irrigation systems.

The gross and net monetary returns and B : C ratio were significantly more under floppy sprinkler than other irrigation systems. Further, the application of irrigation through overhead sprinkler also recorded higher gross and net monetary returns and B : C ratio than surface irrigation system.

Water use efficiency of ginger was the highest and amount of water required for production of one tonne of ginger was the lowest when irrigation was scheduled with drip irrigation system.

The N, P and K content in plant was significantly more and its uptake was significantly higher when irrigation was scheduled under floppy sprinkler system. Nutrient uptake was significantly the lowest under surface irrigation system. The N, P and K nutrient status in soil was recorded more under drip irrigation system than other irrigation systems.

The application of 100 per cent general recommended dose of fertilizer recorded significantly more values of growth attributes and yield contributing characters than all other

Abstract Contd.....

integrated nutrient management practices. Significantly lowest values of these characters were recorded under the application of 100 per cent RDN through organic sources. The application of 100 per cent general recommended dose of fertilizer (75:50:50 N, P_2O_5 and K_2O + 25 t FYM ha^{-1}) produced significantly more fresh and dry rhizome yields, dry straw and total dry matter yields than other integrated nutrient management practices during both the years and in pooled data. The gross and net monetary returns and B : C ratio and water use efficiency and nutrient uptake were also significantly more under application of 100 per cent general recommended dose of fertilizer than other integrated nutrient management practices.

The maximum water use efficiency and minimum water required for production of one tonne of rhizome was with application of 100 per cent general recommended dose of fertilizer.

The quality parameters viz., pH, volatile oil, crude fat, oleoresin, crude fibre, starch and ash content values were significantly higher under the application of 100 per cent RDN through organic sources and was significantly the lowest under 100 per cent general recommended dose of fertilizer.

Abstract Contd.....

The application of 100 per cent general recommended dose of fertilizer recorded significantly more nutrient concentration in plant and uptake of these nutrients and less available nitrogen, phosphorus and potassium in soil at harvest than other integrated nutrient management practices. The application of 100 per cent RDN through organic source recorded significantly higher available N, P and K status in soil after harvest of ginger.

The fresh and dry ginger yields and dry straw and total dry matter yields were significantly more with combination of floppy sprinkler irrigation system and 100 per cent general recommended dose of fertilizer application indicating that ginger crop be irrigated with floppy sprinkler and fertilized with general recommended dose for higher production.

(Pages 1 to 279)

INTRODUCTION

Ginger (*Zingiber officinale* Rosc.) is mainly grown in tropics. It is a perennial type of crop. It belongs to the Zingiberaceae family. The rhizomes of ginger are elongated creeping, multibranched, irregular, fleshy and pungent. Its rhizome is prized for its healing properties since antiquity. It is one of the important spice crop grown all over the world and cultivated for its under ground rhizome which are estimated for its flavour, aroma and pungency. The pungency of ginger is due to gingerol while aroma is due to volatile oil such as lisabolene, zingiberene and zingibero.

The highest area under ginger cultivation is in Nigeria, which is 55 per cent of the total area under cultivation in the world. India crowning as the worlds leader in spices industry and contributing 36 per cent of the total worlds production. Production of 2.8 lakh tonnes of ginger during 2001 in India was the recorded production of ginger in the world followed by China 1.6 lakh tonnes (Vadivel *et al.* 2006). Jamaika and India produce the best quality ginger because of favourable climatic conditions. However, the productivity of ginger in India sums to be less as compared to other countries like USA (52 t ha^{-1}) and Figi Island (38.46 t ha^{-1}). The estimated import of ginger was around 35000 tonnes in different countries of the worlds which valued as US $ 30 million. India and China are major supplier of ginger to the different countries in the world. India exports ginger in dry, fresh, powder, oil and oleoresin form.

In India, 70% of the total ginger production is confined to Kerala. Andhara Pradesh, Kerala, Meghalaya, Mizoram and Orisa states together contribute over 55.63 per cent of total production. Exportable varieties of ginger mainly Calicut and Cochin are grown in Kerala.

The area under ginger in Maharashtra was 3360 ha with an annual production of 33600 tonnes with a productivity of 10 tonnes/ha during the year 2000-2001. Satara district is the largest producer of ginger in the state of Maharashtra. The largest area under ginger to the tune of 2640 ha with a production of 60,700 tonnes was recorded in Satara district of Maharashtra (Anonymous, 2007).

Importance of ginger for health is known from Vedic time and is truly a world domestic remedy. According to the ayurvedic medical system, ginger is considered to be carminative, stimulant and given in dyspensia and flatulent colic. Consumption of ginger improves voice, digestion, removes toxins from body, improves vitality and strengthen the heart. Fresh ginger juice mixed with sugar candy consumed twice a day is good for diabetic patients. A brilliant finding is that ginger reduces cholesterol concentration in a cholesterol rich diet (James Verghese, 2002). Studies by Japanese researchers indicate that ginger has a tonic effect on the heart and much lower blood pressure by restricting blood flow in peripheral area of the body. It is used to treat coi-linduced diseases, nausea, asthma, cough, heart palpitation

and syperia. Latest research finding in United States show that ginger prevent the formation of major tumour such as intestinal and prostate cancer. Ginger compounds are also effective in treating colorectal cancer. Ginger is valued the world over as a culinary, condiment, spice, home remedy and medicinal agent. It is likely that ginger will be enjoyed and valued for the next millennium and new research will undoubtedly reveal new value for this ancient herb.

In general, ginger contains appreciable quantities of proteins (2-3%), fats (0.9%), minerals (1.2 %), carbohydrates (12.3 %), fibre (2.4%) and is good source of calcium, phosphorus, iron and vitamins (Vadivel *et al.*, 2006). The volatile oils, oleoresin, proteoletic enzyme, vitamin B – 6, vitamin – C and linoleic acid are the important constituents of ginger.

Among the several inputs, water is one of the crucial factor for crop production. Its economic and efficient utilization becomes quite imperative. Various technologies have been adopted for its higher use efficiency. In recent years, greater importance has been focussed to increase the efficiency of irrigation water. In ginger, flood method of irrigation is common which is widely practiced in India that results into inefficient use of irrigation water due to different losses viz., losses in deep percolation, seepage and evaporation. Among the various inputs applied to ginger, irrigation water is crucial one. Shortage of irrigation water at

critical stages of crop reduces yield significantly. Appropriate use of irrigation system with higher water use efficiency further elevates productivity. Micro-irrigation ensures higher water use efficiency. Several research workers reported that through micro-irrigation, higher crop yields can be obtained along with considerable saving in irrigation water (Sezen *et al.*, 2006 and Kumar *et al.*, 2007).

The advanced micro-irrigation methods introduced recently such as drip, micro-sprinkler, overhead sprinkler and irrigation through subsurface porous pipe help to increase water use efficiency significantly, besides increasing productivity of crops. Irrigation efficiency of micro-irrigation is more than 90 per cent. These are the methods of watering the plant frequently with the required quantity at low rate to meet daily evapotranspiration need of the plant. The result of experiment showed that water saving from drip varies from 12 to 84 per cent (Narayanmoorty, 2004). Micro-irrigation systems are proved beneficial for fruit, vegetables as well as agronomical crop.

Ginger is an important spice crop of Maharashtra state and is also grown successfully in areas of less rainfall. Yield of ginger is quiet high where adequate attention is given to the better water management of crop. The crop is planted in the month of April – May, a period of summer season under rainfed as well as irrigated condition in different locations of India. During this period, demand for irrigation water is high

but the availability is less. Micro-irrigation, a new approach for irrigation water management, has to play a most significant role to bring more area under irrigation with available water thereby increasing the productivity and water use efficiency (Nalayini *et al*, 2006). It is high frequency irrigation methods of supplying water efficiently to the plant root zone. This is the latest and most efficient method of irrigation which is becoming popular in areas of water scarcity. Adoption of micro-irrigation may help in increasing the area under irrigation, productivity of crops and water use efficiency (Srivanappan, 2004). At present, in our country, the micro-irrigation is practiced for horticultural crops and there is more scope for spice crops in terms of enhancing the crop and water productivity.

Ginger is a fertility exhausting crop and requires heavy manuring. Kannan and Nair (1965) have recommended that ginger crop can be applied 25 to 30 tonnes of FYM, 60-120 kg N, 60-100 kg P_2O_5 and 80-120 kg K_2O ha^{-1}. Vaidya *et al.* (1972) have recommended the dose of 25 to 30 t FYM ha^{-1} before planting and 75 kg N + 30 kg P_2O_5 + 30 kg K_2O ha^{-1} through fertilizers for Maharashtra.

The research report thus indicates that the heavy dose of FYM is being applied to ginger crop. In Maharashtra, the cultivators from the ginger growing area apply still heavy dose of FYM, to the extent of about 40 – 50 t ha^{-1}. Now a days FYM is not abundantly available due to reduction in live stock

population. It is also being costly commodity. Hence, it is necessary to explore the possibility of substituting partly the dose of FYM by chemical fertilizers for obtaining higher yield and quality of ginger.

Nutritional requirement of ginger, when partially met through organic and inorganic sources may enhance the growth and get early boost due to the readily available nutrients through chemical fertilizer. The organic source will help to maintain soil equilibrium whereas, the readily available fertilizer nutrients particularly nitrogen will give a quick start to the crop and finally results in better growth, development and yield of ginger. Majumdar *et al.* (2003) observed that N and FYM interaction was significant for yield of ginger, mineral uptake, oleoresin and residual nutrient build up in the soil.

The indiscriminate use of high analysis chemical fertilizer also resulted in the deficiency of nutrients other than applied and caused decline in organic carbon in soil (Singh *et al.* 2001). It is now considered that restricted use of chemical fertilizer and inclusion of organic material in soil fertility management could be the alternative proposition to over use of agrochemicals (Palaniappan and Annadurai, 1999). Hence the challenge is to combine organic manures of different quality with chemical fertilizer to optimize nutrient availability to crop plant for optimum growth, yield and quality of crop in specific agro-ecological zones.

However, it is observed that the research work on irrigation systems and integrated nutrient management of ginger is very meagre in India in general and Maharashtra in particular. In view of this, it was proposed to conduct an experiment on effect of irrigation systems and integrated nutrient management on growth, yield and quality of ginger during 2005-06 and 2006-07 with the following objectives:

1. To study the effect of different irrigation systems on growth, yield and quality of ginger and suggest suitable irrigation system for high productivity.
2. To study the effect of integrated nutrient management on growth, yield and quality of ginger.
3. To study the interaction effect between irrigation systems and integrated nutrient management on growth, yield and quality of ginger.
4. To find out seasonal water requirement of ginger.
5. To study the economics of ginger production.
6. To study the uptake of nutrients and nutrient balance by ginger.

2. REVIEW OF LITERATURE

Water and nutrients are most crucial inputs in ginger cultivation and its availability in appropriate time and quantity has become major element in achieving sustainable production. There is acute shortage of irrigation water especially during summer season, resulting in decrease of initial growth of ginger ultimately which affects the further growth, development and yield. Against this background, it is imperative to use available water most judiciously and scientifically so as to increase the land and water use efficiency. In this context, the agronomic management practices to avoid moisture stress period would be of prime importance. Integrated nutrient management practices for ginger were observed to be acceptable by the farmers to improve rhizome yield and quality. Addition of organic manures not only improves the soil moisture content and yield but also helps in increasing in situ saturated hydraulic conductivity, organic carbon content and decrease surface bulk density and electric conductivity. The available relevant literatures on irrigation systems and integrated nutrient management on ginger and other related crops wherever the literature is not available there effects on growth, yield, quality, economics, water use efficiency and nutrient uptake are briefly reviewed in this chapter under appropriate headings.

2.1 Effect of drip irrigation system

2.1.1 Effect of drip irrigation on growth

Maher (1991) worked on garlic crop under drip and furrow method of irrigation at Rahuri and reported that plant height, number of functional leaves, leaf area and dry matter per plant were significantly increased with drip irrigation as compared to furrow irrigation.

Awari and Hiwase (1996) in a field trial on potato at Akola (M.S.) reported that the leaf area was the highest with drip irrigation.

Farghali (1998) at Jabalpur observed that, all the growth parameters like number of branches per plant, height, and number of fruits of egg plant were superior under drip irrigation as compared to surface irrigation.

Singh and Lal (1998) conducted experiment at Modipuram (U.P.) and reported that irrigation scheduling through drip and sprinkler methods produced significantly more plant height of potato.

Ahire (1999) carried out an experiment at MPKV, Rahuri on surface and drip methods for potato (Cv. K. Jyoti). The results indicated that the plant height, plant spread, number of functional leaves, number of branches and shoot dry matter per plant were higher in drip irrigation, than surface irrigation.

Gole (2000) carried out field experiment at MPKV, Rahuri on summer onion (cv. *Phule Suvarna*). The growth,

yield and quality parameters were significantly influenced due to micro-irrigation system. The highest yield was obtained due to drip with 125 per cent nitrogen (413.40 q ha^{-1}).

Singandhupe (2003) stated that the crops grown under drip irrigation had more plant height of chilli as compared to surface irrigation.

Manjunatha *et al.* (2004) observed that drip irrigation contributed for the maximum plant height, more number of fruits, number of branches per plant as well as fruit yield per plant of brinjal over surface irrigation.

Patel *et al.* (2006) revealed that irrigation to brinjal through drip method at 80 per cent CPE recorded significantly more plant height and number of fruits per plant than its lower level (40% and 60% CPE) as well as surface irrigation method.

Sankar *et al.* (2008) reported that among the different irrigation methods and level of irrigation evaluated, drip irrigation at 100% pan evaporation recorded the highest plant height of onion followed by micro-sprinkler irrigation at 100% pan evaporation.

2.1.2 Effect of drip irrigation on yield

Agarwal and Singh (1973) reported 46 per cent increase in yield of potato under trickle irrigation system over surface irrigation.

Sivnappan (1979) evaluated drip irrigation at Coimbatore for number of vegetable crops including sweet potato, tomato, okra, brinjal, chilly and radish. The results indicated that drip irrigation increased yield by 10-40 per cent than furrow irrigation.

Goyal (1988) evaluated tomato response to four irrigation systems. The irrigation scheduling was based on soil moisture tension of 15-45 bar. Drip, micro-sprinkler and furrow irrigation in the winter increased yields by 112, 82 and 37 per cent, respectively compared with control plot.

At Modipuram, the experiment was conducted to evaluate trickle and sprinkler irrigation systems. It was reported that trickle system increased 9 per cent potato yield over conventional furrow method of irrigation (Anonymous, 1994a).

With trickle irrigation at 150 per cent CPE water level produced significantly higher yield of potato (253 qha^{-1}) as compared to 100 per cent CPE water level and furrow irrigation (Anonymous, 1994b).

Clark and Smajstrla (1995) studied comparative suitability of drip irrigation over furrow irrigation for winter vegetables like onion, radish, spinach, tomato, turnip and cauliflower and reported that there was increase in yield of these winter vegetables with drip irrigation.

Awari and Hiwase (1996) in a field trial on potato at Akola (M.S.) reported maximum tuber yield with drip

irrigation. Acceptable tuber yield was also the highest with drip irrigation.

Patel *et al.* (1996) conducted field experiment on garlic at Gujarat and reported 8.42 per cent more bulb yield with drip irrigation than furrow irrigation.

Eckstein *et al.* (1998) conducted two trials to determine the most suitable irrigation systems for cool subtropics and hot subtropics in South Africa. Various irrigation systems, viz. drip single line, drip double line, micro-sprinkler, pulsator and overhead floppy system, were tested over 3 cycles. The drip and pulsator systems were irrigated daily. The micro and over head floppy systems were irrigated at intervals of 3-4 days. At cool tropics the micro system averaged the highest bunch mass of banana, drip system tended to have shorter planting to harvest interval. With 3 per cent higher yields, the micro system used 29 per cent more water than the drip systems. At hot subtropics, drip single used 12 per cent less water than drip double but yield was decreased by 7 per cent.

Farghali (1998) at Jabalpur observed that, all growth parameter like branches, height, number of fruits and quality of fruit of brinjal were superior under drip irrigation as compared to surface one.

In drip irrigation system fruit yield of brinjal was 10.2 to 29.8 per cent higher than that of surface (Anonymous, 2001). Further, it was noted that, drip irrigation

applied at 2 days interval, produced 7.4 to 17.67 per cent higher fruit weight, 8.7 to 11.0 per cent higher fruit length, 5.7 to 15.5 per cent higher diameter of fruit, 38.6 to 40.5 per cent higher volume of fruit and 1.1 to 2.2 per cent more moisture in fruit than surface method of irrigation.

Singh and Lal (1998) conducted field experiment at Modipuram (U.P.) and reported that irrigation scheduling through trickle and sprinkle methods produced significantly higher aggregate yield and number of tubers of potato than conventional furrow method of irrigation.

Ahire (1999) carried out field experiment at MPKV, Rahuri on surface and drip method for potato (cv.Jyoti). The results indicated that the number of tubers and tuber weight was maximum under drip method. The tuber yield under drip was 20.43 t ha^{-1} and it was 17.73 t ha^{-1} under surface.

Gole (2000) carried out field experiment at MPKV, Rahuri on summer onion (cv. Phule Suvarna). The yield was significantly influenced due to micro-irrigation system. The highest yield was obtained due to drip with 125 per cent nitrogen i. e. 413.40 q ha^{-1}.

Sharmasarkar *et al.* (2001) revealed that the yield and sugar content in sugar beet under drip irrigation were higher (3-28%) than those with flood irrigation.

Patel and Patel (2001) carried out field experiment at Gujarat to study the response of potato to N fertilizer under trickle and furrow irrigation. The application of irrigation water through trickle method resulted in higher plant yield and tuber yield compared to furrow irrigation. Trickle irrigation with 300 kg N ha^{-1} provided the highest tuber yield and it was at par with 260 kg N ha^{-1}.

Sharmashankar *et al.* (2001a) noted that sugar beet yield, sugar content and nitrogen availability in soil under drip irrigation were higher than those with flood irrigation. Similarly, agronomic water use efficiency and fertilizer use efficiency were higher in drip than flood and also reduced leaching losses.

Togneti *et al.* (2003) indicated that increasing the amount of water applied gave benefit in terms of sugar beet root yield and sucrose accumulation. Drip irrigation appeared to be consistently advantageous with respect to low pressure sprinkler irrigation system for sugar beet production and its performance in semi arid environment.

Manjunatha *et al.* (2004) observed that, drip irrigation contributed for more number of fruits, branches and fruit yield per plant of brinjal over surface irrigation.

Rana *et al.* (2004) showed that fruit yield of brinjal was significantly improved with drip irrigation over surface irrigation.

Drip irrigation produced significantly superior brinjal fruit yield over all other irrigation methods (Anonymous, 2005c).

Kanber *et al.* (2006) conducted research experiment to determine the water and nitrogen requirements of potato crop at Nigda-Nevsehir in Turkey, under sprinkler and trickle irrigation methods. Irrigation treatments were based on class A pan evaporation and nitrogen levels were formed with different nitrogen concentrations. The highest yield, averaging 47,505 kg ha^{-1}, was measured in sprinkler-irrigation plots at the 60 g m^{-3} nitrogen concentration level in the irrigation treatment with limited irrigation (480 mm). Statistically higher tuber yields were obtained at 45 and 60 g m^{-3} nitrogen concentration level in irrigation treatments with full and limited irrigation.

Patel *et al.* (2006) reported that irrigation to brinjal through drip system at 80 per cent of CPE produced significantly the highest fruit yield (35.4 t ha^{-1}) which was 22.3, 13.2 and 19.4 per cent higher than 40 and 60 per cent CPE and surface irrigation, respectively.

Sankar *et al.* (2008) reported that both drip and micro-sprinkler systems improved yield contributing parameters of onion. Among the different irrigation methods and levels tested, the drip irrigation at 100% pan evaporation recorded the highest marketable onion bulb yield 39.6 t ha^{-1}

followed by 33.9 t ha^{-1} micro-sprinkler irrigation at 100% pan evaporation.

2.1.3 Effect of drip irrigation on economics

Berthelot, *et al.* (1990) carried out comparative study of the financial and economic viability of drip and overhead irrigation of sugarcane in Mauritius. Within the context of rising energy cost and limited water resources, drip irrigation of sugarcane was perceived as an alternative to overhead irrigation in Mauritius. Alongside the agronomic and soil physics investigation into drip irrigation initiated under the MSIRI/ IH Drip Irrigation Research Project, a comparative study of the economic and financial viability of the two systems of irrigation sugarcane was undertaken. The relevant economic and financial rates of return were then calculated and the implications of the results, taking into consideration the island's agricultural policy, were discussed. It was found that drip irrigation brings higher returns under Mauritius conditions.

Baviskar (1998) carried out economic analysis for surface irrigation method and drip for sugarcane. The total cost required per ha to raise the crop was Rs.61,933, Rs.52,080 and Rs.45,000 for application of 100% RD through WSF application of 100% RD through straight fertilizer and surface irrigation, respectively. Considering the additional area of 0.70 ha that can be brought under irrigation using drip irrigation (for WSF and SF), the total net income was Rs.

109390 and Rs. 104380 ha^{-1} for WSF and SF, respectively as compared to Rs. 52115 ha^{-1} with surface method of irrigation. The benefit cost ratios were 1.04, 1.18 and 1.01 for 100% WSF, 100% SF and surface treatments. The net seasonal income per hectare was maximum with 100% WSF (Rs.64,347) through drip followed by SF 100% (Rs 61,400) through drip over surface treatment (Rs. 50,200). The net profit/cm water used was maximum in 100% WSF (543.31 Rs/cm) followed by 100% SF (527.12 Rs/cm) and 100% SF (527.12 Rs/cm) through drip system over surface method (249.76 Rs/cm)

Elsheemy and Elsayed (1993) carried out field experiment on economic study of irrigation on sugarcane productivity in Egypt and reported that optimal rate of trickle irrigation applied at the first and second ratoon were 900 m^3 and 1200 m^3, respectively. These rates increased the net income per feddan by about 242.5% and 179.4% (feddan = 0.42 ha).

Sharmashankar *et al.* (2001 b) stated that sugar beet production under drip would be more profitable with pay back period of 7-10 year and higher economic return obtained from larger areas.

Ahire *et al.* (2002) conducted field experiment in entisols to find out economics of different planting systems (normal: 45 x 15 cm and 60 x 15 cm; paired row: 30-60-30 cm and 40-80-40 cm) and irrigation methods (trickle and surface), for *rabi* potato in 1997. It was found that the trickle irrigation

treatment with normal planting of potato (60 x 15 cm) produced maximum income (Rs. 77531 ha^{-1}) along with highest B:C ratio.

Manjunatha *et al.* (2004) reported that the benefit-cost ratio of brinjal was the highest with surface and the lowest with drip due to higher initial cost incurred on installation of drip irrigation. The net profit per unit depth of water used was higher under drip irrigation than surface irrigation.

2.1.4 Effect of drip irrigation on water saving and water use efficiency

Agrawal and Singh (1973) reported that there was 25 per cent saving of water under trickle irrigation system for potato over surface irrigation.

Hansen and Peterson (1974) conducted an experiment on sandy loam soils at San Diego, California (U.S.A.) to compare water use efficiencies and crop yield of onion and sweet corn under drip, sprinkler, furrow and sub-surface methods of irrigation. They reported that drip irrigation recorded maximum water use efficiency, but the highest yield was obtained from sprinkler method.

Hapase (1989) conducted field experiment on economic feasibility of micro irrigation system for sugarcane at Pune. He noted that, although lower irrigation water (107.56 ha-cm) was applied in drip, it recorded higher field water use efficiency (1.631 t $ha^{-1}cm^{-1}$).

At Modipuram, trickle irrigation system increased the crop growth and there by resulted in 50 per cent more yield over sprinkler and furrow irrigation systems. In addition, 40-50 per cent of irrigation water was saved under sprinkler and trickle irrigation methods for potato over conventional furrow irrigation method. Single row trickle irrigation system proved better than double row trickle system (Anonymous, 1990).

At Modipuram (U.P.), drip and sprinkler irrigation systems were evaluated for potato. Use of drip irrigation saved 50 per cent of irrigation water accompanied with 39 per cent increase in potato yield over conventional furrow irrigation. The increase in potato tuber yield by sprinkler irrigation was 20 per cent (Anonymous, 1991).

Saggu and Kaushal (1993) observed maximum WUE of 1.06 t $ha^{-1}cm^{-1}$ using 30 cm of fresh water in case of trickle irrigation method to potato as compared with furrow irrigation.

At Modipuram, the experiment was conducted to evaluate trickle and sprinkle irrigation systems for potato. It was reported 50 per cent water saved by trickle system over conventional furrow method of irrigation (Anonymous, 1994a).

Awari and Hiwase (1996) in a field trial on potato at Akola (M.S.) reported that water use efficiency was the highest under drip irrigation.

Selvaraj *et al.* (1997) reported that application of irrigation water through drip method reduced the irrigation

water requirement of turmeric as 20 to 60 per cent in Tamil Nadu and Maharashtra.

Eckstein *et al.* (1998) conducted two trials of banana to determine the most suitable irrigation systems for cool subtropics and hot subtropics in South Africa. Various irrigation systems, viz. drip single line, drip double line, micro-sprinkler, pulsator and overhead floppy system, were tested over 3 cycles. The drip and pulsator systems were irrigated daily. The micro and overhead floppy systems were irrigated at an interval of 3-4 days. The micro system used 29 per cent more water than the drip systems. At hot subtropics, drip single line used 12 per cent less water than drip double line but yield was decreased by 7 per cent. Overhead floppy did not show any advantage compared with the other systems tested. Microirrigation systems used 29 per cent more water to produce 8 per cent higher yield.

Imtiyaz *et al.* (2000) reported that water use efficiency for drip irrigated broccoli (*Brassica oleracea* L. var. botrytis L) and carrot (*Daucus carota* L v. Sativa D.C.) was more at 80% pan evaporation than at 100% pan evaporation. Higher water use efficiency, water productivity and nitrogen use efficiency were recorded in NK fertigation in 40:40:20 split in both the seasons.

Sankar *et al.* (2001) revealed that double area could be brought under drip and sprinkler irrigation with the same

quantity of water normally used for unit area under surface irrigation method.

Sharmashankar *et al.* (2001a) noted that water use efficiency and fertilizer use efficiency of sugarbeet was higher in drip than flood and also reduced leaching losses.

Shinde *et al.* (2002) reported that drip with 25 per cent of irrigation water with mulch recorded the highest irrigation water use efficiency (447.38) in chilli followed by micro-jet with 50 per cent irrigation water with mulch.

Drip irrigation method utilized maximum profile water required almost half the quantity of water that consumed by other irrigation methods (Anonymous, 2005c).

Kanber *et al.* (2006) conducted research experiment to determine the water and nitrogen requirement of potato crop at Nigda-Nevsehir in Turkey, under sprinkler and trickle irrigation methods. Water use of potato crop ranged from 490 to 760 mm for sprinkler irrigated plots and 565-830 mm for trickle irrigated treatments. The highest water use efficiency (WUE) levels of 7.37 and 4.79 kg m^{-3} was obtained in sprinkler and trickle irrigated plots, respectively.

Patel *et al.* (2006) revealed that irrigation applied to brinjal through drip at 40 per cent CPE recorded higher WUE (44.8 $kgha^{-1}mm^{-1}$) than surface irrigation method.

Rank (2007) revealed that water use efficiency was the highest (3.84 kg ha^{-1}mm) with drip irrigation at IW/CPE of 0.4 continuously for whole season while WUE was the lowest

with border irrigation at 40% depletion of ASM during vegetative growth stage of cotton.

Kannan (2008) reported that among drip irrigation regimes higher water use efficiency, water productivity and nitrogen use efficiency were observed in medicinal coleus in drip irrigation at 80% pan evaporation and 100% pan evaporation compared to drip irrigation at 60% pan evaporation.

Sankar *et al.* (2008) reported that there was saving of irrigation water of 37.8% in drip and 32.5% in sprinkler system compared with the surface irrigation scheduled at 50mm cumulative pan evaporation with 7 cm depth. The highest water use efficiency was observed under drip irrigation system.

2.2 Effect of Floppy and Overhead sprinkler irrigation systems

2.2.1 Effect of Floppy and Overhead sprinkler irrigation systems on growth

Helling (1961) reported that increase in yield of potato crop under sprinkler irrigation method as evidenced, might be due to availability of more water at terminal buds of the plant, which increased the turgidity and cell elongation resulting in better growth, higher rate of photosynthesis and ultimately higher yield. The decreased aeration under surface irrigation could be another cause for reduced yield.

Yadav *et al.* (1988) reviewed the surface, overhead sprinkler and drip irrigation methods on growth, flowering, fruiting, ripening, productivity and quality of anbergines, tomatoes, capsicums and potatoes. They revealed that the sprinkler irrigation was generally most suitable under Indian condition

Kabra (1994) conducted field experiment for *kharif* groundnut revealed that the *kharif* groundnut grown on broad bed furrow (BBF) with daily irrigation through micro-sprinkler showed better performance in respect of growth and yield contributing characters of groundnut.

Singh and Lal (1998) conducted field experiment at Modipuram (U.P.) and reported that irrigation scheduling through trickle and sprinkler methods improved plant height and number of stems per plant of potato than conventional furrow method of irrigation.

Gite (1999) reported that plant height of onion, number of functional leaves, equatorial diameter of onion bulb, neck thickness of bulb and dry matter per plant were significantly more in broad bed furrow with micro-sprinkler spaced at 180 x 180 cm as compared to 210 x 210 cm spacing.

Gogoi (2001) reported maximum plant height (72.86 cm), number of functional leaves per plant (13.30), equatorial diameter of bulb (6.18 cm), neck thickness of bulb (1.14 cm)

and dry matter per plant of onion (14.50 g) under floppy sprinkler spaced at 4.5 x 4.5 m followed by floppy sprinkler spaced at 6.0 x 6.0 m (69.94 cm, 12.63, 5.98 cm and 1.02 cm and 14.36 g) respectively.

Kenter and Hoffman (2002) concluded that growth rate of both leaf and storage root of sugarbeet were higher in sprinkler irrigation than flood and rainfed treatment.

Shinde *et al.* (2002) reported that micro-jet with 75 per cent irrigation water with mulch recorded significantly taller plants of chilli at harvest than check basin.

The application of irrigation at 0.7 IW/CPE under microsprinkler recorded more number of tillers per plant of ginger at 150 days after planting followed by 0.9 IW/CPE (Anonymous, 2009).

2.2.2 Effect of Floppy and Overhead sprinkler irrigation systems on Yield

Hansen and Petterson (1974) conducted an experiment on sandy loam soils at San Diego, California (U.S.A.) to compare water use efficiencies and crop yield of onion and sweet corn under drip, sprinkler, furrow and sub-surface methods of irrigation. They reported that the sprinkler and drip methods of irrigation produced higher yield of onion.

Agarwal *et al.* (1975) observed that sprinkler method of irrigation produced more (50 per cent) tubers, higher per plant yield and also larger size tubers than surface method of irrigation at Hisar.

Deshpande and Gupta (1984) carried out comparative study on sprinkler irrigation with border irrigation for garlic crop at MPKV, Rahuri and found that the yield of garlic crop was 95.99 q ha^{-1} for sprinkler and 86.47 q ha^{-1} for border irrigation.

The yield of dry chilli was recorded to the extent of 17.41 and 21.52 q ha^{-1} in treatments of furrow (irrigated at 80 mm CPE with 60 mm depth) and sprinkler method, sprinkler method gave 38.61 per cent higher yield during 1982-83 and 23.61 per cent during 1983-84 over furrow method (Anonymous,1984).

Gosavi and Deshmukh (1985) compared the sprinkler irrigation system with the border irrigation system for cabbage and found that yield of cabbage crop was increased by 10.30 per cent in sprinkler irrigation as compared to border irrigation.

Lagad and Borude (1987) compared sprinkler method of irrigation with border method for onion at MPKV, Rahuri and reported 22.87 per cent increase in yield and maximum water use efficiency due to sprinkler irrigation over border method.

Mane *et al.* (1987) conducted field experiment to study the comparative performance of sprinkler and surface method of irrigation for summer groundnut, chilli and onion. The sprinkler irrigation resulted in higher yield of groundnut pods than surface irrigation with 31 per cent saving in

irrigation water. They also revealed that in sprinkler method significantly higher onion bulb yield was observed than surface method.

The irrigation with micro-sprinkler system consisting of plastic nozzles with the application rate of 8 mm $hr^{-1,}$ increased the yield of groundnut by 46 per cent over border irrigation method (Anonymous, 1989).

Gutal *et al.* (1989) reported 15% increase in yield of groundnut due to micro-sprinkler irrigation over border irrigation. They further reported that uniformity coefficient of micro-sprinkler, kept at 1.2 X 1.2 m spacing and 30 cm stake height, was 76.8% at 1 kg cm^{-2}. They observed decrease in precipitation rate with increase in stake height. The maximum wetted diameter of soil was reported an 3.30 m at 30 cm stake height with precipitation rate 4.0 mm hr^{-1}, whereas it was 3.10 m at 45 cm stake height with precipitation rate of 3.4mmhr^{-1}.

Gite (1999) reported that average weight of bulb, yield per hectare and bulb to leaves ratio of onion was significantly superior in case of micro-sprinkler spaced at 180 X 180 cm over drip and surface irrigation methods.

Shrivastava *et al. (*1993) conducted experiments on heavy soils of Gujarat Agricultural University research farm to study the response of sugarcane (Co-6304) to sprinkler irrigation and determined optimum IW:CPE ratios 0.30, 0.45, 0.60 and 0.75 in furrow irrigation systems. Sprinkler irrigation increased sugarcane productivity by 17.5% with average water

saving of 30%. Sprinkler irrigation at 0.45 IW:CPE gave the highest yield of 97.23 t/ha with 37.50% water saving and increase of 22.47% in yield.

Sener *et al.* (1993) compared the sprinkler, mobile nozzle, drip, mobile drip and furrow irrigation for potatoes, soybean and maize at Turkey. They reported that the sprinkler irrigation produced the highest yield for all three crops at almost all water volume applied, but furrow method was cheapest irrigation system for the farmers.

Kabra (1994) conducted experiment for *kharif* groundnut reported that the *kharif* groundnut grown on broad bed furrow (BBF) with daily irrigation through micro-sprinkler showed better performance in respect of yield contributing characters of groundnut with increase in yield of 59.04 per cent in case of micro-sprinkler method over surface method of irrigation.

Sanchez *et al.* (1994) conducted six experiments in the field during 1980-88 to evaluate the response of cabbage to sprinkler irrigation. Cabbage yields were significantly increased by sprinkler irrigation.

Eckstein *et al.* (1998) conducted two trials to determine the most suitable irrigation systems for cool subtropics and hot subtropics in South Africa. Under this condition micro-sprinkler proved superior showing yields that averaged 8 per cent higher than pulsator and drip double and 17 per cent higher than drip single.

Singh and Lal (1998) conducted experiment at Modipuram (U.P.) and reported that irrigation scheduling through trickle and sprinkler methods produced significantly higher aggregate yield and number of potato tubers than conventional furrow method of irrigation.

Singh *et al.* (1999) reported that the highest tuber yield was obtained with combination of moisture regime (2.02 cm) by line source method of sprinkler irrigation. WUE and ET recorded for 1.4 cm regime by sprinkler were maximum in potato.

Srivastava *et al.* (1999) determined the water use efficiencies of cabbages irrigated via micro-sprinkler, drip, and micro-tube or surface irrigation method in India. Cabbage was planted at a spacing of 0.5 X 0.6 m. The highest yield was obtained in micro-sprinkler irrigation treatment (40.23 t ha^{-1}) followed by drip irrigation (38.97 t ha^{-1}), surface irrigation (33.76 t ha^{-1}) and micro tube irrigation (32.54 t ha^{-1}). Water use efficiency was the highest for drip irrigation, followed by micro tube irrigation, micro-sprinkler irrigation and surface irrigation, per cent water savings were 61.44, 59.28 and 36.8 for micro tube, drip and micro-sprinkler methods, respectively.

From the experiment conducted at Water Management Project, MPKV, Rahuri (M.S.) it was found that potato tuber yield obtained under sprinkler (21.40 t ha^{-1}) and micro-sprinkler (21.10 t ha^{-1}) were significantly higher than drip and surface methods (16.21 and 14.67 t ha^{-1}). The

increase in potato yield due to sprinkler, micro-sprinkler and drip was to the extent of 45.88, 43.83 and 10.50 per cent, respectively over surface method. The formation of microclimate in crop vicinity favoured growth under sprinkler and micro-sprinkler (Anonymous, 2001).

Gogoi (2001) recorded the maximum average weight of bulb (99.82 g), yield per unit area (5.09 kgm^{-2}), yield per hectare (507.35 q) and bulb to leaves ratio (6.52) of onion were found in floppy sprinkler spaced at 4.5 x 4.5 m, followed by floppy sprinkler spaced at 6.0 x 6.0 m (95.68 g, 4.98 kgm^{-2}, 49897 kg and 6.28), respectively.

From the experiment conducted at Water Management Project, MPKV, Rahuri (M.S.), it was reported that yield of potato under sprinkler, micro-sprinkler and drip was significantly higher (19.08, 17.47, 14.72 t ha^{-1}, respectively) as compared to surface method of irrigation (12.87 t ha^{-1}). The increase in yield due to sprinkler, micro-sprinkler and drip was to the extent of 48.25, 35.74 and 14.37 per cent over surface method of irrigation. The large size tubers were higher in sprinkler method (Anonymous, 2002).

Patil (2003) conducted field experiment to study the response of potato to different irrigation depths and methods during *rabi* season of 2002 at MPKV, Rahuri (M.S.). The treatments were four irrigation methods including sprinkler, micro-sprinkler, trickle and surface and four depths of irrigation. The highest tuber yield (23.29 t ha^{-1}) and haulm

yield (1.68 t ha^{-1}) was recorded under sprinkler method. The big size tubers were observed under sprinkler method while the total number of tubers per plant was higher under micro-sprinkler method.

The application of irrigation at 0.7 IW/CPE under microsprinkler recorded higher fresh rhizome yield of ginger (8.20 t ha^{-1}) followed by 0.9 IW/CPE (7.70 t ha^{-1}) (Anonymous, 2009).

Satyendra Kumar *et al.* (2009) reported that yield of potato increased from 13.53 t ha^{-1} under 0.60 IW/CPE irrigation schedule in furrow irrigation to a maximum of 31.60 t ha^{-1} in microsprinkler irrigation system with irrigation scheduling of 1.20 IW/CPE.

2.2.3 Effect of Floppy and Overhead sprinkler irrigation systems on economics

Agrawal and Rajinder Singh (1977) carried out study on sprinkler irrigation method against the surface irrigation method and observed that though sprinkler irrigation was costly as compared to surface irrigation, the additional cost was totally recovered by other benefits of sprinkler system.

Dixit *et al.* (1994) stated that maximum net returns (Rs. 14130.18 and 9232.11 ha^{-1}) and net returns per rupee investment (Rs.1.25 and 0.78) were recorded under sprinkler method with 6cm depth of irrigation during first and second year to potato.

Shinde and Firake (1998) reported that the net extra income of summer chilli was maximum (Rs.86,723 ha^{-1}) due to stationary micro-sprinkler with benefit cost ratio of 2.74 amongst six micro irrigation systems. However, in case of rotary micro-sprinkler, the net extra income was Rs.79,793 ha^{-1} with gross benefit :cost ratio of 2.29. The yield of green chilli was significantly more in rotary micro-sprinkler irrigation as compared to stationary micro-sprinkler.

Rout *et al.* (1998) reported that micro sprayers with 'X' pattern could be used for sugarcane as a better substitute for drip. They found that, jets of 45 lph capacity installed at 12 feet apart on 16 mm lateral resulted into 65 tonnes/acre cane yield with less management and labour requirement and brining down the cost of micro irrigation system for sugarcane.

The irrigation with micro-sprinkler system consisting of nozzles with an application rate of 8 mm ha^{-1} recorded the maximum benefit cost ratio of groundnut (2.7) under micro-sprinkler than border method (1.7) (Anonymous, 1989).

Malavia *et al.* (1993) conducted the experiment in summer, 1986 for groundnut to evaluate the sprinkler irrigation and revealed that the additional net profit of Rs. 2783 ha^{-1} was obtained under sprinkler method in comparison to surface method of irrigation with net incremental cost : benefit ratio of 1:4.96.

Kabra (1994) reported that in groundnut monetary returns, both gross (Rs. 51,976 ha^{-1}) and net (Rs. 24,230 ha^{-1}) were maximum in broad bed furrow (BBF) with micro-sprinkler irrigation treatments and less in flat bed (Rs. 19,619 ha^{-1}) and surface (Rs. 10,871 ha^{-1}) irrigation. The benefit: cost ratio was more in flat bed with surface irrigation than micro sprinkler. The respective values were 1.87, 1.25 and 1.66 in BBF with micro sprinkler spaced at 150 cm X 150 cm, flat bed with micro sprinkler spaced at 120 cm X 120 cm, and flat bed with micro sprinkler spaced at 180 cm X 180 cm, respectively.

Dhuyvetter *et al.* (1995) conducted economic analysis where the economic profitability of subsurface drip irrigation (SDI) for field corn was compared with a low pressure centre pivot sprinkler irrigation system using partial budgeting. The centre pivot sprinkler system had an economic advantage of $ 55.63 ha^{-1} over the SDI system.

Gite (1999) reported that the monetary returns such as gross income (Rs. 7,99,906 ha^{-1}) and net income (Rs. 7,06,210 ha^{-1}) were maximum and also benefit : cost ratio (8.53) was more in broad bed furrow with micro-sprinklers spaced at 180 X 180 cm in case of onion crop.

Gogoi (2001) found that the maximum B:C ratio in floppy sprinkler spaced at 6.0 x 6.0 m (3.28), followed by floppy sprinkler spaced at 7.5 x 7.5 m (2.74) amongst other spacing. The net extra income over control was the highest in floppy sprinklers space at 6.0 x 6.0 m (Rs.1, 23,802 ha^{-1}). In

control (micro-sprinkler system), the benefit cost ratio was 1.48, because of high system cost. Thus, from economical point of view, the adoption of floppy sprinklers at the spacing of 6.0 x 6.0 m to onion was found to be the best as it resulted in better uniform application of water (88.43%), onion yield (498.97 q ha^{-1}), maximum benefit cost ratio (3.28) and maximum net extra income over control (Rs.1,23,802 ha^{-1}).

Shinde *et al.* (2002) reported that micro-jet with 50 per cent irrigation water with mulch for Chilli recorded the highest gross monetary returns ha^{-1} (Rs.2,06,880 ha^{-1}) and micro-jet with 75 per cent irrigation water with mulch (Rs.2,01,000 ha^{-1}).

Patil (2003) conducted the experiment to study the response of potato to different irrigation depths and methods during the *rabi* season of 2002 at Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.). The treatments were four different irrigation methods including sprinkler, micro-sprinkler, trickle and surface and four depths of irrigation. The gross and net returns were maximum in sprinkler and micro-sprinkler methods.

Pawar and Bhoi (2004) conducted field experiment to evaluate the economic feasibility and assess the optimum fertilizer dose for potato under different pressurized irrigation systems such as trickle, micro-sprinkler and overhead sprinkler. The B:C ratios were found to be 3.89, 2.99, 1.70 and 2.60 for sprinkler, micro-sprinkler, trickle and surface

method of irrigation, respectively. The economic analysis indicated that overhead sprinkler method of irrigation was more economical for potato in terms of total net income (Rs.64,206 ha^{-1}), B:C ratio (3.89), additional income over surface method (Rs.42471 ha^{-1}) and net income per unit of water (Rs.1785.50). Considering net returns and B:C ratios, the overhead sprinkler and micro-sprinklers were found economically feasible for potato.

Satyendra Kumar *et al.* (2009) reported that irrigation scheduling from 0.60 to 1.20 IW/CPE under microsprinkler system resulted significantly higher net returns of potato than furrow irrigation method.

2.2.4 Effect of Floppy and Overhead sprinkler irrigation systems on water saving and water use efficiency

Datta (1973) compared sprinkler irrigation with furrow irrigation for potato. He reported that by sprinkler irrigation the water could be saved to the extent of 35 per cent over furrow irrigation, but the cost of irrigation was observed less in furrow irrigation over sprinkler irrigation.

Hansen and Petterson (1974) conducted the experiment on sandy loam soils as San Diego, California (U.S.A.) to compare water use efficiency and crop yield of onion and sweet corn under drip, sprinkler, furrow and sub surface method of irrigation. They reported that the drip irrigation recorded maximum water use efficiency.

Ceslatal (1978) studied sprinkler irrigation in vegetable production. He found that vegetable crops responded excellently to sprinkler irrigation method. He further suggested that the effectiveness of water supply could be increased by improving the water application efficiency.

An experiment conducted at Water Management Project, MPKV, Rahuri (M.S.) on Chilli crop in *kharif* season showed that sprinkler method could save 21.88 per cent of irrigation water when compared with traditional method of ridges and furrows (Anonymous, 1983). The crop yields obtained in furrow and sprinkler methods were 22.3 and 40.9 q ha^{-1}, respectively with the WUE of 46.5 and 82.4 kg $ha^{-1}cm^{-1}$, respectively.

Gaikwad *et al.* (1983) observed that, by adopting sprinkler method there would be saving in water to the extent of 42 per cent with increase in yield by 19 per cent over surface method of irrigation in case of sunflower.

Deshpande and Gupta (1984) carried out comparative study on sprinkler irrigation with border irrigation for garlic crop at MPKV, Rahuri and found that sprinkler method saved 28 per cent water over border method. WUE was also higher in sprinkler method.

Gosavi and Deshmukh (1985) compared the sprinkler irrigation system with the border irrigation system for cabbage and found that yield of cabbage crop was

increased by 10.30 per cent in sprinkler irrigation as compared to border irrigation.

Suryawanshi and Pampattiwar (1985) at MPKV, Rahuri reported that yield of chilli, groundnut and sunflower were maximum in case of sprinkler irrigation as compared to surface irrigation and 28 to 40 per cent water saving was reported with sprinkler irrigation.

Lagad and Borude (1987) compared sprinkler method of irrigation with border method for onion at MPKV, Rahuri and reported that maximum water use efficiency was observed due to sprinkler irrigation over border method.

Mane *et al.* (1987) conducted the experiment to study the comparative performance of sprinkler and surface methods of irrigation for summer groundnut, chilli and onion. The sprinkler irrigation resulted as 31 per cent saving in irrigation water.

Pampattiwar *et al.* (1987) compared the sprinkler irrigation method with the border irrigation for garlic crop at MPKV, Rahuri and reported 24.45 per cent increase in yield and 33.33 per cent saving in water by sprinkler irrigation over border irrigation.

Gutal *et al.* (1989) reported 24% water saving due to micro-sprinkler irrigation over border irrigation. They further reported that UC of micro-sprinkler, kept at 1.2 X 1.2 m spacing and 30 cm stake height, was 76.8% at 1 kg $cm^{-2.}$ They observed decrease in precipitation rate with increase in stake

height. The maximum wetted diameter of soil was reported as 3.30 m at 30 cm stake height with precipitation rate 4.0 mm hr^{-1}, whereas it was 3.10 m at 45 cm stake height with precipitation rate of 3.4 mm hr^{-1}.

The experiences with drag line overhead sprinkler for sugarcane in Switzerland, South Africa and Kwa-tula revealed that the system can be installed with modest increase in capital cost, well below that comparative costs of other kinds of more automatic irrigation systems but quite a reduced labour requirement for its operation. (Zadratil, 1990). According to climatic conditions the application rate was designed for the values between 0.5 to 1 lps per ha. The system was in operation successfully for many years.

Gorantiwar *et al.* (1991) conducted the experiment on onion variety N–2–4–1 during 1986 – 87 at MPKV, Rahuri and reported the highest WUE (10.4 q ha^{-1} cm) with sprinkler irrigation which was more than border method.

Shrivastava *et al.* (1993) conducted experiments on heavy soils of Gujarat Agricultural University research farm to study the response of sugarcane (Co-6304) to sprinkler irrigation and determined optimum IW:CPE ratios 0.30, 0.45, 0.60 and 0.75 in furrow irrigation systems. The average water saving was about 30%. The best water use efficiency (WUE) was 236.775 kg $ha^{-1}mm^{-1}$ in lowest IW : CPE ratio of 0.3. Sprinkler irrigation at 0.45 IW : CPE gave the highest yield of 97.23 t ha^{-1} with 37.50% water saving.

Dixit *et al.* (1994) reported that significantly higher water use efficiency was recorded under sprinkler method of irrigation to potato over furrow irrigation.

Kabra (1994) conducted the experiment on *kharif* groundnut revealed that the groundnut grown on broad bed furrow (BBF) with daily irrigation through micro-sprinkler showed better performance with water saving of 41.31 per cent and increase in yield of 59.04 per cent in case of micro-sprinkler method over surface method of irrigation.

Singh *et al.* (1999) reported that the highest water use efficiency (WUE) and ET was recorded for 1.4 cm regime by sprinkler in potato.

Srivastava *et al.* (1999) determined the water use efficiencies of cabbages irrigated via micro-sprinkler, drip, micro-tube or surface irrigation method in India. Cabbages were planted at a spacing of 0.5 X 0.6 m. Water use efficiency was the highest for drip irrigation, followed by micro tube irrigation, micro-sprinkler irrigation and surface irrigation, percentage water savings were 61.44, 59.28 and 36.8 per cent for micro tube, drip and micro-sprinkler methods, respectively.

Al-Jamal *et al.* (2001) reported that the IWUE using the sprinkler system was higher compared to subsurface, drip and furrow irrigation methods which indicated that if you are trying to conserve water, then a sprinkler irrigation system should be used with some of irrigation scheduling.

The water use efficiency of ginger was found higher (0.94 q ha^{-1}cm) in 0.7 IW/CPE ratio under microsprinkler irrigation with 18.04% water saving over 0.9 IW/CPE ratio (Anonymous, 2009).

Satyendra Kumar *et al.* (2009) revealed that among different irrigation systems microsprinkler system recorded higher IWUE than drip and furrow irrigation due to higher crop yield with less expense of water.

2.3. Effect of integrated nutrient management

2.3.1. Effect of integrated nutrient management on growth

Vaidya *et al.* (1972) recommended the dose of 25-30 t FYM ha^{-1} before planting and 75 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} to ginger through fertilizers.

The fertilizer recommendation in Gujrat and Himachal Pradesh given by Geus (1973) was 100 kg N, 40 to 50 kg P_2O_5 and 50 to 60 kg K_2O ha^{-1}, with all the P and K given at planting and N in two split applications within 3 months of planting.

Murlidharan *et al.* (1973) observed the maximum plant height (49.99 cm) with 120 kg P_2O_5 and 240 kg K_2O ha^{-1} and maximum number of tillers per clump (5.90) with 100 kg N, 100 kg P_2O_5 and 200 kg K_2O ha^{-1} in ginger.

Murlidharan *et al.* (1974) recorded that the number of Leaves and number of tillers per clump of ginger were increased over the control by application of 70 kg N ha^{-1} to ginger.

Lee *et al.* (1981) reported that application nitrogen significantly increased the number of third order shoots and tiller numbers of ginger.

Nair (1982) concluded the experiment on nutritional aspects of ginger in Kerala and concluded that NPK dose of 80:30:40 kg ha^{-1} was optimum for ginger crop.

Pawar and patil (1987) found that application of nitrogen at 225 kg ha^{-1}, phosphorus 90 kg ha^{-1} and potassium at 180 kg ha^{-1} along with 30 t ha^{-1} of FYM had produced more number of shoots per plant in ginger.

Mohanty *et al.* (1988) studied the influence of fertilizer cum seed rate on ginger and found that NPK at 125:75:150 kg ha^{-1} recorded the highest plant height (46.7cm) and maximum number of leaves per plant (20.7). However, application of NPK at 75.50.50 kg ha^{-1} resulted in more number of tillers per clump (10.9).

Saha (1989) revealed from his studies conducted in Meghalaya that the application of different sources of N, P_2O_5 and K_2O in ginger did not influence the number of leaves and number of tillers per plant, but 90 kg N, 60 kg P_2O_5 and 90 kg K_2O ha^{-1} produced significantly more plant height (43 cm).

Pawar and patil (1990) obtained more number of shoots per plant of ginger, with application of 225, 90 and 80 kg N P and K kg ha^{-1} along with 20 t ha^{-1} of FYM.

Rana and Rattan (1994) reported that the maximum plant height, tillers/plant, leaf length and leaf breath of turmeric were obtained with N 90 kg and P_2O_5 60 kg ha^{-1}.

Khandkar and Nigam (1996) observed that plant height of ginger was greater with FYM than control although there was no significant differences between 3 and 6 t FYM ha^{-1}. FYM 6 t ha^{-1} gave more leaves and tillers per plant. Application of N,P and K at 100, 34.9 and 33.2 kg ha^{-1}, respectively gave more leaves and tillers per plant and taller plants.

Ai-xizhen *et al.* (1997) reported that application of 40 kg N, 75 kg P_2O_5 and 40 kg K_2O/667 m^2 gave the best results with better shoot growth, stronger branching and greater leaf area of ginger.

Lal (1997) observed that turmeric cv. Ancholi recorded higher number of tillers, number of rhizomes, weight of rhizomes at a combination of 120 kg N + 80 kg P_2O_5 + 60 kg K_2O ha^{-1}.

Gupta and Sengar (1998) revealed that application of nitrogen resulted in appreciable improvement in plant height of turmeric.

Mridula and Jayachandran (1998) observed that application of 45 t FYM ha^{-1} + 30 kg N ha^{-1} produced maximum plant height and leaf area index. Application of N at 45 kg ha^{-1} produced maximum number of tillers and leaves.

Similarly, P at 30 kg ha^{-1} produced maximum plant height, number of tillers, leaves and leaf area index of ginger.

Peter (1999) reported that application of N,P and K @ 60, 50 and 120 kg ha^{-1} along with 5 kg Zn ha^{-1} was optimum for better growth of turmeric.

Venkatesha *et al.* (1998) revealed that turmeric plants provided with 150:125:250 NPK (kg ha^{-1}) and 200:175:300 NPK (kg ha^{-1}) were at par and registered increased plant height, number of tillers, number of leaves, leaf area and petiole length over control which recorded least growth.

Nath and Korla (2000) found that all the bio-fertilizer treatments gave better results in respect of plant height, number of tillers and leaves per plant in ginger.

Yamgar *et al.* (2001) reported that there was increase in growth attributes of turmeric due to application of 200:160:100 kg N: P_2O_5:K_2O ha^{-1} as compared to control.

Amaresh *et al.* (2004) reported that neem cake application (2t ha^{-1}) and FYM amendment (10t ha^{-1}) treatments showed higher germination of ginger.

The treatment of 50%RDF + 50% FYM or vermicompost was found more effective in producing more number of leaves per plant of tomato than other treatments and control (Patil *et al.*2004).

Kate *et al.* (2005) revealed that application of RDF + 5 t FYM ha^{-1} + bio-fertilizer was found suitable for better growth and yield of potato.

Madhuri *et al.* (2006) reported that the maximum plant height, number of leaves, size, surface area of leaves, girth of pseudostem and number of tillers per plant of turmeric was recorded in recommended dose of fertilizer (120:60:60 kg NPK ha^{-1}) which was found at par with the treatment of FYM + *Azoto.* + *PSB.*

Chandre Gowda (2007) stated that plants treated with 100% NPK + *Azospirillum* + *Tricoderma Viridae* + vermicompost recorded maximum plant height (70.63 cm), number of leaves (7.66) and plant girth (1.26 cm) of garlic than other integrated nutrient management practices.

2.3.2 Effect of integrated nutrient management on yield attributes and yield.

Murlidharan and Ramankutty (1975) revealed that the application of 20 t FYM, 60 kg P_2O_5 and 120 kg K_2O ha^{-1} increased the yield of ginger of all the clones irrespective of time of application.

The yield of ginger in field plots was doubled by the application of 30 kg Nha^{-1}, with further increase at 90 kg N ha^{-1}. The application of P and K did not affect the yield (Aclan and Quisumbing, 1978).

Mohanty and Sharma (1978) obtained the highest yield of green ginger (234 q ha^{-1}) with FYM at 25 t ha^{-1} + N,P

and K at 75,50 and 50 kg ha^{-1} respectively and mulched with green leaves at 15 t ha^{-1} at planting followed by 2 mulches at 7.5 t ha^{-1} each at 45 and 90 days after planting.

Mohanty and sharma (1979) reported that rhizome yield of ginger was positively and significantly correlated with number of tillers, leaves, secondary rhizome fingers, tertiary rhizome fingers and total rhizome, girth of secondary rhizome fingers and number and weight of adventitious roots.

Sadanandan and Sasidharan (1979) reported that the fresh ginger rhizome yield rise from 29.95 q ha^{-1} in control to 85.87 q ha^{-1} in the plots that received 50 kg N ha^{-1} but declined to 40.19 q ha^{-1} in the plots that received 120 kg N ha^{-1}.

Sadanandan and Rohini Iyer (1986) revealed that application of neem cake @ 2 tonnes ha^{-1} increased the yield of ginger.

Pawar and Patil (1987) found that application of nitrogen at 225 kg ha^{-1}, phosphorus 90 kg ha^{-1} and potassium at 180 kg ha^{-1} along with 30 t ha^{-1} of FYM when harvested 8 months after planting produced high yield (16.41 t ha^{-1}).

Saha (1989) reported that application of 90 kg N, 60 kg P_2O_5 and 90 kg K_2O ha^{-1} produced maximum rhizome yield of ginger (8.26 t ha^{-1}).

Mohanty *et al.* (1990) found that the yield of ginger increased with the increasing fertilizer dose. The maximum

yield (16.16 t ha^{-1}) was obtained with the highest fertilizer application of 125 kg N, 75 kg P_2O_5 and 150 kg K_2O ha^{-1}.

Pawar and Patil (1990) obtained the higher dry matter of rhizome (16.31 g/plant) and fresh yield of ginger (14 t ha^{-1}) with application of 225,90 and 80 kg N,P and K ha^{-1}, respectively along with 20 t ha^{-1} of FYM.

Kolra and Dahroo (1991) reviewed many aspects of ginger cultivation including its manure and fertilizer requirements, cultivars, mulching, weed and disease control and found favourable effects of these factors for increasing ginger yield.

The maximum yield was obtained with the application of 80 kg N ha^{-1}. There was significant increase in green ginger yield with increase in N levels up to 80 kg ha^{-1} in addition to the basal dose of 25 t FYM ha^{-1}, which would be desirable to obtain higher green ginger yield (Pawar *et al.* 1991).

Mohanty *et al.* (1993) found that the fertilizer dose of N 125, P 70 and K 150 kg ha^{-1} gave the maximum yield of ginger (10.16 t ha^{-1}).

Singh and Bhanu (1993) obtained the rhizome of greater length (20 cm) and the highest rhizome yield (18.6 t ha^{-1}) with 150 kg N, 80 kg P_2O_5 and 60 kg K_2O ha^{-1}.

Rana and Rattan (1994) reported that the maximum rhizome length, rhizome breadth, yield/plant and yield ha^{-1} of turmeric were obtained in case of variety ST-35,

when supplied with N 90 kg and P_2O_5 60 kg ha^{-1}. The rhizome yield and yield attributes increased consistently with increasing fertilizer doses.

Sugito and Maftuchah (1995) obtained the highest yield of young rhizome of ginger (171.8 g/plant) with application of 45 t FYM + 600 kg KCL ha^{-1}.

Aiyadyrai (1996) reported that N @ 50-100 kg ha^{-1} increased the yield of ginger by 18 to 32 per cent and improved the dry matter content of rhizome.

Joseph and Jayachandran (1996) revealed the necessity of increasing the quantity of fertilizer to 112.5, 75 and 75 NPK kg ha^{-1} to obtain higher yield of ginger.

Ai-xizhen *et al.* (1997) tried several fertilizer treatments out of which application of 40 kg N, 75 kg P_2O_5 and 40 kg K_2O/667 m^2 gave the better dry matter accumulation and higher yield of ginger.

Gowda *et al.* (1997) found that the application of 150 kg N, 75 kg P_2O_5 and 50 kg K_2O ha^{-1} gave the highest yield of ginger.

Kempe Gowda and Melanta (1998) reported that application of nitrogen at 150 kg ha^{-1} recorded maximum fresh rhizome yield of ginger (19.33 t ha^{-1}) compared to other nitrogen levels.

Peter (1998) reported that application of neem cake @ 2 t ha^{-1} along with N, P and K 75, 50 and 50 kg ha^{-1} significantly increased ginger yield by 33%.

Sadanandan and Hamza (1998) revealed that groundnut cake registered higher ginger yield (4077 kg ha-1) followed by neem cake, cotton cake, NPK with micronutrients and gingily cake and were on par.

Sadanandan *et al.* (1998) found that application of NPK @ 60:50:120 kg ha^{-1} for turmeric was on par with neem cake (2 t ha^{-1}) or groundnut cake (1 t ha^{-1}) with regard to yield.

Venkatesha *et al.* (1998) revealed that the plants provided with 150:125:250 NPK kg ha^{-1} recorded the highest cured yield of turmeric (8.87 t ha^{-1}) compared to other levels of NPK.

Mridula and Jaychandran (1999) concluded a field trial at Kerala revealed that N, P_2O_5 and K_2O at 30:30:60 kg ha^{-1} gave the highest fresh rhizome yield of ginger (33.91 t ha^{-1}) and the highest net returns and B:C ratio.

Srinivasan *et al.* (2000) reported that the significantly higher dry yield in ginger was observed with Raj Phos and Gafsa Phos application with FYM and it was significantly higher than other sources of P applied.

Patil and Biradar (2001) reported that the highest chilli yield of 19.12 qha^{-1} was recorded with the application of 200 per cent RDF + FYM + vermicompost than other nutrient levels.

The rhizome yield of turmeric increases due to application of 200: 160: 100 kg N: P_2O_5: K_2O ha^{-1} as compared to control (Yamgar *et al.* 2001).

Majumdar *et al.* (2002) revealed that the rhizome and straw yield of turmeric increased significantly with increasing N levels up to 90 kg ha^{-1} and there after the increase was non significant.

Soni Aggrawal *et al.* (2002) reported that FYM with mulch was significant superior over others in exhibiting its, better regarding yield contributing characters and finally yield of rhizomes in ginger.

Majumdar *et al.* (2003) stated that the application of 100 kg N along with 5 t FYM ha^{-1} following the practice of mother rhizome removal was an optimum dose to ginger for getting good yield in acidic soils of Meghalaya.

Amaresh *et al.* (2004) revealed that neem cake application (2 t ha^{-1}) and FYM amendment (10 t ha^{-1}) treatments showed higher germination and higher yield of green ginger and reduced soft rot incidence.

Majumdar *et al.* (2005) reported that maximum rhizome yield of ginger was obtained (22.2 t ha^{-1}) at 200 kg K_2O and 5 tonnes farm yard manure ha^{-1} and was 53.1% higher over control yield (14.5 t ha^{-1}).

Madhuri *et al.* (2006) revealed that the maximum fresh yield of turmeric (261.52 q) was recorded in recommended dose of fertilizer (120:60:60 NPK ha^{-1}) followed

by FYM + *Azoto.* + *PSB* (259.59 q) which was also at par with each other.

Swain *et al.* (2006) reported that application of 120:60:120 kg $N:P_2O_5:K_2O$ ha^{-1} recorded increase in yield attributing characters of turmeric viz; rhizome weight, primary fingers/plant, secondary fingers/plant and green rhizome yield compared to control.

Application of 100% NPK + 30 tonnes FYM ha^{-1} to potato resulted in significantly higher tuber yield of 456 q ha^{-1} compared with that of other treatments except 100% NPK + 30 tonnes Nadep/ha and 75% NPK + 30 t FYM ha^{-1} (Singh and Kushwah, 2006).

The application of 100% RDF recorded significantly the higher green turmeric yield (389.84 q ha-1) than other treatments (Anonymous, 2007b).

The application of 100% RDF has recorded significantly higher ginger yield (102.80 q ha-1) than rest of the treatments (Anonymous, 2007c).

Chandre Gowda (2007) reported that maximum fresh (39.66 g) and dry (8.10 g) weight of bulb and yield of garlic (16.18 t/ha) were obtained in treatment combination of 100% NPK + bio-fertilizer + vermicompost than other integrated nutrient management practices.

Mohamed Amanullah *et al.* (2007) revealed that among the fertilizer levels 100 per cents NPK recorded higher yield than 75 per cent NPK in casava.

Velmurugan *et al.* (2007a,b) stated that combined application of FYM along with *Azospirillum* + *Phospobacteria* + VAM recorded supremacy for yield attributes of turmeric viz., more number of mother rhizomes per plant (13.19) and secondary rhizomes per plant (19.89).

Dash *et al.* (2008) reported that the highest fresh rhizome yield of ginger (18.70 t ha^{-1}) was obtained for treatment in which 100% recommended dose of inorganic fertilizer in combination with *Azospirillum sps*. 10 kg ha^{-1} and FYM 10t ha^{-1} applied to the soil.

Amoung the nutrient sources used for ginger the general recommended dose of fertilizer with 25 t FYM (96:60:60 kg N:P:K ha^{-1}) was found significantly superior (11.10 t ha^{-1}) over nutrient source used through organic input (48 kg N through FYM + 48 kg N through Neem seed cake (7.90t ha^{-1}) (Anonymous, 2009).

2.3.3 Effect of integrated nutrient management on quality

Pawar and Patil (1987) reported the highest oleoresin content in ginger (6.11 per cent) on dry weight basis in treatments receiving a dose of 30 t FYM ha^{-1} + 75 Kg N + 30 kg P_2O_5 + 30 kg K_2O ha^{-1} and harvested at 8 months after planting.

Organic nutrition has been reported to increase the yield and improve the quality of ginger. Ginger performs well

with good supply of humus and organic matter, which is positively correlated with yield (Cho *et al.* 1987).

Wiroatmodjo (1990) suggested that application of nitrogen at 0, 200 or 400 kg ha^{-1} did not influence the crude fiber content of the rhizome in ginger variety Badak.

Sugito and Maftuchah (1995) in a field trial in alfisol, ginger plants were supplied with 0, 15, 30 or 45 t of FYM and 0, 300, 600 or 900 kg KCl ha^{-1}. An application of 45 t FYM ha^{-1} + 600 kg KCl ha^{-1} resulted in acceptable quality of ginger in terms of fiber content.

Ai Xizhen *et al.* (1998) concluded that nitrogen application at an optimum rate of 40 kg/ha resulted in the highest content of protein and amino acids and favoured the formation of starch, sugar, ascorbic acid and volatile oil in ginger, but when too much nitrogen was supplied and then all the above contents were decreased. Overall rhizome quality was better when 40 kg N, 75 kg P_2O_5 and 40 kg K_2O ha^{-1} were applied.

Sadanandan and Hamza (1998) reported that application of organic cakes increased oleoresin production of ginger. Neem cake registered higher oleoresin production (320 kg ha^{-1}) followed by groundnut cake.

The highest yield (3.73 t ha^{-1}) and oleoresin (4.02%) was obtained with application of FYM (10 t ha^{-1}) + Coir

compost (1.25 t ha^{-1}) + Azospirillum (20 kg ha^{-1}), which was on par with coir compost + NPK (75:50:50 kg ha^{-1}) with and without FYM (Srinivasan *et al.*, 2000).

Majumdar *et al.* (2003) stated that the application of 100 kg N along with 5 t FYM ha^{-1} following the practice of mother rhizome removal was the optimum dose for getting good quality of ginger in acidic soils of Meghalaya.

2.3.4 Effect of integrated nutrient management on economics

Mohanty *et al.* (1990) obtained the maximum profit (Rs.48000 ha^{-1}) in the treatment with the highest fertilizer application of 125 kg N, 75 kg P_2O_5 and 150 kg K_2O ha^{-1} to ginger.

Economic analysis showed that NPK fertilizers gave maximum B: C ratio followed by groundnut cake to ginger (Sadanandan and Hamza, 1998).

The highest benefit (Rs. 48500 ha^{-1}) was realized with the maximum yield of ginger (10.16 t ha^{-1}), by planting 1.8 tonnes of seed rhizomes with the application of N 125 P 70 K150 kg ha^{-1} under pottangi condition (Orissa) using cv. 'Suruchi' (Mohanty *et al.*, 1993).

FYM @ 6 t ha^{-1} was found to be superior for growth and yield of ginger (3.30 t ha^{-1}) and also gave additional net

profit of Rs. 6820 under Madhyapradesh (Mandsaur) conditions in Madhya Pradesh (Khandkar and Nigam, 1996).

Venkatesha and Khan (1997) reported that application of 150:125:250 N, P_2O_5 and K_2O kg ha^{-1} resulted in the highest benefit:cost ratio in turmeric.

Venkatesha *et al.* (1998) stated that considering the economy, yield and BCR, application of N, P_2O_5, K_2O at the rate of 150:125:250 kg ha^{-1} was found to optimum to turmeric irrespective of the cultivars.

Mridula *et al.* (1999) reported from field trial at Kerala that N, P_2O_5 and K_2O at 30:30:60 kg ha^{-1}, respectively gave the highest fresh rhizome yield of ginger (33.91 t ha^{-1}) and the highest net returns and B:C ratio.

Yamgar *et al.* (2001) reported that the highest Cost: Benefit ratio of 1.62 was obtained by the application of 200: 100: 100 kg N: P_2O_5: K_2O ha^{-1} as compared to other nutrient levels to turmeric.

Dash *et al.* (2008) revealed that the highest benefit : cost ratio of ginger (3.46) was obtained due to application of 100% inorganic N + *Azospirillum* + FYM, 75% inorganic N + *Azospirillum* + FYM and 30% inorganic N + *Azospirillum* + FYM (2.44, 1.97 and 1.80, respectively).

2.3.5 Effect of integrated nutrient management on nutrient uptake

The uptake of N, P and K by leaf and pseudostem increases up to 180 days and then decreased, where as up take in rhizome steadily increases till the harvest. Ginger rhizomes were mainly N and K exhausting, intermediary in P and Mg removal and the least in Ca removal (Nagrajan and Pillai, 1979)

Based on the nutrient requirement of ginger, Hackett and Carolance (1982) placed the elements in the following order : N, K, P, Ca and Mg.

Application of neem cake @ 2 t ha^{-1} to ginger increased the availability of organic carbon and potash in soil. However, maximum availability of exchangeable calcium in the soil was recorded by FYM (10 t ha^{-1}), followed by Neem cake (Sadanandan and Rohini Iyer, 1986).

Haag *et al.*(1990) found that when *Zingiber officinale* cv. *Brasil* rhizome were planted in soil enriched with manure, lime and NPK fertilizers, the macronutrients were accumulated in the following decreasing order N, K, Ca, Mg, S and P and the order for micronutrients was Fe, Mn, Zn, B and Cu.

Konde *et al.* (1990) noticed that the uptake of nitrogen was increased when the ginger setts were inoculated with *Azotobacter chroococcum* or *Azospirillum brasilense* along

with the application of 50 kg N ha^{-1}. Uptake of N, P and K by ginger differed significantly with different levels of nitrogen.

Pawar and Patil (1990) revealed that nitrogen content in ginger was maximum at 6 months and it decreased consistently with delay in harvesting.

Pawar and Gavande (1992) noticed that uptake of N, P and K (59.33, 18.86 and 75.83 kg ha^{-1}, respectively) was maximum at 80 kg N ha^{-1}. However, increase in the nitrogen to 120 kg ha^{-1} resulted in decreased uptake of N, P and K by ginger rhizome.

A ginger crop removes 35-50 kg p ha^{-1}. The leaf N and K content had positive correlation with fresh yield of ginger while leaf N content with dry yield (Murlidharan *et al.* 1974).

Prasad *et al.* (1997) revealed that the cultivar Nadan of ginger removed the more nitrogen (150.31 kg ha^{-1}) and potassium (213.31 kg ha^{-1}) where as, cv. Maran removed the more phosphorus (35.91 kg ha^{-1}) from the soil.

Thakur and Sharma (1997) found that the NPK uptake by ginger increased with increasing N and P rates up to 150 and 90 kg ha^{-1}, respectively.

Joseph *et al.* (1998) concluded that nutrient uptake in ginger increased as fertilizer rates increased. They

recorded higher NPK uptake from treatment 150% RDF. The RDF was 75:50:50 kg NPK ha^{-1}.

Peter (1998) reported that application of neem cake @ 2 t ha^{-1} along with N, P and K @ 75,50 and 50 kg significantly increased nutrient availability in soil and ginger yield by 33%.

Sadanandan and Hamza (1998) reported that application of organic cakes to ginger increased nutrient availability as well as improved physical condition of soil.

The nutrient uptake of ginger (phosphate and potassium) was the highest with application of FYM (10 tha^{-1}) + coir compost (1.25 t ha^{-1}) + *Azospirillum* (20 kg ha^{-1}), which was on par with coir compost + NPK (75:50:50 kg ha^{-1}) with and with out FYM (Srinivasan *et al.*, 2000).

Patil and Biradar (2001) reported that the combined application of NPK with FYM and vermicompost significantly increased the uptake of NPK nutrients by chilli over the application of NPK + FYM alone.

Majumdar *et al.* (2002) revealed that there was significant increase in N,P and K uptake by turmeric with N and farm yard manure application.

3 MATERIAL AND METHOD

The field experiment entitled, “Effect of irrigation systems and integrated nutrient management on growth, yield and quality of ginger” was conducted during the year 2005-06 and 2006-07. The details of material used and methods adopted during the course of investigation are presented in this chapter.

Details of experimental material

Experimental site

The field experiment was laid out in survey number 65 during the year 2005-2006 and 2006-2007 at Instructional Farm of Inter Faculty Department of Irrigation Water Management, Mahatma Phule Krishi Vidyapeeth, Rhauri, Dist. Ahmednagar (M.S.). The project farm is geographically situated between 19^{o} 47’ and 19^{o} 57’ North latitude and 74^{o} 19’ and 74^{o} 32’ East longitude. The altitude varies from 495 to 569 m above the mean sea level.

Soil

The soil of experimental field was 45 cm in depth with uniform and leveled topography. In order to know the physical nature and fertility status of the soil, representative composite soil samples from 0-30 cm depth at 10 different locations of experimental site were collected before the start of experiment

during 2005-06. The data pertaining to physico-chemical properties of experimental site and methods adopted for analysis are presented in Table 1.

Similarly, treatmentwise soil samples were drawn after harvest of each crop during both seasons to determine the availability of nutrient.

The soil of experimental field was well drained, taxonomically sandy clay loam in texture, low in available nitrogen (188.16 kg ha $^{-1}$), medium in available phosphorus (21.76 kg ha $^{-1}$) and high in potassium (358.40 kg ha $^{-1}$). The soil was slightly alkaline in reaction (pH 8.15).

Climatic condition

Geographically, the Mahatma Phule Krishi Vidyapeeth, Rahuri is situated between 19^{0}47' and 19^{0}57' North latitude and 74^{0}19' and 74^{0}32' East longitude. The altitude above mean sea level is 495 to 569 metre. This tract is lying on the eastern side of western ghat and falls under rain shadow area.

Climatologically, this area falls in the scarcity zone (semi-arid tropics) with annual rainfall ranging between 307 and 619 mm. The average rainfall is 520 mm. The rainfall is erratic and ill distributed in 15 to 45 rainy days in different years. Out of total rainfall, about 80 % is received from South West monsoon (June to September), while the rest from North – East monsoon (October and November).

Table1. Physical and chemical properties of experimental soil

Sr. No	Soil properties	Composition	Method adopted	Reference
A.	**Physical properties**			
1.	Particle size distribution (%)			
	i. Coarse sand	12.70	International pipette method	Piper, (1966)
	ii. Fine sand	39.05	International pipette method	Piper,(1966)
	iii. Silt	22.93	International pipette method	Piper,(1966)
	iv. Clay	24.60	International pipette method	Piper, 1966
2.	Textural class	Sandy clay loam		
	Soil moisture constants			
3.	i. Moisture at 33 KPa (%)	27.57	Pressure plate apparatus	Richards, (1965)
	ii. Moisture at 1500 KPa (%)	15.00	Pressure plate apparatus	Richards, (1965)
4.	Bulk density (g cm $^{-3}$)	1.41	Core sampler method	Dastane, (1972)
5.	Hydraulic conductivity (cm hr $^{-1}$)	3.86	Constant head method	Klute and Diskson, (1986)
6.	Infiltration rate (cm hr $^{-1}$)	3.24	Double ring infiltrometer	Dastane, (1972)
B]	**Chemical properties**			
1.	Soil P^{H}(1: 2.5 Soil :water)	8.15	Potentiometric	Jackson, (1973)
2.	Electrical conductivity(ds m^{-1}) (1:2.5 soil :water)	0.37	Conductometric	Jackson, (1973)
3.	Organic carbon (%)	0.70	Walkley and Black's rapid titration method	Piper,(1966)
4.	Organic matter	1.20	O.C.(%)X1.724	
5.	Available nitrogen (kg ha^{-1})	188.16	Alkaline $KmnO_4$ method	Subbaih and Asija, (1956)
6.	Available phosphorus (kg ha^{-1})	21.76	0.5 N $NaHCO_3$ Ascorbic acid	Olsen and Dean (1965)
7.	Available potassium (kg ha^{-1})	358.40	Normal NH_4 OAC flame photometer	Knudsen and Peterson, (1982)

The annual mean maximum temperature is 37.9^{0}C with a range between 33 and 43^{0}C and annual mean minimum temperature is 17.2^{0}C with a range between 3 and 18^{0}C. The mean relative humidity in the morning and evening is 59 and 35 %, respectively. Agro-climatically the location is in the drought prone area of Maharashtra state, characterized by low, erratic rainfall with less rainy days coupled with long dry spells.

3.1.3.1 Nature of season during the experimental period

In order to get an idea about the climatic conditions prevailed during the period of present investigation, the meteorological data recorded on the important weather parameters during both the cropping seasons are presented in Table 2 a and 2 b, respectively and depicted in Fig. 1 and 2.

The total rainfall received during 2005-06 and 2006-07 was 526.60 mm in 27 rainy days and 717.34 mm in 38 rainy days, respectively, which was 1.27 and 37.95 % higher than average annual rainfall of 520 mm. In the year, 2005-06, the rainfall received in 24th MW was 18 mm. The continuous rainfall in every MW was received from 28th to 42nd MW in formative stage of ginger during 2005-06 which helped for better growth and yield during this year. The maximum and minimum weekly temperature in the year 2005-06 ranged between 26.9 and 40.7^{o}C and 7.2 and 24.6^{o}C, respectively. The mean weekly morning relative humidity ranged between 51 and 92 % and evening humidity ranged between 16 and 75 %. The total pan evaporation in the year 2005-06 was 1107.20mm. The daily maximum and minimum pan

Table 2 a). Weekly mean weather during May to February, 2005-06

M.W.	Date	Temperature (°C)		Relative humidity (%)		Wind speed (kmhr^{-1})	Sun shine hrs	Rain fall (mm)	No.of rainy days	Evaporation (mm)
		Max.	Min.	Morn.	Even					
May, 2005										
20	14-20	40	20.6	51	16	4.1	11.5	0	0	10.6
21	21-27	40.7	24.2	54	19	3.7	10	0	0	10.2
22	28-03	36.7	24.6	62	29	4.8	7.1	0	0	8
June,2005										
23	04-10	38.8	22.5	69	31	4.2	10	0	0	8.9
24	11-17	36.4	23.7	76	44	3.3	6.9	18	2	7
25	18-24	35.4	24.4	71	53	7.7	6.9	0	0	8.2
26	25-01	30.2	24.2	79	71	9.7	0.4	3	0	5.4
July, 2005										
27	02-08	30.7	24	74	54	8.8	2.6	0	0	6.4
28	09-15	31.4	23	79	54	4	2.5	4.8	1	4.7
29	16-22	32.8	22.9	86	64	1.5	4.4	95.2	4	4.8
30	23-29	27.3	22.5	87	75	3.7	1.1	42	2	2.3
August,2005										
31	30-05	28.1	22.5	87	75	4.3	1.6	31.2	2	2.6
32	06-12	28.8	22.5	83	64	3.4	2.7	10.2	1	3.2
33	13-19	29.9	21.9	83	64	2.7	3.3	3.8	1	3.4
34	20-26	30.3	20.5	83	57	2.3	6	2.4	0	3.9
35	27-02	32	21.5	84	53	1.6	7.6	43.4	2	4.5
September, 2005										
36	03-09	30.5	22.1	92	74	1.4	3.8	126.6	5	3.1
37	10-16	29.2	22.7	81	67	5.1	2.7	24.2	1	3.1
38	17-23	29.4	22.2	82	69	5.3	3.4	80	2	3.9
39	24-30	29.3	19.9	86	61	8.1	5.5	3.2	1	3.5
October,2005										
40	01-07	31.3	21.2	82	48	0.9	5.1	2.6	0	3.3
41	08-14	32.8	17.9	81	41	2.5	9.2	0	0	5.4
42	15.21	29.4	19.6	86	56	1.6	4.1	33.2	3	2.3
43	22.28	30.8	15.8	84	35	1.3	8.2	0	0	4.1
November,2005										
44	29-04	31	12.8	79	24	0.8	7.6	0	0	3.8
45	05-11	29.4	18.7	74	27	1.7	9.4	0	0	4.2
46	12-18	32.2	10.1	79	24	1.4	9.5	0	0	3.7
47	19-25	30.6	9.8	74	23	1.3	9.6	0	0	4.2
December,2005										
48	26-02	30.1	13.4	71	32	0.8	7.9	0.8	0	3.6
49	03-09	29.5	13.1	75	34	0.4	7.8	0.4	0	2.7
50	10-16	27.7	8.6	78	28	0.5	9.3	0.5	0	2.4
51	17-23	27.6	7.8	76	26	0.6	9	0.6	0	2.3
52	24-31	27.3	8.8	78	32	0.5	9.5	0.5	0	2.4
January,2006										
1	01-07	28.1	9.7	81	34	8.9	0.9	0	0	2.5
2	08-14	29.1	10.1	78	30	9.6	0.7	0	0	2.5
3	15-21	31.6	12.9	75	34	9.4	0.6	0	0	2.8
4	22-28	26.9	7.2	71	22	10.3	1.8	0	0	3.5
5	29-04	30	10.2	64	22	9.9	1.4	0	0	3.5
February,2006										
6	05-11	30.2	11.4	65	16	10.2	1	0	0	3.6
7	12-18	32.2	13.1	65	23	10.1	1.1	0	0	3.8
8	19-25	35	12.8	58	20	10.3	0.7	0	0	4.4
9	26-04	29.5	18.2	64	27	7.5	1.1	0	0	4.2
							Total	**526.6**	**27**	

Table 2b). Weekly mean weather during April 2006 to February,2006-07

M.W.	Date	Temperature (ºC)		Relative humidity (%)		Wind speed (kmhr^{1})	Sun shine hrs	Rain fall (mm)	No. of rainy days	Evaporation (mm)
		Max.	Min.	Morn.	Even.					
May,2006										
18	30-06	39.7	23.2	45	18	10.1	2.6	0	0	7.8
19	07-13	40.1	20.2	47	16	10.3	4.4	0	0	8.8
20	14-20	39.4	20.4	58	23	10.6	6.9	15.8	1	9.5
21	21-27	36.4	23.9	64	32	9.5	5.3	4.8	1	7.8
22	28-03	33.2	23.4	79	51	4.3	5.3	51.4	2	3.8
June,2006										
23	04-10	34.7	21.8	70		9.4	5.4	0	0	5.3
24	11-17	36.4	22.8	62	32	9	3.2	1.4	0	5.9
25	18-24	34.1	22.5	83	58	5.6	3.1	85.4	4	4
26	25-01	35.5	23.9	79	68	2.5	4.8	3.8	0	3
July,2006										
27	02-08	28.5	22.6	83	73	2.1	7.5	91.4	3	3
28	09-15	30.3	23.1	79	60	2.7	8.5	0.04	0	3.9
29	16-22	30.4	22.7	80	63	3.4	5.7	3	0	3.5
30	23-29	28.3	22.7	80	72	1.8	6.8	8.2	1	3.1
31	30-05	28	22.2	81	64	1.8	7.8	7.4	1	3.3
August,2006										
32	06-12	26.2	21.8	86	74	1.4	6.3	95.8	4	2.4
33	13.19	29	22.4	82	65	3.6	6.2	2.2	0	3.6
34	20-26	29.5	21.4	83	65	4.4	3.6	1.6	0	3
35	27-02	29.3	21.4	83	59	2.9	3.9	1.4	0	3.1
September,2006										
36	03-09	30.6	20.7	85	64	5.8	1.9	36.4	2	3
37	10-16	31.4	21.9	88	67	5.9	0.9	103.6	4	2.2
38	17-23	30.5	21.8	86	60	4.8	1.5	75.6	4	2.5
39	24-30	31.1	21.7	83	55	7.6	1.4	18.2	3	3.4
October,2006										
40	01-07	29.8	22.2	88	74	3.9	1.4	45.2	4	2.4
41	08-14	31.7	17.9	80	44	8.3	1.1	0	0	3.5
42	15-21	32.8	18	70	35	9.1	1.1	0	0	3.9
43	22-28	31.2	16.5	75	35	9.5	0.9	7.2	1	3.5
44	29-04	29.8	18	84	51	8.3	1.8	0	0	3.1
November,2006										
45	05-11	29.4	16.3	81	48	7.8	1.1	33.7	1	2.3
46	12-18	28.9	13.3	77	39	9.3	1.3	0	0	2.6
47	19-25	30	16.5	77	49	6.9	0.5	15	1	2
48	26-02	30.8	17.9	77	45	7.3	0.3	8.8	1	2
December,2006										
49	03-09	30.8	13.7	81	37	8.8	0.6	0	0	2.2
50	10-16	28.9	12.1	82	39	9	0.7	0	0	2.2
51	17-23	28.2	9.2	83	35	9	0.9	0	0	2.3
52	24-31	29.6	12.3	79	37	8.5	0.4	0	0	2.4
January,2007										
1	01-07	28.5	10.1	75	36	8.9	0.5	0	0	2.7
2	08-14	29.1	11.3	81	38	8.7	0.5	0	0	2.9
3	15-21	30.1	11	72	33	9.2	0.4	0	0	3
4	22-28	31.2	12.2	54	35	9.3	0.2	0	0	3.6
5	29-04	31.9	14.6	59	35	9	0.4	0	0	3.7
February,2007										
6	05-11	31.5	12.5	51	27	9.5	0.8	0	0	4.6
7	12-18	28.9	12.2	70	32	9.7	1.7	0	0	5.4
							Total	717.34	**38**	

evaporation was 10.9 mm on 23.4.2005 and 1.4 mm on 11.11.2005, respectively.

In year 2006-07, there was late onset of monsoon in 25th MW with sufficient rainfall (85.40 mm). Thereafter, there were continuous showers up to 40th MW. Rainfall received during 45th MW was 33.70 mm.

The maximum and minimum weekly temperatures in year 2006-07 ranged between 26.2 and 40.1^{o}C and 9.2 and 23.9 ^{o}C, respectively. The mean weekly morning relative humidity ranged between 45 and 98 per cent and evening humidity ranged between 16 and 74 per cent. The total pan evaporation during the first year and second year was 1107.20 and 890.90 mm, respectively. The daily maximum and minimum pan evaporation was 11.70 mm on 24.5.2005, 10.90 on 15.5.2006 and 0.6 mm on 16.10.2005, 1.00 on 16.09.2006, respectively.

Cropping history of the experimental plot

The information regarding the crops grown on the experimental plot during previous three years of the investigation is presented in Table 3.

Table 3. Cropping history of the experimental field

Year	Crop			Fertilizers (kg ha^{-1})								
	Kharif	*Rabi*	Summer	*Kharif*			*Rabi*			Summer		
				N	P	K	N	P	K	N	P	K
2002-03	Soybean	Chick pea	Fallow	50	75	0	25	50	0	-	-	-
2003-04	Fallow	Wheat	Fallow	-	-	-	120	60	40	-	-	-
2004-05	Soybean	Chick pea	Fallow	50	75	0	25	50	0	-	-	-

3.1.5 Composition of fertilizers

The composition of N, P_2O_5 and K_2O per cent in organic manures and inorganic fertilizers are presented in Table 4.

Table 4. Composition of organic and inorganic fertilizers

Sr.No.	Manures and fertilizer	N (%)	P_2O_5 (%)	K_2O (%)
1	FYM	0.5	0.30	0.46
2	Neem Cake	5.00	-	-
3	Urea	46.00	-	-
4	Single Super Phosphate	-	16.00	-
5	Muriate of potash	-	-	60.00

3.1.6 Details of pressurized irrigation systems

3.1.6.1 Trickle system

Trickle irrigation is slow and frequent application of water in the vicinity of root zone of the crop, resulting minimum conventional losses, deep percolation, run-off and soil water evaporation. The details of trickle irrigation system are as below

1. Types of main and submain	:	PVC
2. Size of main	:	63 mm
3. Size of submain	:	50 mm
4. Size of manifold	:	40 mm
5. Type of laterals	:	LDPE
6. Size of laterals	:	16 mm
7. Spacing between laterals	:	40 cm
8. Type of emitter	:	P.C
9. Spacing between emitters	:	60 cm
10. Emission uniformity	:	93%
11. Average discharge rate	:	3.67 lph
12. Operating pressure	:	1.0 kg cm^{-2}

3.1.6.2 Sprinkler systems

Floppy sprinkler and overhead sprinkler system comes under sprinkler irrigation. The system details of floppy sprinkler and overhead sprinkler irrigation systems are given below.

1. Types of main and submain	:	PVC
2. Size of main	:	63 mm
3. Size of submain	:	50 mm
4. Size of manifold	:	40 mm
5. Spacing between laterals	:	Floppy sprinkler – 6m Overhead sprinkler- 12m
6. Spacing between nozzle	:	Floppy sprinkler – 6m Overhead sprinkler- 12m

Type of pressurized irrigation system	Operating pressure, kg cm^{-2}	Emitter / Nozzle discharge, lph
Drip irrigation	1.00	4.00
Floppy sprinkler	2.00	280
Overhead sprinkler	2.50	1512

3.2 Methods

3.2.1 Experimental Details

The experiment was laid out in strip plot design with three replications. There were 20 treatment combinations comprising of four irrigation systems viz. Surface, Drip, Floppy sprinkler and Overhead sprinkler enforced at different stages on cumulative pan evaporation basis with constant depth of irrigation and five treatments of integrated nutrient management were used. The gross and net plot sizes were 5.40 x 3.60 m (19.44 m^2) and 4.60 x 3.20 m (14.72 m^2), respectively. The plan of layout of the experiment with allocation of various treatments is depicted in Fig.3.

The treatment details along with symbols used are given below

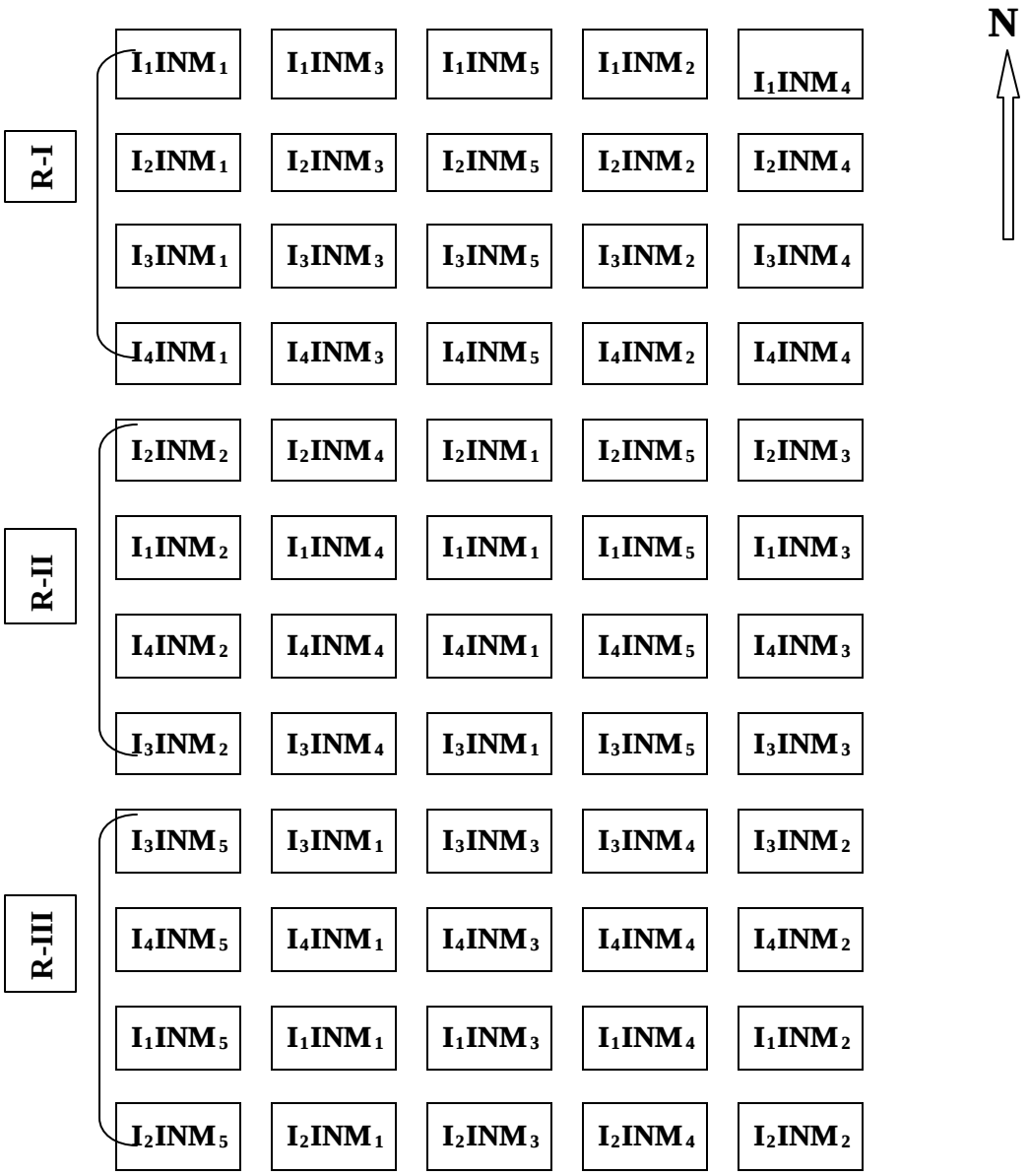
Sr.No.	Treatment details	Symbols
A	**Irrigation systems**	
1	Surface irrigation (70 mm CPE)	I_1
2	Drip irrigation (Alternate day irrigation)	I_2
3	Floppy sprinkler (35 mm + 35 mm CPE-in two splits)	I_3
4	Over head sprinkler irrigation (35 mm + 35 mm CPE-in two splits)	I_4
B	**Integrated Nutrient Management**	
1	100% RDN through organic (50% FYM + 50% neem cake) + *Azotobactor* + *PSB*	INM_1
2	75% RDN through organic (50% FYM + 50% neem cake) + 25% RDN through inorganic fertilizer + *Azotobactor* + *PSB*	INM_2
3	50 % RDN through organic (50% FYM + 50% neem cake) + 50 % RDN through inorganic fertilizer + *Azotobactor* + *PSB*	INM_3
4	25% RDN through organic (50% FYM + 50% neem cake) + 75% RDN through inorganic fertilizer + *Azotobactor* + *PSB*	INM_4
5	100% RDF + 25t FYM + *Azotobactor* + *PSB*	INM_5

N.B. :

1. Recommended dose of FYM (25 t ha $^{-1}$) was applied to all treatments before planting of ginger.
2. Recommended dose of fertilizer was 75 : 50 : 50 NPK kg ha $^{-1}$
3. Four hand weedings : First at 45 DAP and subsequent hand weedings at an interval of 20 days.
4. Seed treatment was given with 50 % Carbaryl 40 g and 50 % Bavistin 10 g in 10 liters of water. *Azotobactor* and *PSB* were applied at the time of irrigation.

Other details of the experiment

Year of commencement	:	2005-06
Design of experiment	:	Strip plot
Replications	:	Three
Plot size	:	Gross-5.40 x 3.60 m^2 Net-4.60 X 3.20 m^2
Planting material	:	Three to five budded rhizomes
Planting season	:	Summer (April–May)
Variety of the crop	:	Mahim
Recommended dose of fertilizer	:	75:50:50 N, P_2O_5, K_2O kg ha^{-1}



Treatments

A) Irrigation systems

1. Surface irrigation – I_1
2. Drip irrigation – I_2
3. Floppy sprinkler – I_3
4. Overhead sprinkler – I_4

Design – Strip plot design

Replications – Three

Plot Size – Gross :5.40x 3.60m
Net : 4.60 x 3.20m

Crop – Ginger (*Zingiber officinale* Rosc.)

Planting date –
May 15,2005 (First trial)
April 30,2006 (Second trial)

B) Integrated nutrient management (INM)

1. 100% RDN through organic sources (50%FYM+50%neem cake) – INM_1
2. 75% RDN through organic (50%FYM+50% neem cake) + 25%RDN through inorganic fertilizer – INM_2
3. 50% RDN through organic (50%FYM+50% neem cake) + 50%RDN through inorganic fertilizer – INM_3
4. 25% RDN through organic (50%FYM+50% neem cake) + 75%RDN through inorganic fertilizer – INM_4
5. 100% RDF + 25 t FYM– INM_5 (*Azotobacter* and *PSB* rhizome treatment as common to all)

Fig.3. Field layout of the experiment

3.2.2 Cultural operations

A chronological sequence of various cultural operations carried out for ginger are presented in Table 5. The details of practices adopted for cultivation of ginger crop are explained below.

3.2.2.1 Seed and planting

Healthy rhizomes of *'Mahim'* cultiver raised at Agricultural School, Borgaon Tal/Dist. Satara were used as a source of seed material for planting. The rhizome size of 30 to 50 g was made by keeping 3 to 4 sprouted eye buds on the each rhizome. Good quality rhizomes with healthy sprouted buds were selected for plantation by rejecting rhizomes having damaged buds and split. To protect against soil borne disease, the rhizomes were allowed to soak in 0.1 per cent solution of Bavistin for 10 minutes. The rhizomes with 3 to 4 sprouted eye duds were planted in 20 cm row spacing and 20 cm plant spacing on 15 May 2005 and 30 April 2006. Healthy rhizomes @ 1500 kg ha^{-1} after storage were used for planting.

3.2.2.2 Seed treatment

Before planting the seed rhizomes were treated with 50% Carbaryl 40g in 10 litre water for 10 minutes. It was also treated with *Azotobacter* and *Phosphate Solublizing Bacteria* (PSB) inoculants treatment wise. These treatments were given after the fungicidal treatment.

Table 5. Schedule of cultural and other operations carried out in the experimental plot

Sr. No.	Name of the operation	2005-06		2006-07	
		Frequency	Date	Frequency	Date
A	**Pre-planting operations**				
1.	Ploughing	1	14.04.2005	1	10.04.2006
2.	Disc harrowing	2	17.04.2005& 21.04.2005	2	13.04.2006& 20.04.2006
3	Harrowing	1	25.04.2005	1	22.04.2006
4.	Stubble collection		29.04.2005		23.04.2006
5	Layout preparation	1	10.05.2005	1	25.04.2006
6	FYM application	1	12.05.2005	1	26.04.2006
B	**Planting of rhizomes**	1	15.05.2005 & 16.05.2005	1	30.04.2006 & 1.05.2006
C	**Irrigation**				
1.	Common irrigation (1)	1	15.05.2005	1	1.05.2006
2.	Installation of system		21.05.2005		6.05.2006
3.	Subsequent irrigation	As per Appendix	-	As per Appendix	-
D	**Post planting operations**				
1.	Gap filling		24.06.2005		05.06.2006
2.	Hand weedings	4	13.06.2005, 11.07.2005, 05.08.2005 & 10.09.2005	4	01.06.2006, 30.07.2006, 31.07.2006 & 1.09.2006
3.	Earthing up	1	10.09.2005	1	1.09.2006
E	**Fertilizer application**				
1.	N in two splits				
i.	6 weeks after planting	1	27.06.2005	1	15.06.2006
ii.	12 weeks after planting	1	08.08.2005	1	30.07.2006

2.	P_2O_5 and K_2O As a basal dose	1	15.05.2005	1	30.04.2006
F	**Plant protection**	2		2	
1.	Spraying of fungicide and insecticide		21.07.2005 & 14.08.2005		03.07.2006 & 07.08.2006
G.	**Harvesting**	1	18.02.2005	1	13.01.2007

3.2.2.3 Gap filling

The gap filling was undertaken within one month to maintain the required plant population of the experimental plot during both the years.

3.2.3 Fertilizer application

The experimental ginger crop was fertilized as per the treatments of Integrated Nutrient Management during both the seasons. The dose of N was applied through different organic sources (FYM and Neem cake) and inorganic fertilizer as urea. The dose of P and K was applied through Single Super Phosphate and Muriate of Potash by substracting added through FYM.

The organic sources of nitrogen was applied as a basal dose and inorganic nitrogen source was applied at 6 and 12 weeks after planting in two equal splits. The full dose of P_2O_5 and K_2O fertilizers were applied as a basal dose at the time of planting of ginger. The fertilizers were applied in bands by opening small furrow with help of *Kudali* on lateral side of ginger row. The bio-fertilizers as *Azotobacter* and *Phosphate solublizing bacteria* were applied as a basal by mixing in soil at initial irrigation time after planting. The same dose of fertilizer

was applied as per treatments to each plots for next year experiment.

3.2.4 Interculturing

For uniform distribution of water during early stage of crop growth, border method was laid out and leveled manually in surface, drip, floppy sprinkler and overhead sprinkler irrigation system during both the year of experimentation. The ginger crop was kept weed free by four hand weedings given on 13.06.2005, 11.07.2005, 5.08.2005 and 10.09.2005 during 2005-06 and on 01.06.2006, 3.07.2006, 31.07.2006 and 1.09.2006 during 2006-07. The earting up was done four month after planting on 10.09.2005 during 2005-06 and on 1.09.2006 during 2006-07 for proper development of underground rhizomes.

3.2.5 Plant protection measures

The need based pest and disease management measures were followed as per recommendations. Dithane M-45 @ 2g per liter of water was sprayed as preventive measure against *Alterneria* leaf spot. Phorate granules @ 2kg $ha^{-1}$was mixed in soil at the time of earthing up to control the rhizome fly. Similar practice was adopted during the next year of experimentation.

3.3. Water management studies

3.3.1 Irrigation scheduling

The pressure plate apparatus was used at 0.33 bars and 15 bar to determine the field capacity and permanent wilting point of soil, respectively. The moisture content of soil samples was determined by gravimetric method.

Scheduling of irrigation was based on climatological approach. Evapotranspiration is the function of climatic parameters and is more accurate in establishing short term fluctuation in ET than empirical formulae. USWB Class A pan was used for measurement of daily pan evaporation (Eo). It was computed as the difference between observed level adjusted for any precipitation measured in a standard rain gauge. Water was added during every day to bring the fixed level to a fixed point in the stilling well.

The daily pan evaporation recorded from USWB Class A pan was summed up. When cumulative pan evaporation (CPE) attained the value of 70 mm, the irrigation was given with a constant depth of irrigation (6 cm). In case of floppy sprinkler and overhead sprinkler, the irrigations were given at 35 mm CPE + 35 mm CPE in two splits of 70 mm CPE. The details of number of irrigations applied alongwith dates of these applications and total depth of water applied inclusive of common irrigation as per irrigation methods are given in Appendix I and II. One common irrigation of 6 cm

depth during 2005-06 and 2006-07 was given after planting for ensuring better germination and uniform stand of the crop.

3.3.2 Surface irrigation

3.3.2.1 Depth of irrigation (d)

A constant depth of irrigation (6 cm) was applied during both the years. As the soil under experimentation during both the years, possessed almost similar retentive capacity of moisture, the depth of irrigation for different treatments was kept constant during both the years.

In case of surface irrigation, depth of irrigation water applied was calculated by using following formula (Dastane, 1972).

$$d = \sum_{i=1}^{n} \frac{(FCi - PWPi)}{100} \times Bdi \times Di \times MAD \quad \text{...Eq. 3.1}$$

where,

d = depth of irrigation water to be applied, cm

FCi = moisture percentage at field capacity, %

PWPi = moisure percentage at permanent wilting point, %

Bdi = bulk density ($g\ cm^{-3}$)

Di = effective root zone depth, cm

MAD = management allowable deficit

3.3.2.2 Time of irrigation

In case of surface irrigation, water was applied at 70mm CPE with 60mm depth at each irrigation turn by using PVC

pipe of 50mm diameter. The discharge of pipe was calibrated at pressure of 1 kg cm^{-2}. Time required to irrigate a plot was calculated by using the following formula (Michael, 1972).

$$t = \frac{A \times d}{q \times 60} \quad \text{... Eq. 3.2}$$

where,

t = application time, min.
A = area to be irrigated, m^2
d = depth of irrigation, m
q = discharge of pipe at pressure 1 kg cm^{-2}, $m^3 s^{-1}$

3.3.3 Performance of pressurized irrigation systems

3.3.3.1 Pressure-discharge relationship

The pressure-discharge relationship of pressurized irrigation systems was determined at various operating pressures. The emitter discharge was measured by volume-time method at the operating pressure of 1.00 kg cm^{-2} in case of trickle system. In case of floppy sprinkler, the emitter discharge was measured at the pressure of 2 kg cm^{-2} and in overhead sprinkler it was measured at 2.5 kg cm^{-2}.

Initially pressure of 1.00 kg cm^{-2} was maintained in drip system with the help of bypass arrangement and pressure gauges. The plastic containers of capacity 3 litre was used to collect the discharge through the emitters at head, middle and tail end of each lateral of treatment plots. The discharged water was measured by using a graduated cylinder. A stop

watch was used for recording the time while carrying out the test.

The discharge of floppy and overhead sprinkler was collected by holding a inverted glass cylinder over a head of the sprinkler without any disturbance. The thrown water was collected by a container of 3 litre capacity kept on the ground. The discharge was collected for 30 minutes for operating pressure of 2 and 2.5 kg cm^{-2} , respectively.

3.3.3.2 Emission uniformity (EU)

Representative four laterals were chosen from manifold of treatment plots and divided each laterals into four equal parts as inlet end, 1/3 down, 2/3 down and far end, thus making 16 divisions. The operating pressure of 1.00 kg cm^{-2} was maintained in the system. The emitter discharge was measured at two middle adjacent emitters, for one minute accurately at each division and then EU was computed by using following equation (Nakayama and Bucks, 1986).

$$EUa = 1/2 \left(\frac{q\ min}{q\ avg} + \frac{q\ avg}{q\ x} \right) 100 \qquad \text{...Eq. 3.3}$$

where,

EUa = absolute emission uniformity, per cent
q min = minimum discharge rate, lph
q avg = average emission flow rate, lph
qx = average of highest 1/8 th of emitter flow rate, lph

3.3.3.3 Uniformity coefficient (UC)

The uniformity coefficient was determined in floppy sprinkler and overhead sprinkler systems. In the process of determination, the open cans were placed at regular intervals i. e. 1.5 m for floppy sprinkler and 3 m for overhead sprinkler, on the area surrounded by four sprinkler heads.

The system was allowed to run for an hour with recommended pressure i. e. 2.0 kg cm^{-2} for floppy sprinkler and 2.5 kg cm^{-2} for overhead sprinkler. The collected volumes in open cans were measured with the help of graduated cylinder. The volume was converted to a depth, dividing the volume by cross section area of the can. The uniformity coefficient was computed by using following equation.

$$UC = 100 \frac{(1 - ? X)}{m \times n} \quad \text{...Eq.3.4}$$

where,

UC = uniformity coefficient of water application, per cent.
m = average depth of all observations, mm.
n = total number of observation points.
?X = sum of absolute values of the mean deviations of irrigations

3.3.3.4 Precipitation rate (P)

The precipitation rate of floppy sprinkler and overhead sprinkler systems were computed with the help of average water depth collected in the cans and the time for which the system was operated.

$$P = \frac{d\,(avg)}{t} \qquad \text{...Eq. 3.5}$$

where,

P = precipitation rate, mm hr^{-1}
d avg = average depth of water collected, mm
t = time of operation of the system, hr.

3.3.4 Scheduling of irrigation for trickle system

3.3.4.1 Depth of irrigation

Irrigation was applied at every alternate day by using pan evaporation data and crop coefficient values. The depth of irrigation water to be applied was calculated by using the formula (Vermerien and Jobling, 1980).

$$Et_c = E_p \times K_p \times K_c \qquad \text{...Eq. 3.6}$$

where,

Etc = evapotranspiration of crop for two days, mm.
E_p = pan evaporation of previous two days, mm.
K_p = pan factor (0.7)
K_c = crop coefficient (as per crop growth stages)

The crop coefficients used for scheduling of irrigation are given in Table 6.

The net quantity of water required per plant at every alternate day was calculated by using following formula.

$$V = Etc \times S_1 \times S_2 \times Wa \quad \text{...Eq.3.7}$$

Where,

Etc = evapotranspiration of crop for two days, mm.

V = volume of water per plant per two days, litres.

S_1 = spacing between rows, m

S_2 = Spacing between plants, m

Wa = wetted area of ginger (100 % or 1)

Table 6. Crop coefficient of ginger in different growth stages

Sr.No.	Days	Crop coefficient (Kc)	Stage indication
1	0 – 40	0.55	Initial growth stage
2	41 – 90	0.85	Crop development stage
3	91 – 205	1.00	Mid season stage
4	206 - 245	0.60	Late season stage

The gross volume of water applied per plot per irrigation was calculated by using the formula,

$$Vg = \frac{V \times N}{EU} \quad \text{...Eq.3.8}$$

Where,

Vg = gross volume of water applied per alternate day per plot, litres.

V = volume of water required per plant per two days, litres.

N = number of plants per plot

EU = emission uniformity of the trickle system of irrigation, fractions.

3.3.4.2 Time of irrigation

The operation time of the system for each irrigation was calculated by the formula.

$$t = \frac{Vg}{q \times Ne} \quad \text{...Eq. 3.9}$$

Where,

t = operation time of the system, hrs.

Vg = gross volume of water per two days per plot, lit.

q = average emitter discharge, lph.

Ne = number of emitters per plot.

3.3.5 Scheduling of irrigation for floppy and overhead sprinkler systems

3.3.5.1 Net depth of irrigation

The same equation (Eq. 3.1) used for finding out the net irrigation depth in case of trickle irrigation as well as for both sprinkler irrigation systems. The gross depth of irrigation was computed dividing the net depth of irrigation by uniformity coefficient of the system.

3.3.5.2 Time of irrigation

Using gross depth (dg) of irrigation and precipitation rate of the system the time of irrigation was computed by the following formula.

$$t = \frac{Dg}{p} \quad \text{...Eq. 3.10}$$

where,

t = time of irrigation, hr.
dg = gross irrigation depth, cm.
p = precipation rate, cm hr^{-1}

3.3.6 Water requirement of crop

Water requirement includes the losses due to evapotranspiration plus the losses during the application of irrigation and the quantity of water required for special operations such as land preparation, planting and for draining of salts. Numerically water requirement (WR) is given by Michael (1978). Considering major sources, viz., irrigation water (IR), effective rain fall (ER) and soil profile contribution (S) including that shallow water table as expressed in depth of water for a given time is as below :

$$WR = IR + ER + S \qquad \text{...Eq. 3.11}$$

As the depth of water table in the soil under experimentation is more than three metre. The soil profile contribution to water requirement in the present studies was not considered and hence only irrigation requirement and effective rainfall were taken in to account for working out water use by the crop. Irrigation requirement in the present case was the net quantity of irrigation water applied as per treatments. The same was measured with the help of replouge flume at the plot head, during both the years.

3.3.6.1 Effective rainfall

The effective rainfall considered for the calculations of water used, was monitored as follows :

All the rainfall received 48 hours after irrigation and less than cumulative pan evaporation values were considered as effective rainfall. The rains received during 48 hours of irrigation were not considered.

3.3.6.2 Field water use efficiency (FWUE)

This may be defined as the ratio of the amount of economic crop yield to the amount of water required for growing crop. It is obtained as follows.

$$FWUE = \frac{Y}{WR} \quad \text{...Eq. 3.12}$$

Where,

FWUE = field water use efficiency, kg ha $^{-1}$mm $^{-1}$

Y = yield, kg ha $^{-1}$

WR = total water requirement, mm.

3.4 Harvest and yield

Harvesting of ginger was done when the crop attained the maturity based on complete defoliation. One month after defoliation, the experimental plot was harvested manually. The rhizomes from net plot area were harvested and the total rhizome weight of each plot was taken. Then, the yield of rhizome per treatment was converted in to the yield (tonnes) per hectare.

3.5 Observations recorded

3.5.1 Sampling techniques and observations recorded

Initially, five ginger plants from each plot were randomly selected, labeled with pegs and subsequently used for recording biometric observations at different growth stages. The post planting observations of ginger during both the years such as plant height, number of shoots (tillers) per plant, number of leaves, leaf area, leaf area index, dry matter(straw) of plant, dry weight of rhizome and total dry matter per plant were recorded. During harvesting stage the rhizome weight (g / plant), straw weight (g / plant), green ginger yield and straw yield per hectare and quality studies viz., P^H, Oleoresin, Oil, Crude fiber, Starch and Total ash (%) were recorded. The details of observations recorded are given in Table 7.

3.5.2 Survival percentage

The number of ginger plants survived at 90 days after planting was counted and survival percentage was worked out.

$$\text{Survival \%} = \frac{\text{Number of plants survived}}{\text{Number of rhizomes planted}} \text{ X } 100$$

3.5.3 Plant height (cm)

Pegs were fixed at the bottom of randomly selected shoots and periodical plant height was recorded from their shoots at regular intervals viz; 90,118,146,172,202,230 days after planting and at harvest. The height of crop was measured

from base of shoot to the base of fully opened last leaf of the shoot. The mean plant height was expressed in cm.

3.5.4 Number of tillers (shoots) per plant.

The total number of tillers of selected five plants was counted and recorded from each plot at 28 days interval from 90 days after planting to harvest.

3.5.5 Number of leaves per plant

The total number of leaves of selected five plants was counted and recorded from each plot at 28 days interval from 90 days after planting to harvest.

3.5.6 Leaf area per plant.

The leaf area studies were undertaken on five plants at 28 days interval from 90 days up to harvest. The leaves are categorized in to big, medium and small groups. The maximum length and breadth of a leaf from each category was measured in centimeter and converted into decimeter and was multiplied with total number of leaves in the respective categories. Finally the leaf area of ginger plant was estimated by using the non destructive formula as given below

$$A = (L \times B) K$$

where,

A= Leaf area per plant (d cm.sq.)
L = Maximum length of leaf (d cm)
B = Maximum leaf width (d cm)
K = Correction factor (0.666).

3.5.7 Leaf Area Index (LAI)

The leaf area index was estimated at 28 days interval from 90 days after planting to harvest.

Leaf area index is the ratio between leaf area to the ground area expressed in the same unit.

$$LAI = \frac{\text{Leaf area}}{\text{Ground area}}$$

3.5.8 Total dry matter accumulation per plant (g)

The plants taken for leaf area determination were used for dry matter studies at 28 days interval from 90 days after planting to harvest. The plants were sun dried and weight of each plant was recorded after oven drying at 65^{o}c $\pm$ 2 ^{o}C until the constant weight was obtained. The mean dry matter per plant was recorded by adding the dry weight of rhizome of the plant.

3.6 Post harvest observations

3.6.1 Rhizome yield.

At the time of harvesting, the rhizome weight of selected five plants under observation were used for individual rhizome weight and average weight was expressed in g.

Green rhizomes were harvested from individual plot. After removal of rhizome roots and soil from rhizome, treatment wise weight of green ginger was reported as yield of ginger in tonnes per hectare.

3.6.2 Straw yield.

According to age of crops to the maturity stage, the ginger leaves turns yellow and subsequently defoliate with stem naturally. At the stage of complete maturity, the dry weight of five plants was used for individual dry weight of plant. Similarly, all the dried plants per plot were collected and weight of dry matter per plot was recorded and it was converted in to dry straw yield in tonnes per hectare. Similar procedure was adopted for dry weight of rhizome.

3.6.3 Harvest index

Harvest index was calculated by using following formula.

$$\text{H.I. (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.7 Quality parameters

The rhizome of randomly selected plants were harvested on clump basis from the tagged plants from each plot and leaves and roots were removed and rhizome portion of ginger plant was used for quality aspects on dry weight basis except pH of ginger pulp viz., Oleoresin, Volatile oil, Crude fiber, Starch and Total ash content (%).

3.7.1 p^H of ginger

After harvest of rhizome it was cleaned and crushed with grinder and juice was collected. The collected juice of fresh rhizome

Table 7. Details of observations recorded on ginger during 2005-06 and 2006-07

Sr. No.	Particulars	Frequency	Days after planting	Sample size
A	**Plant count (survival %)**	1	60	All plants
B.	**Growth studies**			
1.	Plant height (cm)	7	90,118,146,174, 202,230 and at harvest	5 plants
2.	Number of tillers / plant	7	90,118,146,174, 202,230 and at harvest	5 plants
3.	Number of leaves / plant	7	90,118,146,174, 202,230 and at harvest	5 plants
4.	Leaf area / plant	7	90,118,146,174, 202,230 and at harvest	5 plants
5.	Leaf Area Index / plant	7	90,118,146,174, 202,230 and at harvest	5 plants
6.	Dry matter / plant (g)	7	90,118,146,174, 202,230 and at harvest	5 plants
7.	Dry rhizome / plant (g)	7	90,118,146,174, 202,230 and at harvest	5 plants
8.	Total dry matter / plant (g)	7	90,118,146,174, 202,230 and at harvest	5 plants
C.	**Post harvest studies**			
1.	Fresh Ginger yield (t ha^{-1})	1	At harvest	All plants from net plot
2.	Dry rhizome yield (t ha^{-1})	1	At harvest	All plants from net plot
3.	Straw yield (t ha^{-1})	1	At harvest	All plants from net plot
4.	Biological yield (t ha^{-1})	1	At harvest	All plants from net plot

D.	**Quality studies**			
1.	Oleoresin content (%)	1	At harvest	-
2.	Oil content (%)	1	At harvest	-
3.	pH of ginger pulp	1	At harvest	-
4.	Crude fiber content (%)	1	At harvest	-
5.	Starch content (%)	1	At harvest	-
6.	Total ash content (%)	1	At harvest	-
E.	**Chemical studies**			
1.	Initial soil analysis	1	Before experiment	-
2.	Plant analysis for N,P and K content	1	At harvest	-
3.	Soil nutrient status after harvest	1	At harvest	-
4.	Nutrient balance	1	At harvest	-
G.	**Irrigation studies**			
1.	Emitter discharge	1	Before experiment	-
2.	Emission uniformity	1	Before experiment	-
3.	Uniformity coefficient	1	Before experiment	-
4.	Precipitation rate	1	Before experiment	-
5.	Throw radius	1	Before experiment	-
6.	Moisture status	1	Before experiment	-
7.	Water requirement (mm ha^{-1})	1	At harvest	-
8.	Water use efficiency (FWUE) (kg mmha^{-1})	1	At harvest	-
9.	Effective rainfall	1	-	-
10.	Water saving (%)	1	-	-
E.	**Economics**			
1.	Cost of cultivation (Rs ha^{-1})	1	At harvest	
2.	Gross monetary returns (Rs ha^{-1})	1	At harvest	
3.	Net monetary returns (Rs ha^{-1})	1	At harvest	
4.	B : C ratio	1	At harvest	

was used to test the pH with pH meter and recorded the readings.

3.7.2. Oleoresin content (%)

The non volatile ether extract /oleoresin was estimated by distillation with solvent ether (40 – 60 %) in Soxhlet apparatus (A.O.A.C., 1975).

3.7.3. Volatile Oil content (%)

The volatile oil content in rhizome was estimated by modified Clevenger Method (A.O.A.C., 1975)

3.7.4 Crude fiber content (%)

Crude fiber content (%) in rhizome was estimated by acid and alkali digestion method (A.O.A.C., 1975).

3.7.5 Starch content (%)

The starch content in rhizome was estimated by direct acid hydrolysis method (A.O.A.C., 1975).

3.7.6 Total ash content (%)

The total ash content in rhizome was estimated by ignition in furnace at the temperature of 550 ^{O}C as per the method described in A.O.A.C. (1975).

3.8 Economics

The economic evaluation in terms of gross monetary returns, cost of cultivation, net monetary returns and B : C ratio were calculated treatment wise.

3.8.1 Cost of cultivation (Rs. ha^{-1})

The total cost of cultivation (cost C) of ginger was estimated by using the data on various aspects such as wage rate of hired labourer, system cost, irrigation charges, cost of planting material, market rate of fertilizers, plant protection measures, hired charges of machinery and tractor with implements, interest on working capital etc.

3.8.2 Gross monetary returns (Rs. ha^{-1})

The final price of ginger of the year 2005-06 and 2006-07 was obtained from Rahuri Taluka Co-operative Market Committee and was considered for calculation of gross monetary returns. The treatment wise gross monetary returns (Rs.ha$^{-1)}$ were worked out by multiplying the rhizome yield (t ha$^{-1)}$ of first and second season by the market rates of respective years as per the formula given.

Gross monetary returns (Rs.ha^{-1}) = [Rhizome yield X Price of rhizome]

3.8.3 Net monetary returns (Rs. ha^{-1})

The treatment wise net monetary returns (Rs.ha^{-1}) were worked out by subtracting treatment wise cost of cultivation from treatment wise gross monetary returns. The formula used is given below.

Net monetary returns (Rs.ha^{-1}) = Gross monetary returns – Cost of cultivation

3.8.4 Benefit : Cost ratio (B : C ratio)

Estimates of gross income per ha, net income per ha, net returns per rupee invested and B : C ratio were computed based on total cost of cultivation (cost C) and returns per rupee invested was calculated as follows.

$$\text{Returns / Rupee} = \frac{\text{Gross monetary returns (Rs.ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs.ha}^{-1}\text{)}}$$

The treatment wise B : C ratio was worked out by dividing the treatment wise gross monetary returns with the treatment wise cost of cultivation.

3.9 Chemical studies

3.9.1 Soil analysis

The composite soil sample from 0-30 cm layer was collected before planting from experimental site. After harvesting, the soil samples from each treatment were collected for assessment of chemical properties of soil. The appropriate method of estimation were used (Table 1) and the concentrations of these nutrients in the soil samples were worked out and from these observations per hectare availability of nutrients was computed.

3.9.2 Plant analysis

The observation plants collected at harvest were used for chemical analysis. The plant samples taken at harvest for dry matter were dried in oven at 63 ^{O}C $\pm$ 2^{o}C. The

composite samples were made and after grinding into the fine powder, used for analysis of nitrogen, phosphorus and potassium content. Different methods utilized for plant analysis are given in Table 8.

Table 8. Methods used for analysis of NPK from biological material.

Sr. No.	Determination	Method used	Reference
1.	Preparation of acid extract	Conc. H_2SO_4 30% in 1:1 proportion	Parkinson and Allen (1975)
2.	Nitrogen	Micro-kjeldahl's method	Jackson (1973)
3.	Phosphorus	Vandomolybdlate phosphoric yellow colour colorimetric method in nitric acid system	Chapman and Pratt (1961)
4.	Potassium	Flame photometer method	Knudsan and Peterson, 1982

3.9.3 Nutrient uptake

The uptake of nitrogen, phosphorus and potassium was calculated by using % N, P and K content in plant (dry rhizome + dry straw) and their respective dry matter yield.

3.9.4 Nutrient balance

The balance of available N, P and K in soil kg ha^{-1} was calculated as :

Nutrient balance = [Initial available nutrient in soil + addition through fertilizer] – total nutrient uptake by crop

Net loss or gain(kg ha^{-1})=Actual balance – computed balance at harvest

Gain = Actual balance at harvest > computed balance

Loss = Actual balance at harvest < computed balance

3.10 Statistical analysis

All the data collected on various character were statistically analyzed as suggested by Panse and Sukhatme (1995) by using the design fed in to computer and transformation of data were also made wherever required. Whenever results were found significant by the ‘ F test ’ the critical differences (C. D.) values at 5% level of probability were worked out. ‘ NS ’ denoted the treatment differences, which were not significant at 5% The data have been presented graphically at appropriate places.

4. RESULTS AND DISCUSSION

The field experiment was conducted during 2005-06 and 2006-07 at Instructional Farm of Inter Faculty Department of Irrigation Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri to study the response of ginger to irrigation systems and integrated nutrient management practices. The growth parameters, yield attributes, yield, quality, economics, nutrient uptake and nutrient balance were recorded. The details of experimental results are presented under different headings in this chapter.

Growth and development

4.1.1 Survival percentage

Initial plant count and survival percentage of ginger was recorded at 45 days after planting during both the years (Table 9).The mean survival percentage at 45 days after planting during 2005-06 and 2006-07 was 93.87 and 93.89 %, respectively.

Effect of irrigation systems

The effect of irrigation systems on initial plant count and survival percentage of ginger was found to be non significant. This might be due to common irrigation applied initially for ensuring better germination which resulted in uniform crop stand.

Table 9. Mean initial plant count and survival percentage (per net plot) during 2005-06 and 2006-07

Treatment	Plant count		Survival %	
	2005-06	2006-07	2005-06	2006-07
Irrigation methods				
Surface	345.50	343.10	93.87	93.22
Drip	344.70	344.90	93.68	93.71
Floppy Sprinkler	346.10	347.70	94.05	94.49
Overhead Sprinkler	345.40	346.50	93.86	94.15
SE $\pm$	0.65	1.95	0.20	0.53
CD at 5 %	N.S.	N.S.	N.S.	N.S.
RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer				
100% RDN through organic	346.90	350.50	94.27	94.57
75% RDN through organic + 25% RDN through inorganic	346.00	347.00	94.02	94.29
50% RDN through organic + 50% RDN through inorganic	345.60	346.10	93.91	94.04
25% RDN through organic + 75% RDN through inorganic	344.80	343.80	93.7	93.41
100% GRDF	343.80	342.80	93.43	93.16
SE $\pm$	0.62	2.05	0.21	0.56
CD at 5 %	2.02	6.70	0.68	0.79
Interaction				
SE $\pm$	1.12	1.39	0.63	0.95
CD at 5 %	N.S.	N.S.	N.S.	N.S.
General mean	345.43	345.53	93.87	93.89

Effect of integrated nutrient management

Initial plant count and survival percentage were found significantly affected due to application of nitrogen through organic sources. The treatment of application of 100 per cent RDN through organic sources was found significantly superior over the application of 100 per cent general recommended dose of fertilizer but in 2006-07 remaining treatments were found at par with each other. This might be due to more moisture holding for long period of time and ideal soil conditions for better germination of ginger plants. Similar results were reported by Amaresh *et al.* (2004).

Interaction effects

Interaction effects between irrigation systems and integrated nutrient management practices were found to be non significant for survival percentage during both the years.

4.1.2 Plant height

Data pertaining to mean plant height of ginger as influenced by different irrigation systems and integrated nutrient management practices are presented in Table10 and graphically depicted in Fig 4a and 4b.

The mean plant height of ginger crop was increased progressively with advancement in the crop age till 202 days after planting. The mean plant height during the crop growth period increased from 19.65 to 34.27 cm and from 22.32 to 49.74 cm from 90 days after planting till maximum

crop growth stages of plant (202 days) during both the years of experimentation, respectively.

Effect of irrigation systems

The mean plant height of ginger crop was significantly higher under floppy sprinkler irrigation system than surface irrigation at all the crop growth stages during both the years, but it was at par with overhead sprinkler system. Similarly, overhead sprinkler also recorded significantly higher mean plant height over the surface irrigation.

The application of irrigation through floppy sprinkler system recorded significantly higher plant height over all other irrigation systems at 118 days after planting during second year of experimentation.

The irrigation scheduled with floppy sprinkler system produced significantly taller plants (35.98 and 51.47 cm) than surface, drip and overhead sprinkler irrigation systems at 202 days after planting during both the years of experimentation. The increase in plant height under former irrigation system might be attributed to the favourable microclimate, reduced irrigation runoff, controlled deep percolation below the root zone. The increase in plant height under floppy sprinkler might also be due to better availability of moisture during entire growth period favoured the growth attributes. This confirms the finding of Sankar *et al.* (2008).

Table 10. Mean plant height of ginger (cm) as influenced periodically by irrigation systems and integrated nutrient management

Treatment	Days after planting 2005-06							Days after planting 2006-07						
	90	118	146	174	202	230	At Harvest	90	118	146	174	202	230	At Harvest
Irrigation systems														
Surface	17.85	29.36	30.25	31.73	32.74	30.87	30.06	21.19	24.95	39.19	44.48	47.24	45.66	44.20
Drip	18.37	30.09	31.29	32.48	33.22	31.33	30.37	22.13	25.59	40.85	45.91	49.78	48.59	47.20
Floppy Sprinkler	21.58	32.27	33.79	35.13	35.98	33.83	32.77	23.48	27.59	44.01	49.15	51.47	50.01	48.66
Overhead Sprinkler	20.81	30.96	32.77	33.89	35.14	33.11	32.09	22.49	25.49	41.00	47.66	50.47	49.05	47.36
SE m ±	0.25	0.48	0.73	0.80	0.51	0.72	0.76	0.43	0.49	1.10	0.79	0.80	0.97	1.00
CD at 5%	0.88	1.65	2.53	2.78	1.78	2.50	2.61	1.50	1.70	3.81	2.72	2.76	3.37	3.46
Integrated nutrient management :RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer														
100% RDN through organic	17.49	27.37	28.85	29.89	30.71	29.15	27.73	18.84	22.57	32.75	38.99	44.76	43.41	42.00
75% RDN through organic + 25% RDN through inorganic	18.60	29.22	30.30	31.50	32.81	30.64	29.40	21.37	25.06	40.13	45.31	48.06	46.63	45.22
50% RDN through organic + 50% RDN through inorganic	19.62	30.49	31.73	33.13	33.97	32.28	31.54	22.66	26.28	42.72	47.21	48.95	47.66	46.43
25% RDN through organic + 75% RDN through inorganic	20.64	31.77	33.31	34.77	35.64	33.76	32.95	23.58	27.09	44.46	49.83	51.63	50.21	48.72
100% GRDF	21.92	34.49	35.93	37.24	38.21	35.58	34.99	25.16	28.53	46.23	52.65	55.29	53.73	51.90
SE m ±	0.16	0.39	0.42	0.51	0.48	0.40	0.47	0.30	0.45	0.82	0.91	0.52	0.77	0.71
CD at 5%	0.51	1.26	1.38	1.67	1.55	1.29	1.53	0.99	1.46	2.66	2.96	1.69	2.51	2.32
Interaction														
SE m ±	0.83	1.28	1.40	1.35	1.49	1.33	1.48	0.70	0.69	1.27	1.40	1.39	1.45	1.38
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	19.65	30.67	32.03	33.31	34.27	32.28	31.32	22.32	25.91	41.26	46.80	49.74	48.33	46.86

The minimum plant height was recorded with the application of irrigation through surface irrigation which might be due to surface and deep percolation losses.

Effect of integrated nutrient management

The application of 100 per cent general recommended dose of fertilizer recorded significantly more plant height than all other treatments from 90 days onward during both the years of investigation but during second year it was at par with 25 per cent RDN through organic source and 75 per cent RDN through inorganic fertilizer at 118, 146 and 174 days after planting. The ginger plant might have produced better vegetative growth in term of plant height in case of this treatment where the nutrients were applied through inorganic as well as organic sources. The increase in plant height was significantly less where 100 per cent recommended dose of nitrogen was applied through organic sources during both the years. This may be due to immobilization of nitrogen which might have been used for enhanced biological activities in the treatments where more organic manure was applied which ultimately affected the plant height. These results are in confirmity with the findings of Singh and Kushwah (2006).

Interaction effects

Interaction effects between irrigation systems and integrated nutrient management practices were found to be non significant for plant height throughout the crop growth

stages from 90 days of planting till harvest during both the years.

4.1.3 Number of tillers per plant

The data on mean number of tillers (shoots) per plant recorded periodically under different irrigation systems and integrated nutrient management practices are presented in Table 11and depicted in Fig 5a and 5b.

The mean number of tillers per plant increased with increase in age of crop from 90 to 202 days of planting and thereafter it was decreased during both the seasons due to senescences. There were on an average 2.64, 7.90, 10.88, 12.18 and 13.21 tillers per plant in 2005-06 and 3.70, 8.85, 11.69, 17.30, 18.70 tillers per plant in 2006-07.

Effect of irrigation systems

From the data in Table 11, it would be seen that the differences in number of tillers per plant due to different irrigation systems were statistically significant at all the growth stages during both the years except at 90 days after planting in 2005-06. The application of irrigation through different systems increased the number of tillers over the surface irrigation during both the years.

The application of irrigation through floppy sprinkler recorded maximum number of tillers. This was significantly superior over surface irrigation during both the years but was at par with overhead sprinkler during first year. At 146 days

Table 11. Mean number of tillers per plant of ginger as influenced periodically by irrigation systems and integrated nutrient management

Treatment	Days after planting 2005-06							Days after planting 2006-07						
	90	118	146	174	202	230	At Harvest	90	118	146	174	202	230	At Harvest
Irrigation systems														
Surface	2.61	8.44	10.79	11.40	12.53	11.09	10.69	3.36	8.81	11.67	16.88	17.46	15.59	14.49
Drip	2.79	7.09	10.09	12.00	12.71	11.46	11.10	3.67	8.26	11.08	15.83	17.55	16.24	15.00
Floppy Sprinkler	2.72	8.58	12.04	13.21	14.33	13.29	12.91	3.94	9.65	12.76	19.02	20.52	19.36	18.58
Overhead Sprinkler	2.43	7.47	10.55	12.11	13.29	12.19	11.54	3.82	8.67	11.23	17.47	19.28	17.77	16.60
SE m±	0.10	0.41	0.31	0.42	0.50	0.43	0.42	0.12	0.08	0.12	0.41	0.63	0.18	0.36
CD at 5%	0.33	1.42	1.08	1.47	1.71	1.47	1.45	0.40	0.26	0.41	1.41	2.16	0.64	1.25
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer														
100% RDN through organic	2.23	6.27	8.70	9.02	10.83	9.72	9.66	2.66	7.31	9.31	13.65	15.19	13.72	13.26
75% RDN through organic + 25% RDN through inorganic	2.45	7.07	10.02	10.92	12.12	11.35	10.86	3.19	8.01	10.61	15.25	16.45	15.54	14.50
50% RDN through organic + 50% RDN through inorganic	2.63	7.98	10.65	12.02	13.10	12.15	11.53	3.64	8.85	11.39	17.33	18.78	17.02	15.64
25% RDN through organic + 75% RDN through inorganic	2.80	8.58	11.65	13.50	14.05	12.66	12.26	4.47	9.35	12.72	19.30	20.38	18.88	17.48
100% GRDF	3.06	9.57	13.32	15.45	15.98	14.15	13.49	4.52	10.70	14.39	20.97	22.71	21.04	19.95
SE m±	0.20	0.21	0.20	0.27	0.25	0.46	0.33	.12	0.09	0.29	0.51	0.37	0.56	0.39
CD at 5%	0.67	0.67	0.65	0.87	0.83	1.49	1.08	0.38	0.29	0.95	1.64	1.19	1.84	1.27
Interaction														
SE m±	0.25	0.36	0.49	0.83	0.40	0.68	0.70	0.26	0.27	0.38	1.04	0.67	0.76	1.03
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	2.64	7.90	10.88	12.18	13.21	12.01	11.56	3.70	8.85	11.69	17.30	18.70	17.24	16.17

after planting, same treatment was found significantly superior over all irrigation systems in 2005-06. During second year, application of irrigation through floppy sprinkler produced significantly more tillers than all other irrigation systems at all growth stages except overhead sprinkler at 90 and 202 days after planting. The reduction in number of tillers per plant under surface irrigation might be attributed to the mortality of tillers due to deficit soil moisture.

Effect of integrated nutrient management

The application of 100 per cent general recommended dose of fertilizer produced significantly the highest number of tillers per plant at all the crop growth stages during both the years of investigation. Mohanty *et al.* (1988) also reported increase in number of tillers with application of general recommended dose of fertilizer. However, application of 100 per cent general recommended dose of fertilizer and application of 25 per cent recommended dose of nitrogen through organic sources and 75 per cent recommended dose of nitrogen through inorganic fertilizer were found at par with each other at 90, 230 days after planting in first year and at 90 days after planting during second year. The application of nitrogen through inorganic fertilizer and organic manures in combination significantly increased number of tillers per plant. These results are conformity with the finding of Murlidharan, (1973b). The increased photosynthetic activity in turn would have increased

photosynthates assimilation resulting in higher C:N ratio might have helped in increasing number of tillers per plant. Similar results were also reported by Reddy and Reddy (1998). The minimum number of tillers per plant were recorded due to application of 100 per cent recommended dose of nitrogen through organic sources. This might be due to slow mineralization of organic manures and unavailability of nutrients at proper growth stages of crop which may have resulted in reduction of number of tillers per plant

Interaction effect

Interaction effect between irrigation systems and integrated nutrient management practices were absent for the number of tillers per plant at all the growth stages of observations under study.

4.1.4 Number of leaves per plant

The data on mean number of leaves per plant recorded periodically under different irrigation systems and integrated nutrient management practices are presented in Table 12.

The mean number of leaves per plant increased with increase in age of crop from 90 to 202 days after planting and there after it was lowered down to harvest during both the years due to crop senescence. There was on an average 11.91, 12.92, 13.98, 15.13 and 17.26 leaves per plant in 2005-06 and 11.78, 13.39, 16.25, 16.99 and 19.07 leaves per plant in 2006-07at 90,118,146,174 and 202 days, respectively.

Table 12. Mean number of leaves per plant of ginger as influenced periodically by irrigation systems and integrated nutrient management

Treatment	Days after planting 2005-06							Days after planting 2006-07						
	90	118	146	174	202	230	At Harvest	90	118	146	174	202	230	At Harvest
Irrigation systems														
Surface	11.48	12.36	13.77	14.47	16.64	15.04	14.39	11.30	13.06	14.90	16.01	18.32	17.26	16.13
Drip	11.71	12.76	13.95	15.08	16.95	14.37	13.86	11.37	13.30	15.52	15.91	18.75	17.67	16.49
Floppy Sprinkler	12.87	13.56	14.18	15.84	18.13	15.13	14.61	12.39	13.73	17.94	18.81	19.95	18.86	17.54
Overhead Sprinkler	11.60	12.19	14.05	15.15	17.31	14.00	13.56	12.04	13.48	16.64	17.24	19.28	17.98	17.02
SE m ±	0.17	0.15	0.23	0.47	0.34	0.45	0.53	0.26	0.22	0.50	0.12	0.60	0.57	0.45
CD at 5%	0.59	0.53	N.S.	N.S.	1.17	N.S.	N.S.	0.90	N.S.	1.71	0.41	N.S.	N.S.	N.S.
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer														
100% RDN through organic	10.55	11.47	12.49	13.59	15.58	13.03	12.32	10.62	12.05	14.17	15.12	17.45	16.41	15.30
75% RDN through organic + 25% RDN through inorganic	11.32	12.42	13.34	14.45	16.36	13.87	13.40	11.22	12.96	15.40	16.08	18.25	17.21	15.91
50% RDN through organic + 50% RDN through inorganic	12.00	13.00	13.92	15.05	17.13	14.52	14.00	11.66	13.61	16.37	17.07	19.06	18.03	16.84
25% RDN through organic + 75% RDN through inorganic	12.58	13.60	14.36	15.89	18.30	15.55	15.05	12.36	13.91	17.19	17.66	19.70	18.75	17.52
100% GRDF	13.12	14.10	15.81	16.67	18.91	16.22	15.75	13.01	14.42	18.11	19.03	20.91	19.30	18.42
SE m ±	0.19	0.22	0.38	0.42	0.27	0.25	0.21	0.41	0.31	0.21	0.36	0.12	0.14	0.12
CD at 5%	0.61	0.73	1.22	1.36	0.89	0.82	0.69	1.34	1.00	0.69	1.16	0.39	0.44	0.40
Interaction														
SE m ±	0.25	0.59	0.70	0.63	1.02	0.45	0.43	0.84	0.69	0.43	0.55	0.33	0.32	0.36
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	11.91	12.92	13.98	15.13	17.26	14.64	14.10	11.78	13.39	16.25	16.99	19.07	17.94	16.80

Effect of irrigation systems

The data presented in Table 12 indicate that the mean number of leaves per plant was found significantly more under floppy sprinkler irrigation system than all other irrigation systems at 90 and 118 days after planting in 2005-06 and at 174 days after planting in 2006-07 but was at par with overhead sprinkler at 202 days in 2005-06. The increased number of leaves under floppy sprinkler might be due to better availability of moisture and air during entire growth period favoured growth attributes. The results are confirmative with findings of Sankar *et al*. (2008). At remaining growth stages all the irrigation systems were found to be at par with each other during both the years because the crop turns to maturity stage.

Effect of integrated nutrient management

The application of 100 per cent general recommended dose of fertilizer recorded significantly more number of leaves per plant than all other integrated nutrient management practices during both the years, but it was at par with the treatment of application of 25 per cent nitrogen through organic sources and 75 per cent recommended dose of nitrogen through inorganic fertilizer during first year and initial growth stages of second year. The same fertilizer treatment produced significantly more number of leaves per plant than all other integrated nutrient management practices from 146 days after planting to harvest of ginger crop due to steadily availability of nitrogen. The minimum number of leaves per plant was

recorded in the treatment of application of 100 per cent recommended dose of nitrogen through organic sources during both the years. Similar results were reported by Venkatesha *et al.* 1998.

Interaction effect

Interaction effects between irrigation systems and integrated nutrient management practices were found to be non significant for the mean number of leaves per plant at all the days of observations during both the years.

4.1.5 Leaf area

Leaf area is an important measure of assessing growth and productivity.

The data on mean leaf area of ginger as affected by irrigation systems and integrated nutrient management practices are presented in Table 13 and depicted in Fig 6a and 6b.

It was observed that the mean leaf area increased with increase in age of crop till 202 days in both seasons, where it reached to its peak (19.88 and 20.87 dm^2, respectively). Thereafter, it gradually declined at harvest to 18.05 and 19.29 dm^2 respectively, for two consecutive crop seasons due to crop senescence.

Effect of irrigation systems

The application of irrigation through floppy sprinkler system produced significantly more leaf area per

Table 13. Mean leaf area per plant (dm ^{2}) of ginger as influenced periodically by irrigation systems and integrated nutrient management

Treatment	Days after planting 2005-06							Days after planting 2006-07						
	90	118	146	174	202	230	At Harvest	90	118	146	174	202	230	At Harvest
Irrigation systems														
Surface	14.74	15.83	16.69	17.84	19.22	18.29	17.45	16.01	16.90	18.53	18.99	19.58	18.88	18.13
Drip	15.12	16.13	17.55	18.13	19.24	18.54	17.67	16.41	17.61	18.96	19.54	20.39	19.58	18.93
Floppy Sprinkler	15.82	17.17	18.05	19.70	21.06	20.38	18.91	17.70	18.47	20.49	21.11	22.27	21.41	20.61
Overhead Sprinkler	15.47	16.79	16.98	18.94	19.98	19.29	18.16	16.95	17.91	19.67	20.30	21.24	20.30	19.48
SE m ±	0.20	0.11	0.17	0.18	0.15	0.07	0.13	0.18	0.14	0.16	0.22	0.15	0.14	0.12
CD at 5%	0.69	0.36	0.59	0.61	0.53	0.23	0.45	0.61	0.47	0.56	0.77	0.52	0.49	0.41
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer														
100% RDN through organic	13.45	14.18	14.93	16.04	17.22	16.52	15.88	14.50	15.35	16.80	17.30	18.01	17.28	16.66
75% RDN through organic + 25% RDN through inorganic	14.06	15.02	15.93	17.55	18.73	17.86	16.85	15.34	16.56	18.36	18.79	19.72	18.86	18.24
50% RDN through organic + 50% RDN through inorganic	15.32	16.77	17.67	19.08	20.19	19.47	18.44	16.94	18.03	19.71	20.28	21.06	20.11	19.27
25% RDN through organic + 75% RDN through inorganic	16.14	17.65	18.50	19.74	21.02	20.15	19.01	18.03	18.94	20.56	21.16	21.94	21.22	20.40
100% GRDF	17.48	18.76	19.56	20.85	22.21	21.63	20.07	19.04	19.73	21.64	22.39	23.63	22.73	21.88
SE m±	0.10	0.15	0.16	0.26	0.29	0.19	0.21	0.17	0.21	0.19	0.17	0.18	0.14	0.10
CD at 5%	0.32	0.48	0.51	0.87	0.95	0.62	0.68	0.54	0.69	0.62	0.54	0.57	0.46	0.33
Interaction														
SE m±	0.26	0.23	0.27	0.32	0.41	0.36	0.47	0.31	0.40	0.35	0.30	0.28	0.28	0.31
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	15.29	16.48	17.32	18.65	19.88	19.13	18.05	16.77	17.72	19.41	19.98	20.87	20.04	19.29

plant than other irrigation systems at all the crop growth stages, during both the years of experimentation except during early period of 90 days in first year where it was on par with overhead sprinkler and drip irrigation systems at 146 days after planting. The leaf area is reliable index of crop productivity which was thus favourably influenced under this system. Further, application of irrigation through overhead sprinkler system recorded significantly more leaf area over surface and drip irrigation systems during both the seasons but it was at par with drip system at 146 days after planting. However, surface and drip irrigation systems significantly decreased the leaf area throughout the crop growth period during both the years. Reduction in leaf size and leaf curling resulted in reduced leaf area.

Effect of integrated nutrient management

The mean leaf area of ginger crop was significantly more under application of 100 per cent general recommended dose of fertilizer than all other integrated nutrient management practices at all the days of observation during both the seasons. Further, the treatment of application of 25 per cent recommended dose of nitrogen through organic source and 75 per cent recommended dose of nitrogen through inorganic fertilizer was also produced significantly higher leaf area than remaining integrated nutrient management practices during both the years but it was at par with 50% RDN through organic and 50% RDN through inorganic fertilize at 174, 202 and at harvest during first year and 90 days during second year. An increase in leaf area with integrated organic manures, bio-fertilizers and chemical fertilizers over the organic sources could be attributed to more height and greater number of photosynthetically leaves per

plant which might have enhanced production of bioactive substances having effects as that of growth regulators besides nitrogen fixation through bacterial fertilizers. Similar findings were reported by Jayathilake *et al.* 2002 and Bijaya Devi and Limi Ado 2005. The decreased leaf area was noticed under the application of 100 per cent recommended dose of nitrogen through organic sources. This might be due to mineralization of organic manures and less availability of nutrients for vegetative growth of plants.

Interaction effect

Interaction effects between irrigation systems and integrated nutrient management practices were absent for leaf area per plant at all stages of observations under both the years of experimentation.

4.1.6 Leaf area index

The data on leaf area index per plant as affected by different irrigation systems and integrated nutrient management practices are presented in Table 14.

The data presented in Table 14 indicate that the leaf area index per plant increased with increase in age of crop till 202 days during both the years of investigation, where it reached to its peak (4.97 and 5.22, respectively). Thereafter, it gradually declined at harvest to 4.51 and 4.82, respectively during both the years.

Table 14. Mean Leaf area index of ginger as influenced periodically by irrigation systems and integrated nutrient management

Treatment	Days after planting 2005-06							Days after planting 2006-07						
	90	118	146	174	202	230	At Harvest	90	118	146	174	202	230	At Harvest
Irrigation systems														
Surface	3.69	3.96	4.17	4.46	4.80	4.57	4.36	4.00	4.23	4.63	4.75	4.90	4.72	4.53
Drip	3.78	4.03	4.39	4.53	5.00	4.64	4.42	4.10	4.40	4.74	4.88	5.10	4.89	4.73
Floppy Sprinkler	3.95	4.29	4.51	4.93	5.26	5.01	4.73	4.43	4.62	5.12	5.28	5.57	5.35	5.15
Overhead Sprinkler	3.87	4.20	4.25	4.73	4.81	4.82	4.54	4.24	4.48	4.92	5.07	5.31	5.07	4.87
SE m±	0.05	0.03	0.04	0.04	0.04	0.02	0.03	0.05	0.04	0.04	0.06	0.04	0.04	0.03
CD at 5%	0.17	0.09	0.15	0.15	0.14	0.06	0.11	0.15	0.12	0.14	0.19	0.13	0.12	0.10
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer														
100% RDN through organic	3.36	3.54	3.73	4.01	4.31	4.13	3.97	3.62	3.84	4.20	4.32	4.50	4.32	4.16
75% RDN through organic + 25% RDN through inorganic	3.52	3.75	3.98	4.39	4.68	4.46	4.21	3.84	4.14	4.59	4.70	4.93	4.71	4.56
50% RDN through organic + 50% RDN through inorganic	3.83	4.19	4.42	4.77	5.05	4.87	4.61	4.23	4.51	4.93	5.07	5.26	5.03	4.82
25% RDN through organic + 75% RDN through inorganic	4.03	4.41	4.62	4.93	5.26	5.04	4.75	4.51	4.74	5.14	5.29	5.48	5.31	5.10
100% GRDF	4.37	4.69	4.89	5.21	5.55	5.41	5.02	4.76	4.93	5.41	5.60	5.91	5.68	5.47
SE m±	0.03	0.04	0.04	0.07	0.07	0.05	0.05	0.04	0.05	0.05	0.04	0.04	0.04	0.03
CD at 5%	0.08	0.12	0.13	0.22	0.23	0.16	0.17	0.13	0.17	0.15	0.14	0.14	0.12	0.08
Interaction														
SE m ±	0.06	0.06	0.07	0.08	0.10	0.09	0.12	0.08	0.10	0.09	0.08	0.07	0.07	0.08
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	3.82	4.12	4.33	4.66	4.97	4.78	4.51	4.19	4.43	4.85	5.00	5.22	5.01	4.82

Effect of irrigation systems

The application of irrigation through floppy sprinkler system produced significantly more leaf area index than all other irrigation systems at all the crop growth stages during both the years except 90 days after planting during 2005-06. The leaf area index is reliable index of crop productivity which was thus favourably influenced under this system. The application of irrigation through overhead sprinkler produced significantly more leaf area index than surface and drip irrigation systems during both the years except at 90 and 146 days during 2005-06 and 90 and 118 days during 2006-07. However, surface and drip irrigation systems significantly decreased the leaf area index throughout the crop growth period during both the seasons owing to reduction in leaf size and leaf curling.

Effect of integrated nutrient management

The mean leaf area index of ginger was significantly more with application of 100 per cent general recommended dose of fertilizer than all other integrated nutrient management practices at all the days of observations during both the years. The application of 25 per cent recommended dose of nitrogen through organic sources and 75 per cent recommended dose of nitrogen through inorganic fertilizer also produced significantly higher leaf area index than all other integrated nutrient management practices during both the years except the application of 50 per cent recommended dose of nitrogen through organic sources and 50 per cent recommended dose of nitrogen through inorganic fertilizer was

found at par with each other at 174, 202 and at harvesting stage during first year of experiment. The leaf area index was significantly the lowest with the application of 100 per cent recommended dose of nitrogen through organic sources. This might be due to mineralization of organic manures and less availability of nutrients during proper growth period of plants might have reduced the leaf area index during both the years of investigation. These results are confirmity with the findings of Mridula and Jaychandran (1998).

Interaction effect

Interaction effect between irrigation systems and integrated nutrient management practices were found to be non significant for the leaf area index at all the days of observations under investigation.

4.1.7 Dry matter production

The data on dry matter production per plant (g per plant) as influenced periodically by irrigation systems and integrated nutrient management practices during both the seasons are presented in Table 15.

The dry matter production per plant increased with advancement in crop growth. The process of dry matter accumulation was very slow at initial stage of crop and increased gradually upto harvest of the crop. The mean dry matter accumulation per plant at initial stage (90 DAP) was 3.57 and 3.97 g per plant in first and second season, respectively. It increased progressively with advancement of

Table 15. Mean dry matter of shoots per plant (g) as influenced periodically by irrigation systems and integrated nutrient management

Treatment	Days after planting 2005-06							Days after planting 2006-07						
	90	118	146	174	202	230	At Harvest	90	118	146	174	202	230	At Harvest
Irrigation systems														
Surface	3.29	3.95	7.12	9.41	10.86	12.01	13.16	3.47	3.92	7.45	9.18	11.23	12.10	13.20
Drip	3.52	4.38	7.34	9.54	11.08	12.16	13.30	3.91	4.42	7.53	9.38	11.58	12.21	13.34
Floppy Sprinkler	3.72	5.50	7.42	9.53	11.78	13.22	14.36	4.28	5.28	8.03	9.92	12.07	13.27	14.37
Overhead Sprinkler	3.75	5.43	7.12	9.04	11.40	12.54	13.65	4.22	5.02	7.46	9.59	11.79	12.65	13.69
SE m ±	0.28	0.22	0.19	0.10	0.07	0.11	0.07	0.24	0.19	0.11	0.02	0.04	0.09	0.10
CD at 5%	N.S.	0.76	N.S.	0.33	0.24	0.37	0.22	N.S.	0.66	0.37	0.07	0.14	0.31	0.36
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer														
100% RDN through organic	2.93	3.97	6.38	8.76	10.27	11.39	12.30	3.25	3.81	6.54	8.75	10.61	11.42	12.34
75% RDN through organic + 25% RDN through inorganic	3.25	4.27	6.76	9.00	10.62	11.77	12.90	3.64	4.28	6.92	8.97	11.20	11.81	13.10
50% RDN through organic + 50% RDN through inorganic	3.57	4.78	7.16	9.31	11.28	12.45	13.59	4.02	4.56	7.40	9.23	11.66	12.52	13.64
25% RDN through organic + 75% RDN through inorganic	3.87	5.27	7.61	9.77	11.80	12.89	13.96	4.28	4.90	8.25	10.04	12.23	12.93	13.98
100% GRDF	4.21	5.77	8.35	10.06	12.43	13.90	15.34	4.66	5.76	8.98	10.59	12.64	14.00	15.42
SE m ±	0.04	0.06	0.07	0.10	0.09	0.10	0.09	0.08	0.08	0.21	0.12	0.8	0.4	0.12
CD at 5%	0.12	0.20	0.24	0.32	0.28	0.32	0.31	0.26	0.26	0.68	0.39	0.24	0.46	0.38
Interaction														
SE m ±	0.11	0.16	0.13	0.18	0.17	0.25	0.22	0.17	0.20	0.28	0.09	0.05	0.18	0.16
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	Sig.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	3.57	4.81	7.25	9.38	11.28	12.48	13.62	3.97	4.66	7.62	9.92	11.67	12.54	13.68

age and reached maximum of 13.62 and 13.68 g per plant at harvest during both the years, respectively.

Effect of irrigation systems

The dry matter production per plant was found significantly more in floppy sprinkler system than all other irrigation systems from 202 days (11.78 g) after planting till harvest (14.36 g) during first year and from 174 days(9.92 g) after planting to harvest (14.37 g)during second year, but it was on par with overhead sprinkler system at 118 days after planting during both the years. Significantly lower dry matter accumulation per plant was noticed in surface irrigation method which might be attributed to moisture stress during crop growth period affecting dry matter production and finally the yield. These results are similar to those obtained by Gite (1999).

Effect of integrated nutrient management

The application of 100 per cent general recommended dose of fertilizer produced significantly more dry matter production per plant than all other integrated nutrient management practices during both the years of investigation except the application of 25 per cent RDN through organic and 75 per cent RDN through inorganic fertilizer at 174 days after planting during first year. The more dry matter per plant might be due to better nutrient availability during entire growth period favoured the growth attributes which ultimately

contributed to increase in dry matter accumulation. Similarly, the application of 25 per cent RDN through organic sources and 75 per cent RDN through inorganic fertilizers was also found significantly superior over remaining integrated nutrient management practices during both the years, but it was at par with 50 per cent RDN through organic sources and 50 per cent RDN through inorganic fertilizers at 90, 230 and at harvest of experiment during second year. Significantly less dry matter accumulation per plant was recorded under 100 per cent RDN through organic sources. This might be due to mineralization of organic manures which affected the vegetative growth of plants. These results are in agreement with findings of Ai-xihen *et al.* (1997).

Interaction effect

Interaction effects between irrigation systems and integrated nutrient management practices were found to be non significant throughout crop growth period from 90 DAP till 230. However, interaction effects were significant for dry matter production during first year at harvest. The data for the same is presented in Table 16.

From the Table 16, it is observed that irrigating ginger with floppy sprinkler significantly increased dry weight of ginger per plant as compared to other irrigation systems under all integrated nutrient management practices except under 100 per cent RDN through organic sources and

Table 16. Interaction effect of irrigation systems and integrated nutrient management on dry weight of ginger plant (g / plant) at harvest during 2005-06

Irrigation systems	Integrated nutrient management				
	INM 1	INM2	INM3	INM4	INM5
Surface	12.10	12.67	13.23	13.45	14.37
Drip	11.82	12.40	13.40	13.83	15.03
Floppy sprinkler	12.73	13.53	14.10	14.58	16.85
Overhead sprinkler	12.53	13.00	13.63	13.97	15.12
	S.E. m ±	C.D. at 5%			
A at same level of B	0.22	0.64			
B at same level of A	0.21	0.62			

75 per cent RDN through organic sources and 25 per cent RDN through inorganic fertilizers owing to favourable microclimate. The application of general recommended dose of fertilizer produced significantly more dry weight of ginger per plant than other integrated nutrient management practices at harvest during 2005-06 under all the irrigation systems which may be attributed to availability more nutrients owing to improvement in physicochemical properties of soil.

4.1.8 Dry weight of rhizome per plant (g)

The data on dry weight of rhizome per plant production as influenced by different irrigation systems and

integrated nutrient management practices during both the seasons are presented in Table 17.

The dry weight of rhizome per plant increased with advancement in crop age. The process of dry weight accumulation of rhizome was very slow at initial stage of growth and reached maximum at harvest. The mean dry weight of rhizome per plant at initial stage (90DAP) was 6.42 and 6.92 g per plant in first and second season, respectively. It increased progressively with advancement of age and reached maximum of 25.52 and 26.0 g per plant at harvest during first and second year, respectively.

Effect of irrigation systems

The dry weight of rhizome production per plant significantly increased under floppy sprinkler and overhead sprinkler as compared to surface and drip irrigation systems during both the seasons except 174 and 202 days after planting. Micro-irrigation system as floppy sprinkler was found significantly superior over all other irrigation systems at 90 DAP and at harvest during first year but it was on par with overhead sprinkler during second year at 118, 146, 230 and at harvest. Significantly lower dry weight of rhizome per plant was recorded in surface irrigation which might be due to more irrigation interval with more moisture stress during formative phase which is most critical period for water demand and the stress during this period affected dry weight accumulation of rhizome and finally the yield of ginger.

Table17. Mean dry weight of rhizome (g / plant) of ginger as influenced periodically by irrigation systems and integrated nutrient management

Treatment	Days after planting 2005-06							Days after planting 2006-07						
	90	118	146	174	202	230	At Harvest	90	118	146	174	202	230	At Harvest
Irrigation systems														
Surface	6.38	7.74	10.86	16.21	19.14	22.31	24.97	6.62	7.97	10.74	16.23	19.25	22.50	25.18
Drip	6.17	8.16	10.71	16.36	19.32	22.45	25.16	6.82	8.14	10.93	16.46	19.47	22.69	25.49
Floppy Sprinkler	6.81	8.40	11.72	16.54	19.48	22.49	26.40	7.26	9.09	12.03	16.92	20.08	23.15	26.89
Overhead Sprinkler	6.33	8.24	11.12	16.44	19.41	22.54	25.55	6.96	8.65	11.66	16.67	19.56	22.84	26.43
SE m $\pm$	0.12	0.23	0.20	0.13	0.11	0.19	0.19	0.08	0.27	0.16	0.15	0.19	0.13	0.21
CD at 5%	0.39	N.S.	0.68	N.S.	N.S.	N.S.	0.67	0.28	0.92	0.53	0.51	0.64	0.44	0.73
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer														
100% RDN through organic	5.68	7.11	9.72	15.43	18.29	21.13	23.65	6.03	7.05	9.89	15.39	18.56	21.67	24.16
75% RDN through organic + 25% RDN through inorganic	6.16	7.67	10.39	15.83	18.75	21.57	24.51	6.80	8.14	10.43	15.97	19.00	21.93	25.01
50% RDN through organic + 50% RDN through inorganic	6.37	8.19	10.83	16.20	19.19	22.09	25.12	6.91	8.63	11.06	16.31	19.44	22.42	25.40
25% RDN through organic + 75% RDN through inorganic	6.77	8.59	11.83	16.77	19.69	22.61	25.93	7.17	8.95	12.47	17.05	19.92	22.79	26.59
100% GRDF	7.14	9.11	12.74	17.71	20.79	24.84	28.40	7.67	9.54	12.86	18.13	21.04	25.16	28.82
SE m $\pm$	0.04	0.10	0.09	0.11	0.14	0.07	0.08	0.19	0.14	0.29	0.20	0.26	0.20	0.20
CD at 5%	0.12	0.32	0.29	0.35	0.44	0.23	0.26	0.62	0.46	0.93	0.66	0.86	0.64	0.64
Interaction														
SE m $\pm$	0.14	0.23	0.17	0.15	0.15	0.14	0.25	0.22	0.40	0.47	0.40	0.38	0.34	0.40
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	Sig.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	6.42	8.13	11.10	16.39	19.34	22.45	25.52	6.92	8.46	11.34	16.57	19.59	22.79	26.0

Effect of integrated nutrient management

Among all the integrated nutrient management practices, the application of 100 per cent general recommended dose of fertilizer produced significantly higher dry weight of rhizome per plant than other nutrient management practices at all the crop growth stages during both the seasons of investigation except at 90 and 146 DAP during second year which was on par with application of 25 per cent RDN through organic sources and 75 per cent RDN through inorganic fertilizers. The highest dry rhizome production under this treatment could be attributed to more fresh rhizome weight per plant and high uptake of nutrients. These results are in agreement with finding of Raghava Rao and Swamy (1984). Similarly, the treatment of application of 25 per cent RDN through organic source and 75 per cent RDN through inorganic fertilizer was also found significantly superior over all other remaining integrated nutrient management practices during both the years. Significantly lower dry weight of rhizome per plant was recorded in the treatment of application of 100 per cent RDN through organic sources but it was at par with application of 75 per cent RDN through organic and 25 per cent through inorganic fertilizer at 146, 174, 202 and 230 days after planting in 2006-07. This might be due to mineralization of organic matter in the soil which may lead to less availability of nutrients for growth and development of rhizomes. These results are in agreement with findings of Srinivasan *et al.* (2000).

Interaction effect

Interaction between irrigation systems and integrated nutrient management practices were found to be non significant throughout the crop growth stages from 90 DAP till 202 DAP except at 230 days after planting where interaction effect was significant in dry weight of ginger rhizome during 2005-06.The data for same are presented in Table 18.

Table 18. Effect of interaction between irrigation systems and integrated nutrient management on dry weight of ginger rhizome (g / plant) at 230 days after planting during 2005-06

Irrigation systems	Integrated nutrient management				
	INM1	INM2	INM3	INM4	INM5
Surface	21.16	21.52	22.05	22.57	24.27
Drip	21.20	21.64	22.26	22.49	24.65
Floppy sprinkler	20.91	21.42	21.80	22.72	25.60
Overhead sprinkler	21.27	21.69	22.23	22.66	24.83
	S.E. m ±	CD at 5%			
A at same level of B	0.14	0.40			
B at same level of A	0.22	0.66			

Floppy sprinkler irrigation significantly increased dry weight of ginger rhizome over other irrigation systems under general recommended dose of fertilizer. General recommended dose of fertilizer significantly produced more dry

weight of ginger rhizome than other nutrient management practices in all the irrigation systems. The application of 25% RDN through organic + 75% RDN through inorganic sources also produced significantly more dry matter than 100% RDN through organic sources and 75% RDN through organic and 25% RDN through inorganic sources under floppy and overhead sprinkler methods at 230 days after planting during first year of experimentation.

4.1.9 Total dry matter production per plant (g)

The data on total dry matter production as influenced by irrigation systems and integrated nutrient management practices during both the years are presented in Table 19 and graphically depicted in Fig 7a and 7b.

The dry matter production increased with advancement in crop growth. The process of dry matter accumulation was very slow at initial stage of crop and reached maximum at harvest. The mean dry matter accumulation per plant at initial stage (90 DAP) was 9.94 and 10.89 g per plant in first and second season, respectively. It increased progressively with advancement of age and reached maximum of 39.14 and 39.67 g per plant at harvest in first and second season, respectively.

Effect of irrigation systems

The application of irrigation through floppy sprinkler system significantly produced higher total dry matter per plant than all other irrigation systems from 202

Table19. Mean total dry matter weight per plant of ginger (g) as influenced periodically by irrigation systems and integrated nutrient management

Treatment	Days after planting 2005-06							Days after planting 2006-07						
	90	118	146	174	202	230	At Harvest	90	118	146	174	202	230	At Harvest
Irrigation systems														
Surface	9.67	11.69	17.98	25.65	30.00	34.32	38.13	10.10	11.89	18.19	25.45	30.48	34.60	38.38
Drip	9.69	12.54	18.05	25.90	30.40	34.61	38.46	10.73	12.57	18.57	25.84	31.05	34.90	38.83
Floppy Sprinkler	10.53	13.90	19.14	26.07	31.26	35.71	40.76	11.54	14.27	20.02	26.84	32.16	36.42	41.26
Overhead Sprinkler	10.07	13.67	18.24	25.48	30.81	35.08	39.20	11.18	13.67	19.32	26.19	31.25	35.49	40.12
SE m±	0.29	0.38	0.32	0.28	0.10	0.24	0.20	0.29	0.38	0.13	0.16	0.18	0.13	0.17
CD at 5%	N.S.	1.31	1.12	N.S.	0.35	0.83	0.69	1.02	1.30	0.46	0.56	0.61	0.46	0.58
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer														
100% RDN through organic	8.61	11.08	16.10	24.19	28.56	32.52	35.95	9.30	10.81	16.38	24.14	29.17	33.09	36.50
75% RDN through organic + 25% RDN through inorganic	9.40	11.94	17.15	24.83	29.37	33.34	37.41	10.44	12.35	17.35	24.95	30.20	33.74	38.11
50% RDN through organic + 50% RDN through inorganic	9.45	12.97	17.99	25.51	30.47	34.54	38.71	10.94	13.19	18.58	25.54	31.01	34.94	39.04
25% RDN through organic + 75% RDN through inorganic	10.65	13.86	19.44	26.54	31.49	35.50	39.89	11.45	13.85	20.71	27.06	32.12	35.72	40.57
100% GRDF	11.36	14.88	21.09	27.77	33.22	38.74	43.74	12.33	15.30	22.09	28.72	33.68	39.16	44.24
SE m±	0.06	0.24	0.19	0.63	0.15	0.35	0.28	0.24	0.14	0.41	0.21	0.25	0.29	0.16
CD at 5%	0.20	0.79	0.62	2.05	0.49	1.14	0.91	0.76	0.46	1.35	0.70	0.82	0.95	0.52
Interaction														
SE m±	0.18	0.69	0.49	1.13	0.23	0.81	0.43	0.25	0.46	0.48	0.41	0.36	0.37	0.45
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	9.94	12.95	18.35	25.77	30.62	34.93	39.14	10.89	13.10	19.03	26.08	31.24	35.34	39.67

days after planting to harvest which may be due to better development of underground rhizome. However, it was at par with overhead sprinkler at 118, 146 and 230 days after planting of ginger crop during 2005-06 and at 90 days after planting during 2006-07. Similarly, the application of irrigation through overhead sprinkler system was found significantly superior over remaining irrigation systems at 146, 230 DAP and at harvest during second year but was on par with drip irrigation system
during first year and at remaining stages of second year. The higher accumulation of dry matter in the sprinkler irrigation systems over the surface irrigation could be result of increased fertilizer and water use efficiency owing to better availability of moisture and nutrients. The results are in conformity with the finding of Kannan (2008). The total dry matter production per plant was significantly the lowest under surface irrigation . Similar results were reported by Gite (1999).

Effect of integrated nutrient management

The application of 100 per cent general recommended dose of fertilizer recorded significantly higher total dry matter production per plant than other nutrient management practices at all the crop growth stages during both the years except at 174 DAP during first year which was at par with the treatment of application of 25 per cent RDN through organic sources and 75 per cent RDN through inorganic fertilizers. The application of 25 per cent RDN through organic sources and 75 per cent RDN through inorganic fertilizer was found significantly superior over all

other remaining integrated nutrient management practices during both the years of investigation except at 230 DAP. It was at par with application of 50 per cent RDN through organic sources and 50 per cent RDN through inorganic fertilizer at 174 days and 90 days during 2005-06 and 2006-07, respectively. The higher accumulation of dry matter in these treatments might be due to application of nitrogen through inorganic fertilizers and organic manures which resulted in increased fertilizer use efficiency owing to better availability of nutrients. These results are in agreement with findings of Kannan (2008).The total dry matter production per plant was significantly lower under application of 100 per cent RDN through organic sources during both the years. The results are confirmative with Srinivasan *et al.* (2000).

Interaction effect

Interaction effects between irrigation systems and integrated nutrient management practices were found to be non significant for total dry matter production per plant at all days of observations during both the years.

4.1.10 Fresh weight of rhizome per plant (g)

The data on fresh weight of rhizome per plant as influenced by irrigation systems and integrated nutrient management practices during both the seasons are presented in Table 20.

The mean fresh weight of rhizome at harvest was 150.02, 194.63 and 172.33 g per plant in first year, second year and in pooled data over the seasons.

Effect of irrigation systems

The fresh weight of rhizome per plant at harvest was significantly more under floppy sprinkler and overhead sprinkler than surface and drip irrigation systems during both the seasons and when the data were pooled over the seasons owing to adequate availability of soil moisture and favourable microclimatic parameters such as humidity and temperature in crop vicinity might have improved the development of underground rhizomes. The fresh weight of rhizome per plant was significantly lower under surface irrigation.

Integrated nutrient management

The application of 100 per cent general recommended dose of fertilizer recorded significantly more fresh weight of rhizome per plant than other integrated nutrient management practices at harvest of ginger during both the years. Similarly, the application of 25 per cent RDN through organic sources and 75 per cent RDN through inorganic fertilizers was also found significantly superior over all other integrated nutrient management practices during both the years. The higher production of fresh weight of rhizome under these treatments might be due to combined use

Table 20. Mean fresh weight of rhizome per plant (g) at harvest as influenced by different irrigation systems and integrated nutrient management

Treatment	2005-06	2006-07	Pooled
Irrigation systems			
Surface	134.48	167.42	150.95
Drip	136.66	180.99	158.82
Floppy Sprinkler	173.75	221.06	197.40
Overhead Sprinkler	161.87	209.07	185.47
SE m±	0.21	0.24	0.22
CD at 5%	0.63	0.72	0.66
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer			
100% RDN through organic	138.61	162.24	150.42
75% RDN through organic + 25% RDN through inorganic	141.74	178.10	159.92
50% RDN through organic + 50% RDN through inorganic	147.12	191.33	169.22
25% RDN through organic + 75% RDN through inorganic	153.63	203.90	178.76
100% GRDF	162.35	237.61	199.98
SE m±	0.10	0.18	0.15
CD at 5%	0.33	0.54	0.45
Interaction			
SE m±	0.23	0.40	0.35
CD at 5%	N.S.	N.S.	N.S.
General mean	150.02	194.63	172.33

of organic manures as well as inorganic fertilizers resulted in higher uptake of nutrients and consequently better improvement in rhizome weight. Similar results were reported by Raghava Rao and Swamy (1984). Significantly lower fresh weight of rhizome per plant was recorded with application of 100 per cent RDN through organic sources.

Interaction effect

Interaction effects between irrigation systems and integrated nutrient management practices were found to be non significant for fresh rhizome weight per plant at harvest during both the years.

4.2 Yield

4.2.1 Fresh rhizome yield (Green ginger yield)

The data on fresh rhizome yield as affected by various treatments during 2005-06 and 2006-07 and pooled over two years are presented in Table 21 and graphically depicted in Fig 8.

From the data in Table 21, it would be seen that the mean fresh rhizome yield was 14.07 and 15.89 t ha^{-1} in 2005-06 and 2006-07, respectively. When the data were pooled for two years, it was observed that the mean fresh rhizome yield was 14.98 t ha^{-1}.

Effect of irrigation systems

Irrigation scheduling through floppy sprinkler system significantly increased the fresh rhizome yield (17.24 t ha^{-1}) as compared to other irrigation

systems during second year and when the data were pooled over the seasons (16.57 t ha^{-1}) owing to frequent application of water with fairly uniform distribution of water resulted in almost no stress condition throughout the crop growth period in addition to maintenance of favourable microclimate condition as soil and crop temperature and humidity which might have increased fresh rhizome yield. Similar results were reported by Hooda *et al.* (1979). The increase in growth attributes viz., plant height, number of tillers, number of leaves, leaf area and dry matter production per plant and yield component like rhizome weight per plant resulted in increased fresh rhizome yield of ginger. Fresh rhizome yield per plant was positively associated with plant height, number of fingers per plant, weight of fingers and primary rhizome (Pandey and Dobhal, 1993). Singh (2001) reported that plant height followed by number of tillers per plant and leaf length had maximum direct effect on rhizome yield.

Further, it was observed that, irrigation scheduling with overhead sprinkler was on par with drip system for fresh rhizome yield during both the seasons and when the data were pooled over two seasons but it was significantly superior over surface irrigation during 2006-07. This may be ascribed to adequate moisture during formative phase which favourably influenced the development of underground rhizome and fresh rhizome yields. Most of the growth as well as yield attributes were also significantly increased under this irrigation system resulting in increased fresh rhizome yield. These results are

inconformity with findings of Patil (2003) and Sankar *et al.* (2008).

Effect of integrated nutrient management

The fresh rhizome yield was significantly increased with the application of 100 per cent general recommended dose of fertilizer as compared to all other integrated nutrient management practices during both the years as well as in pooled data. Similarly, the application of 25 per cent RDN though organic sources and 75 per cent RDN through inorganic fertilizer was also found significantly superior over other integrated nutrient management practices during second year and in pooled data. The higher yield due to application of organic manure in combination with nitrogenous fertilizers applied at split doses might have resulted in higher mineralization of various essential elements due to increased microbial activity and organic colloids resulting in better availability and uptake of these elements ultimately resulting increased photosynthetic activity. The increased photosynthetic activity in turn would have increased photosynthates assimilation resulting in higher C:N ratio, might have helped in more tillering, plant height, leaf area, rhizome development and ultimately resulting in higher yield. Similar results were reported by Reddy and Reddy (1998). Nitrogen plays an important role in commercial production of ginger. Nitrogen significantly increased the number of third

Table 21. Mean Fresh rhizome, dry rhizome, dry straw and total dry matter yield (t ha^{-1}) and harvest index (%) of ginger at harvest as influenced by different irrigation systems and integrated nutrient management

Treatment	Fresh rhizome yield (tha^{-1})			Dry rhizome yield (t ha^{-1})			Dry straw yield (t ha^{-1})			Total dry matter yield (t ha^{-1})			Harvest Index (%)		
	2005-06	2006-07	Pooled mean	2005-06	2006-07	Pooled mean	2005-06	2006-07	Pooled mean	2005-06	2006-07	Pooled mean	2005-06	2006-07	Pooled mean
Irrigation systems															
Surface	12.96	14.84	13.90	3.24	3.71	3.47	1.81	1.98	1.89	5.05	5.69	5.37	64.16	65.20	64.62
Drip	13.75	15.36	14.55	3.44	3.84	3.64	1.87	2.03	1.95	5.31	5.87	5.59	64.78	65.42	65.11
Floppy Sprinkler	15.90	17.24	16.57	3.72	4.31	4.01	2.06	2.36	2.21	5.78	6.67	6.22	64.36	64.65	64.46
Overhead Sprinkler	14.25	16.11	15.18	3.56	4.03	3.79	1.93	2.21	2.07	5.49	6.24	5.86	64.84	64.58	64.71
SE m±	0.65	0.29	0.40	0.04	0.03	0.08	0.02	0.03	0.04	0.09	0.17	0.12	0.45	0.27	0.37
CD at 5%	1.95	1.00	1.38	0.11	0.08	0.35	0.05	0.10	0.16	0.30	0.58	0.43	N.S.	N.S.	N.S.
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer															
100% RDN through organic	10.06	11.85	10.95	2.51	2.96	2.73	1.68	1.88	1.78	4.19	4.84	4.51	59.90	61.15	60.52
75% RDN through organic + 25% RDN through inorganic	12.46	14.00	13.23	3.11	3.50	3.30	1.79	2.07	1.93	4.90	5.57	5.23	63.47	62.83	63.15
50% RDN through organic + 50% RDN through inorganic	14.02	15.91	14.96	3.51	3.98	3.74	1.90	2.18	2.04	5.41	6.16	5.78	64.88	64.61	64.74
25% RDN through organic + 75% RDN through inorganic	15.57	18.00	16.78	3.89	4.50	4.19	1.98	2.22	2.01	5.87	6.72	6.29	66.27	66.96	66.61
100% GRDF	17.71	19.67	18.69	4.43	4.91	4.67	2.23	2.38	2.30	6.66	7.29	6.97	66.51	67.35	66.93
SE m±	0.50	0.38	0.20	0.05	0.05	0.04	0.02	0.03	0.03	0.06	0.24	0.06	0.75	0.35	0.50
CD at 5%	1.63	1.23	0.65	0.17	0.14	0.16	0.05	0.10	0.12	0.21	0.77	0.19	2.44	1.13	1.60
Interaction															
SE m±	0.78	0.94	0.30	0.06	0.12	0.08	0.06	0.10	0.03	0.17	0.35	0.08	1.44	0.97	0.85
CD at 5%	N.S.	N.S.	Sig.	N.S.	N.S.	Sig.	N.S.	N.S.	N.S.	N.S.	N.S.	Sig.	N.S.	N.S.	N.S.
General mean	14.07	15.89	14.98	3.49	3.97	3.73	1.92	2.15	2.03	5.41	6.12	5.76	64.35	64.75	64.53

order shoots and fourth order rhizome branches and total yield of shoots as reported by Lee *et al.* (1981). Significantly lower yield of fresh rhizome was recorded under the application of 100 per cent RDN through organic sources during both the years and in pooled data. This might be due to slow mineralization of organic manures which may affect the slow growth of plants, less number of tillers, leaf area, dry straw yield and slow development of underground rhizomes. The yield was the highest, when fertilizers were applied in both organic and inorganic forms (75:50:50 NPK kg ha^{-1} + 25 t FYM ha^{-1}). Similar results were also reported by Pawar and Patil (1990) and Singh and Kushwah (2006).

It would be therefore advisable to apply 100 per cent general recommended dose of fertilizer (75: 50: 50 NPK kg ha^{-1} + 25 t FYM) for sustainable production of ginger.

Interaction effect

The interaction effects between irrigation systems and integrated nutrient management practices were significantly influenced in pooled data (Table 22).

The irrigation application through floppy and overhead sprinkler system produced significantly more fresh rhizome yield than surface and drip irrigation systems under all the integrated nutrient management practices owing to favourable microclimate under former irrigation systems when data were pooled over the seasons.

Table 22. Effect of interaction between irrigation systems and integrated nutrient management on pooled fresh rhizome and dry rhizome yields and total dry matter yield of ginger (t ha^{-1}) .

Irrigation systems	Pooled fresh rhizome yield (t ha^{-1})					Pooled dry rhizome yield (t ha^{-1})					Pooled total dry matter yield (t ha^{-1})				
	Integrated nutrient management					Integrated nutrient management					Integrated nutrient management				
	INM_1	INM_2	INM_3	INM_4	INM_5	INM_1	INM_2	INM_3	INM_4	INM_5	INM_1	INM_2	INM_3	INM_4	INM_5
Surface	10.0	12.63	13.90	15.81	17.18	2.59	3.25	3.57	4.04	4.39	4.38	5.16	4.60	6.11	6.62
Drip	11.26	12.91	14.24	15.78	18.54	2.72	3.13	3.46	3.85	4.54	4.55	5.09	5.52	5.95	6.82
Floppy sprinkler	12.03	14.44	16.80	18.93	20.63	2.88	3.48	4.08	4.61	5.03	4.79	5.57	6.27	6.87	7.63
Overhead sprinkler	11.03	13.42	15.41	17.15	18.87	2.76	3.35	3.85	4.29	4.72	4.55	5.31	5.96	6.45	7.03
	S.E. m $\pm$		CD at 5%			S.E. m $\pm$		CD at 5%			S.E. m $\pm$		CD at 5%		
A at same level of B	0.30		0.91			0.07		0.23			0.07		0.23		
B at same level of A	0.40		1.57			0.10		0.39			0.12		0.47		

The pooled fresh rhizome yield was significantly the lowest under application of 100 per cent RDN through organic sources under all the irrigation systems. Further, it was observed that the application of 100 per cent general recommended dose of fertilizer and 25 per cent RDN through organic sources and 75 percent RDN through inorganic fertilizers produced significantly more pooled fresh rhizome yield than remaining integrated nutrient management practices under all the irrigation systems except drip irrigation system.

4.2.2 Dry rhizome yield

The data on dry rhizome yield as affected by irrigation systems and integrated nutrient management practices during 2005-06 and 2006-07 and pooled over season are presented in Table 21 and graphically depicted in Fig 9.

From the data in Table 21, it would seen that mean dry rhizome yield was 3.49 and 3.97 tha^{-1} in 2005-06 and 2006-07, respectively. It was 3.73 tha^{-1} under pooled data.

Effect of irrigation systems

Irrigation scheduling through floppy and overhead sprinkler systems significantly increased dry rhizome yield as compared to other irrigation systems in both the seasons of investigation and when data were pooled over seasons. This might be ascribed to no moisture stress in formative phase which favourably influenced the development of underground rhizome resulting in increased dry rhizome yields. The

increase in growth attributes viz., plant height, number of tillers, number of leaves, leaf area and dry matter production per plant and yield components like rhizome weight per plant resulted in increased dry rhizome yield of ginger. Patil (2003) also reported similar results. Rhizome yield per plant was positively associated with plant height, number of fingers per plant, weight of fingers and primary rhizome (Pandey and Dobhal, 1993). Singh (2001) reported that plant height followed by number of tillers per plant and leaf length had maximum direct effect on rhizome yield.

Significantly low dry rhizome yield of 3.24, 3.71 and 3.47 tha^{-1}, was recorded during 2005-06, 2006-07 and in pooled data except drip under surface irrigation because of reduction in growth and yield attributes as well as nutrient uptake. The lower dry rhizome yield in surface irrigation could be attributed to inefficient use of irrigation water, deep percolation and uneven distribution of irrigation water. This confirms the finding of Sankar *et al*. (2008).

Effect of integrated nutrient management

The dry rhizome yield was significantly increased with the application of 100 per cent general recommended dose of fertilizer as compared to all other integrated nutrient management practices during both the years as well as in pooled data. Similarly, the application of 25 per cent RDN through organic sources and 75 per cent RDN through inorganic fertilizer was also found significantly superior over

other integrated nutrient management practices during both the years and in pooled data. The increase in production under these treatments could be attributed to more fresh weight of rhizome and more uptake of nutrients. These results are conformity with the findings of Raghava Rao and Swamy (1984). Significantly low yield of dry rhizome was recorded under the treatment of application of 100 per cent RDN through organic sources only. This might be due to slow mineralization of organic manures which may affect the slow growth of plants, less number of tillers, leaf area, dry straw yield and slow development of rhizomes. Similar results were reported by Pawar and Patil (1990) and Singh and Kushwah (2006).

Interaction effect

The interaction between irrigation systems and integrated nutrient management practices was significant in pooled data (Table 22).

The application of irrigation through floppy sprinkler system produced significantly more dry rhizome yield than surface and drip irrigation systems but it was at par with overhead sprinkler under all the integrated nutrient management practices owing to favourable microclimate under former irrigation system. Among the integrated nutrient management practices, the application of 100 per cent general recommended dose of fertilizer and 25 per cent RDN through organic sources and 75 per cent RDN through inorganic

fertilizer recorded significantly higher dry rhizome yield than other integrated nutrient management practices under all the irrigation systems. The pooled dry rhizome yield was significantly lowest under application of 100 per cent RDN through organic sources under all the irrigation systems.

4.2.3 Dry straw yield

Data on mean dry straw yield as influenced by different irrigation systems and integrated nutrient management practices are presented in Table 21 and graphically depicted in Fig 9.

The mean dry straw yield was 1.92, 2.15 and 2.03 t ha^{-1}during 2005-06, 2006-07 and when the data were pooled over the seasons, respectively.

Effect of irrigation systems

The scheduling of irrigation with floppy sprinkler system significantly increased dry straw yield as compared to surface, drip and overhead sprinkler irrigation systems during both the seasons and in pooled data but it was found at par with overhead sprinkler system when data were pooled over seasons. The favourable microclimate due to adequate soil moisture under floppy sprinkler system resulted in more dry straw yield. The scheduling of irrigation with overhead sprinkler also significantly increased dry straw yield as compared to surface and drip irrigation systems during both the years and over surface irrigation in pooled data. Significantly low dry straw yield was noticed under surface

irrigation method during both the years and in pooled data because of reduction in growth attributes. This confirms the finding of Gogoi (2001).

Effect of integrated nutrient management

Among the integrated nutrient management practices the dry straw yield was significantly increased with application of 100 per cent general recommended dose of fertilizer as compared to all other integrated nutrient management practices during both the years as well as in pooled data. The more plant height, number of tillers, number of leaves and leaf area per plant were attributed to increase in dry matter accumulation and consequently significant increase in dry straw yield under 100 per cent general recommended dose of fertilizer. Similarly, the application of 25 per cent RDN through organic sources and 75 per cent RDN through inorganic fertilizer was also found significantly superior over other integrated nutrient management practices for dry straw yield during both the seasons but it was on par with the application of 50 per cent RDN through organic sources and 50 per cent RDN through inorganic fertilizer. The higher dry matter production under general recommended dose of fertilizer with bio-fertilizer inoculated plants might be because of facts that root inoculation with *Azotobacter* and *PSB* might have augmented the uptake of NPK helping in acquiring higher dry weight.

Interaction effect

Interaction effects between irrigation systems and integrated nutrient management practices were found to be non significant for dry straw yield of ginger at harvest during both the seasons.

4.2.4 Total dry matter yield (t ha^{-1})

Data on mean dry rhizome, dry straw and total dry matter yield as influenced by different irrigation systems and integrated nutrient management practices are presented in Table 21 and depicted in Fig 9.

The mean total dry matter yield observed was 5.41 t ha^{-1} during 2005-06 and 6.12 t ha^{-1} during 2006-07 and 5.76 t ha^{-1} in pooled data.

Effect of irrigation systems

The total dry matter yield was significantly more under floppy sprinkler than surface and drip irrigation systems during both the years and when the data were pooled over the season (Table 21) owing to favourable microclimate due to adequate soil moisture throughout the crop growth period under floppy sprinkler irrigation system resulted in increased total dry matter yield. These results corroborate the finding of Patil (2003). Further, it was observed that overhead sprinkler irrigation significantly produced more total dry matter yield than surface irrigation during both the years and in pooled data. These results are similar to those reported by Gogoi (2001).

Effect of integrated nutrient management

The total dry matter yield was significantly increased with the application of 100 per cent general recommended dose of fertilizer as compared to all other integrated nutrient management practices during both the years as well as in pooled data. The increase of dry matter accumulation might be due to synergistic effect of nutrient supply to the plants and ultimately resulting in increased production and accumulation of photosynthates. Similar result was reported by Drawid and Biswas (1996). The higher plant height, number of tillers per plant, more fresh weight, driage and more up take of nutrients were attributed to increase in dry matter production. These results are in confirmity with the findings of Raghava Rao and Swamy (1984), Venkatesha *et al.* (1998) and Anchal Dass *et al.* (2008).

The application of FYM and inorganic fertilizer conserving soil moisture also maintained favourable temperature for microbial activities to enhance mineralization and helped to increase the fertilizer use efficiency which as a result increased total dry matter yields. The higher dry matter production under general recommended dose of fertilizer with bio-fertilizer inoculated plants might be because of facts that root inoculation with *Azotobacter* and PSB might have augmented the uptake of NPK helping in acquiring higher dry weight. Similar results were reported by Bijayadevi and Limi Ado (2005).

Interaction effect

The interaction between irrigation systems and integrated nutrient management practices was significant in pooled data (Table 22). The irrigation application through floppy and overhead sprinkler system produced significantly more total dry matter yield in pooled data than surface and drip irrigation systems under all integrated nutrient management practices owing to favourable microclimate under former irrigation system (Table 22). The pooled total dry matter yield was significantly lowest under application of 100 per cent RDN through organic sources under all irrigation systems. Further, it was observed that the application of 100 per cent general recommended dose of fertilizer and 25 per cent RDN through organic sources and 75 per cent RDN through inorganic fertilizer produced significantly more pooled total dry matter yield than remaining integrated nutrient management treatments under all the irrigation systems.

4.2.5 Harvest index (%)

The data on harvest index as influenced by different irrigation systems and integrated nutrient management practices during both the seasons are presented in Table 21.

The mean harvest index was 64.51 and 64.75 during 2005-06 and 2006-07, respectively and 64.53 per cent in pooled data.

Effect of irrigation systems

The harvest index was not significantly influenced due to different irrigation systems during both the years and when the data were pooled over the seasons.

Effect of integrated nutrient management

The application of 100 per cent general recommended dose of fertilizer recorded significantly higher harvest index than all other integrated nutrient management practices during both the years and in pooled data but it was at par with the treatment of application of 25 per cent RDN through organic sources and 75 per cent RDN through inorganic fertilizer and 50 per cent RDN through organic sources and 50 per cent RDN through inorganic fertilizer during first season and with application of 25 per cent RDN through organic sources and 75 per cent RDN through inorganic fertilizer during second year and in pooled data. Significantly minimum harvest index was recorded under the treatment of application of 100 per cent RDN through organic sources.

Interaction effect

Interaction effects between irrigation systems and integrated nutrient management practices were found to be non significant for harvest index during both the seasons.

4.3 Quality studies

4.3.1 p^H of ginger pulp

To know the effect of different treatments on p^H of ginger pulp, green ginger pulp was tested during both the years. The data regarding the same are given in Table 23. The mean p^H of ginger pulp observed was 6.22 and 6.23 in 2005-06 and 2006-07, respectively. This indicates that ginger pulp is acidic in nature.

Effect of irrigation systems

The p^H of ginger pulp was not significantly influenced due to irrigation systems during both the years. However, in pooled data the differences were statically significant. The maximum p^H of 6.24 and 6.25 were observed under the application of irrigation through drip irrigation. In pooled data the application of irrigation through drip irrigation system recorded significantly higher p^H of ginger pulp than surface irrigation system.

Effect of integrated nutrient management

The p^H of ginger pulp under different integrated nutrient management practices were significantly influenced by different treatments during both the years of experimentation. During first year of experimentation the application of 100 per cent RDN through organic sources was found significantly superior over all other integrated nutrient management practices but it was at par with treatment of

application of 75 per cent RDN through organic sources and 25 per cent RDN through inorganic fertilizers. Similarly, data of second year and pooled indicate that the application of 100 per cent RDN through organic sources registered significantly higher p^H of ginger pulp than all other treatments. Significantly the lowest p^H of ginger pulp was observed under the treatment of application of 100 per cent general recommended dose of fertilizer.

Interaction effect

Interaction effects between irrigation systems and integrated nutrient management practices were found to be non significant for p^H of ginger pulp at harvest during both the seasons.

4.3.2 Volatile oil content

The aroma and flavour of ginger are determined by the composition of its stem volatile oil which is comprised mainly of sesquiterpene hydrocarbons, monoterphene hydrocarbons and oxygenated monoterphene. The monoterphene constituents are believed to be the most important contributors to the aroma of ginger and they tends to be relatively more abundant in the natural oil of the fresh (green) rhizome than in the essential oil distilled from dried ginger. Oxygenated sesquiterphenes are relatively minor constituents of the volatile oil but appears to be significant contributors to its flavour properties.

Table 23. Mean per cent acidity, Volatile oil (%), Crude fat (%) and Oleoresin (%) content in ginger at harvest as influenced by different irrigation systems and integrated nutrient management

Treatment	pH			Volatile oil (%)			Crude fat (%)			Oleoresin (%)		
	2005-06	2006-07	Pooled mean	2005-06	2006-07	Pooled mean	2005-06	2006-07	Pooled mean	2005-06	2006-07	Pooled mean
Irrigation systems												
Surface	6.19	6.19	6.19	1.76	1.78	1.77	5.35	5.39	5.37	4.51	4.53	4.52
Drip	6.24	6.25	6.24	1.82	1.83	1.82	5.78	5.80	5.79	4.54	4.55	4.54
Floppy Sprinkler	6.23	6.24	6.23	1.87	1.89	1.88	6.01	6.09	6.05	4.55	4.58	4.56
Overhead Sprinkler	6.19	6.23	6.21	1.85	1.87	1.86	5.86	5.92	5.89	4.54	4.56	4.55
SE m+	0.10	0.03	0.012	0.05	0.02	0.004	0.03	0.05	0.11	0.11	0.02	0.003
CD at 5%	N.S.	N.S.	0.038	N.S.	0.06	0.015	0.09	0.16	0.33	N.S.	N.S.	0.009
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer												
100% RDN through organic	6.61	6.61	6.61	1.85	1.87	1.86	5.86	5.93	5.89	4.71	4.72	4.71
75% RDN through organic + 25% RDN through inorganic	6.28	6.30	6.29	1.83	1.86	1.84	5.81	5.88	5.84	4.68	4.70	4.69
50% RDN through organic + 50% RDN through inorganic	6.18	6.18	6.18	1.83	1.85	1.84	5.75	5.77	5.76	4.59	4.60	4.59
25% RDN through organic + 75% RDN through inorganic	6.08	6.10	6.09	1.81	1.83	1.82	5.69	5.73	5.71	4.39	4.41	4.40
100% GRDF	5.92	5.93	5.92	1.79	1.82	1.80	5.65	5.70	5.67	4.30	4.35	4.32
SE m+	0.11	0.05	0.003	0.06	0.04	0.001	0.16	0.11	0.008	0.11	0.09	0.007
CD at 5%	0.33	0.15	0.010	N.S.	N.S.	0.003	N.S.	N.S.	N.S.	N.S.	0.30	0.022
Interaction												
SE m+	0.24	0.09	0.02	0.16	0.09	0.005	0.20	0.15	0.02	0.28	0.12	0.006
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	6.22	6.23	6.22	1.82	1.85	1.84	5.75	5.80	5.78	4.54	4.56	4.55

Mean volatile oil content in ginger on dry weight basis at the harvest was 1.82 and 1.85 per cent in 2005-06 and 2006-07, respectively. The treatment effects of irrigation systems and integrated nutrient management practices are also depicted graphically in Fig 10a and 11a.

Effect of irrigation systems

The volatile oil content in ginger was not significantly influenced due to irrigation systems during first year of investigation. The volatile oil content of ginger was significantly more under floppy (1.89%) and overhead sprinkler (1.87) irrigation system than surface and drip irrigation systems during 2006-07 and when the data were pooled over the seasons. The increase in volatile oil content in ginger was associated with the adequate application of irrigation water which favourably influenced volatile oil in ginger. During second year of experimentation floppy, overhead and drip irrigation systems were on par with each other.

Effect of integrated nutrient management

The volatile oil content of ginger was not significantly influenced due to different integrated nutrient management practices during both the years of experimentation. However, the volatile oil content of ginger was significantly increased with application of 100 % RDN through organic sources and 75 per cent RDN through organic sources and 25 per cent RDN through inorganic fertilizer when the data were pooled over the seasons except later nutrient management practice was on par with application of 50 per cent RDN through organic sources and 50 per cent RDN

through inorganic fertilizer. These results are in agreement with findings of Ai-xizhen *et al*.(1998).

Interaction effect

Interaction effects between irrigation systems and integrated nutrient management practices were found to be non significant for volatile oil content in ginger at harvest during both the years.

4.3.3 Crude fat content

The data regarding crude fat content (%) in ginger rhizome on dry weight basis as affected by different treatments at harvest are given in Table 23. and graphically shown in Fig 10a. On an average, the crude fat content in ginger rhizome was 5.75 and 5.80 per cent during 2005-06 and 2006-07, respectively.

Effect of irrigation systems

The crude fat content in ginger was influenced significantly due to different irrigation systems during both the years and in pooled data. The application of irrigation through floppy sprinkler significantly increased crude fat content as compared to all other irrigation systems during both the years. Significantly the lowest crude fat content was observed in the treatment of application of irrigation water through surface during both the years of experimentation and in pooled data.

Effect of integrated nutrient management

The data in Table 23 indicate that the crude fat content in ginger was not influenced significantly due to

different integrated nutrient management practices during both the years of experimentation and in pooled data. However, the maximum crude fat content in ginger was noticed under the treatment of application of 100 per cent RDN through organic sources during both the years and in pooled data.

Interaction effect

Interaction effects between irrigation systems and integrated nutrient management practices were found to be non significant for crude fat content in ginger at harvest during both the years and in pooled data.

4.3.4 Oleoresin content

The data regarding oleoresin content (%) in ginger rhizome on dry weight basis as affected by different treatments at harvest are given in Table 23. and graphically shown in Fig 10b and 11b. On an average the oleoresin content in ginger rhizome was 4.54 and 4.56 per cent during 2005-06 and 2006-07, respectively.

Effect of irrigation systems

The oleoresin content in ginger rhizome was not significantly influenced by different irrigation systems during both the years but it was significantly influenced in pooled data. The application of irrigation through floppy sprinkler significantly increased the oleoresin content of ginger as compared to irrigation applied through drip system under pooled data. Further, it was observed that significantly the

lowest oleoresin content was obtained under surface irrigation when the data were pooled over the seasons.

Effect of integrated nutrient management

The oleoresin content in rhizome of ginger was not significantly influenced during first year due to integrated nutrient management practices but it was found significantly influenced during second year and in pooled data. The application of 100 per cent RDN through organic sources significantly increased oleoresin of rhizome as compared to application of 100 per cent RDN through inorganic fertilizers and 100 per cent GRDF during second year of experimentation. Similar results were reported by Majumdar *et al.* (2005). Application of organic cake increased oleoresin production (Rajan and Singh 1973, Sadanandan and Hamza, 1998). Pooled data indicates that the application of 100 per cent RDN through organic sources and 75 per cent RDN through organic sources and 25 per cent RDN through inorganic fertilizer were found significantly superior over all other integrated nutrient management practices. Significantly lower oleoresin content in rhizome of ginger was observed due to application of 100 per cent general recommended dose of fertilizer when the data were pooled over the seasons.

Interaction effect

Interaction effects between irrigation systems and integrated nutrient management practices were found to be

non significant for oleoresin content in rhizome of ginger at harvest during both the years.

4.3.5 Crude fibre content

The crude fibre content is an index of maturity of ginger. It varies from 4.5 to 10 per cent in different varieties. Lower values are desirable for dry ginger. Kerala ginger is considered to be one of the best ones of the country, due to its lower fibre content. Ginger produced in the other states has higher fibre content, except in Assam and is largely used for internal consumption in the form of green ginger. As the harvesting is delayed the fibre content increases. The variation in it may also be due to differences in elevation, rainfall and manurial inputs.

The data on crude fibre content (%) in ginger rhizome on dry weight basis at the harvest for both the years are presented in Table 24 and graphically depicted in Fig 10b and 11b. Mean crude fibre content was 6.63 and 6.66 per cent during 2005-06 and 2006-07.

Effect of irrigation systems

Differences in crude fibre content in ginger were statistically non significant during first season but it was significant during second year and in pooled data. The crude fibre per cent in ginger rhizome was significantly more under floppy and overhead sprinkler irrigation systems than drip and surface irrigation systems during second year of

experimentation and when the data were pooled over the seasons.

Effect of integrated nutrient management

The differences in crude fibre content due to integrated nutrient management practices were statistically significant during both the years. The application of 100 per cent RDN through organic sources significantly increased crude fibre content as compared to other integrated nutrient management practices during first and second year of experimentation and when the data were pooled over the seasons. Similarly, the application of 75 per cent RDN through organic sources and 25 per cent RDN through inorganic fertilizer was also significantly superior over all other treatments except the application of 100 per cent RDN through organic sources and 50 per cent RDN through organic and 50 per cent through inorganic fertilizer during both the years. Significantly lowest crude fibre content was observed under the application of 100 per cent general recommended dose of fertilizer. These results are in agreement with Sugito and Maftuchah (1998). This might be due to slow rate of nitrification as compared to that in the treatments where nitrogen was applied as urea. In general, nitrogen supply in adequate quantity developed the plant succulent. In the case of the treatments where N, P and K was applied only through fertilizers, the quantity of readily available N was more as compared to N supplied through FYM. Hence, there may be less fibre content in the treatment of application of 100 per cent general recommended dose of

Table 24. Mean Crude fibre (%), Starch (%) and Ash (%) content in ginger at harvest as influenced by different irrigation systems and integrated nutrient management

Treatment	Crude fibre (%)			Starch (%)			Ash (%)		
	2005-06	2006-07	Pooled mean	2005-06	2006-07	Pooled mean	2005-06	2006-07	Pooled mean
Irrigation systems									
Surface	6.51	6.53	6.52	46.24	46.40	46.32	6.49	6.54	6.51
Drip	6.53	6.55	6.54	47.36	47.87	47.61	6.53	6.58	6.55
Floppy Sprinkler	6.76	6.79	6.77	51.66	51.65	51.65	6.63	6.66	6.64
Overhead Sprinkler	6.74	6.76	6.75	49.80	49.82	49.81	6.59	6.63	6.61
SE m±	0.09	0.04	0.003	1.07	0.54	0.12	0.06	0.04	0.005
CD at 5%	N.S.	0.14	0.008	3.71	1.87	0.39	N.S.	N.S.	0.017
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer									
100% RDN through organic	7.13	7.13	7.13	50.45	51.59	51.02	6.60	6.65	6.62
75% RDN through organic + 25% RDN through inorganic	6.59	6.61	6.60	49.67	50.20	49.94	6.59	6.61	6.60
50% RDN through organic + 50% RDN through inorganic	6.53	6.56	6.54	48.96	49.09	49.03	6.58	6.60	6.59
25% RDN through organic + 75% RDN through inorganic	6.49	6.52	6.50	47.95	47.58	47.76	6.54	6.60	6.57
100% GRDF	6.42	6.46	6.44	46.79	46.22	46.50	6.48	6.54	6.51
SE m±	0.11	0.12	0.07	1.27	1.31	0.35	0.10	0.08	0.011
CD at 5%	0.37	0.39	0.023	N.S.	4.28	1.30	N.S.	N.S.	0.035
Interaction									
SE m±	0.18	0.15	0.003	1.98	2.35	0.40	0.19	.15	0.02
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	6.63	6.66	6.65	48.76	48.93	48.85	6.56	6.60	6.58

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fertilizer than organic source treatments. Contrary to this Aclan and Quisumbing (1978) and Nair and Das (1982) reported that the fibre content in rhizome was not affected by the fertilizer nitrogen.

Interaction effect

Interaction effect between irrigation systems and integrated nutrient management practices was found to be non significant for crude fibre content in ginger at harvest during both the years and in pooled data.

4.3.6 Starch content

The starch content is also an important quality constituent of dry ginger. It ranges from 40 to 60 per cent in different varieties. This decreases as the maturity is delayed beyond 8 to 9 months after planting. More starch is considered to be better for quality dry ginger.The variation in starch content of ginger may also be due to different elevation, rainfall and manurial inputs.

Starch content (%) in ginger on dry weight basis at the harvest as affected by various treatments was also estimated (Table 24 and Fig 10b and 11b). The average starch content was observed to be 48.76 and 48.93 per cent in 2005-06 and 2006-07.

Effect of irrigation systems

The application of irrigation through floppy sprinkler recorded significantly higher starch content than drip and surface irrigation systems but it was on par with

overhead sprinkler system during both the years of investigation. During second year the application of irrigation through overhead sprinkler was also found significantly superior over drip and surface irrigation systems but was on par with floppy sprinkler system. In pooled data also, the application of irrigation through floppy sprinkler system was found significantly superior over all other irrigation systems. Similarly, the application of irrigation through overhead sprinkler was also found significantly superior over other irrigation systems. Significantly lower starch content in ginger was observed in the treatment of application of irrigation through surface method.

Effect of integrated nutrient management

The differences in starch content in ginger rhizome were found non significant during first year of experimentation but it was found significant during second year and in pooled data. The starch content in rhizome of ginger was significantly more with application of 100 per cent RDN through organic sources over 100 per cent general recommended dose of fertilizer during second year experimentation. Pooled data indicates that the application of 100 per cent RDN through organic sources was found significantly superior over all other treatments for starch content in rhizome of ginger except 75 per cent RDN through organic sources and 25 per cent RDN through inorganic fertilizer. Similarly, this treatment was also found significantly superior over other integrated nutrient

management practices but it was at par with the application of 50 per cent RDN through organic sources and 50 per cent RDN through inorganic fertilizer. This might be due to increased availability of N at higher level of inorganic fertilizers might have induced the succulency in rhizome resulting in reduction in starch concentration in rhizome. These results are in agreement with findings of Calskan *et al.* (2004) and Naveen kumar singh *et al.* (2008).

Thus, the application of NPK helped the plants for better growth and finally better photosynthetic activities. Ultimately this might have increased the starch content in rhizome. In an integrated approach, application of fertilizers increased the starch content in ginger but decreased it with delay in harvesting.

Interaction effect

Interaction effect between irrigation systems and integrated nutrient management practices for starch content in rhizome of ginger was found to be non significant during both the years and in pooled data.

4.3.7 Ash content

Total ash content (%) on dry weight basis at the harvest was estimated from the ginger rhizomes. The data are presented in Table 24 and graphically depicted in Fig 10b and 11b. The average total ash content of ginger rhizome observed was 6.56 and 6.60 per cent in 2005-06 and 2006-07.

Effect of irrigation systems

The total ash content was not significantly influenced due to different irrigation systems during both the years of experimentation. However, it was significantly highest under floppy sprinkler followed by overhead sprinkler, drip and surface irrigation when the data were pooled over the seasons.

Effect of integrated nutrient management

Total ash content in rhizomes of ginger at harvest under integrated nutrient management practices were found statistically non significant during both the years but it was found significant in pooled data. The application of 100 per cent RDN through organic sources significantly increased ash content as compared to application of 100 per cent RDN through inorganic fertilizers in pooled data. Further, it was observed that the total ash content was significantly the lowest under general recommended dose of fertilizers when the data were pooled over the seasons.

Interaction effect

Interaction effect between irrigation systems and integrated nutrient management practices for total ash content in rhizome of ginger was found to be non significant during both the years.

4.4 Water use

The data in respect of water use under irrigation systems and integrated nutrient management practices are

presented in Table 25, 26 and 27. The data are not statistically analyzed and inferences are drawn on the basis of mean values.

The mean values of total water requirement of ginger was 837.92 and 724.73 mm, during the year 2005-06 and 2006-07, respectively whereas field water use efficiency was 169.61 and 219.25 q $ha^{-1}mm^{-1}$, respectively. The water saving was 24.61 and 21.07 per cent and water required for production of 1 tonne of ginger was 60.08 and 46.55, ha mm, respectively. From meteorological data, it is cleare that during second season rainfall distribution was good viz., 9.8 per cent in premonsoon, 73.40 per cent in monsoon and 15 per cent in post monsoon season which was 29.68 % more than first years rainfall. This reflected in lower water requirement of ginger crop during second season.

Effect of irrigation systems

The total water requirement of ginger under surface irrigation method at 70 mm CPE was numerically more than rest of irrigation systems owing to more number of irrigations The water requriment was noticed minimum in drip irrigation system throughout the crop growth period during both seasons and when the data were averaged over the seasons. Irrigation water saving due to drip irrigation compared to surface irrigation ranged from 30.38 to 30.79 %. These results are conformity with the finding of Manicksundaram *et al.*

Table 25. Irrigation water requirement and field water use efficiency of ginger as influenced by different irrigation systems and integrated nutrient management during 2005-06.

Treatment	Ginger yield (q / ha)	Water applied (mm)	Effective rainfall (mm)	Total water requirement (mm)	FWUE ($q\ ha^{-1}mm^{-1}$)	Water saving (%)	Water for 1 t ginger (ha mm)
Irrigation systems							
Surface	129.60	780.00	247.60	1027.60	126.12	-	79.29
Drip	137.50	598.19	113.00	711.19	193.34	30.79	51.72
Floppy Sprinkler	159.00	626.05	180.40	806.45	197.16	21.52	50.72
Overhead Sprinkler	142.50	626.05	180.40	806.45	176.70	21.52	56.59
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer							
100% RDN through organic	100.60	657.57	180.35	837.92	120.01	24.61	83.29
75% RDN through organic + 25% RDN through inorganic	124.60	657.57	180.35	837.92	148.70	24.61	67.24
50% RDN through organic + 50% RDN through inorganic	140.20	657.57	180.35	837.92	167.32	24.61	59.77
25% RDN through organic + 75% RDN through inorganic	155.70	657.57	180.35	837.92	185.82	24.61	53.81
100% GRDF	177.10	657.57	180.35	837.92	211.36	24.61	47.31
General mean	140.70	657.57	180.35	837.92	169.61	24.61	60.08

Table 26. Irrigation water requirement and field water use efficiency of ginger as influenced by different irrigation systems and integrated nutrient management during 2006-07.

Treatment	Ginger yield (t / ha)	Water applied (mm)	Effective rainfall (mm)	Total water requirement (mm)	FWUE ($q\ ha^{-1}mm^{-1}$)	Water saving (%)	Water for 1 t ginger (ha mm)
Irrigation systems							
Surface	148.40	540.00	320.80	860.80	172.40	-	58.00
Drip	153.60	454.88	144.40	599.28	256.31	30.38	39.01
Floppy Sprinkler	172.40	482.02	237.40	719.42	239.64	16.42	41.72
Overhead Sprinkler	161.10	482.02	237.40	719.42	223.93	16.42	44.66
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer							
100% RDN through organic	118.50	489.73	235.00	724.73	162.83	21.07	61.16
75% RDN through organic + 25% RDN through inorganic	140.00	489.73	235.00	724.73	193.17	21.07	51.77
50% RDN through organic + 50% RDN through inorganic	159.10	489.73	235.00	724.73	219.53	21.07	45.55
25% RDN through organic + 75% RDN through inorganic	180.00	489.73	235.00	724.73	248.37	21.07	40.26
100% GRDF	196.70	489.73	235.00	724.73	271.41	21.07	36.84
General mean	158.90	489.73	235.00	724.73	219.25	21.07	46.55

Table 27. Mean irrigation water requirement and field water use efficiency of ginger as influenced by different irrigation systems and integrated nutrient management

Treatment	Ginger yield (t / ha)	Water applied (mm)	Effective rainfall (mm)	Total water requirement (mm)	FWUE ($q\ ha^{-1}mm^{-1}$)	Water saving (%)	Water for 1 t ginger (ha mm)
Irrigation systems							
Surface	139.00	660.00	284.20	944.20	147.21	-	67.93
Drip	145.55	526.53	128.70	655.23	222.14	30.60	45.02
Floppy Sprinkler	165.70	554.03	208.90	762.93	217.19	19.20	46.02
Overhead Sprinkler	151.80	554.03	208.90	762.93	198.97	19.20	50.26
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer							
100% RDN through organic	109.55	573.64	207.67	781.32	140.21	23.00	71.32
75% RDN through organic + 25% RDN through inorganic	132.30	573.64	207.67	781.32	169.33	23.00	59.05
50% RDN through organic + 50% RDN through inorganic	149.65	573.64	207.67	781.32	191.53	23.00	52.20
25% RDN through organic + 75% RDN through inorganic	167.85	573.64	207.67	781.32	214.76	23.00	46.55
100% GRDF	186.90	573.64	207.67	781.32	239.21	23.00	41.80
General mean	149.80	573.64	207.67	781.32	193.39	23.00	53.35

(2002), Nalayini *et al.* (2006) and Kannan (2008). The second best irrigation system observed was floppy sprinkler system than other irrigation systems. The maximum field water use efficiency and less water required to produce 1 metric tonne of ginger was recorded when irrigations were scheduled under drip irrigation system followed by floppy sprinkler system. This might be attributed to the efficient use of irrigation water owing to no moisture stress in formative stage. The enhanced water use efficiency in drip system is because of decreased surface evaporation, reduced irrigation runoff, controlled deep percolation loss below the crop root zone and irrigation of smaller portion of the soil volume. Similar result was reported by Nalyini *et al.* 2006. The better water use efficiency through drip irrigation is attributed to the continuous supply of water in required quantity at right time without flooding to cause hypoxia. Therefore, the roots remain well aerated (Oweis and Hachum 2002, Rank 2007 and Sankar *et al.* 2008). The soils are saturated immediately after the surface irrigation. Later the upper surface layer get continuously depleted of moisture uptil next irrigation. This has a negative effect since most of the active roots are distributed in these layers for long time (Tiwari *et al.* 2003).

Effect of integrated nutrient management

There is no difference between different integrated nutrient management practices for total water applied to ginger during both the seasons. The maximum water use

efficiency was obtained under the treatment of application of 100 per cent general recommended dose of fertilizer which is due to more yield and minimum water requirement for production of 1 metric tonne of rhizome was also noticed under same treatment. The minimum water use efficiency and more water required for production of 1 tonne of rhizome was noticed under application of 100 per cent RDN through organic sources which might be due to more water holding capacity of soil with addition of organic matter and reduction in crop yield.

4.5 Economics

The data on the effect of different irrigation systems and integrated nutrient management practices on cost of cultivation, gross and net monetary returns and B : C ratio in ginger at harvest of both the seasons and in pooled data are presented in Table 28 and graphically depicted in Fig 12a and 12b.

The mean gross monetary returns, cost of cultivation, net monetary returns and B : C ratio were Rs.2,81,520, Rs.1,19,413, Rs.1,59,429 and 2.31, respectively during 2005-06 and representative values for the year 2006-07 were Rs.3,17,840, Rs.1,18,479, Rs.1,95,749 and 2.68.

Effect of irrigation systems

The maximum cost of cultivation was required under surface irrigation due to more number of irrigations during both the years. The gross monetary returns were found

statistically significant during both the years and in pooled data. The application of irrigation through floppy sprinkler system recorded significantly higher gross monetary returns than all other irrigation systems during both the years and in pooled data but it was at par with overhead sprinkler during 2005-06. Significantly lower gross monetary returns were recorded under surface irrigation method.

The net monetary returns were significantly increased with application of irrigation through floppy sprinkler as compared to other irrigation systems during both the years and when the data were pooled over the seasons except overhead sprinkler. The important growth and yield components and fresh and dry rhizome yield were significantly more under floppy sprinkler irrigation system due to adequate soil moisture throughout the crop growing period creating favourable microclimate and resulted in increased net monetary returns. These results are inconformity with the findings of Dixit *et al* (1994). The net monetary returns were significantly the lowest (Rs. 1,33,566 and Rs. 1,71,330 ha^{-1}) with surface irrigation system during both the years owing to moisture stress due to longer irrigation interval resulted in lower values of yield components and low fresh and dry rhizome yield resulting in less net monetary returns. The B:C ratio was more with floppy sprinkler irrigation than drip and surface irrigation systems owing to significantly higher ginger yield under floppy irrigation system. These are similar to those reported by Patil (2003) and Pawar and Bhoi (2004). It would

Table 28.Economics of ginger cultivation under different irrigation systems and integrated nutrient management in relation to gross and net monetary returns (Rs. ha^{-1}), cost of cultivation(Rs. ha^{-1}) and benefit : cost ratio.

Treatment	Gross monetary returns			Cost of cultivation			Net monetary returns			B:C ratio		
	2005-06	2006-07	Pooled mean	2005-06	2006-07	Pooled mean	2005-06	2006-07	Pooled mean	2005-06	2006-07	Pooled mean
Irrigation systems												
Surface	259200	296760	277980	125634	125430	125532	133566	171330	152448	2.06	2.36	2.21
Drip	275000	307200	291100	124265	124570	124417	150735	182630	166682	2.21	2.47	2.34
Floppy sprinkler	318000	345200	331600	126639	127212	126925	191361	217988	204674	2.51	2.71	2.61
Overhead sprinkler	285000	322200	303600	124606	125212	124909	159788	196988	178388	2.29	2.57	2.43
SE m±	12963	5841	9426	-	-	-	12968	5700	9214	0.11	0.06	0.09
CD at 5%	40444	20210	27967	-	-	-	40444	19726	27590	N.S.	0.21	0.28
Integrated nutrient management : RDN through organic(50%FYM+50% neem cake) + inorganic fertilizer												
100%RDN through organic manures	201166	237000	219083	122411	123477	122944	78755	113522	96138	1.64	1.96	1.87
75%RDN O.M + 25%RDN I.F	249250	280050	264650	120938	120504	120721	128311	159545	143928	2.06	2.32	2.19
50%RDN O.M. + 50%RDN I.F.	280366	318300	299333	119404	118970	119187	160962	199329	180145	2.35	2.67	2.51
25%RDN O.M +. 75%RDN I.F	311400	360450	335925	117904	117470	117687	193495	242979	218237	2.64	3.06	2.85
100%GRDF	354300	393400	373850	116406	115972	116189	237893	277427	257660	3.04	3.29	3.16
SE m±	10032	7036	8315	-	-	-	10030	7650	7937	0.12	0.05	0.09
CD at 5%	32715	22946	24850	-	-	-	32709	24949	22790	0.39	0.16	0.28
Interaction												
SE m±	15511	18303	12960	-	-	-	15509	18736	16845	0.16	0.16	0.13
CD at 5%	N.S.	N.S.	N.S.	-	-	-	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	281520	317840	299680	119413	118479	118946	159429	195749	177589	2.31	2.68	2.46

be, therefore, advisable to irrigate ginger with floppy sprinkler irrigation system.

Effect of integrated nutrient management

The maximum cost of cultivation was realized with application of 100 per cent RDN through organic sources which might be due to more quantity and cost of organic manures. The gross and net monetary returns and B : C ratio were significantly increased due to application of 100 per cent general recommended dose of fertilizer and application of 25 per cent RDN through organic sources and 75 per cent RDN through inorganic fertilizer as compared to other integrated nutrient management practices during both the years and in pooled data. This is ascribed to increased growth and yield components and fresh and dry ginger yields under integrated nutrient management practices resulting in increased gross and net monetary returns and B:C ratio. Significantly less gross and net monetary returns and B : C ratio were observed under the application of 100 per cent RDN through organic sources during both the years and in pooled data. These results are conformity with the findings of Singh and Kushwah (2006). This might be due to slow mineralization of organic matter and slow release of the nutrients may lead slow growth and development of crop resulting low fresh and dry ginger yields. It would be, therefore, advisable to apply 100 per cent general recommended dose of fertilizer to ginger.

Interaction effect

Interaction effects between irrigation systems and integrated nutrient management practices for gross monetary returns, net monetary returns and B : C ratio of ginger at harvest were found to be non significant during both the years of experimentation.

4.6 Chemical studies

4.6.1 Nutrient content

Data pertaining to mean N, P and K content in ginger plant at harvest as influenced by irrigation systems and integrated nutrient management practices are presented in Table 29.

The mean N, P and K content in ginger was 0.86, 0.37 and 1.80 %, respectively during first year and it was 0.98, 0.38 and 1.97 % during second year, respectively. The concentration of N, P and K was increased with increase in fertilizer levels.

Effect of irrigation systems

The N, P and K content in ginger at harvest under different irrigation systems was not statistically influenced except N and K content during second year. The maximum N, P and K content in ginger was observed under the treatment of application of irrigation through floppy sprinkler system. This might be due to development of favourable microclimate in the crop vicinity which increased crop stand and proper development of rhizome and optimum uptake of nutrients

Table 29. Mean N, P and K content (%) in ginger at harvest as influenced by different irrigation systems and integrated nutrient management

Treatment	N content		P content		K content	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Irrigation systems						
Surface	0.83	0.91	0.34	0.36	1.72	1.81
Drip	0.84	0.94	0.36	0.36	1.76	1.91
Floppy Sprinkler	0.90	1.08	0.39	0.40	1.90	2.12
Overhead Sprinkler	0.87	1.00	0.38	0.38	1.83	2.03
SE m±	0.03	0.02	0.02	0.02	0.06	0.06
CD at 5%	N.S.	0.07	N.S.	N.S.	N.S.	0.20
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer						
100% RDN through organic	0.82	0.91	0.34	0.34	1.59	1.77
75% RDN through organic + 25% RDN through inorganic	0.83	0.94	0.35	0.36	1.72	1.89
50% RDN through organic + 50% RDN through inorganic	0.85	0.97	0.36	0.38	1.78	2.00
25% RDN through organic + 75% RDN through inorganic	0.88	1.02	0.38	0.39	1.89	2.05
100% GRDF	0.91	1.06	0.39	0.41	2.02	2.13
SE m±	0.03	0.04	0.12	0.02	0.07	0.06
CD at 5%	N.S.	0.12	N.S.	0.05	0.22	0.21
Interaction						
SE m±	0.06	0.06	0.05	0.04	0.14	0.11
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	0.86	0.98	0.37	0.38	1.80	1.97

from rhizosphere of crop. The K content in ginger plant was also found maximum under floppy sprinkler system but it was on par with overhead sprinkler system. Significantly lower N, P and K content was observed under surface irrigation which might be due to loss of nutrients due to leaching, surface runoff, volatilization etc. which resulted in less growth and development of crop.

Effect of integrated nutrient management

The integrated nutrient management practices for N and P content in ginger at harvest did not significantly influence during first year of experimentation and was found significant during second year. The maximum N, P and K content in ginger was recorded with the treatment of application of 100 per cent general recommended dose of fertilizer. During second year, the higher N, P and K content in ginger was noticed with application of 100 per cent general recommended dose of fertilizer but it was at par with 25 per cent RDN through organic sources and 75 per cent RDN through inorganic fertilizers and 50 per cent RDN through organic sources and 50 per cent RDN through inorganic fertilizer. Significantly low N, P and K content in ginger at harvest was recorded under the treatment of application of 100 per cent RDN through organic sources. This might be due to slow mineralization of organic matter and less availability of nutrients for crop growth and development which might have caused less N, P and K content in ginger at harvest.

Interaction effect

Interaction effects between irrigation systems and integrated nutrient management practices for N, P and K content in ginger at harvest were found to be non significant during both the years of experimentation.

4.6.2 Nutrient management

The uptake of N, P and K by leaf and pseudostem increases up to 180 days and then decreases where as that of rhizome uptake steadily increases till the harvest. Application of organic manures with fertilizer N is known to stimulate the mineralizable N fractions and increases the efficiency of inorganic N fertilizer in the soil (Singh *et al.* 2001). Ginger is mainly N and K exchanging, intermediary in P and Mg removal and the least in Ca (Nagrajan and Pillai, 1979).

The mean N,P and K uptake as influenced by irrigation systems and integrated nutrient management practices are presented in Table 30 and depicted in Fig 13, 14 and 15.

The mean N, P and K uptake during first season was 46.40, 19.87 and 98.14 $kgha^{-1}$ the corresponding figures for second season are 60.37, 23.11 and 120.18 $kgha^{-1}$.

Effect of irrigation systems

Irrigation scheduling with floppy sprinkler system increased N, P and K uptake as compared to other irrigation systems because of higher total dry matter production as well as fresh and dry rhizome yield during both the seasons of

Table 30. Nutrient uptake (kg ha $^{-1}$) by Ginger as influenced by different irrigation systems and integrated nutrient management during 2005-06 and 2006-07

Treatment	Nitrogen uptake (kgha $^{-1}$)			Phosphorus uptake (kgha $^{-1}$)			Potassium uptake (kgha $^{-1}$)		
	2005-06	2006-07	Pooled mean	2005-06	2006-07	Pooled mean	2005-06	2006-07	Pooled mean
Irrigation systems									
Surface	41.91	51.78	46.86	17.17	20.48	18.82	86.86	102.99	94.92
Drip	44.60	55.18	49.89	19.12	21.13	20.12	93.45	112.12	102.78
Floppy Sprinkler	52.02	72.04	62.03	22.54	26.68	24.61	109.82	141.40	125.61
Overhead Sprinkler	47.76	62.40	55.08	20.86	23.71	22.28	100.47	126.67	113.57
SE m $\pm$	1.13	0.55	0.81	0.11	0.23	0.25	0.57	0.73	0.80
CD at 5%	3.91	1.89	2.51	0.37	0.79	0.83	1.98	2.53	2.59
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer									
100% RDN through organic	34.36	44.04	39.20	14.25	16.46	15.36	66.62	76.96	71.79
75% RDN through organic + 25% RDN through inorganic	40.67	52.36	46.51	17.15	20.05	18.60	84.28	105.27	94.77
50% RDN through organic + 50% RDN through inorganic	45.98	59.75	52.86	19.48	23.41	21.44	96.30	123.20	109.75
25% RDN through organic + 75% RDN through inorganic	51.66	68.54	60.10	22.31	26.21	24.26	110.94	137.76	124.35
100% GRDF	58.61	77.27	67.94	25.97	29.89	27.93	134.53	155.28	144.90
SE m $\pm$	1.01	1.14	1.32	0.35	0.33	0.39	0.47	1.12	1.00
CD at 5%	3.29	3.72	3.85	1.12	1.08	1.22	1.52	3.66	3.31
Interaction									
SE m $\pm$	2.14	2.26	2.11	0.66	0.87	0.90	1.00	2.26	1.85
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	46.40	60.37	53.38	19.87	23.11	21.49	98.14	120.18	109.16

investigation. Similarly, the application of irrigation through overhead sprinkler was also found significantly superior over surface and drip irrigation systems in N, P and K uptake during second year and in pooled data. Similar results result was reported by Home *et al.* (2002). The N, P and K uptake by ginger was significantly lower under application of irrigation through surface method. Increased soil moisture tension due to reduced moisture exerts a physiological effect on the roots. Elongation, turgidity and number of root hairs decrease with increasing tension. Mitocondria development slows and carries concentration and phosphorilation decreases which reduces nutrient uptake (Bohn *et al.* 2003) .

Effect of integrated nutrient management

The uptake of N, P and K under integrated nutrient management practices were found statistically significant during both the years of investigation and in pooled data. The application of 100 per cent general recommended dose of fertilizer was found significantly superior over all other integrated nutrient management practices for N, P and K uptake during both the seasons and in pooled data. The increase in uptake of nitrogen may be attributed to the direct addition of nitrogen through inorganic fertilizer and steadily availability of nutrients from the FYM added to the soil (Bharadwaj and Kaminwar, 1994 and Reddy and Reddy, 1998). The increase in uptake of P in combination with organic manure might be due to the release of organic matter which might have helped in solubility of

phosphate and making the available of more p to the plants (Khan *et al.* 1984). The applied organic matter might have led to the fully formation of coating on the sesquioxides because of which phosphate fixing capacity of the soil might have been reduced in the organic manure applied plots. Bharadwaj and Kaminwar (1994) and Reddy and Reddy (1998) also reported similar results.

The higher uptake of K due to the application of organic manures might be due to the beneficial effect of organic manure on the reduction of K fixation (Reddy and Reddy, 1998). Similarly, the treatment of application of 25 per cent RDN through organic sources and 75 per cent RDN through inorganic fertilizers were also found significantly superior over other integrated nutrient management practices for N, P and K uptake during both the seasons. The higher uptake of N, P and K might be due to high dry matter yield and rhizome yield obtained due to proper dose of fertilizer application helped better growth and development of crop and rhizome. Significantly lower N, P and K uptake of nutrients were observed with the of application of 100 per cent RDN through organic sources during both the years. The low total dry matter and rhizome yields were obtained due to slow mineralization of nutrients which might cause less uptake of nutrients by the plant. The linear increase in the uptake of NPK nutrients was noticed with increased level of NPK fertilizers. The maximum uptake of NPK nutrients drawn by

the plants provided with 75:50:50 NPK kg ha^{-1} + 25 t FYM. These results are in confirmity with the finding of Venkatesha *et al.* (1998).

The higher uptake of nutrients owing to bio-fertilization might be on account of increase in root proliferation in zones of high nutrient availability. These results are confirmative with the findings of Bijayadevi and Limi Ado (2005).

Interaction effect

Interaction effects between irrigation systems and integrated nutrient management practices for N, P and K uptake was found to be non significant during both the years of experimentation.

4.6.3 Available nutrient status

The available nutrient status at the commencement of the experiment and after harvest of both seasons crop is presented in Table 31 and depicted in Fig 16. Application of organic manure and bio-fertilizers affects the transformation, recycling and availability of plant nutrients.

Initial soil analysis before planting of ginger rhizome revealed that the available N, P and K content in soil was 188.16 kg ha^{-1} (low), 21.76 kg ha^{-1} (medium) and 358.40 kg ha^{-1} (very high), respectively, where as after harvest of first season crop the mean available N, P and K content was 132.99 kg ha^{-1}, 30.54 kg ha^{-1} and 286.71 kg ha^{-1}, respectively during first year. The representative values of these nutrients

after harvest of second season crop were 221.67 kg ha^{-1}, 35.32 kg ha^{-1} and 291.68 kg ha^{-1}, respectively. The nutrient enrichment in soil was observed after harvest of both seasons crop because of whatever fertilizers added were not fully utilized by the crop because of slow mineralization of organic forms of nutrients and as a result available nutrient status of soil was increased.

Effect of irrigation systems

Available nutrient status of soil after harvest of ginger during both seasons was significantly influenced by irrigation systems. The application of irrigation through drip system recorded maximum available N, P and K status in soil after harvest of ginger during both the seasons as compared to other irrigation systems. In drip irrigation, water tension remains low and almost constant for entire growth period of the crop as compared to surface irrigation method. This situation increased the availability of nutrients in soil after harvest of crop. These findings are in agreement with those of Skelke *et al.* (1999) and Sagarka *et al.* (2002). The available N and P left in soil after harvest of ginger was also found significantly more in overhead sprinkler system during first year but it was on par with floppy sprinkler system during second season. Similarly, the application of irrigation through overhead sprinkler recorded maximum available K in soil after harvest of both seasons than other irrigation

Table 31. Available nutrient status of soil after harvest of the ginger as influenced by different irrigation systems and integrated nutrient management

Treatment	Available N (kgha^{-1})		Available P_2O_5 (kg ha^{-1})		Available K_2O (kgha^{-1})	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Irrigation systems						
Surface	127.25	193.85	27.58	32.61	282.75	285.19
Drip	139.01	237.42	33.99	39.53	291.26	298.99
Floppy Sprinkler	130.73	226.15	29.35	34.09	284.82	287.63
Overhead Sprinkler	134.96	229.28	31.25	35.07	288.02	294.91
SE m ±	0.54	0.94	0.50	0.40	0.72	0.77
CD at 5%	1.86	3.24	1.73	1.42	2.50	2.66
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer						
100% RDN through organic	149.71	247.96	40.65	47.90	295.18	302.82
75% RDN through organic + 25% RDN through inorganic	146.46	232.15	33.49	39.35	292.58	298.72
50% RDN through organic + 50% RDN through inorganic	134.67	224.22	30.74	36.56	287.89	293.70
25% RDN through organic + 75% RDN through inorganic	120.00	209.05	25.78	28.69	283.25	285.74
100% GRDF	114.10	194.99	22.04	24.11	274.66	277.41
SE m ±	0.87	1.55	0.51	0.57	0.77	1.01
CD at 5%	2.84	5.04	1.66	1.84	2.52	3.29
Interaction						
SE m ±	1.76	2.54	1.10	1.22	1.56	1.79
CD at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	132.99	221.67	30.54	35.32	286.71	291.68
Initial soil nutrient status	188.16	108.20	21.76	20.14	358.40	271.80

systems. Significantly lower available N, P and K left in soil after harvest of crop was noticed under surface irrigation method. This might be due to absence of adequate soil moisture because of which crop was unable to take up the soil nutrients as efficiently as that of other irrigation systems.

Effect of integrated nutrient management

The available nutrient status of soil after harvest of ginger was significantly influenced by integrated nutrient management practices. Among all integrated nutrient management practices the application of 100 per cent RDN through organic sources was found significantly superior over all other treatments during both the seasons. Similarly, the treatment of application of 75 per cent RDN through organic sources and 25 per cent RDN through inorganic fertilizers was also found significantly superior over all other integrated nutrient management practices. The increase in available N, P and K in soil with addition of FYM and neem cake might be due to increase in microbial population as well as decomposition products of humic substances. Similar results were reported by Shinde and Solanki (1991) and Anchal Das *et al.* (2008). Relatively higher values of available nutrients were recorded under conjoint use of fertilizers and farm yard manure. This increase is possibly due to mineralization of organic nutrients. Significantly lower available N, P and K status in soil after harvest of ginger was noticed in the treatment of application of 100 per cent general recommended

dose of fertilizer. The N, P and K status in soil after harvest of ginger was higher in the treatments having organic sources of nutrients which might cause less uptake of nutrients by the crop.

Interaction effect

The interaction effect between irrigation systems and integrated nutrient management practices for nutrient status in soil after harvest of ginger was absent during both the seasons.

4.6.4 Nutrient balance

The data on balance of N, P and K in soil after harvest of ginger during both the years are presented in balance sheet form in Table 32 and Table 33.

The data are not statistically analyzed and inferences are drawn on the basis of mean values. The negative values indicate the net loss in N, P and K content.

Effect of irrigation systems

The difference between nutrient balance under different irrigation systems are presented in Table 32 and 33. It indicates that the actualbalance obtained under drip irrigation system was higher than other irrigation systems. Alternate day irrigation under drip irrigation system might have caused the deep percolation and leaching losses of nutrients in the subsurface layer of soil which resulted in less uptake of nutrients and retained more actual balance of nutrients. Loss of nitrogen, phosphorus and potassium was

Table 32. Effect of irrigation systems and integrated nutrient management on nutrient balance in soil after harvest of ginger during 2005-06

Treat-ment	Initial soil available			Nutrient Added kg/ha			Nutrient uptake kg/ha			Computed balance kg/ha			Actual balance kg/ha			Net gain / loss kg/ha		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
Irrigation systems																		
I1	188.16	21.76	358.40	75	50	50	41.91	17.17	86.86	221.25	54.55	321.54	127.25	27.58	282.75	-94.00	-27.01	-88.79
I2	188.16	21.76	358.40	75	50	50	44.60	19.12	93.45	218.56	52.64	314.95	139.01	33.98	291.26	-79.55	-18.66	-23.69
I3	188.16	21.76	358.40	75	50	50	52.02	22.54	109.82	211.14	49.22	298.58	130.73	29.35	284.82	-80.41	-19.87	-13.76
I4	188.16	21.76	358.40	75	50	50	47.76	20.86	100.47	215.40	50.90	307.93	134.96	31.25	288.02	-80.44	-19.65	-19.91
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer																		
INM-1	188.16	21.76	358.40	75	50	50	34.36	14.25	66.62	228.80	57.71	341.78	149.75	40.65	295.18	-79.05	-16.86	-46.60
INM-2	188.16	21.76	358.40	75	50	50	40.67	17.15	84.28	222.49	54.61	324.12	146.46	33.49	292.58	-76.08	-21.12	-31.54
INM-3	188.16	21.76	358.40	75	50	50	45.98	19.48	96.30	217.18	52.28	312.10	134.67	30.74	287.88	-82.51	-21.54	-24.22
INM-4	188.16	21.76	358.40	75	50	50	51.66	22.31	110.94	211.50	49.45	297.46	120.00	25.78	283.24	-91.50	-23.67	-14.22
INM-5	188.16	21.76	358.40	75	50	50	58.61	25.97	134.53	204.55	45.79	273.87	114.1	22.04	274.66	-90.45	-23.75	-0.79

Table 33. Effect of irrigation systems and integrated nutrient management on nutrient balance in soil after harvest of ginger during 2006-07

Treat-ment	Initial soil available kg/ha			Nutrient Added kg/ha			Nutrient uptake kg/ha			Computed balance kg/ha			Actual balance kg/ha			Net gain / loss kg/ha		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
Irrigation systems																		
I1	127.25	27.582	282.75	75	50	50	51.78	20.48	102.99	150.47	57.10	229.76	193.85	32.60	285.19	43.38	-24.50	55.43
I2	130.73	29.354	291.26	75	50	50	55.18	21.13	112.12	158.83	62.85	229.14	237.42	39.52	298.99	78.59	23.33	69.85
I3	139.01	33.988	284.82	75	50	50	72.04	26.68	141.40	133.69	52.67	193.42	226.15	34.09	287.63	92.46	18.58	94.21
I4	134.96	31.25	288.02	75	50	50	62.40	23.71	126.67	147.56	57.54	211.35	229.28	35.074	294.91	81.72	-22.47	83.56
Integrated nutrient management : RDN through organic (50% FYM + 50% Neem cake) + inorganic fertilizer																		
INM-1	149.71	40.65	295.19	75	50	50	44.04	16.46	76.96	180.71	74.19	268.22	247.96	47.90	302.82	67.25	-26.29	34.60
INM-2	146.46	33.49	292.58	75	50	50	52.36	20.05	105.27	169.10	63.44	237.31	232.15	39.353	298.72	63.05	-24.09	61.41
INM-3	134.67	30.74	287.89	75	50	50	59.75	23.41	123.20	149.92	57.33	214.68	224.23	36.56	293.71	74.31	-20.77	79.03
INM-4	120.00	25.78	283.24	75	50	50	68.54	26.21	137.76	126.46	49.57	195.48	209.05	28.693	285.74	82.59	-20.88	90.26
INM-5	114.10	22.04	274.66	75	50	50	77.27	29.89	155.28	111.83	42.15	169.38	194.99	24.113	277.41	83.16	-18.04	108.03

recorded more under surface irrigation method after harvest of ginger during first season. Heavy rains in 29th, 36th and 38th MW which have resulted leaching losses of nitrogen and formation of megaphosphates of Ca++ in soil which might caused P fixation on soil colloids.

Similarly, the actual balance of N, P and K in soil after harvest of second season crop was more under drip irrigation system.

The minimum loss and maximum gain of potassium was recorded under floppy sprinkler as compared to other irrigation systems during first and second season, respectively. The gain of potassium is attributed to release of structural K+ upon alteration of minerals during weathering caused due to hydroneum ions (H_3O) in water (Tondon and Sekhon, 1988).

The loss of N, P and K under surface irrigation method might be attributed to due to leaching and deep percolation losses at the time of irrigation and consequently inadequate soil moisture resulted in unavailability of the nutrients to plants.

Effect of integrated nutrient management

The computed balance of N, P and K after harvest of ginger was comparatively more under the treatment of application of 100 per cent RDN through organic sources because of less nutrient uptake. The maximum actual balance of N, P and K in soil after harvest of ginger was noticed under

the same treatment. The net loss of N, P and K nutrients in soil after harvest of ginger crop during both the year was maximum under the treatment of application of 100 per cent general recommended dose of fertilizer. But net gain of N and K during second season was with application of 100 per cent RDN through organic sources. Due to mineralization of organic matter content in soil might have increased the microbial activities in soil and more nutrient balance in soil. From these results it is evident that balanced and integrated nutrient management is a sure way to maintain the soil health. These results are confirmative with finding of Sharma *et al.* (2003).

5. SUMMARY AND CONCLUSIONS

The field investigation on “Effect of irrigation systems and integrated nutrient management on growth, yield and quality of ginger (Zingiber *officinale* Rosc.)” was carried out during 2005-06 and 2006-07 at Instructional farm of Inter Faculty Department of Irrigation Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra).

The soil of the experimental field was sandy clay loam in texture, low in available nitrogen (188.16 kg ha^{-1}), medium in available phosphorus (21.76 kg ha^{-1}) and high in available potassium (358.40 kg ha^{-1}) with slightly alkaline in reaction (pH 8.15). The experiment was laid out in strip plot design with three replications. The total 20 treatment combinations comprising four irrigation systems viz. surface, drip, floppy sprinkler and overhead sprinkler enforced at different stages on cumulative pan evaporation basis with constant depth of irrigation assigned to first factor and five integrated nutrient management practices viz., 100 % RDN through organic source, 75 % RDN through organic sources + 25 % RDN through inorganic fertilizer, 50 % RDN through organic sources + 50 % RDN through inorganic fertilizer, 25 % RDN through organic sources + 75 % RDN through inorganic fertilizer and 100 % general recommended dose of fertilizer were assigned to the second factor.

Ginger variety *Mahim* was planted with three to four sprouted eye buds at 20 cm row spacing and 20 cm plant

spacing on 15th May 2005 and 30th April 2006. In irrigation systems the scheduling of irrigation was based on climatological approach when cumulative pan evaporation (CPE) attained the values of 70 mm. The irrigation was given with a constant depth of irrigation (6 cm). In drip irrigation system the irrigation was given at alternate day. In case of floppy sprinkler and overhead sprinkler the irrigations were given at 35 mm CPE + 35 mm CPE in two splits of 70 mm CPE. One common irrigation of 6 cm depth during 2005 and 2006 was given after planting for ensuring better germination and uniform stand of crop.

The recommended dose of fertilizer was 75:50:50 N, P_2O_5 and K_2O + 25 t FYM ha^{-1}, respectively. The organic sources of nitrogen was applied as a basal dose and inorganic source of nitrogen was applied at 6 and 12 weeks after planting in two equal splits, respectively. The full dose of P_2O_5 and K_2O were applied as a basal dose at the time of planting. The bio-fertilizers as *Azotobacter* and *Phosphate solubilizing bacteria* was applied as a basal by mixing in soil at initial irrigation time at planting. The same dose of fertilizer was applied as per treatments to each plot for next year experiment.

In addition to yield data, periodical observations on plant growth in respect of plant height, number of tillers, number of leaves, leaf area, dry matter accumulation were recorded to evaluate treatment effects. The observations on fresh and dry rhizome yield, dry straw yield, total dry matter yields, quality

studies viz., pH, volatile oil, crude fat, oleoresin, crude fibre, starch and ash content (%) after harvest were also recorded. The economics, water studies, nutrient uptake, available nutrient status and nutrient balance were also considered to test the practical acceptability of irrigation systems and integrated nutrient nutrient management practices. The important findings emerged from present investigation are summarized and conclusions drawn are given in this chapter.

5.1 Summary

5.1.1 Effect of irrigation systems

The application of irrigation through micro-irrigation system as floppy sprinkler recorded significantly higher values of growth parameters viz., plant height, number of tillers per clump, number of leaves and leaf area per plant than rest of irrigation systems during both the years. More water stress was imposed due to surface irrigation at early (formative) stage, vegetative stage and development stage by scheduling of irrigation at 70 mm CPE recorded significantly less values of these characters as compared to drip, floppy sprinkler and overhead sprinkler systems. Similarly, the application of irrigation through overhead sprinkler also recorded significantly higher growth attributing characters as compared to surface and drip irrigation systems during both the seasons.

The dry matter per plant, dry weight of rhizome, total dry matter and fresh rhizome weight per plant values

were significantly more under floppy sprinkler irrigation system. The frequent application of irrigation through micro-irrigation system favours the development of microclimate in the crop vicinity which affects the better crop growth and development activities. The water stress for long period of time in surface irrigation through out crop growth period significantly decreased the dry matter per plant, dry weight of rhizome, total dry matter and fresh rhizome weight per plant during both the years of experimentation.

The important yield attributes viz., fresh rhizome yield, dry straw yield, dry rhizome yield and total dry matter yield (t ha^{-1}) were significantly increased with application of irrigation through floppy sprinkler as compared to other irrigation systems during first and second year. The application of irrigation through overhead sprinkler also produced significantly higher values of these attributes than surface irrigation. The deep percolation and evaporation losses with more moisture stress in surface irrigation throughout the crop growth period resulted in to significant decrease in the values of yield attributes than other irrigation systems during both the years and when data were pooled over the seasons.

The quality parameters viz., pH, volatile oil, crude fat, oleoresin, crude fibre, starch and ash content (%) values were not affected significantly but numerically more values were recorded under floppy sprinkler than other irrigation systems. Further, all the quality parameters were significantly lower

under surface irrigation as compared to other irrigation systems.

The gross and net monetary returns and B : C ratio were significantly more under stress free environment throughout the crop growth maintained by application of irrigation through floppy sprinkler. The application of irrigation through overhead sprinkler also realized numerically more gross and net monetary returns and B : C ratio than surface and drip irrigation systems. The lowest gross monetary returns, net monetary returns and B : C ratio were observed under surface irrigation owing to lower fresh rhizome yield.

The maximum water use efficiency and less water required to produce one metric tonne of ginger was recorded when irrigation was scheduled under drip irrigation system followed by floppy sprinkler system. The second best irrigation system noticed was floppy sprinkler in which there was also more water use efficiency and less water required to produce one metric tonne of ginger than surface irrigation. The mean N, P and K content in ginger at harvest were more and their uptake were significantly more under stress free environmental condition of floppy sprinkler system. In drip irrigation, the water tension remains low and almost constant for entire growth period of the crop as compared to surface irrigation. The availability of N, P and K nutrients in soil after harvest of ginger crop was significantly more when irrigation

was given through drip irrigation system (I_2) than surface irrigation.

5.1.2 Effect of integrated nutrient management

The application of 100 per cent general recommended dose of fertilizer (75:50:50 N, P_2O_5 and K_2O + 25 t FYM ha^{-1}) recorded significantly higher values of growth characters, dry matter per plant, dry rhizome weight and total dry matter resulting in significant improvement in fresh rhizome weight per plant and yield contributing characters like fresh rhizome yield, dry straw yield, dry rhizome yield and total dry matter yield than other integrated nutrient management practices. Similarly, the application of 25 per cent RDN through organic sources and 75 per cent RDN through chemical fertilizer also recorded significantly more growth and yield contributing characters and yield of ginger than rest of integrated nutrient management practices.

The quality parameters viz., pH, volatile oil, crude fat, oleoresin, crude fibre, starch and ash content (%) values were significantly higher under the application of 100 per cent RDN through organic sources. Further, all these quality parameters were recorded significantly the lowest under application of 100 per cent RDN through general recommended dose of fertilizers.

The gross monetary returns, net monetary returns and B: C ratio was significantly more with the application of 100 per cent general recommended dose of fertilizer than other

nutrient management practices owing higher fresh and dry rhizome yields. The maximum water use efficiency was obtained under the application of 100 per cent general recommended dose of fertilizer which is due to more yield and minimum water requirement for production of one metric tonne of rhizome.

The application of 100 per cent general recommended dose of fertilizer recorded the highest N, P and K concentration and uptake of these nutrients by ginger than other integrated nutrient management practices during both the years. Significantly less nutrient content and uptake was noticed in application of 100 per cent RDN through organic sources. The application of 100 per cent RDN through organic sources recorded significantly higher available N, P and K status of soil after harvest during both the seasons. Similarly, the application of 75 per cent RDN through organic sources and 25 per cent RDN through inorganic fertilizers also recorded significantly more available nutrient status in soil after harvest than other integrated nutrient management practices.

Interaction effect

The interactions between irrigation systems and integrated nutrient management practices were non significant for all the growth characters. The dry straw yield, dry rhizome yield, total dry straw yield and fresh rhizome yield per plant were also non significant except dry matter per plant at

harvest and dry weight of rhizome per plant at 230 days after planting during first year where irrigation applied through floppy sprinkler and application of 100 per cent general recommended dose of fertilizer recorded higher dry matter and dry weight of rhizome per plant than other irrigation systems and integrated nutrient management practices.

The interaction effects between irrigation systems and integrated nutrient management practices were non significant in fresh rhizome yield, dry straw yield, dry rhizome yield and total dry matter yields (t ha^{-1}) during both the years but it was significant in pooled data for fresh rhizome yield, dry rhizome yield and total dry matter yield due to application of irrigation through floppy sprinkler and 100 per cent general recommended dose of fertilizer than other irrigation systems and integrated nutrient management practices. Further, application of irrigation through overhead sprinkler and 25 per cent RDN through organic sources and 75 per cent RDN through inorganic fertilizer was followed (I_4-INM_4) the next in order of significance.

Interactions between irrigation systems and integrated nutrient management practices were non significant for all quality parameters, nutrient concentration in ginger, their uptake and available nutrient status in soil after harvest of crop.

5.2 Conclusions

1. The floppy sprinkler irrigation system increased fresh (16.57 t ha^{-1}) and dry ginger yield (4.01 t ha^{-1}) and gross (Rs.3,31,600 ha^{-1}) and net (Rs.2,04,674 ha^{-1}) monetary returns. It would be, therefore, advisable to irrigate ginger with floppy sprinkler for higher productivity and better monetary returns.
2. The application of 100 per cent general recommended dose of fertilizer (75:50:50 N, P_2O_5 and K_2O kg ha^{-1} + 25 t FYM ha^{-1}) improved fresh (18.69 t ha^{-1}) and dry ginger yields (4.67 t ha^{-1}) and gross (Rs. 3,73,850 ha^{-1}) and net (Rs.2,57,660 ha^{-1}) monetary returns and B : C ratio (3.16). It would be, therefore, suggested to fertilize ginger with general recommended dose of fertilizer viz., (75:50:50 N, P_2O_5 and K_2O kg ha^{-1} + 25 t FYM ha^{-1}).
3. The dry matter production per plant, fresh and dry ginger yield was higher with combination of floppy sprinkler irrigation system and 100 per cent general recommended dose of fertilizer. It would be, therefore, advisable that ginger crop be irrigated with floppy sprinkler and fertilized with recommended dose for higher productivity.
4. The field water use efficiency (222.14 q $ha^{-1}mm^{-1}$) and water saving (30.60 %) was maximum under drip irrigation system than other irrigation systems.

5. The quality parameters viz., volatile oil (1.88 %), crude fat (6.05 %) and starch content (51.65 %) were improved under floppy sprinkler than other irrigation systems. The application of 100 per cent RDN through organic sources improved quality aspects viz., p^H (6.61), crude fibre (7.13 %), starch (51.02 %) and ash (6.62 %) content in ginger.
6. The uptake of N, P and K was more under floppy sprinkler irrigation than other irrigation systems. The application of general recommended dose of fertilizer also increased N, P and K uptake compared to other integrated nutrient management practices.
7. The available N, P and K left after second cycle was more under drip and less under surface irrigation method. The available N, P and K left after second cycle was higher under 100 % RDN through organic sources and lower in 100 per cent general recommended dose of fertilizer.

Thus, it is suggested to irrigate ginger through floppy sprinkler and apply 100 per cent general recommended dose of fertilizer for sustainable production with higher monetary benefits and efficient utilization of water.

Considering the scares irrigation and organic manure resources in Maharashtra research on microirrigation systems in relation to microclimate development viz., soil temperature, canopy temperature, stomatal conductance and registence, leaf water potential, PAR components and light use efficiency on ginger in relation to climate change be undertaken.

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* Origionals not seen.

APPENDIX-I (A)

Detail of irrigation schedule for ginger

Quantity of water applied in Surface [irrigation plots (2005-2006)

Date	Kc	PE	CPE	Raifall	Water applied			ER
		mm	mm	mm	lit/plot	lit/ha	mm/ha	mm
2005-May								
15	0	9.6	0		1166.4	600000	60	
16	0.55	11.5	11.5					
17	0.55	11.4	22.9					
18	0.55	11.5	34.4					
19	0.55	9.1	43.5					
20	0.55	10.9	54.4					
21	0.55	10	64.4					
22	0.55	10.4	74.8		1166.4	600000.00	60.00	
23	0.55	11.5	16.3					
24	0.55	11.7	28					
25	0.55	11.1	39.1					
26	0.55	8	47.1					
27	0.55	8.9	56					
28	0.55	10	66					
29	0.55	10	76		1166.4	600000.00	60.00	
30	0.55	8.5	14.5					
31	0.55	9.4	23.9					
June								
1	0.55	9.4	33.3					
2	0.55	9.8	43.1					
3	0.55	8.9	52					
4	0.55	8.4	60.4					
5	0.55	9.2	69.6					
6	0.55	9.6	79.2		1166.4	600000.00	60.00	
7	0.55	8.3	17.5					
8	0.55	8.2	25.7					
9	0.55	9	34.7					
10	0.55	9.3	44					
11	0.55	8.6	52.6	1.3				
12	0.55	4	56.6					
13	0.55	7.6	64.2					
14	0.55	5.6	69.8	0.8				
15	0.85	7.2	77		1166.4	600000.00	60.00	
16	0.85	7.2	14.2					
17	0.85	8.6	18.2	4.6				4.6
18	0.85	6	24.2					
19	0.85	7.7	31.9					
20	0.85	9.3	41.2					
21	0.85	7.7	48.9					
22	0.85	9	57.9					
23	0.85	9.6	67.5					
24	0.85	7.8	75.3		1166.4	600000.00	60.00	

25	0.85	6	11.3					
26	0.85	6	17.3	0.4				
27	0.85	6.3	23.6					
28	0.85	4.8	28.4	1.2				
29	0.85	4	32.4	1.2				
30	0.85	4.2	36.6					
July								
1	0.85	6.2	42.8					
2	0.85	7.8	50.6					
3	0.85	6.3	56.9					
4	0.85	4	60.9					
5	0.85	4	64.9					
6	0.85	6.6	71.5		1166.4	600000.00	60.00	
7	0.85	10.3	11.8					
8	0.85	5.8	17.6					
9	0.85	6	23.6					
10	0.85	2.9	23.1	3.4				3.4
11	0.85	2.4	25.5	1.4				
12	0.85	4.5	30					
13	0.85	5.9	35.9					
14	0.85	6.5	42.4					
15	0.85	4.8	47.2					
16	0.85	5.7	52.9					
17	0.85	5.2	53.3	4.8				4.8
18	0.85	4.4	48.3	9.4				9.4
19	0.85	4.2	21.3	31.2				31.2
20	0.85	5.3	26.6	29.4				26.6
21	0.85	5	5	25.2				5
22	0.85	3.9	3.9					
23	0.85	3.7	7.6					
24	0.85	4.9	12.5					
25	1	1.2	13.7	1.2				
26	1	0.9	14.6	1.6				
27	1	1.4	16	23.4				16
28	1	1	1	14.6				1
29	1	2.2	2.2	1.2				
30	1	4.7	6.9					
31	1	3.1	10					
Aug.								
1	1	1.5	11.5	13.6				11.5
2	1	2.2	2.2	15.2				2.2
3	1	2.3	2.3	1.2				
4	1	3.2	5.5					
5	1	1.2	6.7	1.2				
6	1	0.6	7.3	7.8				7.3
7	1	2.6	2.6					
8	1	2.4	5	1				
9	1	1.4	6.4	1.4				

10	1	5.2	11.6					
11	1	5.1	16.7					
12	1	4.5	21.7					
13	1	4.6	25.8	0.6				
14	1	3.4	29.2					
15	1	4.4	33.6					
16	1	3	36.6					
17	1	1	34.6	3				3
18	1	2.8	37.4	0.2				
19	1	4.8	42.2					
20	1	3.2	45.4					
21	1	2.3	47.7	1.4				
22	1	2	49.7					
23	1	5.5	55.5					
24	1	3.8	59	0.4				
25	1	5.1	64.1					
26	1	5.2	69.3					
27	1	3.1	72.4	1.8	1166.4	600000.00	60.00	
28	1	3.9	6.3					
29	1	5.3	11.6					
30	1	3.8	7.6	7.8				
31	1	5.5	13.1					7.8
Sept.								
1	1	5.4	18.5	33.8				18.5
2	1	4.8	4.8					
3	1	3.7	8.5					
4	1	3.4	11.9	61.2				11.9
5	1	3.8	3.8	9.8				3.8
6	1	2.5	2.5	4.2				2.5
7	1	3.8	3.8	35.2				3.8
8	1	3.2	3.2	13.7				3.2
9	1	1.2	1.2	3.2				1.2
10	1	1.4	1.4	19.6				1.4
11	1	5.6	5.6	1.6				
12	1	2.8	8.4	0.8				
13	1	4.4	10.4					
14	1	2.8	12.8	2.2				
15	1	3.2	16					
16	1	2.6	18.6					
17	1	5.6	24.2					
18	1	3.6	27.8					
19	1	5.9	33.7					
20	1	3.1	36.8					
21	1	3.1	10.1	29.8				29.8
22	1	1.4	11.5	50.2				11.5
23	1	4.7	4.7					
24	1	2.7	7.4					
25	1	4.3	11.7					

26	1	3.5	15.2					
27	1	3.7	18.9					
28	1	4.4	23.3					
29	1	3.1	23.2	3.2				3.2
30	1	2.6	25.8					
Oct.								
1	1	2.7	28.5					
2	1	2.8	31.3					
3	1	3.4	34.7	0.2				
4	1	1.8	36.5					
5	1	3.5	40	2.4				
6	1	4.1	44.1					
7	1	4.9	49					
8	1	5.3	54.3					
9	1	4.7	59					
10	1	6.3	65.3					
11	1	5.1	70.4		1166.4	600000.00	60.00	
12	1	5.2	5.6					
13	1	5.3	10.9					
14	1	5.7	12.4	4.2				4.2
15	1	2	14.4	2				
16	1	0.6	8	7				7
17	1	1.5	9.5	1.8				
18	1	2.3	11.8	18.4				11.8
19	1	2.5	2.5					
20	1	3.3	5.8					
21	1	4	9.8					
22	1	4.4	14.2					
23	1	3.7	17.9					
24	1	3.8	21.7					
25	1	4.7	26.4					
26	1	3.6	30					
27	1	3.7	33.7					
28	1	4.8	38.7					
29	1	3	41.5					
30	1	3.5	45					
31	1	4.5	49.5					
Nov.								
1	1	4.1	53.6					
2	1	3.7	57.3					
3	1	3.8	61.1					
4	1	4.2	65.3					
5	1	4.4	69.7					
6	1	4	73.7		1166.4	600000.00	60.00	
7	1	4.7	8.4					
8	1	3.2	11.6					
9	1	4	15.6					
10	1	4.8	20.4					

11	1	4.4	24.8					
12	1	3.5	28.3					
13	1	4.1	32.4					
14	1	4	36.4					
15	1	3.4	39.8					
16	1	3.4	43.2					
17	0.6	4.2	47.4					
18	0.6	3.6	51					
19	0.6	4.2	55.2					
20	0.6	4.4	59.6					
21	0.6	4.7	64.3					
22	0.6	4.4	68.7					
23	0.6	4.3	73		1166.4	600000.00	60.00	
24	0.6	3.8	6.8					
25	0.6	3.4	10.2					
26	0.6	4.1	14.3					
27	0.6	3.2	17.5					
28	0.6	3.4	20.9					
29	0.6	4	24.9					
30	0.6	3.4	28.3					
Dec.	0.6							
1	0.6	4.1	32.4					
2	0.6	2.8	35.2					
3	0.6	3	38.2					
4	0.6	2.1	40.3					
5	0.6	3.3	43.6					
6	0.6	3.1	46.7					
7	0.6	2.9	49.6					
8	0.6	2.5	52.1					
9	0.6	2.1	54.2					
10	0.6	3	57.2					
11	0.6	3.2	60.4					
12	0.6	2.1	62.5					
13	0.6	2.4	64.9					
14	0.6	2.4	67.3					
15	0.6	1.8	69.1					
16	0.6	2.2	71.3		1166.4	600000.00	60.00	
17	0.6	2.5	3.8					
18	0.6	2.6	6.4					
19	0.6	3.1	9.5					
20	0.6	2.7	12.2					
21	0.6	3.1	15.3					
22	0.6	2.5	17.8					
23	0.6	2.5	20.3					
24	0.6	2.5	22.8					
25	0.6	2.7	25.5					
26	0.6	2.5	28					
27	0.6	2.1	30.1					

28	0.6	2.3	32.4					
29	0.6	2.7	35.1					
30	0.6	2.9	38					
31	0.6	3	41					
January	0.6							
1	0.6	3	44					
2	0.6	3.1	47.1					
3	0.6	3.2	50.3					
4	0.6	2.8	53.1					
5	0.6	3.1	56.2					
6	0.6	3.2	59.4					
7	0.6	3.2	62.6					
8	0.6	3.2	65.8					
9	0.6	3	68.8					
10	0.6	2.9	71.7					
11	0.6	2.5	74.2					
12	0.6	3	77.2		1166.4	600000.00	60.00	
		1107.2		**517.4**	**15163.2**	**7800000.00**	**780.00**	**247.6**

APPENDIX-I (A)

Detail of irrigation schedule for ginger

Quantity of water applied in drip[irrigation plots (2005-2006)

Date	Kc	PE	CPE	Raifall	Water Applied				ER
		mm	mm	mm	lit/plot	Time/plot	lit/ha	mm/ha	mm
2005-May									
15	0	9.6	0		1166.4	0	600000	60	
16	0.55	11.5							
17	0.55	11.4	22.9		184.1849	55.81	94745.34	9.47	
18	0.55	11.5							
19	0.55	9.1	20.6		165.686	50.21	85229.43	8.52	
20	0.55	10.9							
21	0.55	10	20.9		168.0989	50.94	86470.64	8.65	
22	0.55	10.4							
23	0.55	11.5	21.9		176.1419	53.38	90607.99	9.06	
24	0.55	11.7							
25	0.55	11.1	22.8		183.3806	55.57	94331.61	9.43	
26	0.55	8							
27	0.55	8.9	16.9		135.9269	41.19	69921.24	6.99	
28	0.55	10							
29	0.55	10	20		160.8602	48.75	82747.02	8.27	
30	0.55	8.5							
31	0.55	9.4	17.9		143.9699	43.63	74058.59	7.41	
June									
1	0.55	9.4							
2	0.55	9.8	19.2		154.4258	46.80	79437.14	7.94	
3	0.55	8.9							
4	0.55	8.4	17.3		139.1441	42.16	71576.18	7.16	
5	0.55	9.2							
6	0.55	9.6	18.8		151.2086	45.82	77782.20	7.78	
7	0.55	8.3							
8	0.55	8.2	16.5		132.7097	40.22	68266.29	6.83	
9	0.55	9							
10	0.55	9.3	18.3		147.1871	44.60	75713.53	7.57	
11	0.55	8.6		1.3					
12	0.55	4	12.6		101.3419	30.71	52130.63	5.21	
13	0.55	7.6							
14	0.55	5.6	13.2	0.8	106.1677	32.17	54613.04	5.46	
15	0.85	7.2							
16	0.85	7.2	14.4		179.1484	54.29	92154.52	9.22	
17	0.85	8.6		4.6					4.6
18	0.85	6	10		124.4086	37.70	63996.19	6.40	
19	0.85	7.7							
20	0.85	9.3	17		211.4946	64.09	108793.5	10.88	
21	0.85	7.7							
22	0.85	9	16.7		207.7624	62.96	106873.6	10.69	
23	0.85	9.6							
24	0.85	7.8	17.4		216.471	65.60	11353.4	11.14	

25	0.85	6							
26	0.85	6	12	0.4	149.2903	45.24	76795.43	7.68	
27	0.85	6.3							
28	0.85	4.8	11.11	1.2	138.218	41.88	71099.77	7.11	
29	0.85	4		1.2					
30	0.85	4.2	8.2		102.0151	30.91	52476.88	5.25	
July									
1	0.85	6.2							
2	0.85	7.8	14		174.172	52.78	89594.67	8.96	
3	0.85	6.3			0				
4	0.85	4	10.3		128.1409	38.83	65916.08	6.59	
5	0.85	4							
6	0.85	6.6	10.6		131.8731	39.96	67835.97	6.78	
7	0.85	10.3							
8	0.85	5.8	16.1		200.2978	60.70	103033.9	10.30	
9	0.85	6							
10	0.85	2.9	5.5	3.4	68.42473	20.73	35197.91	3.52	3.4
11	0.85	2.4		1.4					
12	0.85	4.5	6.9		85.84194	26.01	44157.37	4.42	
13	0.85	5.9							
14	0.85	6.5	12.4		154.2667	46.75	79355.28	7.94	
15	0.85	4.8							
16	0.85	5.7	10.5		130.629	39.58	67196.00	6.72	
17	0.85	5.2		4.8					
18	0.85	4.4	9.6	9.4	0	0.00	0.00	0.00	9.6
19	0.85	4.2		31.2					
20	0.85	5.3	9.5	29.4	0	0.00	0.00	0.00	9.5
21	0.85	5		25.2	0	0.00	0.00	0.00	
22	0.85	3.9	8.9		0	0.00	0.00	0.00	8.9
23	0.85	3.7			0				
24	0.85	4.9	8.6		0	0.00	0.00	0.00	
25	1	1.2		1.2					
26	1	0.9	2.1	1.6	30.70968	9.31	15797.16	1.58	
27	1	1.4		23.4					
28	1	1	2.4	14.6	0	0.00	0.00	0.00	2.4
29	1	2.2		1.2					
30	1	4.7	6.9		0	0.00	0.00	0.00	
31	1	3.1							
Aug.									
1	1	1.5	4.6	13.6	0	0.00	0.00	0.00	4.6
2	1	2.2		15.2					
3	1	2.3	4.5	1.2	0	0.00	0.00	0.00	4.5
4	1	3.2							
5	1	1.2	4.4	1.2	0	0.00	0.00	0.00	
6	1	0.6		7.8					
7	1	2.6	3.2		0	0.00	0.00	0.00	3.2
8	1	2.4		1					

9	1	1.4	3.8	1.4	55.56989	16.84	28585.34	2.86	
10	1	5.2			0				
11	1	5.1	10.3		150.6237	45.64	77481.30	7.75	
12	1	4.5			0				
13	1	4.6	9.1	0.6	133.0753	40.33	68454.36	6.85	
14	1	3.4			0				
15	1	4.4	7.8		114.0645	34.57	58675.16	5.87	
16	1	3			0				
17	1	1	1	3	14.62366	4.43	7522.46	0.75	3
18	1	2.8		0.2	0				
19	1	4.8	7.6		111.1398	33.68	57170.67	5.72	
20	1	3.2			0				
21	1	2.3	5.5	1.4	80.43011	24.37	41373.51	4.14	
22	1	2			0				
23	1	5.5	7.5		109.6774	33.24	56418.43	5.64	
24	1	3.8		0.4	0				
25	1	5.1	8.9		130.1505	39.44	66949.87	6.69	
26	1	5.2			0				
27	1	3.1	8.3	1.8	121.3763	36.78	62436.39	6.24	
28	1	3.9			0				
29	1	5.3	9.2		134.5376	40.77	69206.60	6.92	
30	1	3.8		7.8	0				
31	1	5.5	1.5		21.93548	6.65	11283.69	1.13	7.8
Sept.									
1	1	5.4		33.8	0				
2	1	4.8	10.2		0	0.00	0.00	0.00	10.2
3	1	3.7			0				
4	1	3.4	7.1	61.2	0	0.00	0.00	0.00	7.1
5	1	3.8		9.8	0				
6	1	2.5	6.3	4.2	0	0.00	0.00	0.00	6.3
7	1	3.8		35.2	0				
8	1	3.2	7	13.7	0	0.00	0.00	0.00	7
9	1	1.2		3.2	0				
10	1	1.4	2.6	19.6	0	0.00	0.00	0.00	2.6
11	1	5.6		1.6	0				
12	1	2.8	8.4	0.8	0	0.00	0.00	0.00	
13	1	4.4			0				
14	1	2.8	7.2	2.2	105.2903	31.91	54161.69	5.42	
15	1	3.2			0				
16	1	2.6	5.8		84.8172	25.70	43630.25	4.36	
17	1	5.6			0				
18	1	3.6	9.2		134.5376	40.77	69206.60	6.92	
19	1	5.9			0				
20	1	3.1	9		131.6129	39.88	67702.11	6.77	
21	1	3.1		29.8	0				
22	1	1.4	4.5	50.2	0	0.00	0.00	0.00	4.5
23	1	4.7			0				
24	1	2.7	7.4		0	0.00	0.00	0.00	

25	1	4.3			0				
26	1	3.5	7.8		114.0645	34.57	58675.16	5.87	
27	1	3.7			0				
28	1	4.4	8.1		118.4516	35.89	60931.90	6.09	
29	1	3.1		3.2	0				
30	1	2.6	2.5		36.55914	11.08	18806.14	1.88	3.2
Oct.									
1	1	2.7			0				
2	1	2.8	5.5		80.43011	24.37	41373.51	4.14	
3	1	3.4		0.2	0				
4	1	1.8	5.2		76.04301	23.04	39116.78	3.91	
5	1	3.5		2.4	0				
6	1	4.1	7.6		111.1398	33.68	57170.67	5.72	
7	1	4.9			0				
8	1	5.3	10.2		149.1613	45.20	76729.06	7.67	
9	1	4.7			0				
10	1	6.3	11		160.8602	48.75	82747.02	8.27	
11	1	5.1			0				
12	1	5.2	10.3		150.6237	45.64	77481.30	7.75	
13	1	5.3			0				
14	1	5.7	6.8	4.2	99.44086	30.13	51152.71	5.12	4.2
15	1	2		2	0				
16	1	0.6	2.6	7	38.02151	11.52	19558.39	1.96	2.6
17	1	1.5		1.8	0				
18	1	2.3	3.8	18.4	0	0.00	0.00	0.00	3.8
19	1	2.5			0				
20	1	3.3	5.8		0	0.00	0.00	0.00	
21	1	4			0				
22	1	4.4	8.4		122.8387	37.22	63188.64	6.32	
23	1	3.7			0				
24	1	3.8	7.5		109.6774	33.24	56418.43	5.64	
25	1	4.7			0				
26	1	3.6	8.3		121.3763	36.78	62436.39	6.24	
27	1	3.7			0				
28	1	4.8	8.5		124.3011	37.67	63940.88	6.39	
29	1	3			0				
30	1	3.5	6.5		95.05376	28.80	48895.97	4.89	
31	1	4.5			0				
Nov.					0				
1	1	4.1	8.6		125.7634	38.11	64693.13	6.47	
2	1	3.7			0				
3	1	3.8	7.5		109.6774	33.24	56418.43	5.64	
4	1	4.2			0				
5	1	4.4	8.6		125.7634	38.11	64693.13	6.47	
6	1	4			0				
7	1	4.7	8.7		127.2258	38.55	65445.37	6.54	
8	1	3.2			0				
9	1	4	7.2		105.2903	31.91	54161.69	5.42	

10	1	4.8			0				
11	1	4.4	9.2		134.5376	40.77	69206.60	6.92	
12	1	3.5			0				
13	1	4.1	7.6		111.1398	33.68	57170.67	5.72	
14	1	4			0				
15	1	3.4	7.4		108.2151	32.79	55666.18	5.57	
16	1	3.4							
17	0.6	4.2	7.6		66.68387	20.21	34302.40	3.43	
18	0.6	3.6			0				
19	0.6	4.2	7.8		68.43871	20.74	35205.10	3.52	
20	0.6	4.4			0				
21	0.6	4.7	9.1		79.84516	24.20	41072.61	4.11	
22	0.6	4.4			0				
23	0.6	4.3	8.7		76.33548	23.13	39267.22	3.93	
24	0.6	3.8			0				
25	0.6	3.4	7.2		63.17419	19.14	32497.01	3.25	
26	0.6	4.1			0				
27	0.6	3.2	7.3		64.05161	19.41	32948.36	3.29	
28	0.6	3.4			0				
29	0.6	4	7.4		64.92903	19.68	33399.71	3.34	
30	0.6	3.4			0				
Dec.	0.6				0				
1	0.6	4.1	7.5		65.80645	19.94	33851.06	3.39	
2	0.6	2.8			0				
3	0.6	3	5.8		50.89032	15.42	26178.15	2.62	
4	0.6	2.1			0				
5	0.6	3.3	5.4		47.38065	14.36	24372.76	2.44	
6	0.6	3.1			0				
7	0.6	2.9	6		52.64516	15.95	27080.84	2.71	
8	0.6	2.5			0				
9	0.6	2.1	4.6		40.36129	12.23	20761.98	2.08	
10	0.6	3			0				
11	0.6	3.2	6.2		54.4	16.48	27983.54	2.80	
12	0.6	2.1			0				
13	0.6	2.4	4.5		39.48387	11.96	20310.63	2.03	
14	0.6	2.4			0				
15	0.6	1.8	4.2		36.85161	11.17	18956.59	1.90	
16	0.6	2.2			0				
17	0.6	2.5	4.7		41.23871	12.50	21213.33	2.12	
18	0.6	2.6			0				
19	0.6	3.1	5.7		50.0129	15.16	25726.80	2.57	
20	0.6	2.7			0				
21	0.6	3.1	5.8		50.89032	15.42	26178.15	2.62	
22	0.6	2.5			0				
23	0.6	2.5	5		43.87097	13.29	22567.37	2.26	
24	0.6	2.5			0				
25	0.6	2.7	5.2		45.62581	13.83	23470.07	2.35	
26	0.6	2.5							

27	0.06	2.1	4.6		40.36129	12.23	20761.98	2.08	
28	0.06	2.3			0	0.00	0.00	0.00	
29	0.06	2.7	5		43.87097	13.29	22567.37	2.26	
30	0.06	2.9			0	0.00	0.00	0.00	
31	0.06	3	5.9		51.76774	15.69	26629.50	2.66	
Jan					0	0.00	0.00	0.00	
1	0.06	3			0	0.00	0.00	0.00	
2	0.06	3.1	6.1		53.52258	16.22	27532.19	2.75	
3	0.06	3.2			0	0.00	0.00	0.00	
4	0.06	2.8	6		52.64516	15.95	27080.84	2.71	
5	0.06	3.1			0	0.00	0.00	0.00	
6	0.06	3.2	6.3		55.27742	16.75	28434.89	2.84	
7	0.06	3.2			0	0.00	0.00	0.00	
8	0.06	3.2	6.4		56.15484	17.02	28886.23	2.89	
9	0.06	3			0	0.00	0.00	0.00	
10	0.06	2.9	5.9		51.76774	15.69	26629.50	2.66	
		1101.7	**1065.91**	**517.4**	**11647.4**	**3176.061**	**5991461**	**599.1461**	**113**

APPENDIX-I (A)

Detail of irrigation schedule for ginger

Quantity of water applied in Floppy Sprinkler irrigation plots (2005-2006)

Date	Kc	PE	CPE	Raifall	Water Applied				ER
		mm	mm	mm	lit/plot	Time/ha	lit/ha	mm/ha	mm
2005-May						minutes			
15	0	9.6	0		1166.4	0	600000	60	
16	0.55	11.5	11.5						
17	0.55	11.4	22.9						
18	0.55	11.5	34.4						
19	0.55	9.1	43.5		308	126.18	158436.21	15.84	
20	0.55	10.9	19.4						
21	0.55	10	29.4						
22	0.55	10.4	39.8		308	126.18	158436.21	15.84	
23	0.55	11.5	16.3						
24	0.55	11.7	28						
25	0.55	11.1	39.1		308	126.18	158436.21	15.84	
26	0.55	8	12.1						
27	0.55	8.9	21						
28	0.55	10	31						
29	0.55	10	41		308	126.18	158436.21	15.84	
30	0.55	8.5	14.5						
31	0.55	9.4	23.9						
June									
1	0.55	9.4	33.3						
2	0.55	9.8	43.1		308	126.18	158436.21	15.84	
3	0.55	8.9	17						
4	0.55	8.4	25.4						
5	0.55	9.2	34.6						
6	0.55	9.6	44.2		308	126.18	158436.21	15.84	
7	0.55	8.3	17.5						
8	0.55	8.2	25.7						
9	0.55	9	34.7						
10	0.55	9.3	44		308	126.18	158436.21	15.84	
11	0.55	8.6	17.6	1.3					
12	0.55	4	21.6						
13	0.55	7.6	29.2						
14	0.55	5.6	34.8	0.8					
15	0.85	7.2	42		308	126.18	158436.21	15.84	
16	0.85	7.2	14.2						
17	0.85	8.6	18.2	4.6					4.6
18	0.85	6	24.2						
19	0.85	7.7	31.9						
20	0.85	9.3	41.2		476	195.01	244855.97	24.49	
21	0.85	7.7	13.9						

22	0.85	9	22.9						
23	0.85	9.6	32.5						
24	0.85	7.8	40.3		476	195.01	244855.97	24.49	
25	0.85	6	11.3						
26	0.85	6	17.3	0.4					
27	0.85	6.3	23.6						
28	0.85	4.8	28.4	1.2					
29	0.85	4	32.4	1.2					
30	0.85	4.2	36.6		476	195.01	244855.97	24.49	
July									
1	0.85	6.2	7.8						
2	0.85	7.8	15.6						
3	0.85	6.3	21.9						
4	0.85	4	25.9						
5	0.85	4	29.9						
6	0.85	6.6	36.5		476	195.01	244855.97	24.49	
7	0.85	10.3	11.8						
8	0.85	5.8	17.6						
9	0.85	6	23.6						
10	0.85	2.9	23.1	3.4					3.4
11	0.85	2.4	25.5	1.4					
12	0.85	4.5	30						
13	0.85	5.9	35.9		476	195.01	244855.97	24.49	
14	0.85	6.5	7.4						
15	0.85	4.8	12.2						
16	0.85	5.7	17.9						
17	0.85	5.2	18.3	4.8					4.8
18	0.85	4.4	13.3	9.4					9.4
19	0.85	4.2	17.5	31.2					17.5
20	0.85	5.3	5.3	29.4					5.3
21	0.85	5	5	25.2					5
22	0.85	3.9	3.9						
23	0.85	3.7	7.6						
24	0.85	4.9	12.5						
25	1	1.2	13.7	1.2					
26	1	0.9	14.6	1.6					
27	1	1.4	16	23.4					16
28	1	1	1	14.6					1
29	1	2.2	2.2	1.2					
30	1	4.7	6.9						
31	1	3.1	10						
Aug.									
1	1	1.5	11.5	13.6					11.5
2	1	2.2	2.2	15.2					2.2
3	1	2.3	2.3	1.2					
4	1	3.2	5.5						
5	1	1.2	6.7	1.2					
6	1	0.6	7.3	7.8					7.3

7	1	2.6	2.6						
8	1	2.4	5	1					
9	1	1.4	6.4	1.4					
10	1	5.2	11.6						
11	1	5.1	16.7						
12	1	4.5	21.2						
13	1	4.6	25.8	0.6					
14	1	3.4	29.2						
15	1	4.4	33.6						
16	1	3	36.6		560.4118	229.42	288065.84	28.81	
17	1	1	2.6	3					2.6
18	1	2.8	2.8	0.2					
19	1	4.8	7.6						
20	1	3.2	10.8						
21	1	2.3	13.1	1.4					
22	1	2	15.1						
23	1	5.5	20.6						
24	1	3.8	24.4	0.4					
25	1	5.1	29.5						
26	1	5.2	34.7						
27	1	3.1	37.8	1.8	560.4118	229.42	288065.84	28.81	
28	1	3.9	6.7						
29	1	5.3	12						
30	1	3.8	8	7.8					7.8
31	1	5.5	13.5						
Sept.									
1	1	5.4	18.9	33.8					18.9
2	1	4.8	4.8						
3	1	3.7	8.5						
4	1	3.4	11.9	61.2					11.9
5	1	3.8	3.8	9.8					3.8
6	1	2.5	2.5	4.2					2.5
7	1	3.8	3.8	35.2					3.8
8	1	3.2	3.2	13.7					3.2
9	1	1.2	1.2	3.2					1.2
10	1	1.4	1.4	19.6					1.4
11	1	5.6	5.6	1.6					
12	1	2.8	8.4	0.8					
13	1	4.4	12.8						
14	1	2.8	15.6	2.2					
15	1	3.2	18.8						
16	1	2.6	21.4						
17	1	5.6	27						
18	1	3.6	30.6						
19	1	5.9	36.5		560.4118	229.42	288065.84	28.81	
20	1	3.1	4.6						
21	1	3.1	7.7	29.8					7.7
22	1	1.4	1.4	50.2					1.4

23	1	4.7	4.7						
24	1	2.7	7.4						
25	1	4.3	11.7						
26	1	3.5	15.2						
27	1	3.7	18.9						
28	1	4.4	23.3						
29	1	3.1	23.2	3.2					3.2
30	1	2.6	25.8						
Oct.									
1	1	2.7	28.5						
2	1	2.8	31.3						
3	1	3.4	34.7	0.2					
4	1	1.8	36.5		560.4118	229.42	288065.84	28.81	
5	1	3.5	5	2.4					
6	1	4.1	9.1						
7	1	4.9	14						
8	1	5.3	19.3						
9	1	4.7	24						
10	1	6.3	30.3						
11	1	5.1	35.4		560.4118	229.42	288065.84	28.81	
12	1	5.2	5.6						
13	1	5.3	10.9						
14	1	5.7	12.4	4.2					4.2
15	1	2	14.4	2					
16	1	0.6	8	7					7
17	1	1.5	9.5	1.8					
18	1	2.3	11.8	18.4					11.8
19	1	2.5	2.5						
20	1	3.3	5.8						
21	1	4	9.8						
22	1	4.4	14.2						
23	1	3.7	17.9						
24	1	3.8	21.7						
25	1	4.7	26.4						
26	1	3.6	30						
27	1	3.7	33.7						
28	1	4.8	38.5		560.4118	229.42	288065.84	28.81	
29	1	3	6.5						
30	1	3.5	10						
31	1	4.5	14.5						
Nov.									
1	1	4.1	18.6						
2	1	3.7	22.3						
3	1	3.8	26.1						
4	1	4.2	30.3						
5	1	4.4	34.7						
6	1	4	38.7		560.4118	229.42	288065.84	28.81	
7	1	4.7	8.4						

8	1	3.2	11.6						
9	1	4	15.6						
10	1	4.8	20.4						
11	1	4.4	24.8						
12	1	3.5	28.3						
13	1	4.1	32.4						
14	1	4	36.4		560.4118	229.42	288065.84	28.81	
15	1	3.4	4.8						
16	1	3.4	8.2						
17	0.6	4.2	12.4						
18	0.6	3.6	16						
19	0.6	4.2	20.2						
20	0.6	4.4	24.6						
21	0.6	4.7	29.3						
22	0.6	4.4	33.7						
23	0.6	4.3	38		336	137.65	172839.51	17.28	
24	0.6	3.8	6.8						
25	0.6	3.4	10.2						
26	0.6	4.1	14.3						
27	0.6	3.2	17.5						
28	0.6	3.4	20.9						
29	0.6	4	24.9						
30	0.6	3.4	28.3						
Dec.	0.6								
1	0.6	4.1	32.4						
2	0.6	2.8	35.2		336	137.65	172839.51	17.28	
3	0.6	3	3.2						
4	0.6	2.1	5.3						
5	0.6	3.3	8.6						
6	0.6	3.1	11.7						
7	0.6	2.9	14.6						
8	0.6	2.5	17.1						
9	0.6	2.1	19.2						
10	0.6	3	22.2						
11	0.6	3.2	25.4						
12	0.6	2.1	27.5						
13	0.6	2.4	29.9						
14	0.6	2.4	32.3						
15	0.6	1.8	34.1						
16	0.6	2.2	36.3		336	137.65	172839.5	17.28	
17	0.6	2.5	3.8						
18	0.6	2.6	6.4						
19	0.6	3.1	9.5						
20	0.6	2.7	12.2						
21	0.6	3.1	15.3						
22	0.6	2.5	17.8						
23	0.6	2.5	20.3						
24	0.6	2.5	22.8						

25	0.6	2.7	25.5						
26	0.6	2.5	28						
27	0.6	2.1	30.1						
28	0.6	2.3	32.4						
29	0.6	2.7	35.1		336	137.65	172839.5	17.28	
30	0.6	2.9	**3**						
31	0.6	3	6						
Jan									
1	0.6	3	9						
2	0.6	3.1	12.1						
3	0.6	3.2	15.3						
4	0.6	2.8	18.1						
5	0.6	3.1	21.2						
6	0.6	3.2	24.4						
7	0.6	3.2	27.6						
8	0.6	3.2	30.8						
9	0.6	3	33.8						
10	0.6	2.9	36.7		336	137.65	172839.51	17.28	
		1101.7	**4698.9**		**12173.7**	**4508.077**	**6260494**	**626.0454**	**180.4**

APPENDIX-I (A)

Detail of irrigation schedule for ginger

Quantity of water applied in Over head Sprinkler irrigation plots (2005-2006)

Date	Kc	PE	CPE	Raifall	Water Applied				ER
		mm	mm	mm	lit/plot	Time/ha	lit/ha	mm/ha	mm
2005-May						minutes			
15	0	9.6	0		1166.4	0	600000	60	
16	0.55	11.5	11.5						
17	0.55	11.4	22.9						
18	0.55	11.5	34.4						
19	0.55	9.1	43.5		308	126.18	158436.21	15.84	
20	0.55	10.9	19.4						
21	0.55	10	29.4						
22	0.55	10.4	39.8		308	126.18	158436.21	15.84	
23	0.55	11.5	16.3						
24	0.55	11.7	28						
25	0.55	11.1	39.1		308	126.18	158436.21	15.84	
26	0.55	8	12.1						
27	0.55	8.9	21						
28	0.55	10	31						
29	0.55	10	41		308	126.18	158436.21	15.84	
30	0.55	8.5	14.5						
31	0.55	9.4	23.9						
June									
1	0.55	9.4	33.3						
2	0.55	9.8	43.1		308	126.18	158436.21	15.84	
3	0.55	8.9	17						
4	0.55	8.4	25.4						
5	0.55	9.2	34.6						
6	0.55	9.6	44.2		308	126.18	158436.21	15.84	
7	0.55	8.3	17.5						
8	0.55	8.2	25.7						
9	0.55	9	34.7						
10	0.55	9.3	44		308	126.18	158436.21	15.84	
11	0.55	8.6	17.6	1.3					
12	0.55	4	21.6						
13	0.55	7.6	29.2						
14	0.55	5.6	34.8	0.8					
15	0.85	7.2	42		308	126.18	158436.21	15.84	
16	0.85	7.2	14.2						
17	0.85	8.6	18.2	4.6					4.6
18	0.85	6	24.2						
19	0.85	7.7	31.9						
20	0.85	9.3	41.2		476	195.01	244855.97	24.49	
21	0.85	7.7	13.9						
22	0.85	9	22.9						

23	0.85	9.6	32.5						
24	0.85	7.8	40.3		476	195.01	244855.97	24.49	
25	0.85	6	11.3						
26	0.85	6	17.3	0.4					
27	0.85	6.3	23.6						
28	0.85	4.8	28.4	1.2					
29	0.85	4	32.4	1.2					
30	0.85	4.2	36.6		476	195.01	244855.97	24.49	
July									
1	0.85	6.2	7.8						
2	0.85	7.8	15.6						
3	0.85	6.3	21.9						
4	0.85	4	25.9						
5	0.85	4	29.9						
6	0.85	6.6	36.5		476	195.01	244855.97	24.49	
7	0.85	10.3	11.8						
8	0.85	5.8	17.6						
9	0.85	6	23.6						
10	0.85	2.9	23.1	3.4					3.4
11	0.85	2.4	25.5	1.4					
12	0.85	4.5	30						
13	0.85	5.9	35.9		476	195.01	244855.97	24.49	
14	0.85	6.5	7.4						
15	0.85	4.8	12.2						
16	0.85	5.7	17.9						
17	0.85	5.2	18.3	4.8					4.8
18	0.85	4.4	13.3	9.4					9.4
19	0.85	4.2	17.5	31.2					17.5
20	0.85	5.3	5.3	29.4					5.3
21	0.85	5	5	25.2					5
22	0.85	3.9	3.9						
23	0.85	3.7	7.6						
24	0.85	4.9	12.5						
25	1	1.2	13.7	1.2					
26	1	0.9	14.6	1.6					
27	1	1.4	16	23.4					16
28	1	1	1	14.6					1
29	1	2.2	2.2	1.2					
30	1	4.7	6.9						
31	1	3.1	10						
Aug.									
1	1	1.5	11.5	13.6					11.5
2	1	2.2	2.2	15.2					2.2
3	1	2.3	2.3	1.2					
4	1	3.2	5.5						
5	1	1.2	6.7	1.2					
6	1	0.6	7.3	7.8					7.3
7	1	2.6	2.6						

8	1	2.4	5	1					
9	1	1.4	6.4	1.4					
10	1	5.2	11.6						
11	1	5.1	16.7						
12	1	4.5	21.2						
13	1	4.6	25.8	0.6					
14	1	3.4	29.2						
15	1	4.4	33.6						
16	1	3	36.6		560.4118	229.42	288065.84	28.81	
17	1	1	2.6	3					2.6
18	1	2.8	2.8	0.2					
19	1	4.8	7.6						
20	1	3.2	10.8						
21	1	2.3	13.1	1.4					
22	1	2	15.1						
23	1	5.5	20.6						
24	1	3.8	24.4	0.4					
25	1	5.1	29.5						
26	1	5.2	34.7						
27	1	3.1	37.8	1.8	560.4118	229.42	288065.84	28.81	
28	1	3.9	6.7						
29	1	5.3	12						
30	1	3.8	8	7.8					7.8
31	1	5.5	13.5						
Sept.									
1	1	5.4	18.9	33.8					18.9
2	1	4.8	4.8						
3	1	3.7	8.5						
4	1	3.4	11.9	61.2					11.9
5	1	3.8	3.8	9.8					3.8
6	1	2.5	2.5	4.2					2.5
7	1	3.8	3.8	35.2					3.8
8	1	3.2	3.2	13.7					3.2
9	1	1.2	1.2	3.2					1.2
10	1	1.4	1.4	19.6					1.4
11	1	5.6	5.6	1.6					
12	1	2.8	8.4	0.8					
13	1	4.4	12.8						
14	1	2.8	15.6	2.2					
15	1	3.2	18.8						
16	1	2.6	21.4						
17	1	5.6	27						
18	1	3.6	30.6						
19	1	5.9	36.5		560.4118	229.42	288065.84	28.81	
20	1	3.1	4.6						
21	1	3.1	7.7	29.8					7.7
22	1	1.4	1.4	50.2					1.4
23	1	4.7	4.7						

24	1	2.7	7.4						
25	1	4.3	11.7						
26	1	3.5	15.2						
27	1	3.7	18.9						
28	1	4.4	23.3						
29	1	3.1	23.2	3.2					3.2
30	1	2.6	25.8						
Oct.									
1	1	2.7	28.5						
2	1	2.8	31.3						
3	1	3.4	34.7	0.2					
4	1	1.8	36.5		560.4118	229.42	288065.84	28.81	
5	1	3.5	5	2.4					
6	1	4.1	9.1						
7	1	4.9	14						
8	1	5.3	19.3						
9	1	4.7	24						
10	1	6.3	30.3						
11	1	5.1	35.4		560.4118	229.42	288065.84	28.81	
12	1	5.2	5.6						
13	1	5.3	10.9						
14	1	5.7	12.4	4.2					4.2
15	1	2	14.4	2					
16	1	0.6	8	7					7
17	1	1.5	9.5	1.8					
18	1	2.3	11.8	18.4					11.8
19	1	2.5	2.5						
20	1	3.3	5.8						
21	1	4	9.8						
22	1	4.4	14.2						
23	1	3.7	17.9						
24	1	3.8	21.7						
25	1	4.7	26.4						
26	1	3.6	30						
27	1	3.7	33.7						
28	1	4.8	38.5		560.4118	229.42	288065.84	28.81	
29	1	3	6.5						
30	1	3.5	10						
31	1	4.5	14.5						
Nov.									
1	1	4.1	18.6						
2	1	3.7	22.3						
3	1	3.8	26.1						
4	1	4.2	30.3						
5	1	4.4	34.7						
6	1	4	38.7		560.4118	229.42	288065.84	28.81	
7	1	4.7	8.4						
8	1	3.2	11.6						

9	1	4	15.6						
10	1	4.8	20.4						
11	1	4.4	24.8						
12	1	3.5	28.3						
13	1	4.1	32.4						
14	1	4	36.4		560.4118	229.42	288065.84	28.81	
15	1	3.4	4.8						
16	1	3.4	8.2						
17	0.6	4.2	12.4						
18	0.6	3.6	16						
19	0.6	4.2	20.2						
20	0.6	4.4	24.6						
21	0.6	4.7	29.3						
22	0.6	4.4	33.7						
23	0.6	4.3	38		336	137.65	172839.51	17.28	
24	0.6	3.8	6.8						
25	0.6	3.4	10.2						
26	0.6	4.1	14.3						
27	0.6	3.2	17.5						
28	0.6	3.4	20.9						
29	0.6	4	24.9						
30	0.6	3.4	28.3						
Dec.	0.6								
1	0.6	4.1	32.4						
2	0.6	2.8	35.2		336	137.65	172839.51	17.28	
3	0.6	3	3.2						
4	0.6	2.1	5.3						
5	0.6	3.3	8.6						
6	0.6	3.1	11.7						
7	0.6	2.9	14.6						
8	0.6	2.5	17.1						
9	0.6	2.1	19.2						
10	0.6	3	22.2						
11	0.6	3.2	25.4						
12	0.6	2.1	27.5						
13	0.6	2.4	29.9						
14	0.6	2.4	32.3						
15	0.6	1.8	34.1						
16	0.6	2.2	36.3		336	137.65	172839.51	17.28	
17	0.6	2.5	3.8						
18	0.6	2.6	6.4						
19	0.6	3.1	9.5						
20	0.6	2.7	12.2						
21	0.6	3.1	15.3						
22	0.6	2.5	17.8						
23	0.6	2.5	20.3						
24	0.6	2.5	22.8						
25	0.6	2.7	25.5						

26	0.6	2.5	28						
27	0.6	2.1	30.1						
28	0.6	2.3	32.4						
29	0.6	2.7	35.1		336	137.65	172839.51	17.28	
30	0.6	2.9	**3**						
31	0.6	3	6						
Jan									
1	0.6	3	9						
2	0.6	3.1	12.1						
3	0.6	3.2	15.3						
4	0.6	2.8	18.1						
5	0.6	3.1	21.2						
6	0.6	3.2	24.4						
7	0.6	3.2	27.6						
8	0.6	3.2	30.8						
9	0.6	3	33.8						
10	0.6	2.9	36.7		336	137.65	172839.51	17.28	
		1101.7	**4699**		**12173.7**	**4508.077**	**6260494**	**626.045**	**180.4**

APPENDIX-II (A)

Detail of irrigation schedule for ginger

Quantity of water applied through Surface irrigation method (2006-2007)

Date	Kc	PE	CPE	Raifall	Water applied			ER
		mm	mm	mm	lit/plot	lit/ha	mm/ha	mm
Apr-06								
30	0.55	8.4	0		1166.4	600000	60	
2006-May								
1	0.55	8.1	8.1					
2	0.55	8.2	16.3					
3	0.55	7	23.3					
4	0.55	7.7	31					
5	0.55	6.9	37.9					
6	0.55	8	45.9					
7	0.55	7	52.9					
8	0.55	8	60.9					
9	0.55	8.7	69.6					
10	0.55	8.2	77.8		1166.4	600000.00	60.00	
11	0.55	9.8	17.6					
12	0.55	9.4	27					
13	0.55	10.2	37.2					
14	0.55	10.8	48					
15	0.55	10.9	58.9					
16	0.55	10.4	69.3					
17	0.55	8.6	77.9		1166.4	600000.00	60.00	
18	0.55	8.9	16.8					
19	0.55	7.6	24.4					
20	0.55	9.1	33.5					
21	0.55	8.4	41.9					
22	0.55	8	49.9					
23	0.55	8.2	58.1					
24	0.55	9.5	67.6					
25	0.55	7.8	75.4		1166.4	600000.00	60.00	
26	0.55	8.1	13.5					
27	0.55	5.7	14.4	4.8				4.8
28	0.55	5.5	19.9	23.6				19.9
29	0.55	5.2	5.2					
30	0.55	4.4	9.6	1.2				
31	0.85	2.1	11.7	25				11.7
June								
1	0.85	4.4	4.4	1.2				
2	0.85	3	7.4					
3	0.85	1.8	9.2					
4	0.85	2.1	11.3					
5	0.85	2	13.3					
6	0.85	4.2	17.5					
7	0.85	6.2	23.7					
8	0.85	7.7	31.4					

9	0.85	7.1	38.5					
10	0.85	7.5	46					
11	0.85	5.4	51.4	1.4				
12	0.85	5.2	56.6					
13	0.85	5.6	62.2					
14	0.85	6.5	68.7					
15	0.85	6.4	75.1		1166.4	600000.00	60.00	
16	0.85	6.7	11.8					
17	0.85	5.7	17.5					
18	0.85	5	22.5					
19	0.85	4	26.5					
20	0.85	2.6	29.1					
21	0.85	1.5	26.4	4.2				4.2
22	0.85	7.5	33.9	0.6				
23	0.85	5.2	14.7	24.4				24.4
24	0.85	2	16.7	28.2				16.7
25	0.85	2	2	2.2				
26	0.85	1.6	3.6	0.6				
27	0.85	2.6	6.2	0.8				
28	0.85	2.8	9					
29	0.85	3.5	12.5					
30	0.85	5.5	18					
July								
1	0.85	2.8	20.8	0.8				
2	0.85	2.2	23	0.2				
3	0.85	4.3	22.7	4.6				4.6
4	0.85	1.5	10.6	13.6				13.6
5	0.85	1.2	11.8	72				11.8
6	0.85	4.6	4.6	1				
7	0.85	2.4	7					
8	0.85	4.8	11.8					
9	0.85	6	17.8					
10	1	4.6	22.4					
11	1	3	25.4					
12	1	4.8	30.2	0.4				
13	1	2.4	32.6					
14	1	3.2	35.8					
15	1	3.4	39.2					
16	1	3.4	42.6					
17	1	5.5	48.1					
18	1	5.5	53.6					
19	1	2	55.6					
20	1	2.8	58.4	0.9				
21	1	4.3	62.7	0.4				
22	1	3.9	66.6	1.8				
23	1	3.2	69.6	1.6				
24	1	4	73.6		1166.4	600000.00	60.00	
25	1	4.1	7.7					

26	1	4	11.7					
27	1	3.6	10.5	4.8				4.8
28	1	2.4	12.9					
29	1	1.2	14.1	1.8				
30	1	3.4	17.5					
31	1	4.9	22.4					
Aug.								
1	1	3.6	26					
2	1	3.6	29.6					
3	1	4	33.6					
4	1	2.9	36.5					
5	1	3	39.5	2.4				
6	1	1.9	18.8	22.6				22.6
7	1	3	21.8	35.4				21.8
8	1	2	2	26				2
9	1	1.5	1.5	10.8				1.5
10	1	1.9	1.9	1				
11	1	2.4	4.3	1.8				
12	1	4.2	8.5					
13	1	4.4	12.9					
14	1	5.1	18					
15	1	3.4	21.4					
16	1	5	26.4					
17	1	1.4	27.8	2.2				
18	1	2.1	29.9					
19	1	4.8	34.7					
20	1	2.9	37.6					
21	1	4.5	42.1					
22	1	3.8	45.9	0.4				
23	1	1.9	47.8					
24	1	2.8	50.6	1.2				
25	1	2.4	53					
26	1	3	56					
27	1	3.3	59.3					
28	1	3.6	62.9	1.4				
29	1	2	64.9					
30	1	2.5	67.4					
31	1	3.8	71.3		1166.4	600000.00	60.00	
Sept.								
1	1	3.3	4.6					
2	1	3	7.6					
3	1	3.4	11					
4	1	4.7	15.7					
5	1	4.1	19.8					
6	1	1.8	21.6	0.4				
7	1	1.2	13.8	9				9
8	1	3	16.8					
9	1	2.7	19.5	27				19.5

10	1	3.5	3.5					
11	1	3.3	6.8					
12	1	2.3	9.1	56.8				9.1
13	1	1.9	1.9	7.8				1.9
14	1	2	2					
15	1	1.4	3.4	32.8				3.4
16	1	1	1	6.2				1
17	1	1.1	1.1	13.2				1.1
18	1	2.7	2.7	12.2				2.7
19	1	2.1	2.1	2.4				
20	1	2.7	4.8	26.4				4.8
21	1	3.6	3.6	21				3.6
22	1	3	3	0.4				
23	1	2.2	5.2					
24	1	3.4	3.6	5				5
25	1	2.8	6.4	6.6				6.4
26	1	4	4					
27	1	4.2	1.6	6.6				6.6
28	1	3.1	4.7					
29	1	3.2	7.9					
30	1	2.8	10.7					
Oct.								
1	1	2.9	13.6	14.6				
2	1	1.6	1.6	8.6				13.6
3	1	2	2					1.6
4	1	2.4	4.4					
5	1	2.6	7					
6	1	3.4	2.4	8				8
7	1	1.9	4.3	14				4.3
8	1	2.4	2.4					
9	1	3	5.4					
10	1	3.4	8.8					
11	1	3.1	11.9					
12	1	4.2	16.1					
13	1	4	20.1					
14	1	4.2	24.3					
15	1	3.8	28.1					
16	1	3.7	31.8					
17	1	3.8	35.6					
18	1	4	39.6					
19	1	4.5	44.1					
20	1	3.8	47.9					
21	1	3.8	51.7					
22	1	2.5	54.2					
23	1	3	50	7.2				7.2
24	1	2.7	52.7					
25	1	3	55.7					
26	1	4	59.7					

27	1	4	63.7					
28	1	3.4	67.1					
29	1	3.8	70.9		1166.4	600000.00	60.00	
30	1	2.1	3					
31	1	3.1	6.1					
Nov.								
1	1	3.4	9.5					
2	0.6	3.5	13					
3	0.6	2.6	15.6					
4	0.6	3.2	18.8					
5	0.6	2.8	21.6					
6	0.6	1.7	23.3					
7	0.6	1.4	24.7	33.3				24.2
8	0.6	2.4	2.4	0.4				
9	0.6	2.8	5.2					
10	0.6	2.2	7.4					
11	0.6	2.6	10					
12	0.6	2.4	12.4					
13	0.6	2.4	14.8					
14	0.6	2.6	17.4					
15	0.6	2.5	19.9					
16	0.6	2.9	22.8					
17	0.6	2.5	25.3					
18	0.6	2.6	27.9					
19	0.6	2.4	30.3					
20	0.6	2.1	32.4					
21	0.6	2.4	34.8					
22	0.6	2.2	37					
23	0.6	1.5	23.9	14.6				14.6
24	0.6	2	25.9	0.4				
25	0.6	1.6	27.5	8.8				
26	0.6	1.5	20.2					8.8
27	0.6	1.8	22					
28	0.6	2.2	24.2					
29	0.6	2.1	26.3					
30	0.6	2	28.3					
Dec.								
1	0.6	2.5	30.8					
2	0.6	2.2	33					
3	0.6	2	35					
4	0.6	2	37					
5	0.6	2.4	39.4					
6	0.6	2.1	41.5					
7	0.6	2	43.5					
8	0.6	2.5	46					
9	0.6	2.3	48.3					
10	0.6	2.4	50.7					
11	0.6	2.5	53.2					

12	0.6	2.6	55.8					
13	0.6	2.2	58					
14	0.6	2	60					
15	0.6	2	62					
16	0.6	1.8	63.8					
17	0.6	2.2	66					
18	0.6	2.5	68.5					
19	0.6	2.6	71.1		1166.4	600000.00	60.00	
		890.9	**6659.9**	**671**	**10497.6**	**5400000**	**540**	**320.8**

APPENDIX-II (A)

Detail of irrigation schedule for ginger

Quantity of water applied through Drip irrigation method (2006-2007)

Date	Kc	PE	CPE	Raifall	Water applied				ER
		mm	mm	mm	lit/plot	Time/plot	lit/ha	mm/ha	mm
Apr-06									
30	0.55	8.4	0		1166.4		600000	60	
2006-May									
1	0.55	8.1							
2	0.55	8.2	16.3		131.1011	39.73	67438.82	6.74	
3	0.55	7							
4	0.55	7.7	14.7		118.2323	35.83	60819.06	6.08	
5	0.55	6.9							
6	0.55	8	14.9		119.8409	36.32	61646.53	6.16	
7	0.55	7							
8	0.55	8	15		120.6452	36.56	62060.27	6.21	
9	0.55	8.7							
10	0.55	8.2	16.9		135.9269	41.19	69921.24	6.99	
11	0.55	9.8							
12	0.55	9.4	19.2		154.4258	46.80	79437.14	7.94	
13	0.55	10.2							
14	0.55	10.8	21		168.9032	51.18	86884.38	8.69	
15	0.55	10.9							
16	0.55	10.4	21.3		171.3161	51.91	88125.58	8.81	
17	0.55	8.6							
18	0.55	8.9	17.5		140.7527	42.65	72403.65	7.24	
19	0.55	7.6							
20	0.55	9.1	16.7		134.3183	40.70	69093.77	6.91	
21	0.55	8.4							
22	0.55	8	16.4		131.9054	39.97	67852.56	6.79	
23	0.55	8.2							
24	0.55	9.5	17.9		143.9699	43.63	74058.59	7.41	
25	0.55	7.8							
26	0.55	8.1	15.9		127.8839	38.75	65783.88	6.58	
27	0.55	5.7		4.8					
28	0.55	5.5	11.2	23.6	0	0.00	0.00	0.00	11.2
29	0.55	5.2							
30	0.55	4.4	9.6	1.2	0	0.00	0.00	0.00	
31	0.85	2.1		25					11.7
June									
1	0.85	4.4	6.5	1.2	0	0.00	0.00	0	6.5
2	0.85	3							
3	0.85	1.8	4.8		0	0.00	0.00	0.00	
4	0.85	2.1							
5	0.85	2	4.1		51.00753	15.46	26238.44	2.62	
6	0.85	4.2							
7	0.85	6.2	10.4		129.3849	39.21	66556.04	6.66	
8	0.85	7.7							

9	0.85	7.1	14.8		184.1247	55.80	94714.37	9.47	
10	0.85	7.5							
11	0.85	5.4	12.9	1.4	160.4871	48.63	82555.09	8.26	
12	0.85	5.2							
13	0.85	5.6	10.8		134.3613	40.72	69115.89	6.91	
14	0.85	6.5							
15	0.85	6.4	12.9		160.4871	48.63	82555.09	8.26	
16	0.85	6.7							
17	0.85	5.7	12.4		154.2667	46.75	79355.28	7.94	
18	0.85	5							
19	0.85	4	9		111.9677	33.93	57596.58	5.76	
20	0.85	2.6							
21	0.85	1.5	0.1	4.2	1.244086	0.38	639.96	0.06	4.1
22	0.85	7.5		0.6					
23	0.85	5.2	0	24.4	0	0.00	0.00	0.00	12.7
24	0.85	2		28.2					
25	0.85	2	0	2.2	0	0.00	0.00	0.00	
26	0.85	1.6		0.6					
27	0.85	2.6	4.2	0.8	0	0.00	0.00	0.00	
28	0.85	2.8							
29	0.85	3.5	6.3		78.37742	23.75	40317.60	4.03	
30	0.85	5.5							
July									
1	0.85	2.8	8.3	0.8	103.2591	31.29	53116.84	5.31	
2	0.85	2.2		0.2					
3	0.85	4.3	1.9	4.6	23.63763	7.16	12159.28	1.22	4.6
4	0.85	1.5		13.6					
5	0.85	1.2	0	72	0	0.00	0.00	0.00	2.7
6	0.85	4.6		1					
7	0.85	2.4	7		0	0.00	0.00	0.00	
8	0.85	4.8							
9	0.85	6	10.8		134.3613	40.72	69115.89	6.91	
10	1	4.6							
11	1	3	7.6		111.1398	33.68	57170.67	5.72	
12	1	4.8		0.4					
13	1	2.4	7.2		105.2903	31.91	54161.69	5.42	
14	1	3.2							
15	1	3.4	6.6		96.51613	29.25	49648.21	4.96	
16	1	3.4							
17	1	5.5	8.9		130.1505	39.44	66949.87	6.69	
18	1	5.5							
19	1	2	7.5		109.6774	33.24	56418.43	5.64	
20	1	2.8		0.9					
21	1	4.3	7.1	0.4	103.828	31.46	53409.44	5.34	
22	1	3.9		1.8					
23	1	3.2	7.1	1.6	103.828	31.46	53409.44	5.34	
24	1	4							
25	1	4.1	8.1		118.4516	35.89	60931.90	6.09	

26	1	4							
27	1	3.6	2.8	4.8	40.94624	12.41	21062.88	2.11	4.8
28	1	2.4							
29	1	1.2	3.6	1.8	52.64516	15.95	27080.84	2.71	
30	1	3.4							
31	1	4.9	8.3		121.3763	36.78	62436.39	6.24	
Aug.									
1	1	3.6							
2	1	3.6	7.2		105.2903	31.91	54161.69	5.42	
3	1	4							
4	1	2.9	6.9		100.9032	30.58	51904.95	5.19	
5	1	3		2.4					
6	1	1.9	0	22.6	0	0.00	0.00	0.00	4.9
7	1	3		35.4					
8	1	2	0	26	0	0.00	0.00	0.00	5
9	1	1.5		10.8					
10	1	1.9	0	1	0	0.00	0.00	0.00	3.4
11	1	2.4		1.8					
12	1	4.2	6.6		0	0.00	0.00	0.00	
13	1	4.4							
14	1	5.1	9.5		138.9247	42.10	71463.34	7.15	
15	1	3.4							
16	1	5	8.4		122.8387	37.22	63188.64	6.32	
17	1	1.4		2.2					
18	1	2.1	3.5		51.1828	15.51	26328.60	2.63	
19	1	4.8							
20	1	2.9	7.7		112.6022	34.12	57922.92	5.79	
21	1	4.5							
22	1	3.8	8.3	0.4	121.3763	36.78	62436.39	6.24	
23	1	1.9							
24	1	2.8	4.7	1.2	68.73118	20.83	35355.55	3.54	
25	1	2.4							
26	1	3	5.4		78.96774	23.93	40621.27	4.06	
27	1	3.3							
28	1	3.6	6.9	1.4	100.9032	30.58	51904.95	5.19	
29	1	2							
30	1	2.5	4.5		65.80645	19.94	33851.06	3.39	
31	1	3.8							
Sept.									
1	1	3.3	7.1		103.828	31.46	53409.44	5.34	
2	1	3							
3	1	3.4	6.4		93.5914	28.36	48143.72	4.81	
4	1	4.7							
5	1	4.1	8.5		124.3011	37.67	63940.88	6.39	
6	1	1.8		0.4					
7	1	1.2	0	9	0	0.00	0.00	0.00	3
8	1	3							
9	1	2.7	0	27	0	0.00	0.00	0.00	5.7

10	1	3.5							
11	1	3.3	6.8		0	0.00	0.00	0.00	
12	1	2.3		56.8					
13	1	1.9	0	7.8	0	0.00	0.00	0.00	4.2
14	1	2							
15	1	1.4	0	32.8	0	0.00	0.00	0.00	3.4
16	1	1		6.2					
17	1	1.1	0	13.2	0	0.00	0.00	0.00	2.1
18	1	2.7		12.2					
19	1	2.1	0	2.4	0	0.00	0.00	0.00	4.8
20	1	2.7		26.4					
21	1	3.6	0	21	0	0.00	0.00	0.00	6.3
22	1	3		0.4					
23	1	2.2	5.2		0	0.00	0.00	0.00	
24	1	3.4		5					
25	1	2.8	0	6.6	0	0.00	0.00	0.00	6.2
26	1	4							
27	1	4.2	8.2	6.6	0	0.00	0.00	0.00	6.6
28	1	3.1							
29	1	3.2	6.3		0	0.00	0.00	0.00	
30	1	2.8							
Oct.									
1	1	2.9	0	14.6	0	0.00	0.00	0.00	5.7
2	1	1.6		8.6					
3	1	2	3.6		0	0.00	0.00	0.00	3.6
4	1	2.4							
5	1	2.6	5		0	0.00	0.00	0.00	
6	1	3.4		8					
7	1	1.9	0	14	0	0.00	0.00	0.00	5.3
8	1	2.4							
9	1	3	5.4		0	0.00	0.00	0.00	
10	1	3.4							
11	1	3.1	6.5		95.05376	28.80	48895.97	4.89	
12	1	4.2							
13	1	4	8.2		119.914	36.34	61684.15	6.17	
14	1	4.2							
15	1	3.8	8		116.9892	35.45	60179.65	6.02	
16	1	3.7							
17	1	3.8	7.5		109.6774	33.24	56418.43	5.64	
18	1	4							
19	1	4.5	8.5		124.3011	37.67	63940.88	6.39	
20	1	3.8							
21	1	3.8	7.6		111.1398	33.68	57170.67	5.72	
22	1	2.5							
23	1	3	0	7.2	0	0.00	0.00	0.00	5.5
24	1	2.7							
25	1	3	5.7		0	0.00	0.00	0.00	
26	1	4							

27	1	4	8		116.9892	35.45	60179.65	6.02	
28	1	3.4							
29	1	3.8	7.2		105.2903	31.91	54161.69	5.42	
30	1	2.1							
31	1	3.1	5.2		76.04301	23.04	39116.78	3.91	
Nov.									
1	1	3.4							
2	0.6	3.5	6.9		60.54194	18.35	31142.97	3.11	
3	0.6	2.6							
4	0.6	3.2	5.8		50.89032	15.42	26178.15	2.62	
5	0.6	2.8							
6	0.6	1.7	4.5		39.48387	11.96	20310.63	2.03	
7	0.6	1.4		33.3					
8	0.6	2.4	0	0.4	0	0.00	0.00	0.00	3.8
9	0.6	2.8							
10	0.6	2.2	5		0	0.00	0.00	0.00	
11	0.6	2.6							
12	0.6	2.4	5		43.87097	13.29	22567.37	2.26	
13	0.6	2.4							
14	0.6	2.6	5		43.87097	13.29	22567.37	2.26	
15	0.6	2.5							
16	0.6	2.9	5.4		47.38065	14.36	24372.76	2.44	
17	0.6	2.5							
18	0.6	2.6	5.1		44.74839	13.56	23018.72	2.30	
19	0.6	2.4							
20	0.6	2.1	4.5		39.48387	11.96	20310.63	2.03	
21	0.6	2.4							
22	0.6	2.2	4.6		40.36129	12.23	20761.98	2.08	
23	0.6	1.5		14.6					
24	0.6	2	0	0.4	0	0.00	0.00	0.00	3.5
25	0.6	1.6		8.8					
26	0.6	1.5	0		0	0.00	0.00	0.00	3.1
27	0.6	1.8							
28	0.6	2.2	4		0	0.00	0.00	0.00	
29	0.6	2.1							
30	0.6	2	4.1		35.97419	10.90	18505.24	1.85	
Dec.									
1	0.6	2.5							
2	0.6	2.2	4.7		41.23871	12.50	21213.33	2.12	
3	0.6	2							
4	0.6	2	4		35.09677	10.64	18053.90	1.81	
5	0.6	2.4							
6	0.6	2.1	4.5		39.48387	11.96	20310.63	2.03	
7	0.6	2							
8	0.6	2.5	4.5		39.48387	11.96	20310.63	2.03	
9	0.6	2.3							
10	0.6	2.4	4.7		41.23871	12.50	21213.33	2.12	
11	0.6	2.5							

12	0.6	2.6	5.1		44.74839	13.56	23018.72	2.30	
13	0.6	2.2							
14	0.6	2	4.2		36.85161	11.17	18956.59	1.90	
15	0.6	2							
16	0.6	1.8	3.8		33.34194	10.10	17151.20	1.72	
17	0.6	2.2							
18	0.6	2.5	4.7		41.23871	12.50	21213.33	2.12	
19	0.6	2.6							
20	0.6	2.2	4.8		42.11613	12.76	21664.68	2.17	
21	0.6	2							
22	0.6	2.5	4.5		39.48387	11.96	20310.63	2.03	
23	0.6	2							
24	0.6	1.8	3.8		33.34194	10.10	17151.20	1.72	
25	0.6	1.8							
26	0.6	2	3.8		33.34194	10.10	17151.20	1.72	
27	0.6	2.4							
28	0.6	2.8	5.2		45.62581	13.83	23470.07	2.35	
		910.4	**793.2**	**671**	**8844.322**	**2326.643**	**4549548**	**454.9548**	**144.4**

APPENDIX-II (A)									
Detail of irrigation schedule for ginger									
Quantity of water applied in Floppy Sprinkler irrigation plots (2006-2007)									
Date	**Kc**	**PE**	**CPE**	**Raifall**	**Water Applied**				**ER**
		mm	**mm**	**mm**	**lit/plot**	**Time/ha**	**lit/ha**	**mm/ha**	**mm**
Apr-06						**minutes**			
30	0.55	8.4			1166.4	0	600000	60	
2006-May									
1	0.55	8.1	8.1						
2	0.55	8.2	16.3						
3	0.55	7	23.3						
4	0.55	7.7	31						
5	0.55	6.9	37.9		308	126.18	158436.21	15.84	
6	0.55	8	10.9						
7	0.55	7	17.9						
8	0.55	8	25.9						
9	0.55	8.7	34.6						
10	0.55	8.2	42.8		308	126.18	158436.21	15.84	
11	0.55	9.8	17.6						
12	0.55	9.4	27						
13	0.55	10.2	37.2		308	126.18	158436.21	15.84	
14	0.55	10.8	13						
15	0.55	10.9	23.9						
16	0.55	10.4	34.3						
17	0.55	8.6	42.9		308	126.18	158436.21	15.84	
18	0.55	8.9	16.8						
19	0.55	7.6	24.4						
20	0.55	9.1	33.5						
21	0.55	8.4	41.9		308	126.18	158436.21	15.84	
22	0.55	8	14.9						
23	0.55	8.2	23.1						
24	0.55	9.5	32.6						
25	0.55	7.8	40.4		308	126.18	158436.21	15.84	
26	0.55	8.1	13.5						
27	0.55	5.7	14.4	4.8					4.8
28	0.55	5.5	19.9	23.6					19.9
29	0.55	5.2	5.2						
30	0.55	4.4	9.6	1.2					
31	0.85	2.1	11.7	25					11.7
June									
1	0.85	4.4	4.4	1.2					
2	0.85	3	7.4						
3	0.85	1.8	9.2						
4	0.85	2.1	11.3						
5	0.85	2	13.3						
6	0.85	4.2	17.5						
7	0.85	6.2	23.7						

8	0.85	7.7	31.4						
9	0.85	7.1	38.5		476	195.01	244855.97	24.49	
10	0.85	7.5	11						
11	0.85	5.4	16.4	1.4					
12	0.85	5.2	21.6						
13	0.85	5.6	27.2						
14	0.85	6.5	33.7						
15	0.85	6.4	40.1		476	195.01	244855.97	24.49	
16	0.85	6.7	11.8						
17	0.85	5.7	17.5						
18	0.85	5	22.5						
19	0.85	4	26.5						
20	0.85	2.6	29.1						
21	0.85	2.6	27.5	4.2					4.2
22	0.85	7.5	35	0.6	476	195.01	244855.97	24.49	
23	0.85	5.2	5.2	24.4					5.2
24	0.85	2	2	28.2					2
25	0.85	2	2	2.2					
26	0.85	1.6	3.6	0.6					
27	0.85	2.6	6.2	0.8					
28	0.85	2.8	9						
29	0.85	3.5	12.5						
30	0.85	5.5	18						
July									
1	0.85	2.8	20.8	0.8					
2	0.85	2.2	23	0.2					
3	0.85	4.3	22.7	4.6					4.6
4	0.85	1.5	10.6	13.6					13.6
5	0.85	1.2	11.8	72					11.8
6	0.85	4.6	4.6	1					
7	0.85	2.4	7						
8	0.85	4.8	11.8						
9	0.85	6	17.8						
10	1	4.6	22.4						
11	1	3	25.4						
12	1	4.8	30.2	0.4					
13	1	2.4	32.6						
14	1	3.2	35.8		560.4118	229.42	288065.84	28.81	
15	1	3.4	4.2						
16	1	3.4	7.6						
17	1	5.5	13.1						
18	1	5.5	18.6						
19	1	2	20.6						
20	1	2.8	23.4	0.9					
21	1	4.3	27.7	0.4					
22	1	3.9	31.6	1.8					
23	1	3.2	34.8	1.6					
24	1	4	38.8		560.4118	229.42	288065.84	28.81	

25	1	4.1	7.9						
26	1	4	11.9						
27	1	3.6	10.7	4.8					4.8
28	1	2.4	13.1						
29	1	1.2	14.3	1.8					
30	1	3.4	17.7						
31	1	4.9	22.6						
Aug.									
1	1	3.6	26.2						
2	1	3.6	29.8						
3	1	4	33.8						
4	1	2.9	36.7		560.4118	229.42	288065.84	28.81	
5	1	3	4.7	2.4					
6	1	1.9	6.6	22.6					6.6
7	1	3	3	35.4					3
8	1	2	2	26					2
9	1	1.5	1.5	10.8					1.5
10	1	1.9	1.9	1					
11	1	2.4	4.3	1.8					
12	1	4.2	8.5						
13	1	4.4	12.9						
14	1	5.1	18						
15	1	3.4	21.4						
16	1	5	26.4						
17	1	1.4	27.8	2.2					
18	1	2.1	29.9						
19	1	4.8	34.7						
20	1	2.9	37.6		560.4118	229.42	288065.84	28.81	
21	1	4.5	7.1						
22	1	3.8	10.9	0.4					
23	1	1.9	12.8						
24	1	2.8	15.6	1.2					
25	1	2.4	18						
26	1	3	21						
27	1	3.3	24.3						
28	1	3.6	27.9	1.4					
29	1	2	29.9						
30	1	2.5	32.4						
31	1	3.8	36.2		560.4118	229.42	288065.84	28.81	
Sept.									
1	1	3.3	4.5						
2	1	3	7.5						
3	1	3.4	10.9						
4	1	4.7	15.3						
5	1	4.1	19.4						
6	1	1.8	21.2	0.4					
7	1	1.2	13.4	9					9
8	1	3	16.4						

9	1	2.7	19.1	27					19.1
10	1	3.5	3.5						
11	1	3.3	6.8						
12	1	2.3	9.1	56.8					9.1
13	1	1.9	1.9	7.8					1.9
14	1	2	2						
15	1	1.4	3.4	32.8					3.4
16	1	1	1	6.2					1
17	1	1.1	1.1	13.2					1.1
18	1	2.7	2.7	12.2					2.7
19	1	2.1	2.1	2.4					
20	1	2.7	4.8	26.4					4.8
21	1	3.6	3.6	21					3.6
22	1	3	3	0.4					
23	1	2.2	5.2						
24	1	3.4	3.6	5					5
25	1	2.8	6.4	6.6					6.4
26	1	4	4						
27	1	4.2	1.6	6.6					6.6
28	1	3.1	4.7						
29	1	3.2	7.9						
30	1	2.8	10.7						
Oct.									
1	1	2.9	13.6	14.6					13.6
2	1	1.6	1.6	8.6					1.6
3	1	2	2						
4	1	2.4	4.4						
5	1	2.6	7						
6	1	3.4	2.4	8					8
7	1	1.9	4.3	14					4.3
8	1	2.4	2.4						
9	1	3	5.4						
10	1	3.4	8.8						
11	1	3.1	11.9						
12	1	4.2	16.1						
13	1	4	20.1						
14	1	4.2	24.3						
15	1	3.8	28.1						
16	1	3.7	31.8						
17	1	3.8	35.6		560.4118	229.42	288065.84	28.81	
18	1	4	4.6						
19	1	4.5	9.1						
20	1	3.8	12.9						
21	1	3.8	16.7						
22	1	2.5	19.2						
23	1	3	15	7.2					7.2
24	1	2.7	17.7						
25	1	3	20.7						

26	1	4	24.7						
27	1	4	28.7						
28	1	3.4	32.1						
29	1	3.8	35.9		560.4118	229.42	288065.84	28.81	
30	1	2.1	3						
31	1	3.1	6.1						
Nov.									
1	1	3.4	9.5						
2	0.6	3.5	13						
3	0.6	2.6	15.6						
4	0.6	3.2	18.8						
5	0.6	2.8	21.6						
6	0.6	1.7	23.3						
7	0.6	1.4	24.7	33.3					24.7
8	0.6	2.4	2.4						
9	0.6	2.8	5.2	0.4					
10	0.6	2.2	7.4						
11	0.6	2.6	10						
12	0.6	2.4	12.4						
13	0.6	2.4	14.8						
14	0.6	2.6	17.4						
15	0.6	2.5	19.9						
16	0.6	2.9	22.8						
17	0.6	2.5	25.3						
18	0.6	2.6	27.9						
19	0.6	2.4	30.36						
20	0.6	2.1	32.4						
21	0.6	2.4	34.8						
22	0.6	2.2	37		336	137.65	172839.51	17.28	
23	0.6	1.5	3.5	14.6					3.5
24	0.6	2	2						
25	0.6	1.6	3.6	0.4					
26	0.6	1.5	5.1	8.8					5.1
27	0.6	1.8	1.8						
28	0.6	2.2	4						
29	0.6	2.1	6.1						
30	0.6	2	8.1						
Dec.									
1	0.6	2.5	10.6						
2	0.6	2.2	12.8						
3	0.6	2	14.8						
4	0.6	2	16.8						
5	0.6	2.4	19.2						
6	0.6	2.1	21.3						
7	0.6	2	23.3						
8	0.6	2.5	25.8						
9	0.6	2.3	28.1						
10	0.6	2.4	30.5						

11	0.6	2.5	33						
12	0.6	2.6	35.6		336	137.65	172839.51	17.28	
13	0.6	2.2	2.8						
14	0.6	2	4.8						
15	0.6	2	6.8						
16	0.6	1.8	8.6						
17	0.6	2.2	10.6						
18	0.6	2.5	13.3						
19	0.6	2.6	15.9						
20	0.6	2.2	18.1						
21	0.6	2	20.1						
22	0.6	2.5	22.6						
23	0.6	2	24.6						
24	0.6	1.8	26.4						
25	0.6	1.8	28.2						
26	0.6	2	30.2						
27	0.6	2.4	32.6						
28	0.6	2.8	35.6		336	137.65	172839.51	17.28	
		911.5	**4197.26**	**671**	**9373.282**	**3360.988**	**4820165**	**482.0169**	**237.4**

APPENDIX-II (A)

Detail of irrigation schedule for ginger

Quantity of water applied in Over head Sprinkler irrigation plots (2006-2007)

Date	Kc	PE	CPE	Raifall	Water Applied				ER
		mm	mm	mm	lit/plot	Time/ha	lit/ha	mm/ha	mm
Apr-06						minutes			
30	0.55	8.4			1166.4	0	600000	60	
2006-May									
1	0.55	8.1	8.1						
2	0.55	8.2	16.3						
3	0.55	7	23.3						
4	0.55	7.7	31						
5	0.55	6.9	37.9		308	126.18	158436.21	15.84	
6	0.55	8	10.9						
7	0.55	7	17.9						
8	0.55	8	25.9						
9	0.55	8.7	34.6						
10	0.55	8.2	42.8		308	126.18	158436.21	15.84	
11	0.55	9.8	17.6						
12	0.55	9.4	27						
13	0.55	10.2	37.2		308	126.18	158436.21	15.84	
14	0.55	10.8	13						
15	0.55	10.9	23.9						
16	0.55	10.4	34.3						
17	0.55	8.6	42.9		308	126.18	158436.21	15.84	
18	0.55	8.9	16.8						
19	0.55	7.6	24.4						
20	0.55	9.1	33.5						
21	0.55	8.4	41.9		308	126.18	158436.21	15.84	
22	0.55	8	14.9						
23	0.55	8.2	23.1						
24	0.55	9.5	32.6						
25	0.55	7.8	40.4		308	126.18	158436.21	15.84	
26	0.55	8.1	13.5						
27	0.55	5.7	14.4	4.8					4.8
28	0.55	5.5	19.9	23.6					19.9
29	0.55	5.2	5.2						
30	0.55	4.4	9.6	1.2					
31	0.85	2.1	11.7	25					11.7
June									
1	0.85	4.4	4.4	1.2					
2	0.85	3	7.4						
3	0.85	1.8	9.2						
4	0.85	2.1	11.3						
5	0.85	2	13.3						
6	0.85	4.2	17.5						
7	0.85	6.2	23.7						

8	0.85	7.7	31.4						
9	0.85	7.1	38.5		476	195.01	244855.97	24.49	
10	0.85	7.5	11						
11	0.85	5.4	16.4	1.4					
12	0.85	5.2	21.6						
13	0.85	5.6	27.2						
14	0.85	6.5	33.7						
15	0.85	6.4	40.1		476	195.01	244855.97	24.49	
16	0.85	6.7	11.8						
17	0.85	5.7	17.5						
18	0.85	5	22.5						
19	0.85	4	26.5						
20	0.85	2.6	29.1						
21	0.85	2.6	27.5	4.2					4.2
22	0.85	7.5	35	0.6	476	195.01	244855.97	24.49	
23	0.85	5.2	5.2	24.4					5.2
24	0.85	2	2	28.2					2
25	0.85	2	2	2.2					
26	0.85	1.6	3.6	0.6					
27	0.85	2.6	6.2	0.8					
28	0.85	2.8	9						
29	0.85	3.5	12.5						
30	0.85	5.5	18						
July									
1	0.85	2.8	20.8	0.8					
2	0.85	2.2	23	0.2					
3	0.85	4.3	22.7	4.6					4.6
4	0.85	1.5	10.6	13.6					13.6
5	0.85	1.2	11.8	72					11.8
6	0.85	4.6	4.6	1					
7	0.85	2.4	7						
8	0.85	4.8	11.8						
9	0.85	6	17.8						
10	1	4.6	22.4						
11	1	3	25.4						
12	1	4.8	30.2	0.4					
13	1	2.4	32.6						
14	1	3.2	35.8		560.4118	229.42	288065.84	28.81	
15	1	3.4	4.2						
16	1	3.4	7.6						
17	1	5.5	13.1						
18	1	5.5	18.6						
19	1	2	20.6						
20	1	2.8	23.4	0.9					
21	1	4.3	27.7	0.4					
22	1	3.9	31.6	1.8					
23	1	3.2	34.8	1.6					
24	1	4	38.8		560.4118	229.42	288065.84	28.81	

25	1	4.1	7.9						
26	1	4	11.9						
27	1	3.6	10.7	4.8					4.8
28	1	2.4	13.1						
29	1	1.2	14.3	1.8					
30	1	3.4	17.7						
31	1	4.9	22.6						
Aug.									
1	1	3.6	26.2						
2	1	3.6	29.8						
3	1	4	33.8						
4	1	2.9	36.7		560.4118	229.42	288065.84	28.81	
5	1	3	4.7	2.4					
6	1	1.9	6.6	22.6					6.6
7	1	3	3	35.4					3
8	1	2	2	26					2
9	1	1.5	1.5	10.8					1.5
10	1	1.9	1.9	1					
11	1	2.4	4.3	1.8					
12	1	4.2	8.5						
13	1	4.4	12.9						
14	1	5.1	18						
15	1	3.4	21.4						
16	1	5	26.4						
17	1	1.4	27.8	2.2					
18	1	2.1	29.9						
19	1	4.8	34.7						
20	1	2.9	37.6		560.4118	229.42	288065.84	28.81	
21	1	4.5	7.1						
22	1	3.8	10.9	0.4					
23	1	1.9	12.8						
24	1	2.8	15.6	1.2					
25	1	2.4	18						
26	1	3	21						
27	1	3.3	24.3						
28	1	3.6	27.9	1.4					
29	1	2	29.9						
30	1	2.5	32.4						
31	1	3.8	36.2		560.4118	229.42	288065.84	28.81	
Sept.									
1	1	3.3	4.5						
2	1	3	7.5						
3	1	3.4	10.9						
4	1	4.7	15.3						
5	1	4.1	19.4						
6	1	1.8	21.2	0.4					
7	1	1.2	13.4	9					9
8	1	3	16.4						

9	1	2.7	19.1	27					19.1
10	1	3.5	3.5						
11	1	3.3	6.8						
12	1	2.3	9.1	56.8					9.1
13	1	1.9	1.9	7.8					1.9
14	1	2	2						
15	1	1.4	3.4	32.8					3.4
16	1	1	1	6.2					1
17	1	1.1	1.1	13.2					1.1
18	1	2.7	2.7	12.2					2.7
19	1	2.1	2.1	2.4					
20	1	2.7	4.8	26.4					4.8
21	1	3.6	3.6	21					3.6
22	1	3	3	0.4					
23	1	2.2	5.2						
24	1	3.4	3.6	5					5
25	1	2.8	6.4	6.6					6.4
26	1	4	4						
27	1	4.2	1.6	6.6					6.6
28	1	3.1	4.7						
29	1	3.2	7.9						
30	1	2.8	10.7						
Oct.									
1	1	2.9	13.6	14.6					13.6
2	1	1.6	1.6	8.6					1.6
3	1	2	2						
4	1	2.4	4.4						
5	1	2.6	7						
6	1	3.4	2.4	8					8
7	1	1.9	4.3	14					4.3
8	1	2.4	2.4						
9	1	3	5.4						
10	1	3.4	8.8						
11	1	3.1	11.9						
12	1	4.2	16.1						
13	1	4	20.1						
14	1	4.2	24.3						
15	1	3.8	28.1						
16	1	3.7	31.8						
17	1	3.8	35.6		560.4118	229.42	288065.84	28.81	
18	1	4	4.6						
19	1	4.5	9.1						
20	1	3.8	12.9						
21	1	3.8	16.7						
22	1	2.5	19.2						
23	1	3	15	7.2					7.2
24	1	2.7	17.7						
25	1	3	20.7						

26	1	4	24.7						
27	1	4	28.7						
28	1	3.4	32.1						
29	1	3.8	35.9		560.4118	229.42	288065.84	28.81	
30	1	2.1	3						
31	1	3.1	6.1						
Nov.									
1	1	3.4	9.5						
2	0.6	3.5	13						
3	0.6	2.6	15.6						
4	0.6	3.2	18.8						
5	0.6	2.8	21.6						
6	0.6	1.7	23.3						
7	0.6	1.4	24.7	33.3					24.7
8	0.6	2.4	2.4						
9	0.6	2.8	5.2	0.4					
10	0.6	2.2	7.4						
11	0.6	2.6	10						
12	0.6	2.4	12.4						
13	0.6	2.4	14.8						
14	0.6	2.6	17.4						
15	0.6	2.5	19.9						
16	0.6	2.9	22.8						
17	0.6	2.5	25.3						
18	0.6	2.6	27.9						
19	0.6	2.4	30.36						
20	0.6	2.1	32.4						
21	0.6	2.4	34.8						
22	0.6	2.2	37		336	137.65	172839.51	17.28	
23	0.6	1.5	3.5	14.6					3.5
24	0.6	2	2						
25	0.6	1.6	3.6	0.4					
26	0.6	1.5	5.1	8.8					5.1
27	0.6	1.8	1.8						
28	0.6	2.2	4						
29	0.6	2.1	6.1						
30	0.6	2	8.1						
Dec.									
1	0.6	2.5	10.6						
2	0.6	2.2	12.8						
3	0.6	2	14.8						
4	0.6	2	16.8						
5	0.6	2.4	19.2						
6	0.6	2.1	21.3						
7	0.6	2	23.3						
8	0.6	2.5	25.8						
9	0.6	2.3	28.1						
10	0.6	2.4	30.5						

11	0.6	2.5	33						
12	0.6	2.6	35.6		336	137.65	172839.51	17.28	
13	0.6	2.2	2.8						
14	0.6	2	4.8						
15	0.6	2	6.8						
16	0.6	1.8	8.6						
17	0.6	2.2	10.6						
18	0.6	2.5	13.3						
19	0.6	2.6	15.9						
20	0.6	2.2	18.1						
21	0.6	2	20.1						
22	0.6	2.5	22.6						
23	0.6	2	24.6						
24	0.6	1.8	26.4						
25	0.6	1.8	28.2						
26	0.6	2	30.2						
27	0.6	2.4	32.6						
28	0.6	2.8	35.6		336	137.65	172839.51	17.28	
		911.5	**4197.26**	**671**	**9373.282**	**3360.988**	**4820165**	**482.0169**	**237.4**

APPENDIX – III (A)

Cost of component of drip irrigation system per hectare

Item	Specification	Unit price Rs.	Quantity	Amount Rs.	Life years	Depreciation per season	Interest @ 12 p.a.	Repairs and maintenan @ 2% p.a.Rs.
Centrifugal pump with accessories	3 HP	5982.20	1.00	5982.20	20	201.90	538.40	89.73
Filters Nos.								
Sand filter (63mm)	40 m^3 hr^{-1}	11946.48	1.00	11946.48	20	403.19	1075.18	179.20
Screen, Nos.	40 m^3 hr^{-1}	2546.96	1.00	2546.96	20	85.96	229.22	38.20
Ball Valve, Nos	63 mm	553.85	4.00	2215.41	20	18.69	49.85	8.31
Air release valve, Nos.	63 mm	446.16	2.00	892.32	12	25.09	40.15	6.69
Threaded flushing cap, Nos.	63 mm	66.87	4.00	267.49	12	3.76	6.02	1.00
90° PVC elbow	63 mm	32.08	2.00	64.17	12	1.80	2.89	0.48
PVC pipe, m	63 mm	31.25	365.00	11406.25	12	1.76	2.81	0.47
Sockets PVC Nos.	63 mm	45.97	61.00	2804.17	12	2.58	4.14	0.69
Tees, Nos.	63 mm	41.60	3.00	124.80	12	2.34	3.74	0.62
LDPE, m	16 mm	4.16	15359	63893.44	6	0.47	0.37	0.06
GTO, Nos	16 mm	1.46	465	678.90	6	0.16	0.13	0.02
End cap, Nos.	16 mm	1.35	465	627.75	6	0.15	0.12	0.02
Drip Emitters, Nos.	4 lph, pc	2.50	16461	41152.50	6	0.29	0.22	0.04
Pressure gauge Nos.	-	158.34	1.00	158.34	12	8.90	14.25	2.37
Solvent cement, lit	-	259.73	1.00	259.73	0	0	23.37	3.89
Total				1,39,038.71		557.03	1990.86	331.79

APPENDIX – III (B)

Cost of component of floppy sprinkler irrigation system per hectare

Item	Specifications	Unit price Rs.	Quantity	Amount Rs.	Life years	Depreciation per season	Interest @ 12 p.a.	Repairs and maintenance @ 2% p.a.Rs.
Centrifugal pump with accessories	5 HP	8452.20	1.00	8452.20	20	285.26	760.70	126.78
Filters Nos.								
Sand filter (63mm)	40 $m^3 hr^{-1}$	11946.48	1.00	11946.48	20	403.19	1075.18	179.20
Screen, Nos.	40 $m^3 hr^{-1}$	2546.96	1.00	2546.96	20	85.98	229.22	38.20
Valve, Nos	63 mm	553.85	1.00	553.85	12	31.15	49.84	8.31
90^o PVC elbow	50 mm	280.07	4.00	1120.28	12	15.75	25.20	4.20
Air release valve, Nos.	63 mm	446.16	2.00	892.32	12	25.09	40.15	6.69
Threaded flushing cap, Nos.	63 mm	66.87	1.00	66.87	12	3.76	6.02	1.00
	50 mm	57.09	4.00	228.36	12	3.21	5.14	0.85
	63 mm	32.08	3.00	96.24	12	1.80	2.89	0.48
PVC pipe, m	63 mm	31.25	528.0	16500	12	1.75	2.81	0.47
	50 mm	29.43	1298.0	38200	12	1.65	2.65	0.44
End cap PVC, Nos.	50 mm	5.50	32.00	176	12	0.30	0.49	0.08
Sockets PVC Nos.	63 mm	45.97	88.00	4045.36	12	2.58	4.14	0.68
	50 mm	23.92	216.00	5166.72	12	1.34	2.15	0.36
Tees, Nos.	63 mm	41.60	20.00	832	12	2.34	3.74	0.62
Reducers, Nos.	63-50 mm	14.06	20.00	281.20	12	0.79	1.26	0.21
LDPE, m	16 mm	6.34	195.00	1236.30	6	0.71	0.57	0.09
GTO, Nos	16 mm	1.66	278.00	461.48	6	0.19	0.15	0.02
Floppy sprinkler heads, Nos.	180 lph	102.18	278.00	28406.04	6	11.49	9.20	1.53
Stakes Nos.	Floppy	9.31	278	2588.18	6	1.05	0.84	0.14
Adapter, Nos.	-	4.73	278	158.34	6	0.53	0.42	0.07
Pressure gaugeNos.	-	158.34	1.00	519.46	12	8.90	14.25	2.37
Solvent cement, lit	-	259.73	2.00		-	-	23.37	3.89
Total	-			124475		888.81	2260.38	376.68

APPENDIX – III (C)
Cost of component of Overhead sprinkler irrigation system per hectare

Item	Specifications	Unit price Rs.	Quantity	Amount Rs.	Life years	Depreciation per season	Interest @ 12 p.a.	Repairs and maintenan@ 2% p.a.Rs.
Centrifugal pump with accessories	5 HP	8452.20	1.00	8452.20	20	285.26	760.70	126.78
Screen filter, Nos.	40 m^3 hr^{-1}	2854	1.00	2854	20	1302.07	346.86	57.81
Bypass assembly	-	250	1.00	250	20	8.44	22.50	3.75
HDPE 75 mm Pipes @ 120/m	-	720	19	13680	20	24.30	64.80	10.8
Sprinkler nozzle	-	360	8	2880	20	12.15	32.40	5.40
75 mm HDPE bend 1 No.	-	325	1	325	20	10.97	29.25	4.87
75 mm HDPE tee	-	465	1	465	20	15.69	41.85	6.97
Sprinkler riser pipes	-	135	8	1080	20	4.55	12.15	2.02
75 mm HDPE end cap	-	70	2	140	20	2.36	6.30	1.05
Total	-			30,126.20		493.79	1316.81	219.45

APPENDIX – IV (A)

Cost of cultivation (Rs. ha^{-1}) for different irrigation systems during 2005-06

Item	Unit Price Rs.	Surface		Drip		Floppy sprinkler		Overhead sprinkler	
		Quantity	Cost Rs.	Quantity	Cost Rs.	Quantity	Cost Rs.	Quantity	Cost Rs.
Labour charges @ Rs.51/day	51.00	90	4597	49	2499	71	3621	65	3315
Ploughing charges @ Rs. 1000/ ha	1000.00	1.00	1000	1.00	1000	1.00	1000	1.00	1000
Harrowing charges @ Rs.500/ha	500.00	1.00	500	1.00	500	1.00	500	1.00	500
Ginger seed @ Rs.60 / kg.	60.00	1500	90000	1500	90000	1500	90000	1500	90000
Pesticide and insecticide			1725		1725		1725		1725
Fertilizer			6805		6805		6805		6805
Electric charges			1092		467		874		705
Working capital			105719		102996		104525		104050
Interest on working capital @ 13 % p.a.			13743		13389		13588		13526
Rental value of land (10 % of the value of land)			5000		5000		5000		5000
Total			124462		121385		123113		122576

APPENDIX – IV (B)

Cost of cultivation (Rs. ha^{-1}) for different irrigation systems during 2006-07

Item	Unit price Rs.	Surface		Drip		Floppy sprinkler		Overhead sprinkler	
		Quantity	Cost Rs.	Quantity	Cost Rs.	Quantity	Cost Rs.	Quantity	Cost Rs.
Labour charges @ Rs.51/day	51.00	82	4182	51	2601	77	3027	71	3621
Ploughing charges @ Rs. 1000/ ha	1000.00	1.00	1000	1.00	1000	1.00	1000	1.00	1000
Harrowing charges @ Rs.500/ha	500.00	1.00	500	1.00	500	1.00	500	1.00	500
Ginger seed @ Rs.60 / kg.	40.00	1500	90000	1500	90000	1500	90000	1500	90000
Pesticide and insecticide			1850		1850		1850		1850
Fertilizer			6,805		6805		6805		6805
Electric charges			1200		510		950		810
Working capital			105537		103266		105032		104586
Interest on working capital @ 13 % p.a.			13720		13424		13654		13596
Rental value of land (10 % of the value of land)			5000		5000		5000		5000
Total			124257		121690		123686		123182

APPENDIX – V (A)

Benefit cost ratio of ginger crop production under different irrigation systems during 2005-06

Sr.No.	Item	Surface	Drip	Floppy Sprinkler	Overhead Sprinkler
1	Fixed cost, Rs.	8452.20	139038.71	124475	30126.20
a.	Depreciation cost, Rs.	285.26	557.03	888.81	493.79
b.	Interest, Rs.	760.70	1990.86	2260.38	1316.81
c.	Repair and maintenance, Rs.	126.78	331.79	376.68	219.45
d.	Total (a+ b+ c), Rs.	1172.74	2879.68	3525.87	2030.05
2	Cost of cultivation, Rs/ ha.	124462	121385	123113	122576
3	Seasonal total cost, Rs.	125634	124265	126639	124606
4	Water used, mm	1027.60	711.19	806.45	806.45
5	Yield of ginger, t/ha	13.75	12.96	15.90	14.25
6	Selling price, Rs / t.	20000	20000	20000	20000
7	Income from produce,Rs.(5 x 6)	275000	259200	318000	285000
8	Net seasonal income, Rs.(7-3)	149366	134935	191361	160394
9	Additional area cultivated due to saving of water, ha.	0.00	0.44	0.27	0.27
10	Additional expenditure due to additional area Rs.	0.00	54676	34192	33643
11	Additional income due to additional area (7 x 9)	0.00	114048	85860	76950
12	Additional net income(11-10)Rs.	0.00	59372	51668	43307
13	Total cost of production (3+10)	125634	178941	160831	158249
14	Gross income (7 + 11)	275000	373248	403860	361950
15	Net income (14 – 13)	149366	194307	243029	203701
16	Gross benefit cost ratio (14/13)	2.19	2.08	2.51	2.29
17	Gross income over surface due to pressurized system, Rs.	-	98248	128860	86950
18	Net extra income over surface due to pressurized system, %	-	30.08	63	36
19	Productivity of water, Rs. mm^{-1} (15/4)	145.35	273.21	301.35	252.59

APPENDIX – V (B)

Benefit cost ratio of ginger crop production under different irrigation systems during 2006-07

Sr.No.	Item	Surface	Drip	Floppy Sprinkler	Overhead Sprinkler
1	Fixed cost, Rs.	8452.20	139038.71	124475	30126.20
a.	Depreciation cost, Rs.	285.26	557.03	888.81	493.79
b.	Interest, Rs.	760.70	1990.86	2260.38	1316.81
c.	Repair and maintenance, Rs.	126.78	331.79	376.68	219.45
d.	Total (a+ b+ c), Rs.	1172.74	2879.68	3525.87	2030.05
2	Cost of cultivation, Rs/ ha.	124257	121690	123686	123182
3	Seasonal total cost, Rs.	125430	124570	127212	125212
4	Water used, mm	860.80	599.28	719.42	719.42
5	Yield of ginger, t/ha	14.84	15.36	17.24	16.11
6	Selling price, Rs / t.	20000	20000	20000	20000
7	Income from produce,Rs.(5 x 6)	296800	307200	344800	322200
8	Net seasonal income, Rs. (7-3)	171370	182630	207588	196988
9	Additional area cultivated due to saving of water, ha.	0.00	0.44	0.20	0.20
10	Additional expenditure due to additional area Rs.	0.00	54811	25442	25042
11	Additional income due to additional area (7 x 9)	0.00	135168	68960	64440
12	Additional net income(11-10Rs.	0.00	80357	43518	39398
13	Total cost of production (3+10)	125430	179381	152654	150254
14	Gross income (7 + 11)	296800	442368	413760	386640
15	Net income (14 – 13)	171370	262987	261106	236386
16	Gross benefit cost ratio (14/13)	2.36	2.47	2.71	2.57
17	Gross income over surface due to pressurized system, Rs.	-	145568	116960	89840
18	Net extra income over surface due to pressurized system, %	-	53.46	52.36	37.94
19	Productivity of water, Rs. mm^{-1} (15/4)	199.08	438.84	362.93	328.57

APPENDIX – V (C)

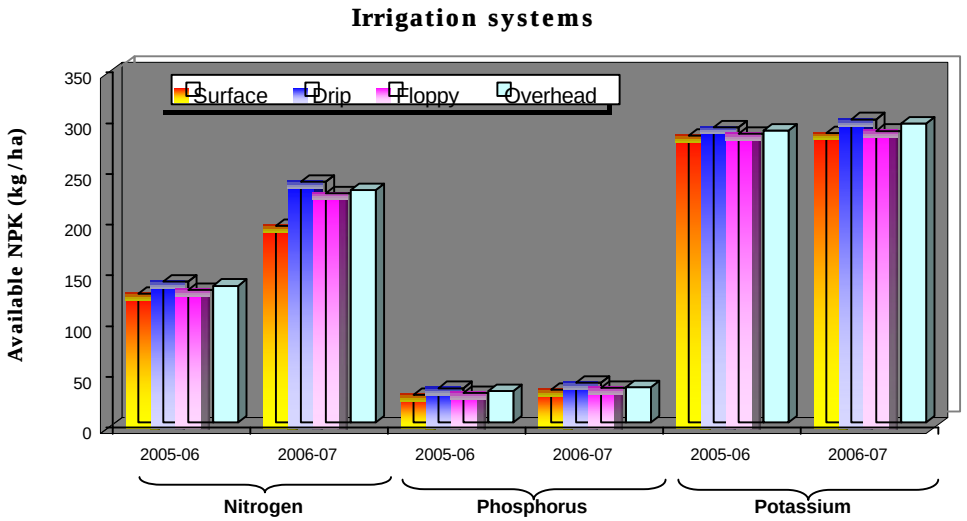
Mean benefit cost ratio of ginger crop production under different irrigation systems during 2005-06 and 2006-07

Sr.No.	Item	Surface	Drip	Floppy Sprinkler	Overhead Sprinkler
1	Fixed cost, Rs.	8452.20	139038.71	124475	30126.20
a.	Depreciation cost, Rs.	285.26	557.03	888.81	493.79
b.	Interest, Rs.	760.70	1990.86	2260.38	1316.81
c.	Repair and maintenance, Rs.	126.78	331.79	376.68	219.45
d.	Total (a+ b+ c), Rs.	1172.74	2879.68	3525.87	2030.05
2	Cost of cultivation, Rs/ ha.	124359	121537	123399	122879
3	Seasonal total cost, Rs.	125532	124417	126925	124909
4	Water used, mm	944.20	655.23	762.93	762.93
5	Yield of ginger, t/ha	14.295	14.16	16.57	15.18
6	Selling price, Rs / t.	20000	20000	20000	20000
7	Income from produce,Rs.(5 x 6)	285900	283200	331400	303600
8	Net seasonal income, Rs. (7-3)	160368	158783	199475	178691
9	Additional area cultivated due to saving of water, ha.	0.00	0.44	0.24	0.24
10	Additional expenditure due to additional area Rs.	0.00	54743	30462	30462
11	Additional income due to additional area (7 x 9)	0.00	124608	79536	77136
12	Additional net income(11-10 Rs.	0.00	69865	49074	46674
13	Total cost of production (3+10)	125532	179160	157387	155371
14	Gross income (7 + 11)	285900	407808	410936	380736
15	Net income (14 – 13)	160368	228648	253549	225365
16	Gross benefit cost ratio (14 / 13)	2.27	2.28	2.61	2.45
17	Gross income over surface due to pressurized system, Rs.	-	121908	125036	94836
18	Net extra income over surface due to pressurized system, %	-	42.57	58.10	40.52
19	Productivity of water, Rs. mm^{-1}	169.84	348.96	332.33	295.39

7. VITA

DATTATRAYA ARJUN SONAWANE
A candidate for the degree
of
DOCTOR OF PHILOSOPHY (AGRICULTURE)
in
AGRONOMY
2009

Title of Thesis	:	" Effect of irrigation systems and integrated nutrient management on growth, yield and quality of Ginger (*Zingiber officinale* Rosc.)".
Major field	:	Agronomy
Biographical Information Personal	:	Born at Mumbai, on October 29, 1969. Son of Shri. Arjun Laxman Sonawane and Sau. Sonabai Arjun Sonawane
Educational	:	Attended Secondary School in Jawaharlal Shetaki High School, Piliv. Received the Bachelor of Science (Agriculture) degree with first class in 1994 and Master of Science (Agriculture) degree in Agronomy with first class at College of Agiculture, Pune under M.P.K.V. Rahuri
Professional Experience	:	Junior Research Assistant, College of Agriculture Kolhapur ; 1996 – 1999. Assistant Professor of Agronomy, Inter Faculty Department of Irrigation Water Management, M.P.K.V., Rahuri ; 1999 – 2006. Presently working as Associate Professor of Agronomy at College of Agriculture, Dhule since 2006.
Publications	:	Research papers – 14 Technical papers – 11 Book – Janawaransathi Chara Utpadan Popular articles – 45 TV Talk – 2, Radio Talk – 5



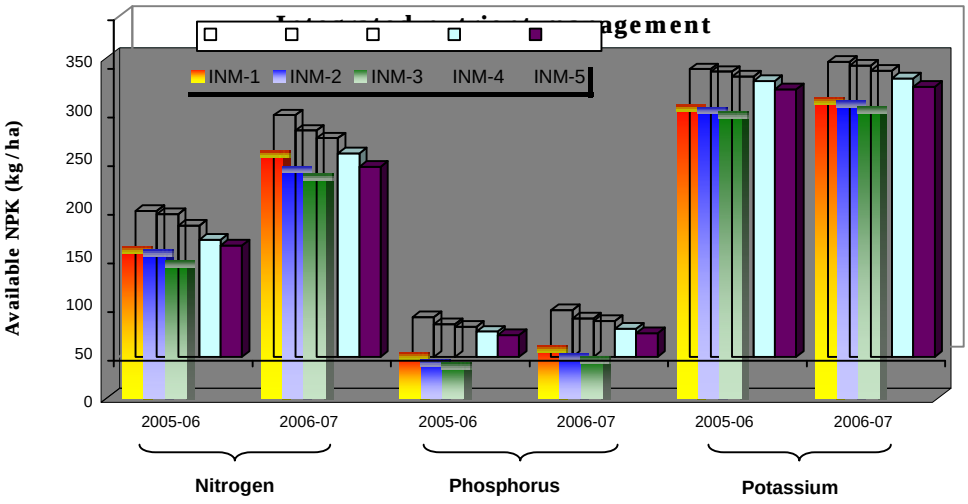


Fig 16 : Effect of irrigation systems and integrated nutrient management on available N,P and K (kg/ha) content in the soil (0-30 cm depth) at the harvest of ginger crop during 2005-06 and 2006-07

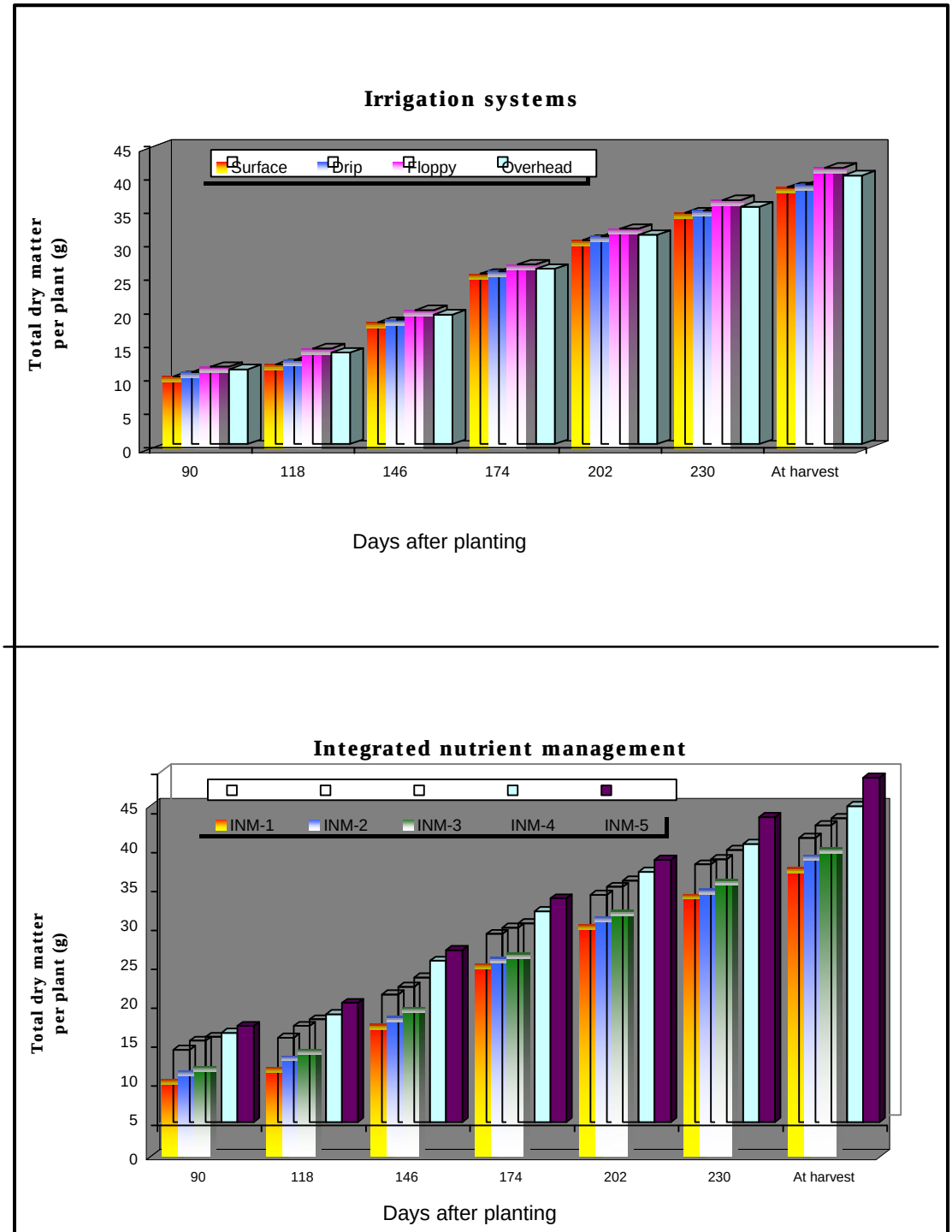


Fig. 7b). Periodical total dry matter (g) per plant as influenced by irrigation systems and integrated nutrient management during 2006-07

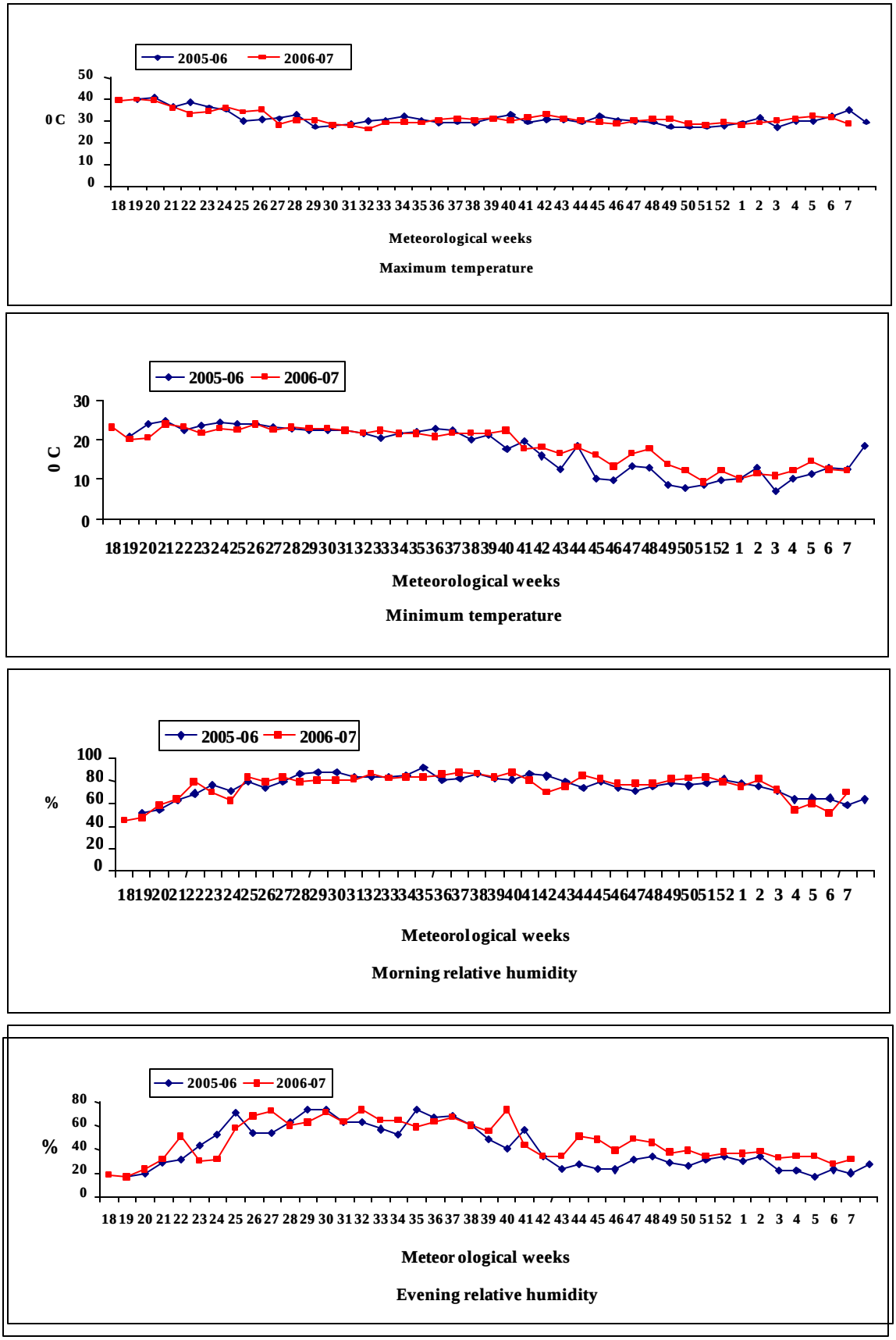
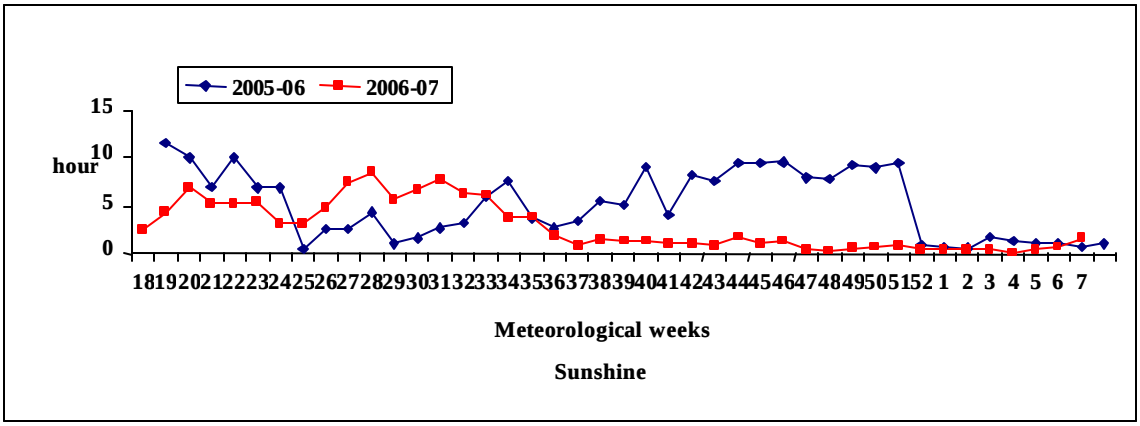
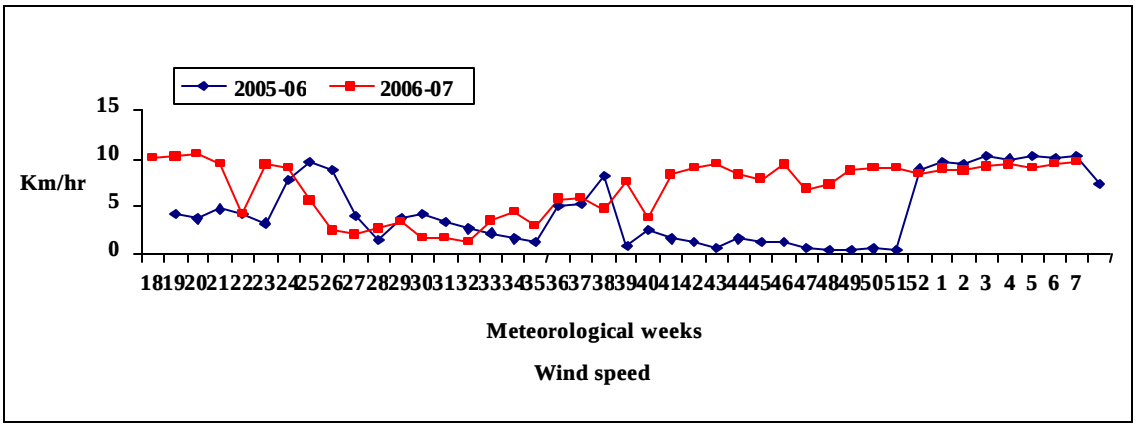
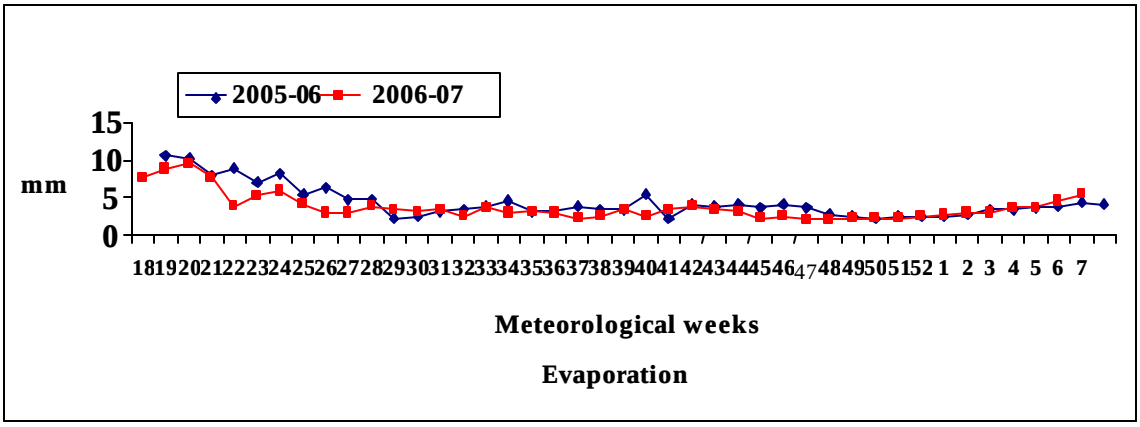


Fig 1: Meteorological observations recorded during the crop growth period (2005-06 and 2006-07)







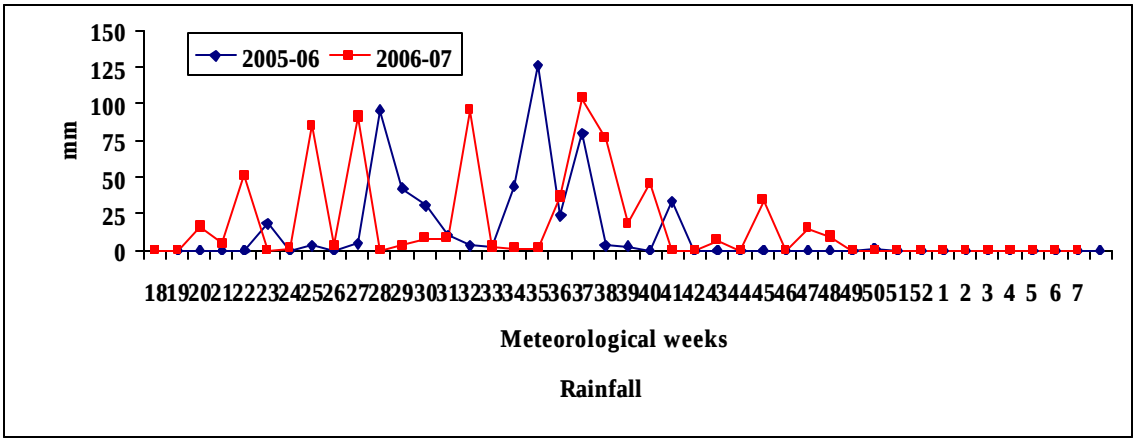
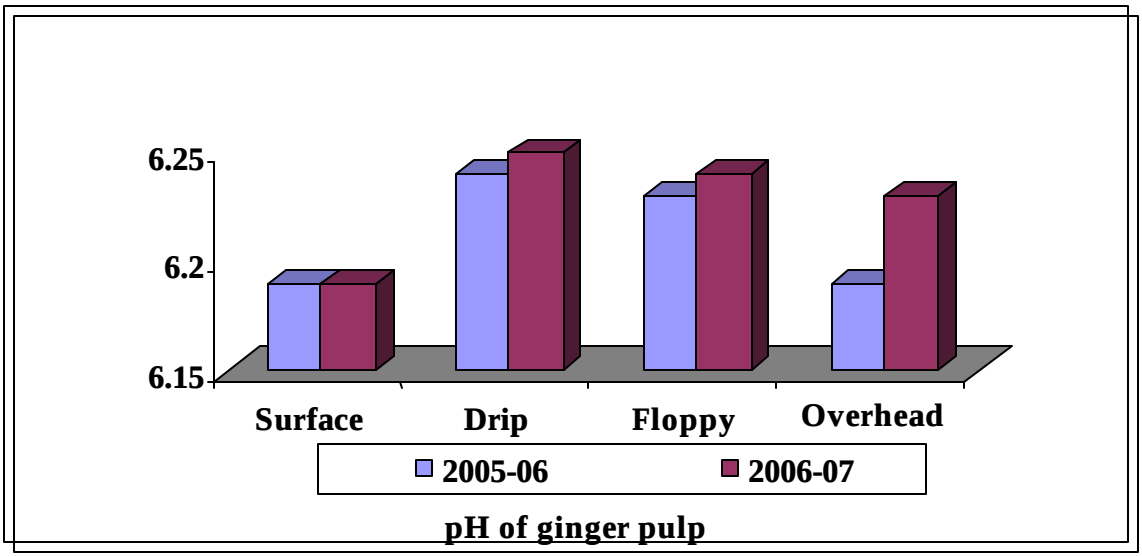
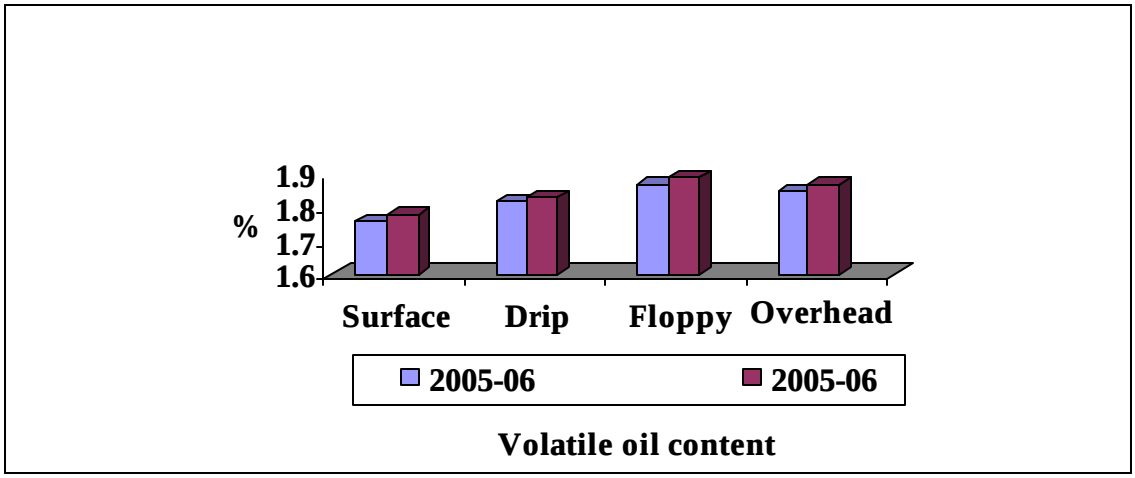


Fig 2: Meteorological observations recorded during the crop growth period (2005-06 and 2006-07)





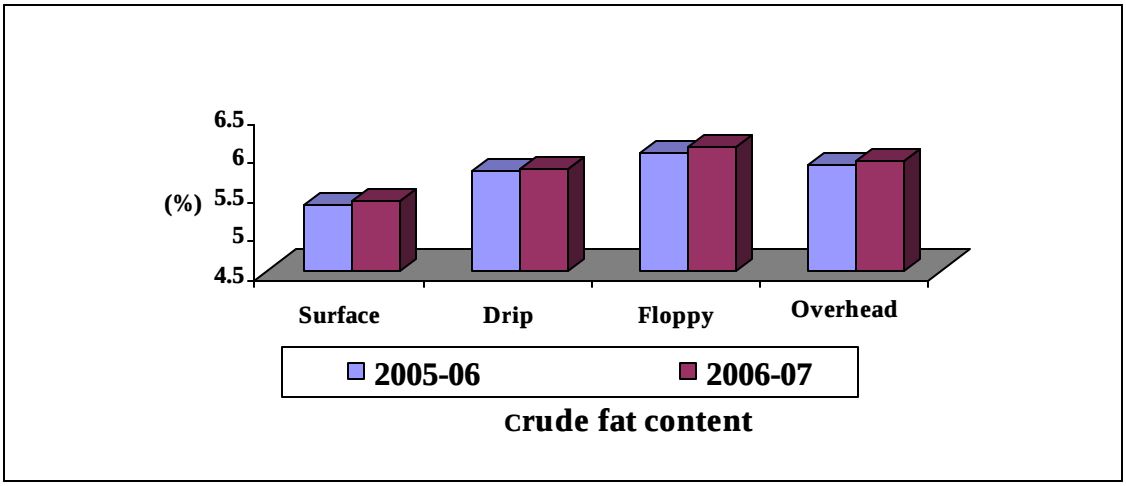
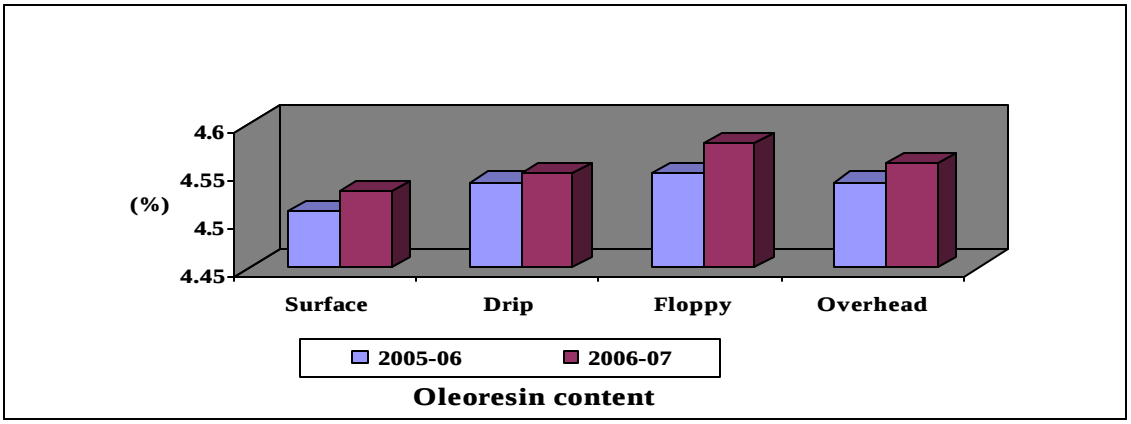
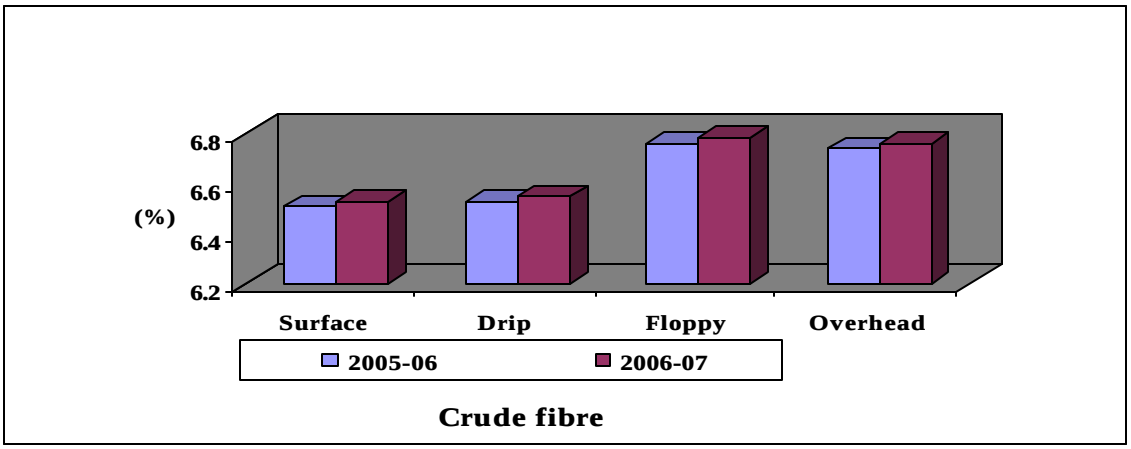
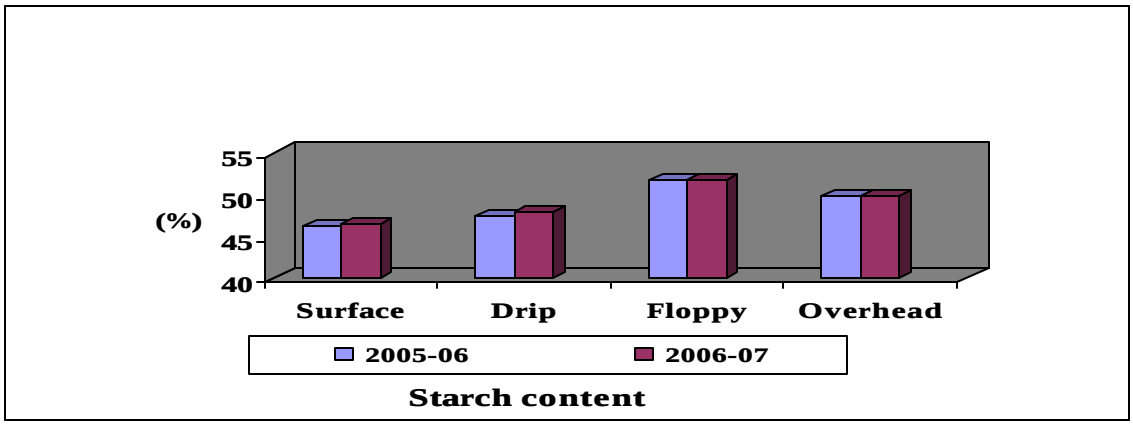


Fig 10a). Effect of irrigation systems on quality parameters of ginger viz. pH, volatile oil and crude fat content at harvest during 2005-06 and 2006-07.







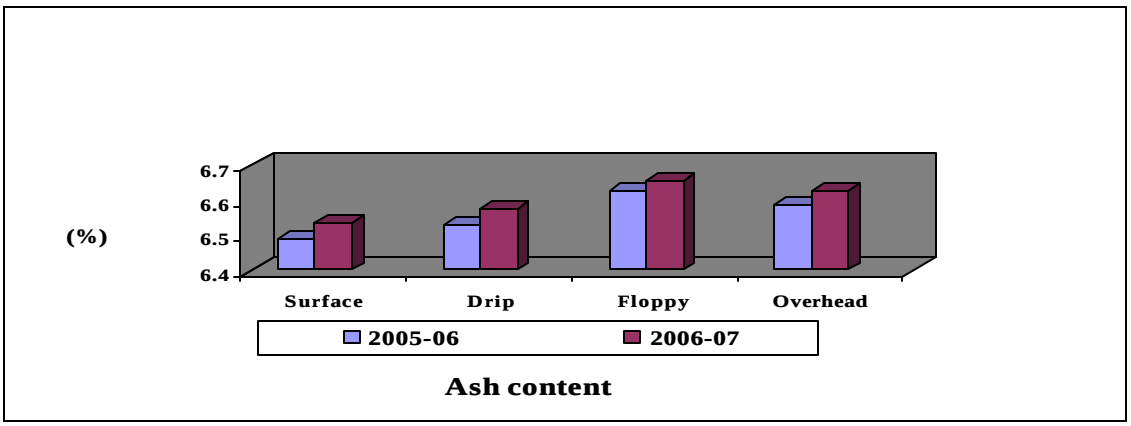
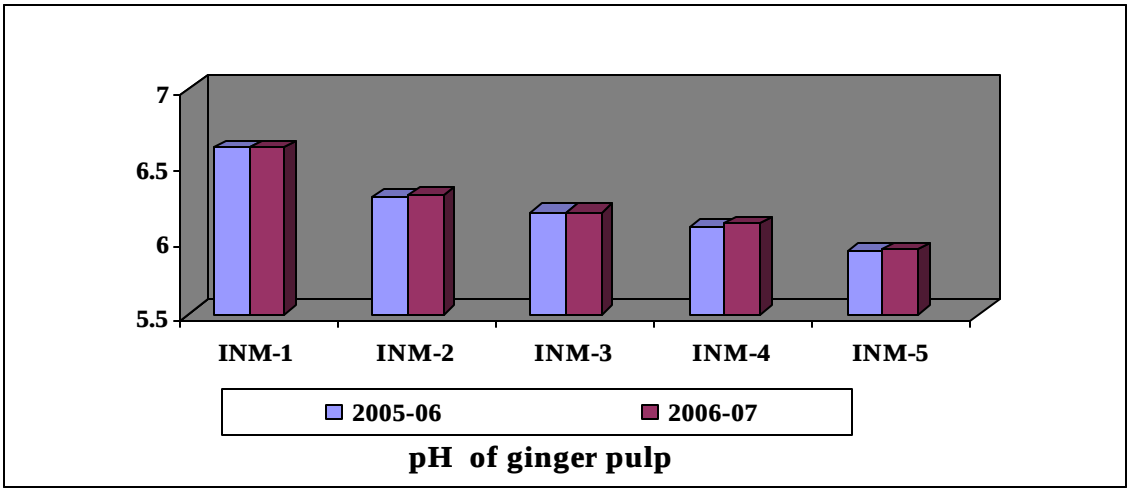
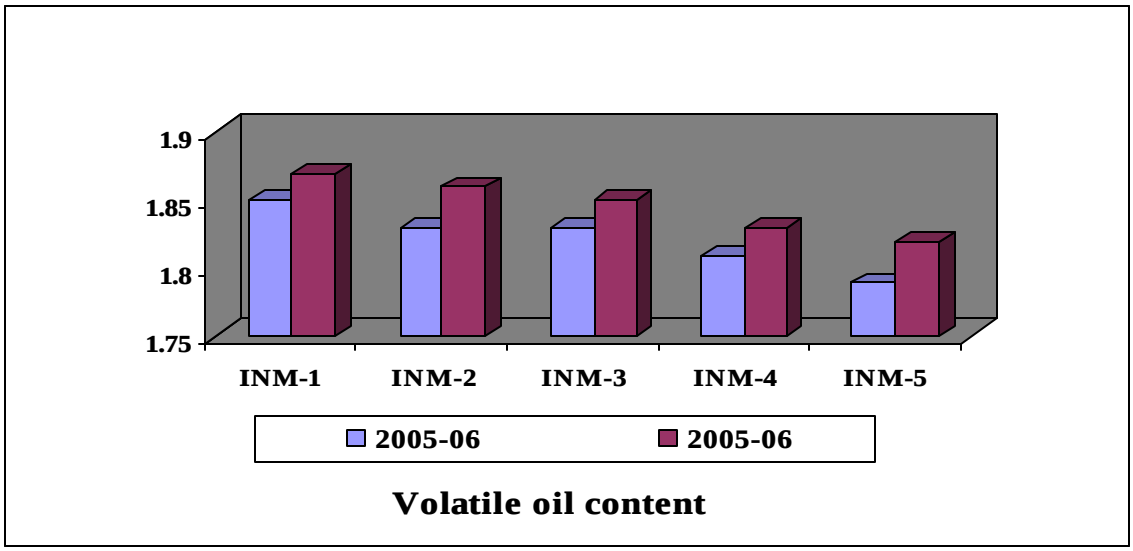


Fig 10b). Effect of irrigation systems on quality parameters of ginger viz. oleoresin, crude fibre, starch and ash content at harvest during 2005-06 and 2006-07.





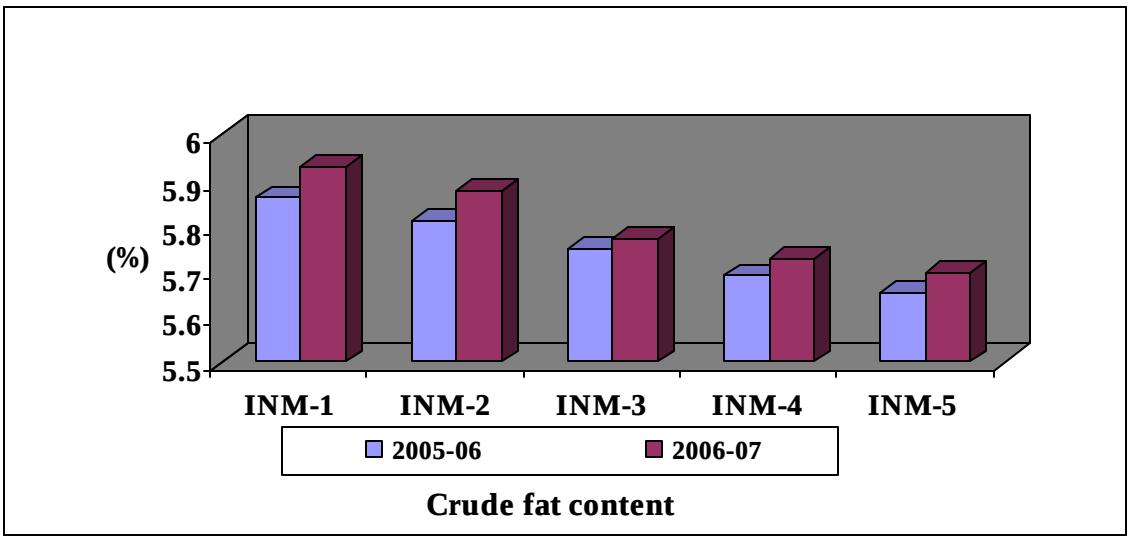
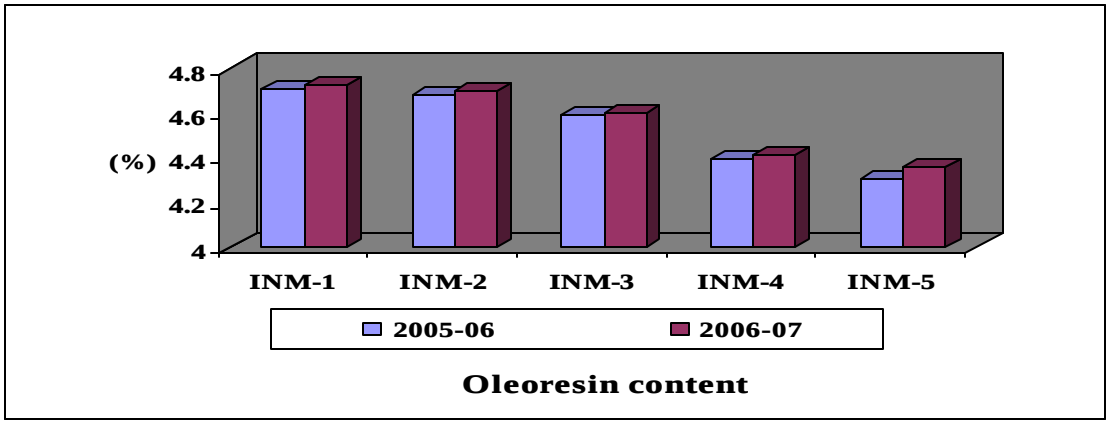
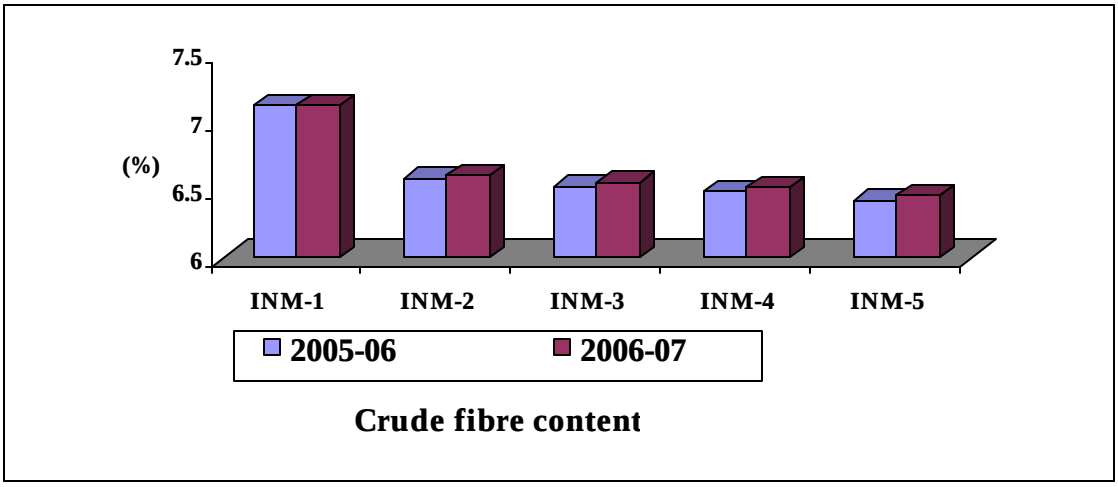
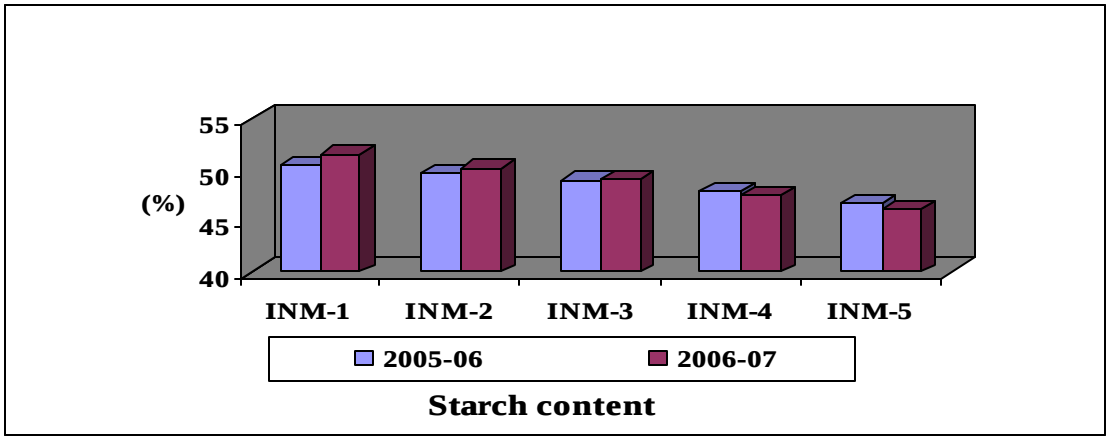


Fig 11a). Effect of integrated nutrient management on quality parameters of ginger viz. pH, volatile oil and crude fat content at harvest during 2005-06 and 2006-07.







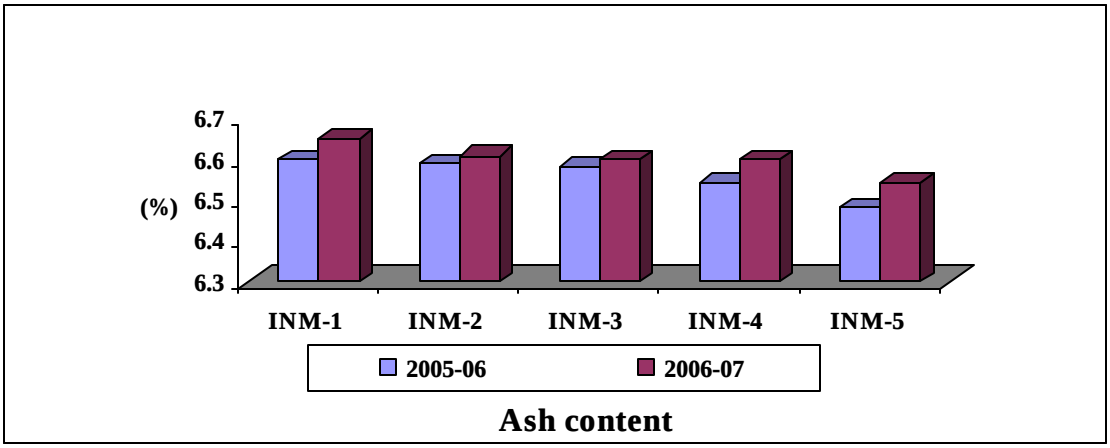
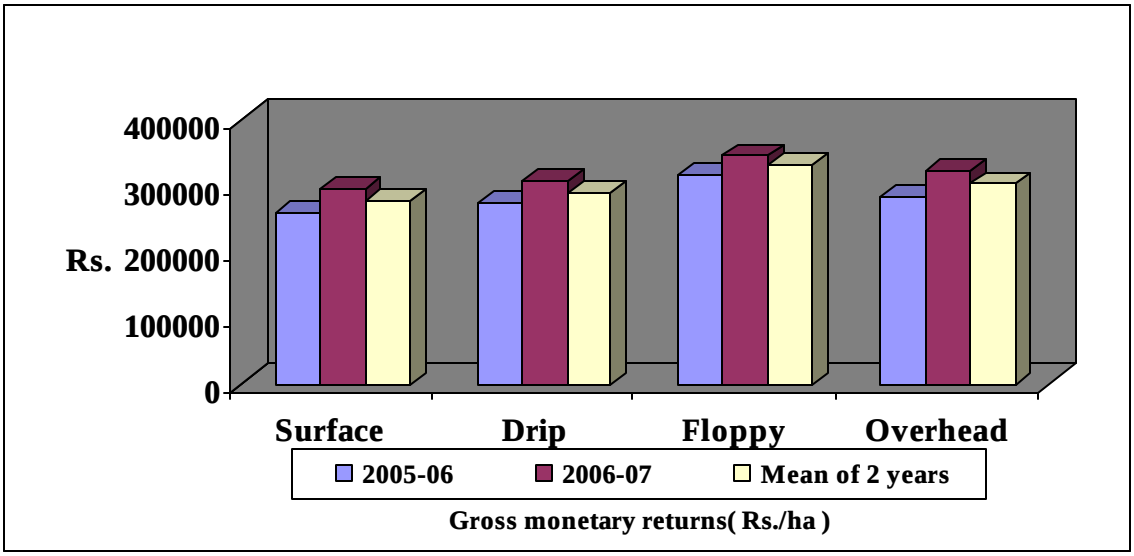
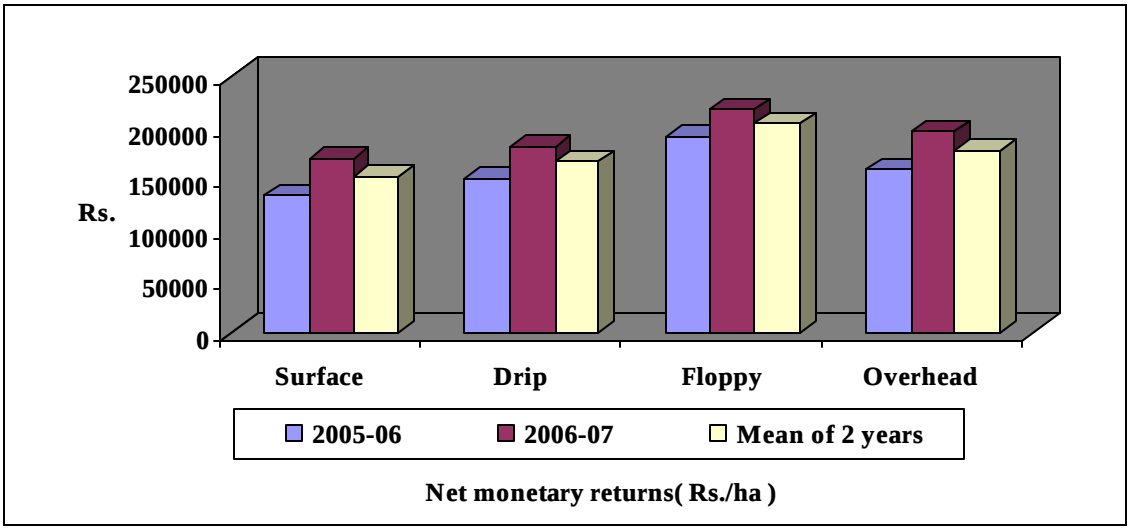


Fig 11b). Effect of integrated nutrient management on quality parameters of ginger viz. oleoresin, crude fiber, starch and ash content at harvest during 2005-06 and 2006-07.





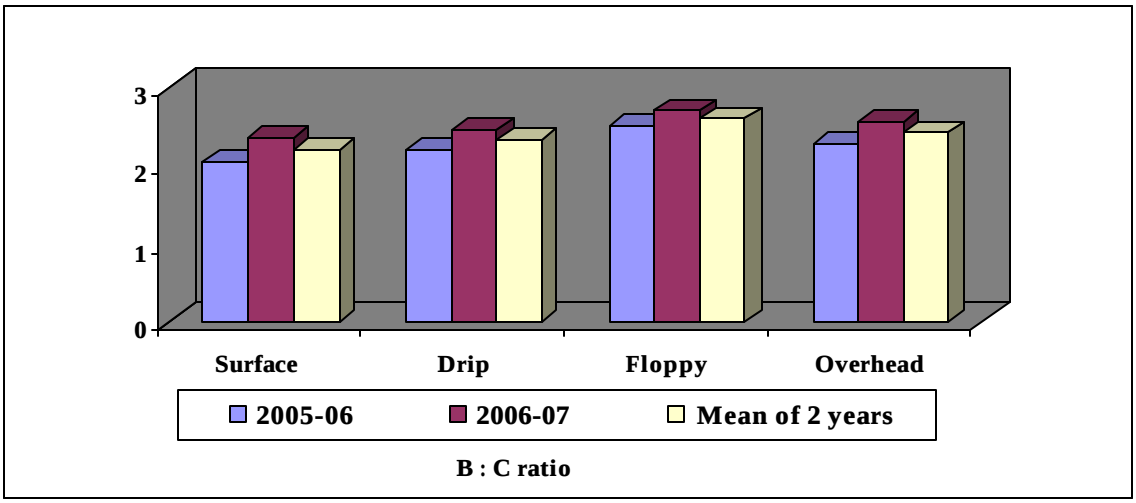
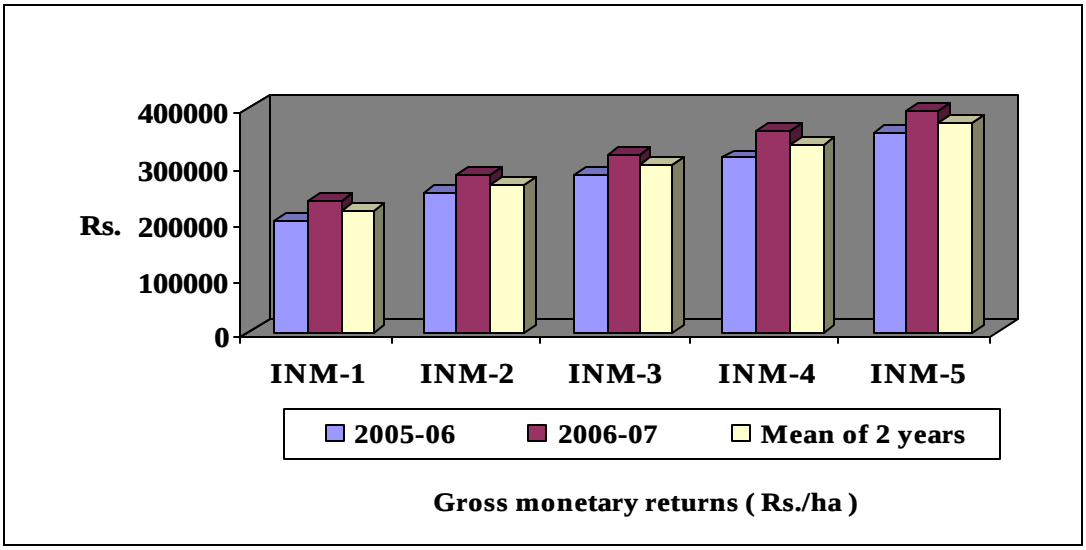
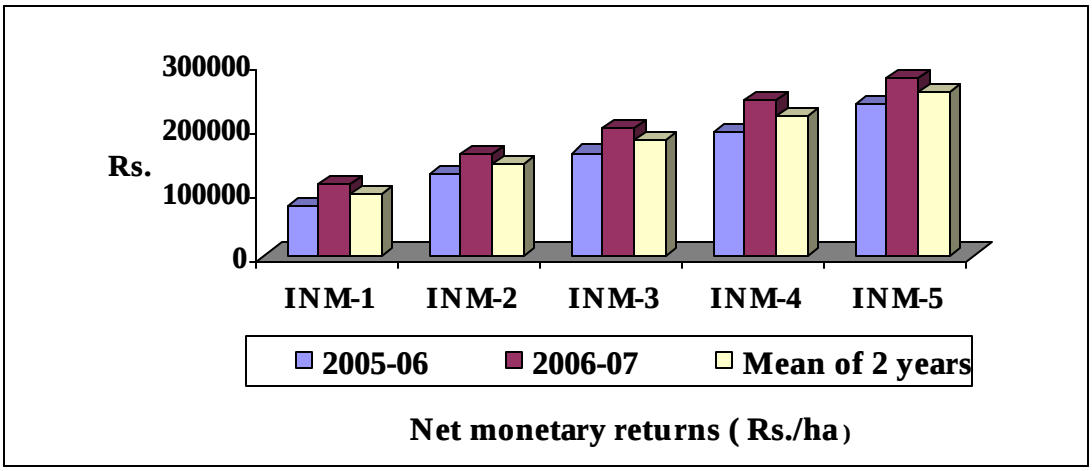


Fig 12a). Effect of irrigation systems on gross and net monetary returns and B:C ratio of ginger during 2005-06 , 2006-07 and in pooled mean.





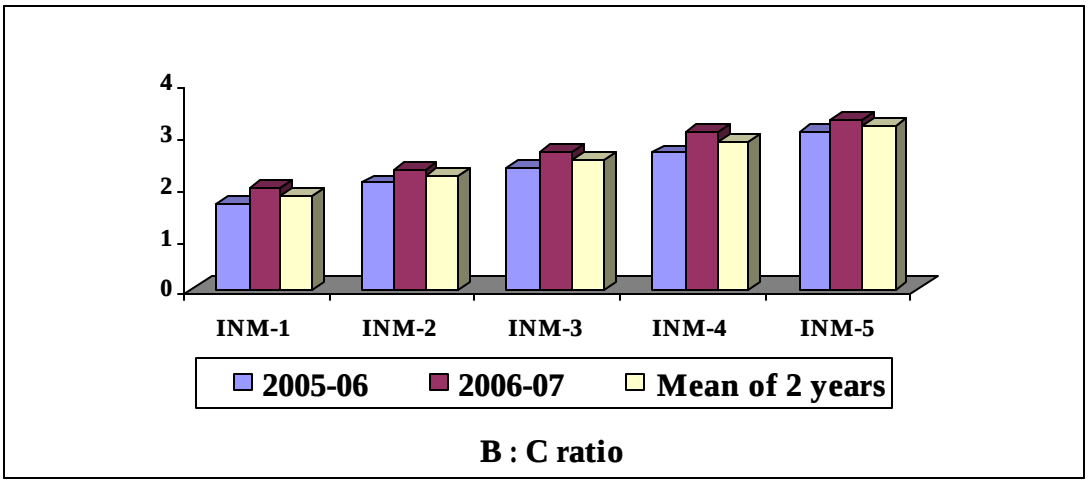


Fig 12b). Effect of integrated nutrient management on gross and net monetary returns and B:C ratio of ginger during 2005-06 , 2006-07 and in pooled mean.