STUDIES ON POTASSIUM FRACTIONS IN SOIL AND YIELD OF RATOON BANANA AS INFLUENCED BY FERTIGATION

By

Miss. Pawar Shilpa Ramesh
(Reg. No. 13/181)

A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST.AHMEDNAGAR,
MAHARASHTRA, INDIA.

in partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

IRRIGATION WATER MANAGEMENT

INTERFACULTY DEPARTMENT OF IRRIGATION WATER MANAGEMENT

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH,
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2015

CANDIDATE'S DECLARATION

I hereby declare that this thesis or a part

there of has not been submitted

by me or any other person

to any other University

or Institute for

a Degree or

Diploma

Place: MPKV, Rahuri **(S. R. Pawar)**

Dated: / /2015

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C E R T I F I C A T E

This is to certify that the thesis entitled, **"STUDIES ON POTASSIUM FRACTIONS IN SOIL AND YIELD OF RATOON BANANA AS INFLUENCED BY FERTIGATION"**, submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.) in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **IRRIGATION WATER MANAGEMENT**, embodies the results of a piece of bonafide research work carried out by **MISS. PAWAR SHILPA RAMESH** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or publication in other form. The assistance and help received during the course of these investigations have been duly acknowledged.

Place : M.P.K.V., Rahuri **(K. D. KALE)**

Dated : / /2015 (Research Guide)

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Place : M.P.K.V., Rahuri **(B. R. Ulmek)**

Dated : / /2015

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Place : M.P.K.V., Rahuri
Date : / / 2015 (S. R. Pawar)

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@	:	At the rate of
^{0}C	:	Dégrée Celsius
^{0}E	:	Degree East
^{0}N	:	Degree North
C.D.	:	Critical difference
CF	:	Conventional fertilizers
cm	:	Centimetre
CPE	:	Cumulative pan evaporation
Cv.	:	Cultivar
DAP	:	Days after planting
dSm^{-1}	:	Desi Simen per meter
EC	:	Electrical conductivity
Ep	:	Pan Evaporation
ER	:	Effective rainfall
et al.	:	And others
ET	:	Evapo-transpiration
etc.	:	Excrètera
Fig.	:	Figure
FUE	:	Fertilizer use efficiency
FYM	:	Farm yard manure
g	:	gram (s)
GTO	:	Grommet take off
ha	:	hectare
ha-mm	:	Hectare-millimetre
hr	:	Hour (s)
i.e.	:	That is
IR	:	Irrigation requirement

IW/CPE	:	Ratio of irrigation water to cumulative pan evaporation
K	:	Potassium
Kc	:	Crop coefficient
kg ha^{-1}	:	kilogram per hectare
kg	:	Kilo gram (s)
Kp	:	Pan coefficient
LDPE	:	Low density polyethylene
lph	:	Litre per hour
m	:	metre
mg kg^{-1}	:	Mili gram per kilogram
ml	:	Millilitre (s)
mm	:	Millimetre
N	:	Nitrogen
N.S.	:	Non significant
No.	:	Number
P	:	Phosphorus
PAR	:	Photosynthetic active radiation
PE	:	Pan evaporation
PVC	:	Polyvinyl chloride
q	:	Quintal (s)
RDF	:	Recommended dose of fertilizers
Rs	:	Rupees
S.E.	:	Standard error of means
viz.,	:	Videlicet (Namely)
WSF	:	Water soluble fertilizers
WUE	:	Water use efficiency

ABSTRACT

STUDIES ON POTASSIUM FRACTIONS IN SOIL AND YIELD OF RATOON BANANA AS INFLUENCED BY FERTIGATION

By

PAWAR SHILPA RAMESH

A candidate for the degree
of
MASTER OF SCIENCE (AGRICULTURE)
in
IRRIGATION WATER MANAGEMENT
2015

Research Guide	:	Dr. K .D. Kale
Department	:	Interfaculty Department of Irrigation Water Management

The field experiment entitled "Studies on potassium fractions in soil and yield of ratoon banana as influenced by fertigation" was conducted at Instructional Farm of Inter-faculty Department of Irrigation Water Management, M.P.K.V., Rahuri (Maharashtra) during 2013-14. The objectives of investigation were to study the effect of fertigation on the periodical potassium fractions in soil, yield of ratoon banana and relationship among the fractions of K, crop yield, NPK uptake by banana and soil properties and moisture distribution pattern.

The experiment was laid out in a randomized block design with nine treatments replicated thrice. The experiment comprised two fertilizers sources and three levels of water soluble fertilizers applied through drip as per schedule, drip with conventional fertilizers through soil as a control and DI with no fertilizer treatment for comparison.

Application of WSF through drip resulted in more availability of potassium fractions than conventional fertilizer. The treatment (T_1) 100 % RD of WSF resulted in higher availability of K fractions in soil at 9 months after ratoon than 80 % level (T_2), which was followed by 60 % RDF level. The availability of different potassium fractions were in the decreasing trend as given below. The Total K (5600.00 mg kg^{-1})> Lattice K (4591 mg kg^{-1}) > Non exchangeable K (761.6 mg kg^{-1}) > Available K (221.5 mg kg^{-1}) > Exchangeable K (191.3 mg kg^{-1})> Water soluble K (31.5 mg kg^{-1}).

The application of water soluble fertilizers significantly increased yield and yield contributing characters of banana over conventional fertilizer. The treatment T_1 recorded significantly maximum plant height (3.16 m), plant girth (59.13 cm), number of leaves (17.00), number of fingers per bunch (156.33) and weight of bunch (18.03 kg).

Treatment T_1 drip with 100 % RD of WSF as per growth stages recorded significantly higher yield (82.35 t ha^{-1}) over other treatments. However, it was at par with T_6 and T_2 and it was more than no fertilizer treatments. The banana yield obtained under 60 % RD of WSF (T_3) was (67.89 t ha^{-1}) significantly more than drip with CF (T_8) (60.23 t ha^{-1}). Thus indicated that fertigation using WSF can save 40% fertilizer.

The moisture content was observed at optimum level and close to the field capacity in all drip irrigated treatments. It was increased upto 40 cm vertically from the dripper and then decreased upto 80 cm depth.

Application of WSF through drip resulted in more nutrient availability in soil than CF. As far as levels of fertilizer considered, 100 per cent RD level resulted in more nutrient availability in soil at 9 months after ratoon (313: 49.2: 599.0 kg ha^{-1} NPK, respectively) than 80 % (T_6) level (NPK 287.0: 43.2: 580 kg ha^{-1}), which was followed by 60% RD level.

The nutrient uptake was improved in fertigation treatments as compared with conventional fertilizer. Treatment T_1 recorded significantly higher total NPK uptake at harvest (395.82, 88.05 and 941.21 kg ha^{-1}) over other treatments.

The positive correlation between periodical availability of different forms of K with yield and yield attributors showed that as period of crop increases the availability of these forms in soil also increased. The value of various K fractions were correlated to identify their interdependence. Total K had positive and significant correlation with all the fractions of K.

The available K was increased to larger extent in fertigation treatment as compared to conventional fertilizer applied through soil, which has improved the growth and yield of ratoon banana. In view of this, application of water soluble fertilizers in splits as per growth stages is recommended for improved productivity, efficient nutrient and water use by ratoon banana cultivated in medium deep soils.

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1. INTRODUCTION

Potassium is an essential element for plant growth and its importance in agriculture is well recognized as the major nutrient element. Potassium is usually the most abundant in soil. The lithosphere contains an average of 2.6 % K in the earth crust. Potassium is a major essential nutrient element denoted by K is involved in many physiological, biochemical functions of plant growth and yield. The quantity of K consumed by high yielding varieties of crops is frequently higher than nitrogen and phosphorus. This gained significance in the context of modern intensive agriculture where growers aim at higher yields of crops per unit area and per unit time.

Potassium is known to occur in a number of form in soil viz., water soluble, exchangeable, non-exchangeable, available and total K. The forms of K in soil in the order of their availability to plant are soluble, exchangeable, non-exchangeable and mineral form (Martin and Sparks, 1985).

The distribution of K forms differs from soil to soil as a function of dominant clay minerals present. The different forms of K are known to exist in dynamic equilibrium with each other. When K is added to soil it would get fixed which is released on intensive cropping. Thus, any decrease in soil soluble K would be made up by the exchangeable K and decrease in the exchangeable K is maintained by the release of non-exchangeable to the exchangeable form.

Potassium supplying capacity of soil depends on the total K content and the availability of potassium is regulated by various physio-chemical processes in soil, among these adsorption and desorption kinetics of potassium are some of the important processes in controlling K availability in soil (Sharma *et al.* 1994). Therefore, the knowledge regarding the forms of soil potassium and the condition controlling their availability is of importance in an appraisal of available potassium status of soil.

India has no indigenous source of potash. Although potash is consumed in 150 countries in the world, only about a dozen countries are blessed with reserves of potash. Canada is world's largest producer with about 53 % of world's potash reserves. Other leading producers are Germany, Israel and Jordan. Indian companies import potash from Canada, Belarus, Jordan, Israel, UK and Germany. Rising prices of muriate of potash (MOP) has forced the farmer to prefer urea, which caused imbalance of fertilizer use and as a consequence, the soil health has been affected adversely. The import of potash fertilizer is depleting our foreign reserves. Thus, there is need to control this expenditure through soil fertility evaluation and research on potassium in country (Kinekar, 2011).

The K content and its fractions in soil are mainly dependent on the nature of parent material, mineralogical make up and topographical features of the area. These factors have direct influence on potassium reserve, fixation capacity, K supplying power and response to applied K fertilizers. For formulating sound fertilizer recommendations, the knowledge of forms of K and their profile distribution are of relevance in assessing long term K availability to crops. Considerable variation in different forms of K in surface soils of varying agro-climatic zones of Maharashtra is well documented (Kadrekar and Kibe, 1972 and Talele *et al.,* 1992).

The actual K uptake by plants denotes the K supplying power of soil (Ramanathan and Krishnamoorthy, 1982). The ease with which the K released from non exchangeable source without K application is an index on K supplying power. Therefore, precise prediction of K supplying power of soil both exchangeable and non–exchangeable forms of K needs consideration for better K management.

Banana (*Musa paradisica*) is one of most popular and important fruit crop grown worldwide and a major fruit crop grown predominantly in central and peninsular India. India ranks first with an area of 0.65 million ha under banana cultivation, producing 24.46 million tones of banana with a productivity of 37.0 t ha^{-1}. Southern part of India is leading in banana production due to presence of suitable climatic conditions. Maharashtra is second leading state in country after Tamil Nadu, having area of 0.74 lakh ha with a production of 4.65 million tones. The productivity of banana in Maharashtra is 62.90 t/ha (Anonymous, 2014). Though, India ranks first in the world in Banana production, its share in the world trade is insignificant due to scattered production and unsatisfactory quality. The major hurdle in quality banana production is lack of professional outlook and mismanagement of available natural resources. Water is the most important factor which significantly deviate the quality and productivity. Many previous worker have reported that water deficit adversely affect the crop growth and yield.

Irrigation is one of the essential inputs for banana cultivation where there is little or no rains during the growing season. Water being a limited resource, its efficient use is a basis for survival of agricultural all over the world. Indian farmers are mostly adopting conventional method of irrigation *i.e* surface irrigation; due to this the available water resources are not being used judiciously. There are more losses of water during conveyances in open channels. Prolonged application of excess water not only spoils productive lands but also causes loss in costly fertilizers by the way of leaching. Under conventional method of irrigation, fertilizer use efficiency is also less as considerable amount of fertilizer is lost by leaching.

As Maharashtra is having considerable area and production under banana and also facing the problem of limited irrigation conditions, to boost the banana productivity with efficient use of water, we have to turn towards advanced irrigation system, such as micro irrigation system (drip and microsprinkler *etc*). The drip irrigation/ micro-irrigation is a hi-tech system and developing very fast in the country and is become increasingly popular in the state of Maharashtra. In the country, drip irrigation is commonly adopted for crops like orchard, vines, vegetable and cash crops like sugarcane and cotton. The area under drip irrigation in India is 3.70 lakh ha (Anonymous 2014).

For better yields, combined use of all nutrients and growth regulator are important. It increases the yield and growth of the crops significantly, if used in proper proportion through drip system.

Fertigation is a new technology of applying water soluble fertilizers through drip irrigation. The use of drip irrigation coupled with fertigation is gradually gaining much importance. Application of fertilizers through drip irrigation is most convenient with or without micronutrient. Fertigation has number of advantages like improvement in nutrient use efficiency, yield and quality, placement of fertilizer in the vicinity of root zone of the crop, saving of fertilizer and trace element can also be applied along with major nutrients. Different grades of solid soluble and liquid fertilizer are commonly used for fertigation. However, very high cost of these grades is main constraint in their adoption. The conventional fertilizer soluble in water viz, urea, diammonium phosphate and muriate of potash can also be used for fertigation and are quite cheaper as compared to solid soluble fertilizer. However, there is no sufficient data generated regarding regarding the periodical availability of potassium fractions in soil and its correlation with banana yield and other soil properties. Hence, present investigation was planned to study the periodical availability of different forms of K in soil and yield of ratoon banana.

In the context of above considerations, the investigation entitled "Studies on potassium fractions in soil and yield of ratoon banana as influenced by fertigation" cv. Grand Naine was conducted with the following objectives.

1. To study the effect of fertigation on the periodical potassium fractions in soil.
2. To study the effect of fertigation on yield of ratoon banana
3. To study the periodical moisture content in soil.
4. To study the relationship among the fractions of K, crop yield, NPK uptake by ratoon banana and soil properties.

2. REVIEW OF LITERATURE

The work done on potassium fractions in soil as influenced by fertigation to banana, the literature related to the recent investigations are reviewed under forms of potassium, effect of fertigation on yield and yield contributing characters of banana, effect of fertigation on NPK uptake and soil nutrient availability and correlation of K fractions with yield of banana and other soil properties.

2.1 Forms of potassium

The forms of potassium in order of their availability to plants and microbes are water soluble, exchangeable, non-exchangeable and total K. These all forms are in dynamic equilibrium.

Kadrekar and Kibe (1974) studied different forms of K in soils of Maharashtra and reported an average value of 6878 mg kg^{-1} of total potassium.

2.1.1 Water soluble potassium

It is the ionic form of potassium which is directly taken up by plants and microbes and is also subjected to leaching. It is usually found in low quantities. It fluctuates greatly and difficult to measure (Martin and Spark, 1985).

Subba Rao and Sekhon (1991) reported the range of water soluble K is 0.06-0.07 m mol L^{-1} for some Vertisols of Maharashtra and Madhya Pradesh.

Bhosale *et al.* (1992) obtained 3-39.7 mg kg^{-1} water soluble K in smectitic soils of India.

Gaikwad (2002) studied horizon wise distribution of water soluble K in different soil series of Vertisols, Inceptisols and Entisols ranged from 9-18 mg kg^{-1}.

Bhalerao and Pharande (2003) reported average values of water soluble K in saline, saline-sodic and sodic soils 11.6, 19.24, and 15.41 mg kg^{-1}, respectively.

Kaul and Gupta (2005) studied forms of potassium in 50 surface and sub-surface soils from various locations of Jammu region (Jammu and Kashmir state), representing four agro-climatic zones and ten great soil groups belonging to three orders. The average contents of water soluble forms of potassium irrespective of agro-climatic zones and great soil groups were 47 mg kg^{-1}, in surface and 34 mg kg^{-1} in sub-surface soils.

Ingole (2007) reported that contribution of water soluble potassium 2.99, 2.26 and 1.85% of total K in Vertisols, Inceptisols and Entisols, respectively of farm of M.P.K.V., Rahuri.

2.1.2 Exchangeable Potassium

Exchangeable potassium is held by the negative charges of clay minerals and organic matter. It is available to plant. Talele *et al.* (1992) assessed different forms of potassium in soil of different agro-climatic zones of Maharashtra. Their studies indicated fairly high content of all forms of K. Exchangeable K reported was 12.03-46.80 mg 100 g^{-1} soil.

Pal *et al.* (1996) assessed different forms of potassium of benchmark soil series of Gujarat. Their results showed that the exchangeable potassium varies from 52 - 1189 mg kg^{-1}.

Hirekurbar *et al.* (2000) showed that the exchangeable potassium in shrink-swell soil series of Karnataka was in the range of 133-237 mg kg^{-1} with mean value of 182.71 mg kg^{-1}.

Ghosh and Singh (2001) studied potassium release characteristics of some soils of Uttar Pradesh hills varying in altitude and their relationship with forms of soil K and clay mineralogy. The soil series were then grouped under three classes with respect to altitude and exchangeable K contents, *viz.*, 1250, 1650 and 2250 m AMSL with exchangeable K content with soil groups were 40 ± 5, 90 ± 15 and 140 ± 15 mg kg^{-1} soil, respectively.

Gaikwad (2002) studied horizon-wise distribution of exchangeable K in different soil series and from the mean values in the Entisol surface soil showed lowest content of exchangeable K (236 mg kg^{-1}) followed by Vertisols (342 mg kg^{-1}) and highest in Inceptisols (491 mg kg^{-1}).

Bhalerao and Pharande (2003) reported highest content of exchangeable potassium in saline-sodic (265 mg kg^{-1}) followed by sodic (258 mg kg^{-1}) and lowest in saline soil (195 mg kg^{-1}).

Kaul and Gupta (2005) studied different forms of potassium in 50 surface and subsurface soils from various locations of Jammu region (Jammu and Kashmir state), representing four agro-climatic zones and ten great soil groups belonging to three orders. The average contents of exchangeable potassium irrespective of agro-climatic zones and great soil groups, were 15 mg kg^{-1}, respectively in surface and 81 mg kg^{-1} in sub-surface soils.

Ingole (2007) reported 6.70, 5.45, and 4.66 per cent, exchangeable potassium in Vertisols, Inceptisols and Entisols, respectively, in Agriculture farm at M.P.K.V., Rahuri.

2.1.3 Non-Exchangeable Potassium :

Non-Exchangeable K is a distinct form of mineral K. It is not bounded co-valently within the crystal structures of soil mineral particles. It is rather held between adjacent tetrahedral lattics.

Murthy (1988) indicated that the content of non exchangeable K in most of the Indian soils ranged from 1.5 to 3.6 mg 100 g^{-1} soils.

Shyamapura *et al.* (1994) assessed the shrink- swell soils of Rajasthan for potassium. The non exchangeable K in soils ranged from 0.92 - 5.10 cmol kg $^{-1}$ soil.

Singh *et al.* (1997) reported the Non-exchangeable K from 430-1160 mg kg^{-1} in shrink- swell soils of Rajasthan.

Srinivasa Rao *et al.* (2001) reviewed the soils of India for non-exchangeable K which was in range of 500-1875 mg kg^{-1} with average value of 592.39 mg kg^{-1}.

Byju *et al.* (2002) reported the effect of K rates (0,25, 50, 75 and 100 kg K ha^{-1}) on different K fraction and found increasing trend of non-exchangeable K up to 50 kg K ha^{-1} (430 mg kg^{-1}).

Aziz (2003) reported that the non-exchangeable K status of Sawargaon soil series of Inceptisols was higher than

Pargaon soil series of Entisols with mean value 941 mg kg^{-1} and 821 mg kg^{-1}, respectively.

Wani (2009) studied the Kinetics of non-exchangeable K release from some soil and their separates of Himalayas of India at different altitude zone of Kashmir valley. Non-exchangeable K value obtained was high at high MSL (95.2 to 106.9 mg kg^{-1}), medium altitude (92.8-95.9 mg $kg^{-1)}$ and low altitude (67.01-74.9 mg kg^{-1}).

2.1.4 Total and Lattice Potassium

The bulk of the total K is in the mineral from and is generally assumed to be slowly available to plant. The potassium bearing minerals are primary source of total K in soil.

Sharma and Dubey (1988) reported that the majority of total K was in lattice which ranged from 888 to 1139 mg kg^{-1} and distributed nearly 78.6 to 86.6 per cent of total K.

Dhillon and Dhillon (1994) assessed some benchmark shrink-swell soils of India and they indicated that smectitic shrink-swell soil contained the largest amount of total potassium (14.87 to 27.85 cmol kg^{-1}).

Sonar and Patil (1996) studied 53 soils of different agro-climatic zones of Maharashtra and revealed that the lattice K ranged from 83.3 to 97.0 per cent of total K.

Bhalerao and Pharande (2003) reported the average lattice K content of saline, saline-sodic and sodic soil was 6031, 6550 and 6775 mg kg^{-1} respectively and average total K content of saline, saline- sodic and sodic soil was 0.65, 0.71, 0.74 per cent, respectively.

Kaul and Gupta (2005) studied different forms of potassium in 50 surface and sub-surface soils from various locations of Jammu region (Jammu & Kashmir state), representing four agro-climatic zones and ten great soil groups belonging to three orders. The average contents of water soluble forms of potassium irrespective of agro-climatic zones and great soil groups, were 18,500 mg kg^{-1} respectively in surface and 20,000 mg kg^{-1} in sub-surface soils, respectively.

Ingole (2007) reported lattice K was predominant followed by non exchangeable, exchangeable, available and water soluble contributing towards the total K. Lattice K observed in Vertisols, Inceptisols and Entisols was 81.30 83.80, 84.86 per cent, respectively.

2.2 Fertilizer management

2.2.1 Growth contributing characters

Chattopadhyaya and Bose (1986) tried three levels of N, P, K *viz.*, N (0,120 and 240 g $plant^{-1}$) P_2O_5 (0, 45 and 90 g $plant^{-1}$) and K_2O (0, 240 and 480 g $plant^{-1}$) and reported that increased application of nutrients, significantly increased plant height, girth and leaf number. Maximum height was recorded at 240 g N $plant^{-1}$ (201.3 cm) significant increase in plant height was also noted with higher levels of K_2O in combination with different levels of N. The highest level of N x K_2O caused about 109 per cent increase in height over control. The interaction of N, P_2O_5 and K_2O clearly indicated the beneficial effect of mainly N and K on stem girth in banana.

Ram and Prasad (1989) reported that plant growth varied significantly with levels of fertilizer application. Maximum plant height (389.73 cm) was recorded with application of 300 g N, 120 g P_2O_5 and 200 g K_2O plant^{-1}, which was significantly superior over other treatment combinations.

Hazirika and Mohan (1991) reported that increasing N levels resulted in increased vegetative growth, greatest plant height and pseudostem girth, yield attributing characters and yield were increased with increasing level of N fertilizer.

Hegde and Shrinivas (1991) reported that increasing level of N fertilization had no significant effect on growth, yield and water use efficiency but nutrient uptake and total soluble solids increased in the plant crop with increasing N application. Increasing level of K application improved growth, yield, total soluble solids, nutrient uptake and water use efficiency but decreased pulp: peel ratio.

Shawky *et al.* (1993) conducted a study on effect of different levels of nitrogen on vegetative growth and nutrient content of banana plants grown in sand culture. The results revealed that vegetative growth increased with increasing N application. Reducing or removing N had no effect on the appearance of young leaves but caused chlorosis of older leaves especially when no N was applied. Leaf N content increased while leaf Ca content decreased with increasing N application rate.

Pawar *et al.* (1997) conducted a study on effect of fertilizer doses and their application on production of banana and reported that growth attributing characters of banana were significantly influenced due to various fertilizer levels. Significantly higher plant diameter, height, number of leaves per plant and less days required for flowering were observed in higher fertilizer dose treatments.

Reddy *et al.* (2002) conducted a study on response of Robusta banana to N and K fertigation. The results revealed that the plant height increased rapidly up to 180 days after planting and later marginally up to 330 days. Increase in levels of fertigation increased the plant height gradually. Soil application of N and K recorded lower plant height at most of the stages. Stem girth and number of leaves were also significantly increased with increase in fertilizer dose.

Dahiwalkar *et al.* (2004) conducted a study on relative performance of fertigation on growth, yield and quality of banana and reported that maximum plant height and stem girth of banana at flowering stage was recorded under paired row planting with 70% N and 80% P and K by solid soluble fertilizers through drip irrigation treatment among all treatments and was significantly higher than the other treatment having low levels of fertilizers.

Kavino *et al.* (2004) conducted a study of effect of fertigation on the growth and development of banana and reported that growth characteristics such as pseudostem height, girth number of leaves and total leaf area all increased with increasing fertilizer level. Increase in leaf area also increased photosynthetic efficiency and ultimately biomass production also increased.

Kumar *et al.* (2007) conducted a trial on effect of fertigation on banana through drip irrigation and reported that the vegetative growth of banana was influenced by fertigation treatment. A rapid growth of plant height and slow growth in plant girth was found during initial stage, but later on reverse trend was obtained. Maximum height and number of leaves were found in treatment having heighest fertilizer. Maximum horizontal and vertical spread of roots was found in fertigation treatment.

2.2.2 Duration of the crop

Singh *et al.* (1974) conducted a trial on effect of NPK fertilization on growth, yield and quality of banana and observed that duration required for flowering to harvesting and total duration was reduced with increase in fertilizer dose up to 150:90:170 g N, P_2O_5 and K_2O per plant, respectively.

Chattopadhyaya and Bose (1986) reported that flowering was advanced by 67 days due to treatment with 240 g N per plant compared with untreated plants. The variation in the time of flowering due to the highest and lowest levels of phosphorus was 14 days only while application of K at 480 g per plant induced flowering in 386 days in comparison to 412 days in the untreated plants. Increased application of N was found to delay fruit maturity, but on the other hand potassium enhanced the maturity of fruit. The interaction of different levels of N, P_2O_5 and K_2O on fruit maturity was not significant.

Upadhyay (1988) reported significantly early flowering in banana was initiated due to N and P both (180 g N + 130 g

P_2O_5) indicated earlier flowering as compared to N alone or to all combinations with P and K separately.

Ram and Prasad (1989) reported beneficial effect of NPK on flowering. There was significant reduction in days required for induction of flowering with application of 200 g N (402 days). It was also found that flowering was delayed at the highest level of N (300 g).

Divekar (2001) reported that in banana, the treatment with higher dose of fertilizer and paired row planting completed their life cycle earlier (358.20 days) as compared to the surface irrigation and less quantity of fertilizer treated plants (417.50 days).

Kode (2001) reported that days required to fruit maturity in banana was influenced significantly by the fertilizer levels. The treatment of normal planting with 100 per cent of water soluble fertilizer through drip recorded less days to mature and to complete its life cycle (105 days) whereas, treatment with normal planting and 50 per cent straight fertilizer through drip recorded more days to maturity and completion of the life cycle.

Kavino *et al.* (2004) reported that total duration in banana ratoon crop ranged from 357.53 to 443.00 days indicating a substantial variation in the duration of crop due to the fertigation treatments. Higher fertilizer dose subject the plant to early maturity.

2.2.3 Yield and yield contributing characters

Leigh (1969) reported that dressing of 200 lb N, 50-100 lb P_2O_5 and 450 lb K_2O per acre per annum with 3 to 4 splits found to be better for higher yields.

Singh *et al.* (1974) reported that N at 168 g plants^{-1} + K_2O at 336 g plant^{-1} (with adequate P_2O_5 at 84 g plant^{-1}) when applied, an increased yield of 5.75 kg plant^{-1} was obtained, whereas N and K individually showed an increase of 3.25 kg and 1 kg plant^{-1}, respectively. Number of hands and fingers were increased by the application of N while the response of K was in the form of increased weight, volume and density of the fruit.

Pillai *et al.* (1977) reported that N and K exerted a significant positive influence on fruit number and bunch weight in Nendran banana. The optimum dose of K_2O corresponding to maximum yield of fruit has been worked out as 191 and 301 g N plant^{-1}, respectively.

Lin-Shang Ke and Din-Fanke (1980) showed that yield of banana, number of hands and fingers per bunch were higher at higher fertilizer and moisture level.

Mu-Lien Lin and Tsai-Fva Chin (1980) reported that both nitrogen and potassium affected fruit yield significantly. No response to phosphorus was observed.

Pillai and Khadar (1980) observed that the plants receiving 100:40:400 kg N, P_2O_5 and K_2O acre^{-1} in 3 split doses produced significantly heavier bunches (26.6 kg). The number of hands and fingers recorded the highest in same treatment.

Obiefuna and Onyele (1987) reported that an annual application of 200 g N and 500 g K plant^{-1} produced the heaviest bunch weight and was the most economic.

Khandare *et al.* (1988) conducted a study on effects of fertilizer doses on yield of banana ratoon crop and reported that higher fertilizer doses showed very distinct and significant increase in total weight of bunch per hill, average weight of bunch/plant and yield/acre in banana over the treatments having 100 per cent dose of fertilizers.

Roy *et al.* (1988) conducted an experiment to study the effect of NPK fertilizers on Harisal banana at Basti. The study revealed that increased fertilizer application had marked effect on yield. A mixture of 180 g N + 260 g P_2O_5 plant^{-1} gave maximum yield. N and P alone and in combination significantly increased the yield.

Nair *et al.* (1990) carried out an experiment in cereal crop fallow fields with N rates of 200, 300 and 400 g plant^{-1} and K rates of 300, 450 and 600 g plant^{-1}. They reported that the best results generally were obtained on plot receiving the highest N and K rates in 6 split application. This treatment gave the heaviest bunches with an average weight of 12.02 kg. They also reported that the response of N had not significantly increased the weight of bunches, while the bunch weight showed a greater linear correlation with higher levels of K_2O. Interaction of N and K_2O was also to be significant with 400 g plant^{-1} N and 600 g K_2O producing bunches having maximum weight of 12.02 kg.

Pandit *et al.* (1992) conducted a trial at Ranchi with N rates at 200, 300 and 400 g $(NH_4)_2SO_4$, P_2O_5 at 150, 300 and 450 g single super phosphate and K at 150, 200 and 250 g muriate of potash plant^{-1}. The fertilizers were applied to individual stool of dwarf Cavendish banana. The highest yield 35 t ha^{-1} and number of hands bunch^{-1} were achieved by applying 400 g $(NH_4)_2SO_4$ + 300 g single super phosphate + 250 g muriate of potash stool^{-1}. While the control yielded only 7.8 t ha^{-1}.

Roy and Yadav (1994) conducted a study on response of Basarai banana to different doses and timing of nitrogen application in calcareous soil of North Bihar. The results revealed that the highest yield were obtained with annual applications of 250 g N/plant applied in 7 split applications and also gave the highest benefit : cost ratio.

Guerrero *et al.* (1996) conducted a study on response of banana to fertigation with different potassium sources at Cienaga. The results revealed that application of KNO_3 increased average bunch weight, extra hands per bunch, more fingers per hands and more yield were obtained due to K_2SO_4 through drip.

Berad *et al.* (1998) reported that yield attributes *viz.* number of hands/bunch, number of fingers/bunch and bunch weight were of higher magnitude in the treatment with higher N doses through drip. Yield reduced with decreasing doses of fertilizers.

Chemte (2000) reported that the application of 100% recommended dose of fertilizer increased the yield and showed superior yield contributing characters as compared to lower fertilizer doses.

Divekar (2001) reported that yield of banana increased with the increase in the quantity of fertilizers *i.e.* percent of N, P and K., yield contributing characters such as length of finger, girth, number of hands per bunch etc., also showed positive influence with increasing fertilizers.

Kode (2001) reported that yield and yield contributing characters such as length of finger, girth of finger, number of fingers per plant etc., increased with the increasing dose of fertilizers.

Reddy *et al.* (2002) reported that the fruit yield was highest with 200 g plant^{-1} N and K fertigation and the yield increase between 100 and 200 g plant $^{-1}$ was not significant.

Meena and Samasundaram (2004) reported that application of 150 per cent of recommended N and K applied in 3 and 4 splits, respectively recorded the highest fruit yield. This treatment registered an increase in yield of 31.79 per cent over the recommended dose. Irrespective of number of splits, application of higher quantity of N and K registered an increased yield over recommended dose.

Nalina *et al.* (2007) reported that higher doses of fertilizers exerted a positive influence on yield and yield attributes *viz.*, number of hands per bunch, number of fingers per bunch and weight of fingers. But application of nutrients beyond 150 per cent did not correspondingly increase the bunch weight. Excessive nitrate accumulation limits the yield.

2.2.4 Quality of fruit

Martin Prevel (1969) reported that excess K application compared to N reduced fruit quality.

Singh *et al* (1974) reported that fruit quality of Robusta banana was appreciably improved by treatments having K combinations.

Chattopadhyay and Bose (1986) reported that quality of fruits was significantly increased with increasing level of NPK. Potassium level has very marked effect on TSS and acidity.

Ram and Prasad (1989) studied the effect of N, P_2O_5 and K_2O levels (N:100, 200, 300, P_2O_5:40, 80, 120, K_2O:100, 200, 300 g plant^{-1}) on fruit quality of banana and concluded that maximum TSS (21.21%) was obtained with 200 g N, 80 g P_2O_5 and 200 g K_2O plant^{-1}.

Patel *et al.* (1993) conducted a study on effect of method and levels of irrigation on physical and biochemical constituents of banana fruits. The results revealed that fruit TSS and total yellow pigment contents were highest in the treatments irrigated by furrow method at 75 mm CPE and by drip irrigation at the 60 per cent level, indicating that these treatments could be used to retard ripening and extend post harvesting life.

Berad (1996) reported that pulp : peel ratio was not affected significantly but TSS was positively increased due to increased fertilizer levels.

Reddy *et al.* (2002) reported that total soluble solids in banana fruits increased with increase in fertilizer level, while pulp : peel ratio also increased with increase in N and K levels.

Dahiwalkar *et al.* (2004) reported that the increase of fertilizer levels increased the TSS content. Similarly, pulp : peel ratio was also higher in high fertilizer treatments.

Meena and Samasundaram (2004) reported that in banana TSS was influenced by different levels and time of application of N and K. Maximum TSS in terms of brix value was recorded in the plants which received 150 per cent of recommended N and K (20.10 and 19.60 %), whereas in control it was only 16.80 and 15.90 per cent. Similarly, total sugar content also increased with the increase in fertilizer levels, where as acidity was decreased.

2.3 Fertigation and water soluble fertilizers

Application of liquid fertilizer through drip irrigation system was more efficient than conventional method of fertilizer application, since it confined nutrient placement to the area of greatest root concentration.

Geissler *et al. (1972)* compared solid and liquid fertilizers for green house cucumber and reported that liquid fertilizers increased yield as compared to solid fertilizers.

Hamar (1974) reported that when Hungarian liquid fertilizer MP-142 (5 % N, 20 % P_2O_5 and 10 % K_2O chloride free) applied from planter increased tomato yield and profits substantially.

Tukolova and Yukolova (1976) reported that liquid fertilizers hastened the growth and development of tomato plants and advanced early yield up to 25 per cent, when compared with plots treated with dry compound fertilizer. The total yield was similar in both cases.

Eisert and Terekhova (1979) reported that all apple trees receiving LAP (Liquid ammonium phosphate) produced higher yield and the fruits had higher dry matter and ascorbic acid content than those receiving NPK in conventional forms.

Oswiecimkiv (1981) carried out trial on green house tomatoes with solution of mineral fertilizers and the best results were obtained when the N levels in liquid nutrients was reduced to 40 per cent.

Tosl (1981) reported that strawberry plants with water soluble fertilizers yielded 22.5 g more fruits each than plants given solid soluble fertilizers.

Pawar *et al.* (1985) studied the effect of different starter solution on flowering and fruiting in chilli and reported that liquid fertilizers registered the higher yield than control.

Palma *et al.* (1988) reported that the returns in coffee (cv. Caluri) were 35 to 50 per cent more from liquid fertilizer than granular fertilizers.

Paydas *et al.* (1988) studied the effect of chemical (ammonium sulphate, triple super phosphate and potassium sulphate), liquid (wuxal suspension No.5) and slow release (SD-999) fertilizers at equivalent nutrient rates on banana. The results revealed that neither pomological character of the fruits nor bunch weight were affected. However, the fruit yield was improved by SD-999 and chemical fertilizers but not by liquid fertilizers.

Sergeeva and Kravchenko (1990) conducted a trial to study the effect of liquid fertilizer on productivity of apple. Solid fertilizer treatment was compared with liquid fertilizer. It is observed that yield with liquid treatments was 20 to 30 per cent higher than control, while it was 10 to 20 per cent more in solid fertilization treatment compared to control.

Dukre (1991) conducted experiment on okra for evaluating liquid N fertilizer through twin drip irrigation method and he observed that 50 per cent of the recommended dose through drip was the best.

Rakh (1992) conducted experiment on cabbage crop to assess the effect of liquid fertilizer. The treatments of liquid fertilizer were superior in respect of yield, yield contributing characters and water use efficiency.

Berad *et al.* (1998) reported that 75 per cent level of recommended fertilizer applied through drip on banana was found equally productive to that of 100 per cent level indicating 25 per cent fertilizer saving. The lower response to increase levels of liquid form of fertilizer was might be due to under utilization of nutrients supplied coupled with losses of fertilizers through leaching due to periodical heavy rains.

Deolankar and Firake (2001) reported that yield and yield contributing characters *viz.*, plant height, stem girth, number of hands per bunch and bunch weight of banana were not influenced significantly due to type of fertilizers. However, the number of fingers per bunch was significantly superior in the premium grade fertilizer over the regular grade fertilizer. The increase in number of fingers per bunch due to premium grade was 3.5 per cent more over that of regular grade.

Kode (2001) reported that application of water soluble fertilizers to banana found beneficial in improving growth, yield and quantity of banana giving 4.4 percent higher yield than straight fertilizer.

Kavino *et al.* (2004) reported that higher levels of water as well as nutrients supplied through the most effective soluble form could be possible reason for more number of total leaves in these treatments. Similarly when conventional fertilizers were used, the bunches showed lower weight (23.20 kg) as against 26.50 kg obtained with water soluble fertilizers.

Jadhav (2008) reported that application of water soluble fertilizers with recommended dose of fertilizers and 10 tons ha^{-1} FYM resulted in increasing uptake of all the essential major nutrients with the increasing dose of fertilizers and yield also increased.

Patil (2008) reported that increasing dose of fertilizers caused increase in uptake of nutrients by banana plant. Recommended dose of fertilizers with 10 ton ha^{-1} FYM resulted in to optimum nutrient uptake.

2.4 Economic studies

Hedge and Srinivas (1990) reported that in banana net returns in drip irrigation were Rs. 99115 and 80730 for plant and ratoon crops, respectively and Rs. 95170 ha^{-1} and Rs.72915 ha^{-1}, respectively with basin irrigation.

In banana additional land could be brought under irrigation with drip irrigation when compared to surface method. Net extra income obtained due to drip was Rs.2,62,600/ha over surface irrigation treatments. Net profit per mm of water use was

Rs.226.29 in drip and Rs.75.20 in surface irrigation. The net seasonal income obtained was Rs. 2,19,500/ha in drip, while Rs. 1,32,500/ha in surface treatments.

Kode (2001) reported that the net income was higher in straight fertilizers (Rs. 304323 ha^{-1}) as compared to water soluble fertilizers (Rs. 247166 ha^{-1}), due to high price of water soluble fertilizers. Similarly B : C ratio was also higher in straight fertilizers (2.64) than water soluble fertilizers (1.92).

Agarwal and Agarwal (2005) reported that the highest net seasonal income of Rs. 76,904 ha^{-1} was obtained in drip irrigated treatments as compared to control (Rs. 22708 ha^{-1}). The B : C ratio was higher in drip irrigated treatments than control. Due to poor quality fruits in surface irrigated control, the market price of fruits were less (Rs. 285 q^{-1}) as compared to drip treatments (Rs. 300 q^{-1}).

From the foregoing review it can be concluded that drip irrigation method results in better growth, with higher production in relatively short period as compared to conventional method of irrigation. It can also be concluded that banana responds well to increasing levels of fertilizer particularly nitrogen,phosphorus and potassium. The water soluble fertilizers proved their superiority over conventional fertilizers but are costly from economic point of view.

3. MATERIAL AND METHODS

The present investigation entitled “Studies on potassium fractions in soil and yield of ratoon banana as influenced by fertigation” was conducted during the year 2014-15. The details of material used and methods adopted during experimentation are described in this chapter under the following heads.

3.1 Material

3.1.1 Experimental site

The field trial was conducted at the Instructional Farm of Inter Faculty Department of Irrigation Water Management at the Central Campus, Mahatma Phule Krishi Vidyapeeth Rahuri, Dist. Ahmednagar during the year 2014-15.

3.1.2 Climatic condition

3.1.2.1 General

Geographically, the Central Campus of Mahatma Phule Krishi Vidyapeeth, Rahuri is situated on 19^0 24’ N and 74^0 39’ E. The altitude is about 500 m above mean sea level. Climatologically the area falls under semi-arid and sub-tropical zone with annual rainfall varying from 307 to 619 mm. The mean annual rainfall is 520 mm which mostly concentrated during the monsoon months from June to September. The number of rainy days varies from 19 to 45. The annual mean maximum temperature is 33.7 ^{0}C with a range from 32.0 ^{0}C to 43.0^{0}C. The annual mean minimum temperature is 17.2 ^{0}C with a range from 6.6 ^{0}C to 23.0 ^{0}C. The mean relative humidity ranges from 28.90 to 92.90 %. The area falls under scarcity zone of Maharashtra.

3.1.2.2 Nature of season during investigation

The mean maximum temperature during the investigation period was ranged from 25.7 ^{0}C to 40.2 ^{0}C and the minimum temperature was ranged from 7.5^{0}C to 24.7^{0}C. The maximum and minimum relative humidity was ranged from 36 to 81 and 17 to 72 % respectively. The total rainfall received was 493.6 mm with 47 rainy days during investigation period.

3.1.3 Soils

The topography of the experimental field was uniform and levelled. The soil was well drained clayey with slightly alkaline in reaction with pH value of 8.0. The soil had average depth of 0.8 m. Representative soil samples were collected from 0-80 cm depth from five location of the field. The samples were then prepared and stored in cool dry place in the laboratory. Physical and chemical properties of the soil with analytical methods employed are given in Table 3.1.

3.2 Experimental details

The experiment was laid out in randomized block design with 9 treatments and 3 replications as given in Table 3.6. The plan of experimental layout is shown in Fig. 3.2.

3.2.1 Planting material

The Grand Naine banana saplings developed by Tissue culture technology at Department of Biotechnology, Mahatma Phule Krishi Vidyapeeth, Rahuri. Dist. Ahmednagar (M.S) were used for planting.

Table 3.1 Physico-chemical composition of soil and method of determination.

Sr. No.	Characteristics	Compo sition	Method adopted	Reference
I.	**Soil analysis**			
A.	**Physical properties**			
1.	Soil texture Course sand (%) Fine sand (%) Silt (%) Clay (%)	clay 08.0 14.0 26.8 50.5	International pipette method	Piper (1966)
2.	Bulk density (mg m^{-3})	1.27	Core sample method	Klute *et al.* (1986)
3.	Field capacity (%)	39.2	Pressure plate apparatus	Black (1965)
4.	Permanent wilting point (%)	17.90	Pressure plate apparatus	Black (1965)
5.	Available water content (%)	21.3	Pressure plate apparatus	Black (1965)
6.	Hydraulic conductivity (cm/hr)	1.5	Constant head method	Bruce and Klute (1954)
B.	**Chemical properties**			
1.	Soil pH (1:2.5)	8.15	Potentiometer	Piper (1966)
2.	Electrical conductivity (dSm^{-1} at 25^0C) (1:2.5)	0.31	Conductomteric method	Jackson (1973)
3.	Organic carbon (%)	0.70	Walkley and Black method	Nelson and Sommers (1982)
4.	Available nitrogen (kg/ha)	157.0	Alkaline $KMnO_4$ method	Subbiah and Asija (1956)
5.	Available phosphorus (kg/ha)	14.20	0.5 M $NaHCO_3$ (pH 8.5)	Olsen *et al.* (1954)
6.	Available potassium (kg/ha)	465.0	N N NH_4OAC	Hanway and Haidal (1967)

Table 3.2 Methods used for determination of forms of potassium

Sr. No.	Parameter	Method used	Reference
1	Water soluble-K	Water (1:5)	Richard (1954)
2	Exchangeable-K	N N NH_4OAC (pH 7.0)	Kundsen et al., (1982)
3	Non-exchangeable-K	1N boiling HNO_3	Wood and De Turk (1941)
4	Available-K	(Water-soluble +Exchangeable)	Page *et al.* (1982)
5	Total-K	HF-$HCLO_4$ digestion	Jackson (1973)

Table 3.3 Methods used for plant analysis

Sr. No.	Parameter	Method used	Reference
1.	Preparation of acid extract from plant	Binary mixture of H_2S0_4 and H_2O_2 (1:1)	Parkinson and Allen (1975)
2.	Total-N	Micro-Kjeldahl	A.O.A.C.(1990)
3.	Total-P	Vanadomolybdate yellow colour method in nitric acid	Jackson (1973)
4.	Total-K	Flame photometer	Jackson (1973)

Table 3.4 Cropping history of an experimental field

Sr. No	Year	Season	Crop
1.	2012-13	*Kharif* *Rabi*	Onion seed production Fallow
2.	2013-14	*Kharif* *Rabi* Summer	Banana Plantation
3.	2014-15	*Kharif* *Rabi* *Summer*	Ratoon banana

3.2.2 Fertilizers

The recommended dose of fertilizers for banana is 200:40:200 g N, P_2O_5 and K_2O/plant.

In conventional fertilizer treatments the urea, diammonium phosphate and muriate of potash were used. In fertigation treatments, different grades of fertilizer *viz*; mono ammonium phosphate, sulphate of potash and special grade (9:5:33) were used.

Table 3.5 Characterization of fertilizer sources (1:10)

Sr. No	Sources	pH	EC (dSm^{-1})
1.	09:5:33	2.20	1.00
2.	12:61:00	4.40	1.10
3.	Urea	7.10	0.12
4.	DAP	3.00	1.20
5.	MOP	6.60	1.15

3.3 Details of cultivation

3.3.1 Experimental Details

The details of experiment are listed below

1.	Crop and variety	:	Banana Cv. Grand Naine
2.	Date of ratooning	:	1st oct 2013
3.	Spacing	:	1.5 m x 1.5 m.
4.	Plot size	:	6 m x 6 m
5.	Design	:	Randomized Block Design
6.	Number of treatments	:	9
7.	Number of replication	:	3
8.	Total number of plots	:	27
9.	Plant population/plot	:	16 plants
10.	Plant population	:	4444 plants
11.	RD of fertilizer	:	200g N: 40g P_2O_5: 200g K_2O

3.3.2 Treatment Details

Fertilizers Sources

a. Water soluble fertilizer	**$N:P_2O_5:K_2O$ (%)**
Special grade	9:5:33
Mono ammonium phosphate (MAP)	12:61:00
Sulphate of potash	00:00:50
b. Conventional fertilizer	
Urea	46:00:00
Di ammonium phosphate	18:46:00
Muriate of potash	00:00:60

Table 3.6 Details of treatments and symbol used

Symbol	Treatment details
T_1	Drip with 100% RDF (200:40:200 g NPK/plant) as per schedule with Urea, MAP, and SOP.
T_2	Drip with 80% RDF with Urea, MAP & SOP as per schedule.
T_3	Drip with 60% RDF with Urea, MAP & SOP as per schedule.
T_4	Drip with 80% RDF with 9:5:33 without N and P_2O_5 balancing.
T_5	Drip with 60% RDF with 9:5:33 without N and P_2O_5 balancing.
T_6	Drip with 80% RDF with 9:5:33 and N & P_2O_5 balanced as per schedule.
T_7	Drip with 60% RDF with 9:5:33 and N & P_2O_5 balanced as per schedule.
T_8	Drip with 100% RDF of CF applied through soil.
T_9	Drip with no fertilizer.

3.3.4 Fertilizer application

The conventional fertilizers (urea, diammonium phosphate and muriate of potash) were applied as 20 % N + full P_2O_5 and 20 % K_2O as a basal dose whereas remaining dose of N and K were applied in four splits of 20 % N and 20% K at 75, 120, 165 and 210 days after ratooning. The water soluble fertilizers were applied as per schedule through fertilizer injector pump. In all fertigation treatments, fertilizers were applied in 18 equal splits from date of ratooning. The details of fertilizer quantity (Table 3.7) and fertigation schedule is as given below.

Fertigation schedule for banana:

Portion of nutrients to be applied in 18 equal fortnight splits.

Days after ratoon	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
First 2 month	15	30	10
3-4 months	40	50	20
5-6 months	25	20	25
7 month	20	-	30
8-9 months	-	-	15
Total	**100**	**100**	**100**

3.3.5 Cultural operations

Various cultural operations were carried out in the experimental plot are presented in Table 3.8.

3.3.6 Earthing up

Loose soil in the inter row spaces was diverted towards plants on both sides manually to give support to the banana plants where laterals were laid along the row.

3.3.7 Irrigation scheduling

In case of drip system, irrigation water was applied at alternate days. The quantity of water to be applied and time of operation was calculated by using pan evaporation method (FAO-56) data. Irrigation system was operated at 1.0 kg/cm^2 pressure.

In case of surface irrigation method, irrigation were scheduled at 75 mm CPE.

3.3.8 Weeding

Weeding was necessary upto 6 months age of plant. Regular weeding was done (3 times) with manual labours. No chemicals were used for weed control.

Table 3.7. Fertilizer schedule of water soluble fertilizers as per schedule

Sr. No.	Time of application	Date of application	Grade of WSF	Total quantity of water soluble fertilizers per split per treatment (g/plant)						
				Treatments						
				T_1 : 100 % urea MAP & SOP	T_2 : 80 % urea MAP & SOP	T_3 : 60 % Urea, MAP and SOP	T_4 : 80 % 9:5:33 without balance	T_5 : 60 % 9:5:33 without balance	T_6 : 80 % 9:5:33 with balance	T_7 : 60 % 9:5:33 with balance
1.	0-2 months	1.10.13, 16.10.13, 1.11.13, 16.11.13	Urea, MAP, SOP 9:5:33	60.08: 19.67: 40: 00	48.09: 15.73 : 32: 00	36.04 : 11.80 : 24: 00	00: 00: 00: 48.48	00: 00: 00: 36.36	39.60: 11.80: 00: 48.48	29.73 : 8.85 : 00 : 36.36
2.	3-4 months	1.12.13, 16.12.13, 1.1.14, 16.1.14	Urea, MAP, SOP 9:5:33	160.24: 52.45: 80: 00	128.19: 41.96: 64: 00	96.14 : 31.47 : 48: 00	00: 00: 00: 96.96	00 : 00 : 00 : 72.72	115.41: 18.29: 00: 96.96	86.56: 13.72: 00 : 72.72
3.	5-6 months	1.12.14, 15.2.14, 1.3.14, 16.3.14	Urea, MAP, SOP 9:5:33	105.28 : 13.11 : 100: 00	84.22 : 10.48: 80: 00.00	63.16 : 7.87: 60: 00	00 : 00 : 00 : 121.21	00 : 00 : 00 : 90.90	63.10 : 0.65 : 00 : 121.21	47.33 : 0.49 : 00 : 90.91
4.	7 months	1.4.14, 16.4.14,	Urea, MAP, SOP 9:5:33	86.95: 00 : 120 : 00	69.56 : 00 : 00 : 00	52.17: 00 : 00 : 00	00 : 00 : 00 : 145.45	00 : 00 : 00 : 109.09	41.10: 00 : 00 : 145.45	30.83: 00 : 00 : 109.09
5.	8-9 months	1.5.14, 16.5.14, 1.6.14, 16.6.14	Urea, MAP, SOP 9:5:33	00 : 00 : 60 : 00	00 : 00 : 48 : 00	00 : 00 : 36 : 00	00 : 00 : 00 : 72.72	00 : 00 : 00 : 54.54	00 : 00 : 00 : 72.72	00 : 00 : 00 : 54.54
	Total		Urea, MAP, SOP 9:5:33	412.55: 85.23: 400: 00	330.06: 68.17: 224: 00	247.51: 51.14: 168: 00	00: 00: 00: 484.82	00: 00: 00: 363.61	259.21: 30.74: 00: 484.82	194.45: 23.06: 00: 363.61

Table 3.8 Cultural operations followed during experiment

Sr. No.	Field operations	Frequ-ency	Date
A.	**Irrigation**		
1.	Subsequent irrigation as per CPE		As per CPE
B.	**Post planting**		
1.	Earthing up	2	25.11.13, 18.12.13
C.	**Interculturing**	2	30.10.13, 4.11.13
1.	Weeding	2	15.10.13, 16.11.13
2.	Desukering upto flowering and then keeping one follower at each hill		Daily supervision
D.	**Fertilizers**		As per fertilizer schedule
E.	**Plant protection**		
1.	Spraying		
a.	Dithane M-45 + Diamethoate	1	16.11.13
b.	Dithane M-45	1	16.12.13
c.	Metasystox and Blitox	1	14.1.2014
F.	**Harvesting**	6	6.10.14, 20.10.14, 3.11.14, 17.11.14, 8.12.14, 31.12.14

3.3.9 Plant protection measures

At ratoon 2.5 g thimate was applied at each hill to control the soil borne pests and nematodes. Spraying with dithane M-45 (2.5 gm/lit) and Diamethoate 2 ml/lit was followed 15 days after ratoon for control of aphids and fungal diseases. Dithane M-45 (2.5gm/lit) was applied for control of fungal diseases (cigatoka) one month after ratoon. Metasystox (2 ml/lit) and Blitox (2.5gm/lit) were applied to control outbreak of thrips and fungal diseases two months after ratoon.

3.4 Water management

3.4.1 Water distribution system

The water used for irrigation by drip was lifted from bore well and subsequently stored in a storage tank of 40,000 lit capacity. When required, it was made available by using electric motor of 0.5 HP and supplied to the plots. The diagramatic view of main and manifold layout are shown in fig 3.3.

Details of drip design are as follows

1.	Type of dripper	:	Pressure compensating
2.	Discharge and number of drippers per plant	:	2 drippers 4 lph capacity
3.	Dripper spacing along the lateral	:	75 cm
4.	Lateral size	:	16 mm
5.	Lateral spacing	:	1.5 m
6.	Lateral length	:	6 m
7.	Number of laterals / treatment	:	4 laterals
8.	Manifold size	:	40 mm
9.	Length of manifold	:	6 m

10. Submain line size : 63 mm
11. Length of submain line : 60 m

3.4.2 Irrigation scheduling

The irrigation water was applied every alternate days by using the pan evaporation data through drip irrigation. The details of scheduling of irrigation are given in Appendix-I. The quantity of irrigation water was estimated by using formula FAO 56 (Allen *et al.*,1998).

$$Etc = Ep \times Kp \times Kc \qquad \text{.... } \mathbf{(3.1)}$$

Where,

Etc = Evapotranspiration of crop (mm/two days)

Ep = Pan evaporation (mm/two days)

Kc = Crop coefficient (as per crop growth stages)

Kp = Pan coefficient (0.7)

The net quantity of water requirement per emitter at every alternate day was calculated by following formula.

$$V = Etc \times S_1 \times S_2 \times Wa \qquad \text{.... } \mathbf{(3.2)}$$

Where,

V = Volume of water per two days in liters/plant

S_1 = Spacing between dripper (m)

S_2 = Spacing between lateral (m)

Wa = Wetted area (70 %)

The gross volume of water applied per emmiter per irrigation was calculated by using following formula.

$$Vg = \frac{V}{E} \qquad \text{.... } \mathbf{(3.3)}$$

Where,

Vg = Gross volume of water applied per alternate days in litres/emmiter/plant.

V = Volume of water applied per two days in litre.

E = Emission uniformity of the system was calculated by

$$T = \frac{Vg}{Q \times n} \quad \text{.... (3.4)}$$

Where,

T = Operating time of system, hrs.

Vg = Gross volume of water applied per two days in litre

Q = Emitter discharge, (4 lph)

n = No. of dripper/plant

3.4.3 Water requirement in surface irrigation

The water requirement of the crop was determined by the procedure described by Michael (2010). The formula used was

$$WR = IR + ER + S \quad \text{.... (3.5)}$$

Where,

WR = Water requirement, mm

IR = Irrigation requirement, mm

ER = Effective rainfall, mm

S = Soil moisture contribution, mm

The soil moisture contribution was considered zero as the water table was too deep from soil surface.

Irrigation requirement was considered by taking the recommendation of parent university M.P.K.V., Rahuri. 8 cm irrigation depth was applied at every 75 mm CPE.

Volume of water to be applied/plot was computed by using equation.

$$V = D \times L \times W \quad \text{.... (3.6)}$$

Where,

V = Volume of water to be applied (lit)

D = Depth of water (mm)

L = Length of plot (m)

W = Width of plot (m)

3.4.4 Field water use efficiency (FWUE)

Field water use efficiency (FWUE) is the ratio of marketable produce of the crop to the total amount of water use (Michael, 2010).

$$FWUE = \frac{Y}{TWU} \quad \text{.... (3.7)}$$

Where,

FWUE = Field water use efficiency, kg/ha-mm

Y = Yield, kg ha^{-1}

TWU = Total water use, mm

3.4.5 Measurement of soil moisture

The most of the banana roots are concentrated up to 60 cm of soil with only few roots below 75 cm. This indicates that water uptake below 80 cm is most unlikely; therefore, a depth of 80 cm for the measurement of soil moisture was considered when planning the observations.

The soil samples were taken by soil sampler at 0, 20, 40, 60 and 80 cm at vertically and horizontally from emitter as per grid shown below. Hence, twenty five observations from each treatment were taken for moisture studies. These samples were collected in moisture box and then fresh weight of moisture was recorded. Then samples kept in hot air oven for 24 hours at a control temperature of 105^{0}c. After that dry weight of moisture sample were recorded.

```
           0 cm    20 cm     40 cm   60 cm   80 cm
                  ---------->
0 cm   |   0---------0----------0---------0--------0
20 cm  v   0---------0----------0---------0--------0
40 cm      0---------0----------0---------0--------0
60 cm      0---------0----------0---------0--------0
80 cm      0---------0----------0---------0--------0
```

Where, 0 is the place where moisture sample taken at corresponding distance and depth from the selected emitter (one) in each treatment. % moisture was calculated by using following formula (Micheal, 2010),

$$\%\ \text{moisture} = \frac{\text{Fresh weight} - \text{Oven dry weight}}{\text{Oven dry weight}} \times 100 \quad \text{.....(7)}$$

The moisture observations were recorded at every 3 months intervals upto the harvest.

3.5 Different forms of potassium

Different forms of potassium were determined by following standard methods as given below.

3.5.1 Water soluble potassium

The water soluble K was determined by using the method given by Richard (1954). In this method 5 g air dry soil was placed in conical flask. Twenty five milliliter of distilled water was added in it (1:5 ratio) and shaken for one hour on mechanical shaker. The content was centrifuged for 5 to 7 minute at 5000 rpm. The content was collected from centrifuge tube and filtered. From filtrate K was estimated on flame photometer.

3.5.2 Exchangeable potassium

The method described by Knudsen et al., (1982) was used for the determination of exchangeable K. In this method 5 g soil was placed in 50 mL centrifuge tube, 25 mL 1*N* NH_4OAc was added and centrifuge tube was shaken for 10 minutes. Then, it was centrifuged at 1000 rpm, the supernatant liquid was decanted into a 100 mL volumetric flask. Three additional extractions were made in the same manner. The combined extraction was diluted to 100 mL with 1*N* NH_4OAc and potassium was determined by flame photometer.

3.5.3 Non-exchangeable potassium

It was determined by the method of Wood and De Turk (1941), (1*N* boiling HNO_3). In this method 2.5 g of finely ground soil (1mm) was added in 100 ml Erlenmeyer flask. 25 mL of 1*N* HNO_3 was added and the flask was placed on hot electrical plate. The suspension was boiled gently for 10 min. Then the flask was removed and after cooling, the content was filtered and the filtrate was received in a 100 mL volumetric flask. The soil was washed for four times with 15 mL portions of 0.1 *N* HNO_3. The solution was cooled, diluted to make volume, mixed thoroughly and K was determined using flame photometer.

3.5.4 Total potassium

0.5 g soil was placed in a platinum crucible, moistened with a few drops of 18 *N* H_2SO_4. Then 1 ml 70 % $HClO_4$ and 5 ml 48 % HF were added. The 2/3rd of the crucible was covered with platinum lid and placed on electrical hot plate regulated at 200 - 225^{0}C after which acids were evaporated to dryness. The heating rate was so regulated that H_2SO_4 fumes evolved while the solution did not boil. Additional portions of the H_2SO_4 and HF acids for a similar evaporation were added for total 3 treatments. Few drops of H_2SO_4 were then added to the mixture and heated to remove fluorides. The crucible was cooled and 6 *N* HCl was added. The suspension was diluted to 20 mL with distilled water in a crucible and boiled genetly on low flame. The solution of dissolved residue was transferred into 100 mL volumetric flask and K was determined after appropriate dilutions on flame photometer (Jackson, 1973).

3.5.5 Soil Available potassium

It was calculated by summation of water soluble potassium and exchangeable potassium.

3.6 Biometric observations

It included growth and development studies.

3.6.1 Sampling technique

For recording various observations, five plants were randomly selected from each treatment in each replication. The sample plants were tagged for identification. The observations *viz.*, height, pseudostem girth, number of functional leaves, etc., were recorded at an interval of three month.

3.7 Growth observations

3.7.1 Plant height

The height of pseudostem in cm, from ground level to throat of the plant was recorded with the help of metallic tape.

3.7.2 Girth of the stem

Girth of pseudostem in cm was recorded at the base of pseudostem 15 cm above the ground level.

3.7.3 Number of functional leaves

The fully opened leaves which were physiologically active were counted as functional leaves.

3.7.4 Mean days to flowering

When 15 cm portion of lower bud was visible. It was taken as days required for flowering after planting.

3.7.5 Mean days to maturity

When most of the fingers from the bunch started changing their colour from dark green to light green and when edges of the individual fruit disappeared and when tapped, gave metallic sound, was considered as physiological maturity stage and days were counted from shooting to physiological maturity stage.

3.7.6 Total duration

Days from planting to physiological maturity stage were counted and recorded.

3.8 Yield an yield contributing characters

3.8.1 Bunch weight

It was measured by using the spring balance.

3.8.2 Hands per bunch

Number of hands from individual bunch were counted and recorded.

3.8.3 Number of fingers per bunch

Total number of fingers per bunch were counted from selected plants in net plot and average was drawn.

3.8.4 Length of finger

Middle two fingers of second hand from base were taken to measure the length of fruit. The length was measured in cm from the attached portion of pedicel of fruit up to apex along the curved surface.

3.8.5 Girth of fruit

Middle circumference of the same selected fruits was measured in cm.

3.9 Quality parameters

3.9.1 Pulp : Peel ratio

The same fruits were used to measure the pulp : peel ratio and it was measured on w/w basis.

3.9.2 Total soluble solids (T.S.S)

The two fingers, which were used to measure the length, girth and pulp : peel ratio were taken after ripening for quality studies. The pulp of the fruit was taken in mortar and crushed to prepare a homogenous paste. Then the juice was extracted with help of muslin cloth and TSS was recorded with the help of a Hand refractometer.

3.9.3 Acidity

The same pulp was used for the determination of acidity. Ten gm of pulp was blended with 200 ml of water. It was filtered and the extract was used for titration.

Fifty ml of the above extract was taken in a conical flask and titrated against 0.01 N NaOH using phenolphthalein as an indicator. The acidity is expressed as grams of gluconic acid per 100 gm of pulp.

3.9.4 Organoleptic taste

Sample banana fruit from each treatment was given to staff and students for taste and sensory evaluation was carried out by giving point to each taste.

3.10 Soil analysis

3.10.1 Physical properties of soil

The method used for estimation of various physical properties of soil was indicated in table 3.1

3.10.2 Chemical properties of soil

The method used for estimation of various chemical properties of soil was indicated in table 3.1

3.10.3 Periodical soil analysis for available N, P, K

The soil sample from the field before ratooning 3, 6, 9 month and at harvest were collected and analysed for available N, P and K content in soil.

3.10.4 Nutrient uptake

Single plant from each treatment was selected and bunch, stem and leaves were weighted separately as fresh weight. Then middle portion of stem, leaves and central banana fruit in a bunch were taken, weighted and dried in oven as a representative sample. Then it was grinded and 0.2 g of sample was digested with H_2SO_4 and H_2O_2 from this the content of NPK was determined.

3.11 Economics

3.11.1 System cost per ha

The cost of each unit of the drip system was noted and summed up. Then it was calculated for per ha.

3.11.2 Cost of cultivation

Total expenditure incurred right from preparatory tillage to harvesting were recorded and cost of cultivation was calculated.

3.11.3 Gross monetary returns

The gross monetary returns per hectare were worked out by considering the yield from different treatmentss and the prevailing market prices. The returns from all treatments were considered as gross monetary returns.

3.11.4 Net return

The net returns were worked out by substracting the cost of production from the gross returns, for each treatment respectively.

3.11.5 Benefit cost ratio

The benefit cost ratio was worked out by dividing the cost of production to the gross monetary returns in each treatment under study.

3.11.6 Net profit / mm of water

Net profit per mm of water was worked out by dividing the net seasonal income (Rs/ha) by the total water used. This was worked out for each treatment respectively.

3.12 Statistical analysis

The data relating to each character was statistically analyzed by randomized block design. Simple correlation coefficients were calculated among and between different forms of K, morphological character, crop yield, NPK uptake, NPK availability in soil at 3, 6, 9 month after ratoon and at harvest. A standard method of analysis of variance indicated by Panse and Sukhatme (1967) was used.

4. RESULTS AND DISCUSSION

The results obtained from the present investigation are presented in the tables in appropriate form after the necessary statistical analysis. The results obtained are interpreted in an integrated manner to draw the broad conclusions in succeeding chapter.

4.1 Forms of potassium

4.1.1 Water soluble potassium

The data in respect of water soluble K in soil as influenced by period and level of fertilizer are presented in Table 4.1 and Fig. 4.1. The periodical availability of water soluble K was increased with period and maximum was observed at 9 months after ratoon and decreased at harvest due to more removal of water soluble K by plant. The range of water soluble K content in soil was 12.60- 31.50 mg kg^{-1}. At 9 months of crop growth (Table 4.1) availability of water soluble potassium was significantly maximum in treatment T_1 (RD with 100 % WSF through urea, MAP and SOP in 18 splits) (31.5 mg kg^{-1}) over all other treatments. However, it was at par with T_6, T_2, T_4, and T_7. Treatment T_9 (No fertilizer treatment) recorded lowest water soluble K (15.6 mg kg^{-1}) content in soil. The water soluble fertilizer recorded higher water soluble K fractions as compared to conventional fertilizer (T_8). This might be due to release of nutrient in water soluble and readily available form from water soluble fertilizers. Similar trend of water soluble K content in soil was observed at 3rd and 6th months after ratoon and at harvest. This form of K is directly taken up by plants and microbes and is

Table 4.1 Water soluble K in soil as influenced by various treatment in ratoon banana

Treatment	Water soluble K (mg/kg^{-1})			
	3 months after ratoon	6 months after ratoon	9 months after ratoon	At harvest
T_1	24.5	28.4	31.5	20.6
T_2	23.1	27.1	30.5	15.5
T_3	21.1	25.1	29.1	13.1
T_4	22.3	26.3	30.3	15.1
T_5	20.4	24.5	28.4	12.5
T_6	23.6	27.6	31.0	18.3
T_7	21.5	25.6	29.5	13.5
T_8	18.3	22.3	26.3	10.3
T_9	12.6	14.6	15.6	6.5
S.Em. $\pm$	1.14	0.88	1.10	1.38
CD at 5 %	3.43	2.64	2.32	4.13
Mean	20.86	24.6	28.08	13.9

also subjected to leaching. It is usually found in low quantities as compared to other forms of K (Martin and Spark, 1985).

4.1.2 Exchangeable potassium

The data in respect of exchangeable K in soil as influenced by period and level of fertilizers are presented in Table 4.2 and Fig.4.2. The periodical availability of exchangeable K was increased with period and maximum exchangeable K was recorded at 9 month after ratoon and decreased at harvest due to more removal of exchangeable K by plant. The range of exchangeable K in soil was observed to be 97.3 – 192.3 mg kg^{-1}.

At 9 months crop growth (Fig. 4.2) availability of exchangeable K was significantly higher in treatment T_1 (DI with 100 % RD of WSF through urea, MAP and SOP in 18 splits as per schedule) (192.30 mg kg^{-1}) over all other treatments except T_6 (DI with 80 % RD of WSF through 9:5:33 with N, P balance), T_2 (DI with 80 % RD with urea, MAP, SOP in first 150 days) and T_4 (DI with 80 % RD of WSF through 9:5:33 without N, P balance). Treatment T_9 (No fertilizer treatment) recorded lowest exchangeable K (103.5 mg kg^{-1}) content in soil. The water soluble fertilizers recorded higher availability of exchangeable K as compared to conventional fertilizers T_8 (156.4 mg/kg).

Similar trend of exchangeable K content in soil was observed at 3rd and 6th months after ratoon (Fig. 4.2) and at harvest. Exchangeable K is held by the negative charges of clay minerals and organic matter. This form of K is available to plant. Addition of water soluble fertilizers as per crop growth stages enhanced the release of potassium into the easily available

Table 4.2 Exchangeable K in soil as influenced by various treatment in ratoon banana

Treatment	Exchangeable K (mg kg^{-1})			
	3 months after ratoon	6 months after ratoon	9 months after ratoon	At harvest
T_1	162.3	180.6	191.3	150.3
T_2	159.3	176.7	186.6	148.3
T_3	145.7	165.3	173.5	136.7
T_4	158.6	175.4	185.2	146.6
T_5	133.3	154.4	165.5	139.2
T_6	160.4	178.3	190.6	149.6
T_7	150.3	169.4	179.3	137.5
T_8	125.1	144.5	156.4	113.4
T_9	97.3	102.4	103.5	87.6
S.E. $\pm$	1.27	1.33	1.70	1.23
CD at 5 %	3.80	4.00	5.10	3.70
Mean	143.0	160.5	170.32	133.91

exchange pool from its non exchangeable form. Similar observations were recorded by Pal *et al.* (1996) in bench mark soil series of Gujarat.

4.1.3 Non-exchangeable potassium

The data in respect of non exchangeable K in soil as influenced by period and level of fertilizer are presented in Table 4.3 and Fig. 4.3. The periodical availability of non exchangeable K was increased with period and was maximum at 9 months after ratoon and decreased at harvest. The range of non exchangeable K content in soil was from 549.64-761.6 mg kg^{-1}.

At 9 months of crop growth (Fig. 4.3) content of non exchangeable K was significantly higher in treatment T_1 (DI with 100 % RD of WSF through urea, MAP and SOP in 18 splits as per schedule) (761.60 mg kg^{-1}) over other treatments. However, it was at par with T_6, T_2 and T_4. Treatment T_9 recorded the lowest non exchangeable K (415.7 mg kg^{-1}) content in soil. The water soluble fertilizers recorded the higher content of non exchangeable K fraction as compared to conventional fertilizers T_8 (710.5 mg kg^{-1}).

Similar trend of non exchangeable K content in soil was observed at 3 and 6 months after ratoon (Fig. 4.3) and at harvest. The non exchangeable K content in soil increased with increase in period upto 9 months might be attributed to the appreciable conversion of exchangeable K to water soluble K resulting in release of non exchangeable K to maintain the equilibrium. Similar observations were recorded by Dhanorkar *et al.* (1994) in long term application of NPK in Vertisols.

Table 4.3 Non-exchangeable K in soil as influenced by various treatment in ratoon banana

Treatment	Non-exchangeable K (mg kg $^{-1}$)			
	3 months after ratoon	6 months after ratoon	9 months after ratoon	At harvest
T_1	696.7	728.6	761.6	651.7
T_2	692.6	724.9	756.9	647.7
T_3	686.7	716.7	745.7	632.7
T_4	691.6	722.5	753.5	646.9
T_5	684.7	714.6	744.6	634.6
T_6	694.8	726.7	759.7	649.7
T_7	688.8	718.6	748.6	638.6
T_8	650.6	680.5	710.5	605.4
T_9	549.6	551.1	555.6	415.7
S.E. $\pm$	1.70	2.00	2.70	1.73
CD at 5 %	5.10	6.00	8.10	5.20
Mean	670.58	697.81	725.10	612.00

4.1.4 Available potassium

The data in respect of available K in soil as influenced by period and levels of fertilizer are presented in Table 4.4. The periodical availability of K was increased with period and was maximum at 9 months after ratoon and decreased at harvest due to removal of available K by plant. The range of available K content in soil was observed to be 108.0 – 222.5 mg kg^{-1}.

At 9 months of crop growth (Fig. 4.4.) availability of K was significantly maximum in treatment T_1 (222.5 mg kg^{-1}) over other treatments. However, it was at par with T_6, T_2 and T_4. The release of higher available K fractions in soil from water soluble fertilizers as compared to conventional fertilizer might be due to more solubility of WSF fertilizers in soil which will increase the availability of nutrients in root zone. Treatment T_9 recorded the lowest available K (132.2 mg kg^{-1}) content in soil. The water soluble fertilizer recorded higher available K fractions as compared to conventional fertilizer T_8 (173.4 mg/kg).This might be due to release of available K fractions in water soluble and readily available form.

Similar trend of available K content in soil was observed at 3 and 6 months after ratoon (Fig. 4.4) and at harvest. Water soluble and exchangeable K contributed 31.5 and 192.3 mg kg^{-1} to the soil available K. Dhanorkar *et al.* (1994) observed increase in available K due to fertilizer application as it was bound to enrich K status. Singh *et al.* (2001) also reported that use of fertilizer increased the soil available K status of the soil.

Table 4.4 Soil available K in soil as influenced by various treatment in ratoon banana

Treatment	Soil available K (mg kg^{-1})			
	3 months after ratoon	6 months after ratoon	9 months after ratoon	At harvest
T_1	186.0	204.5	221.5	168.3
T_2	180.9	200.3	218.6	167.2
T_3	166.8	187.4	206.6	158.5
T_4	180.0	199.7	217.3	165.4
T_5	172.7	180.3	201.5	144.5
T_6	182.4	203.4	220.7	167.5
T_7	175.5	192.6	212.5	161.4
T_8	138.7	170.4	173.4	125.3
T_9	108.0	125.3	132.2	98.0
S.E. $\pm$	0.66	2.7	0.38	1.00
CD at 5 %	4.40	4.80	4.20	3.00
Mean	165.1	185.1	200.4	150.6

4.1.5 Lattice potassium

The data in respect of lattice K content in soil as influenced by period and level of fertilizers are presented in Table 4.5. The periodical availability of lattice K was increased with period and maximum lattice K was observed at 9 months after ratoon and decreased at harvest due to more removal of lattice K by plant. The range of lattice K in soil was observed to be 2507.9 - 4691.0 mg kg^{-1}.

At 9 months of crop growth (Fig. 4.5.) availability of lattice K was significantly maximum in treatment T_1 (DI with 100 % RD of WSF through urea, MAP and SOP in 18 splits as per schedule) (4691 mg kg^{-1}) over all other treatments except T_6, T_2 and T_4. Treatment T_9 recorded the lowest lattice K (3010.4 mg kg^{-1}) content in soil. The availability of lattice K fractions was improved in fertigation treatment as compared to conventional fertilizers applied through soil. Similar trend of lattice K content in soil was observed at 3rd and 6th months after ratoon (Fig. 4.5) and at harvest.

4.1.6 Total potassium

The data in respect of total K in soil as influenced by period and level of fertilizers are presented in Table 4.6 and Fig. 4.6. The periodical content of total K was increased with period and maximum at 9 months after ratoon and decreased at harvest due to more removal of total K by plant. The range of total K in soil was observed between 3001.5 - 5600.2 mg kg^{-1}. The content of total K fractions in soil was improved in fertigation treatment as compared to conventional fertilizers

Table 4.5 Lattice K in soil as influenced by various treatment in ratoon banana

Treatment	Lattice K (mg kg^{-1})			
	3 months after ratoon	6 months after ratoon	9 months after ratoon	At harvest
T_1	3520.4	4190.0	4591.0	3249.5
T_2	3505.9	4138.5	4582.3	3196.1
T_3	3285.3	3970.1	4370.1	3037.2
T_4	3503.5	4131.6	4563.5	3186.1
T_5	2997.3	3760.7	4248.2	2970.7
T_6	3515.6	4161.4	4597.2	3222.5
T_7	3492.5	4110.1	4541.4	3161.7
T_8	2875.3	3720.7	4194.7	2840.2
T_9	2507.9	2903.5	3010.4	2405.7
S.E. $\pm$	15.34	25.32	29.68	21.56
CD at 5 %	42.46	63.78	84.67	70.76
Mean	3244.8	3899.7	4310.9	3027.2

Table 4.6 Soil total K in soil as influenced by various treatment in ratoon banana

Treatment	Soil total K (mg kg^{-1})			
	3 months after ratoon	6 months after ratoon	9 months after ratoon	At harvest
T_1	4420.5	5100.9	5600.0	4055.3
T_2	4370.6	5063.3	5550.2	3990.4
T_3	4090.4	4947.4	5305.0	3780.3
T_4	4366.3	5051.1	5529.0	3970.5
T_5	3746.6	4626.6	5093.2	3693.5
T_6	4386.6	5093.3	5569.0	4033.3
T_7	4350.3	5026.6	5504.0	3960.4
T_8	3506.6	4386.6	4893.1	3426.0
T_9	3001.5	3402.6	3501.4	2802.8
S.E. $\pm$	23.08	17.00	24.3	28.27
CD at 5 %	64.70	51.00	73.00	84.80
Mean	4029.90	4744.28	5171.68	3745.85

applied through soil. At 9 months of crop growth (Fig. 4.6) availability of total K was significantly maximum in treatment T_1 (5600.20 mg kg^{-1}) over other treatments. However, it was at par with T_6, T_2 and T_4. The maximum availability under fertigation treatment might be due to more release of K fractions in water soluble and readily available form. Treatment T_9 recorded the lowest total K (3500.4 mg kg^{-1}) content in soil. The release of total K content was higher in 100% RD through WSF treatment (T_1) as compared to lower levels. This might be due to higher amount of fertilizer added. More quantum of water available beneath the dripper in the soil, there was corresponding increase in available nutrients in soil. This inferred direct association between different forms potassium in soil (Kaul and Gupta, 2005).

Similar trend of total K content in soil was observed at 3 and 6 months after ratoon (Fig. 4.6) and at harvest. In general, these soils are rich in total K due to the dominance of K bearing minerals. Similar results were also reported by Singh and Datta (1986) for the soils of Mizoram.

4.2 Growth

Periodical growth observations were recorded at an interval of three months for major growth contributing characters *viz.* plant height, pseudostem girth and number of functional leaves. Periodical data of all these parameters are given in Tables 4.7, 4.8 and 4.9, respectively.

4.2.1 Plant height

The periodical data in respect of the plant height (m) with rate of increase in growth are presented in Table 4.7 and Fig. 4.7.

It was observed that for the first three months, height of the plants were nearly same (1.11 m) except T_1 (100% WSF) which was slightly higher (1.15 m) and no fertilizer treatment (T_9) recorded lowest plant height (0.97 m). After six months, banana plant showed increasing trend in height with the increase in dose of fertilizers. It was also observed that treatment T_1 recorded significantly maximum height (1.80) over all other treatments except T_6 (80 % WSF) (1.78 m) and T_2 (DI with 80 % RD with urea, MAP, SOP in first 150 days) as compared to T_4 where as 80 % RD of WSF and T_8 i.e. DI with conventional fertilizer applied through soil. This might be due to more quantity of fertilizers were given to T_1, T_6 and T_2 in first four months. After nine months plant height showed increasing trend with increase in fertilizer levels. At harvest the height showed the similar trend as that of 3, 6 and 9 months after ratoon. These results are in conformity with those reported by Kode (2001).

Application of water soluble fertilizers recorded higher plant height than that of application of straight fertilizers and 60 and 80 per cent of fertilizer levels (Pawar *et al.*, 1997).

4.2.2 Pseudostem girth

The periodical data regarding the pseudostem girth (cm) and rate of increase in the girth with period are presented in Table 4.8 and Fig. 4.8. From the data, it is

Table 4.7 Periodical plant height as influenced by various treatment in ratoon banana

Treatment	Plant height (m)			
	3 months after ratoon	6 months after ratoon	9 months after ratoon	At harvest
T_1	1.15	1.80	3.16	3.04
T_2	1.11	1.76	3.13	2.98
T_3	1.10	1.68	3.08	2.93
T_4	1.10	1.73	3.10	2.96
T_5	1.10	1.66	3.07	2.91
T_6	1.12	1.78	3.14	2.99
T_7	1.10	1.70	3.09	2.94
T_8	1.07	1.66	2.97	2.89
T_9	0.97	1.32	2.10	2.69
S.E. $\pm$	0.014	0.017	0.02	0.027
CD at 5 %	0.04	0.05	0.06	0.08
Mean	1.10	1.68	2.97	2.92

Table 4.8 Periodical pseudostem girth as influenced by various treatment in ratoon banana

Treatment	Pseudostem girth (cm)			
	3 months after ratoon	6 months after ratoon	9 months after ratoon	At harvest
T_1	36.68	55.6	59.13	61.10
T_2	35.45	52.20	57.89	59.50
T_3	30.90	47.34	55.34	58.80
T_4	33.73	50.38	57.02	58.60
T_5	30.36	46.5	55.12	58.70
T_6	36.05	54.34	58.78	59.90
T_7	29.12	48.78	54.36	59.20
T_8	32.21	46.04	53.12	58.50
T_9	26.2	43.07	51.10	57.20
S.E. $\pm$	0.42	1.21	0.41	0.53
CD at 5 %	1.25	3.64	1.24	1.60
Mean	32.3	49.36	55.76	59.03

observed that pseudostem girth followed the increasing trend of growth upto six months, but thereafter, it was relatively constant. However, at all the stages of observations *i.e.* three months, six months, nine months and at harvest, it was observed that pseudostem girth increased with increasing levels of fertilizers.

At harvest treatment T_1 recorded significantly maximum pseudostem girth (60.01 cm) over all other treatments except T_6 and T_2). At all the stages, no fertilizer (T_9) treatment recorded the lowest pseudostem girth (57.2 cm). The maximum pseudostem girth was recorded in fertigation treatment as compared to conventional fertilizer applied through soil (T_8). This might be due to release of nutrients in proper proportion as per plant growth stages which results in utilization of food material for flowering and fruiting.

Similar trend of results were also reported by Hegade and Srinivas (1990), Berad (1996) and Pawar *et al.* (1997).

4.2.3 Number of functional leaves

The data in respect of the number of functional leaves are presented in Table 4.9 and in Fig. 4.9.

From the data, it can be observed that, for first three months, T_1 (100 % WSF) treatment recorded significantly maximum number of functional leaves (16.00) over all other treatments except T_6 and T_2. Similar results in respect of number of leaves were observed at 6 months, where both the treatments T_1 and T_6 recorded more number of leaves (17 and 16) than remaining treatments. It was also observed

Table 4.9 Number of leaves of banana as influenced by various treatment in ratoon banana

Treatment	Number of functional leaves			
	3 months after ratoon	6months after ratoon	9 months after ratoon	At harvest
T_1	16.00	17.00	13.00	8
T_2	15.54	15.66	12.33	7
T_3	14.01	14.66	11.66	7
T_4	15.35	15.60	12.00	7
T_5	13.34	14.66	11.33	6
T_6	15.68	16.00	12.66	8
T_7	14.68	15.33	12.00	7
T_8	12.70	14.33	11.00	6
T_9	11.19	14.00	10.66	6
S.E. $\pm$	0.23	0.47	0.23	0.33
CD at 5 %	0.70	1.40	0.70	0.99
Mean	14.26	15.14	11.88	7.07

that with the increase in levels of fertilizers, number of leaves were also increased. At nine months and at harvest number of leaves reduced from fifteen to twelve and eight, respectively.

Treatment T_8 (100 % CF through soil) also shows significantly less number of functional leaves as compared to fertigation treatments. This was because of the reason that fruits requires more food material for growth and maturity, which was translocated from the leaves. Therefore, less number of leaves were observed in conventional fertilizer treatment as compared to fertigation. Similar results were reported by Pawar *et al.* (1997).

4.3 Duration of the crop

4.3.1 Days required to flowering

The data pertaining to days required to flower from date of ratoon are presented in Table 4.10 and graphically represented in Fig. 4.10. From the data, it can be observed that treatment T_1 required minimum number of days to put it's flower out (241 days). Treatment T_6 (242 days) and T_2 (244 days) also recorded relatively less number of days to flower than rest of treatments. Treatment T_9 (No fertilizer) took maximum days for flowering as compared to drip irrigated treatments (290 days). Treatment T_8 required significantly more days for flowering (258 days) than fertigation treatment T_1. The earliness in flowering in fertigation treatments (T_1 and T_6) over other treatments could be attributed to optimum availability of nutrients at all stages as well as better below and above ground microclimate resulting in shortening of vegetative phase and making it to put earlier flowers.

Table 4.10 Duration of the crop as influenced by different treatments in ratoon banana

Treatment	Mean days to flowering	Mean days to maturity	Total crop duration
T_1	241	322	332
T_2	244	333	351
T_3	247	342	353
T_4	245	336	352
T_5	255	345	357
T_6	242	330	346
T_7	246	342	352
T_8	258	352	362
T_9	290	381	385
S.E. $\pm$	0.987	0.631	0.641
CD at 5 %	2.957	1.81	1.92
Mean	252	342.5	354.4

These results confirmed the earlier findings reported by Hegade and Srinivas (1990).

In water soluble fertilizer treatments positive response to early flowering was observed with increased fertilizer levels. These fertilizers proved superior to straight fertilizers. Increasing dose of fertilizers also had a significant effect over days to flowering. The results obtained confirmed the findings of previous fertilizer trials on banana conducted by Chattopadhyay and Bose (1986) and Chemte (2000).

4.3.2 Maturity period

The data pertaining to days required to fruit maturity are presented in Table 4.10 and in Fig. 4.10. From the data, it was observed that treatment T_1 recorded minimum and significantly less days to maturity (322 days) than all other treatments. Treatment T_8 required maximum days as compared with T_1, T_6 and T_7). Treatment T_9 recorded maximum and significantly more days to maturity (381.00). Days to maturity were reduced with increased levels of fertilizers and thus, negative correlations were observed between increased levels of fertilizers and days required to fruit maturity. Similar results were also reported by Singh *et al.* (1974).

4.3.3 Total duration

The data regarding total duration are presented in Table 4.10 and in Fig. 4.10. It was observed that treatment T_1 (332) completed it's life cycle earlier as compared to all other treatments. Treatment T_6 completed life cycle (346 days) latter than T_1. Application of conventional fertilizer through soil required more days as compared to the application of water soluble fertilizers. T_9 (No fertilizer) treatment took significantly more days (385 days) to complete it's life cycle.

From these results it can be concluded that with the increase in levels of fertilizers and application of fertilizers as per crop growth stages reduced the crop duration. The data also revealed that total crop duration can be reduced by about 15 days due to fertigation. The results obtained were in conformity with those reported earlier by Hegade and Srinivas (1991), Singh *et al.* (1997) and Divekar (2001).

4.4 Yield and yield contributing characters

4.4.1 Length of finger

The data regarding the length of finger (cm) are presented in Table 4.11. The results revealed that fertigation through drip dominated over the conventional fertilizer application treatments in regards to length of finger. The significantly the higher finger length was recorded in T_1 (23.26 cm), however, it was at par with T_6 (22.76 cm) and T_2 (22.67 cm). The finger length was improved in fertigation treatments as compared to application of fertilizers through soil (T_8) (20.31cm). This might be due to more availability of nutrients at proper growth stage in fertigation treatment than straight fertilizer application through soil. Treatment T_9 (19.01 cm) recorded the shorter length of finger. Length of finger was increased with an increased levels of fertilizers.

Table 4.11 Length and Girth of banana fingers as influenced by various treatment in ratoon banana

Treatment	Length of fingers (cm)	Girth of fingers (cm)
T_1	23.26	13.07
T_2	22.67	12.64
T_3	21.16	11.87
T_4	21.65	12.47
T_5	20.61	11.56
T_6	22.76	12.88
T_7	21.48	12.15
T_8	20.31	11.08
T_9	19.01	8.17
S.E. $\pm$	0.20	0.15
CD at 5 %	0.60	0.44
Mean	21.33	11.77

4.4.2 Girth of finger

The data pertaining to girth of the finger (cm) are presented in Table 4.11. Treatment T_1 recorded significantly maximum finger girth (13.07 cm) over other treatments. However, it was at par with 80 and 60 per cent WSF treatments. Treatment T_8 showed finger girth (11.07 cm) higher than T_9. Treatment T_9 recorded the less finger girth (8.17 cm) than other treatment. Girth of finger was increased with an increased fertilizer levels.

4.4.3 Number of hands bunch^{-1}

The data pertaining to number of hands per bunch are presented in Table 4.12. From the data it is clear that treatment T_1 recorded significantly higher number of hands (9.07) than the other treatments. However, it was at par with T_6 and T_2). Treatment T_9 (6.40) recorded the lowest number of hands.

Water soluble fertilizers registered significant variation in number of hands per bunch as compared to straight fertilizers. Fertilizer application time affect the number of hands per bunch markedly. Similar results were reported by Deolankar and Firake (2001).

4.4.4 Number of fingers bunch^{-1}

From the data in Table 4.12 it was observed that number of fingers per bunch in various treatments differed significantly. The number of fingers per bunch was observed significantly higher in treatments T_1 (156.33). However, it was at par with T_6 (80 % RD 9:5:33) (148.66). Treatment T_9 (112.33)

Table 4.12 Yield and yield contributing characters of banana as influenced by different treatments in ratoon banana

Treatment	Number of hands/ bunch	Number of finger/ bunch	Bunch weight (kg)	Yield (t/ha)
T_1	9.07	156.33	18.03	82.35
T_2	8.56	142.12	17.18	77.21
T_3	8.00	133.33	15.41	67.89
T_4	8.37	138.66	16.62	72.98
T_5	7.66	131.36	14.71	65.52
T_6	8.67	148.66	17.75	79.66
T_7	8.34	136.7	16.35	70.84
T_8	7.3	129.64	13.81	60.23
T_9	6.4	112.33	11.31	48.08
S.E. ±	0.17	2.57	1.65	1.84
CD at 5 %	0.51	7.70	1.50	5.44

recorded the lowest number of fingers per bunch. This was due to no fertilizer application and lower uptake of nutrients.

From the Table 4.12, it was observed that different levels of fertilizers and application as per growth stages significantly affected the number of fingers per bunch. Similarly, sources of fertilizer *i.e.* water soluble fertilizers significantly increased the number of fingers per bunch over the straight fertilizers. These results are in confirmation with the findings of Nalina *et al.* (2007), Deolankar and Firake (2001).

4.4.5 Bunch weight

The data regarding the average bunch weight (kg) are presented in Table 4.12. The data revealed that treatment T_1 (18.03 kg) registered maximum bunch weight but it was at par with treatment T_6 (17.75 kg), T_2 (17.18 kg) and T_4 (16.62 kg). The lowest bunch weight was observed in T_9 (11.31 kg).

From the data it was clear that the levels of fertilizers application affected the bunch weight significantly. Sources of fertilizer also had little effect on the bunch weight. The water soluble fertilizer showed significant effect over soil application method with almost 4.22 kg increase in average bunch weight. This might be due to application of conventional fertilizer through soil and uptake was very low which ultimately resulted into reduced bunch weight. These results are in conformity with the research findings of Berad (1996), Deolankar and Firake (2001) and Nalina *et al.* (2007).

4.4.6 Yield

The data regarding the yield of banana in tones ha^{-1} are presented in Table 4.12 and graphically depicted in Fig. 4.11. The bunch weight itself is the function of photosynthesis by plant and their translocation efficiency. The photosynthate production in turn are affected by all the growth parameters such as plant height, number of leaves and yield parameters such as length of finger, girth of finger, number of hands per bunch, number of fingers per bunch and individual bunch weight.

From the data, it was observed that treatment T_1 (82.35 t/ha) recorded significantly higher yield as compared to other treatments. However, it was at par with T_6 and T_2 .The banana yield obtained under T_3 was (67.89 t/ha) which was at par with T_8 whereas 100 % RD of CF (60.23 t/ha) was applied through soil. This showed that fertilizer application as per growth stages resulted into more yield. Overall, it was observed that yield increased with increasing dose of fertilizers. T_9 treatment recorded the lowest yield (48.08) as compared to drip irrigated treatments. These results are in confirmation with Berad (1996), Kode (2001) and Nalina *et al.* (2007).

4.5 Quality of fruit

Quality of fruit is a very important parameter in any crop. In banana, quality is assessed with the help of TSS, acidity, pulp : peel ratio and organoleptic test.

4.5.1 Pulp : peel ratio

The data regarding the pulp: peel ratio are presented in Table 4.13. It was observed that treatment T_1 recorded maximum pulp: peel ratio (2.62) and significantly superior over all other treatments and at par with treatment T_6 (2.63). The reason may be transfer of more food material into pulp in fertigation treatment as compared to conventional fertilizer applied through soil. Treatment T_9 (2.50) recorded the lowest pulp: peel ratio, which might be due to less availability of water and fertilizer. This results are similar to the research findings of Dahiwalkar *et al.* (2004) and Chemte (2000).

4.5.2 Total soluble solid contents

The data regarding the total soluble solid contents in fruit pulp expressed in percentage are presented in Table 4.13. From the data it is observed that TSS content of T_1 (21.72 %) were more than all other treatments. Treatment T_9 (18.20 %) recorded the lowest TSS content and was significantly less than others. It was observed that as the fertilizer levels increased, TSS content also increased. Application of fertilizers as per growth stages had a positive effect on TSS content as compared to application of conventional fertilizer to soil. The results are in conformity with the research findings of Dahiwalkar *et al.* (2004) and Kode (2001).

Table 4.13 Quality of fruit as influenced by different treatments in ratoon banana

Treatment	Pulp : peel ratio	Total soluble solids (%)	Acidity (mg/g gluconic acid)
T_1	2.65	21.72	0.31
T_2	2.60	20.8	0.34
T_3	2.57	20.33	0.35
T_4	2.59	20.8	0.33
T_5	2.56	20.33	0.35
T_6	2.63	21.65	0.32
T_7	2.59	20.66	0.34
T_8	2.54	19.8	0.37
T_9	2.5	18.2	0.4
S.E. $\pm$	0.015	0.024	0.010
CD at 5 %	0.04	0.072	0.031

4.5.3 Acidity of fruit

The data regarding the percent fruit acidity are presented in Table 4.13. From the data, it could be observed that percent acidity was significantly affected due to various treatments. Treatment T_1 (0.31 mg/g gluconic acid) recorded lowest acidity but it was on par with T_6 (0.32 mg/g gluconic acid) and T_4 (0.33 mg/g gluconic acid). Acidity was decreased with increase in fertilizer level which confirmed the findings reported by Singh *et al.* (1977). Fruit quality was improved with fertigation.

4.5.4 Organoleptic test

The data regarding organoleptic in terms of grades given to different treatmentss are presented in Table 4.14.

4.5.4.1 Colour and appearance

From the data, it is clear that treatment T_1 (8.1) was superior over other treatments in colour and appearance followed by treatment T_6 (8.0). Lowest grade was given to T_9 (7.4) *i.e.* no fertilizer treatment. Colour and appearance of fruits in fertigation treatment was good as compared to conventional fertilizers, might be due to proper availability of nutrients as per growth stages (Patel *et al.*, 1993).

4.5.4.2 Flavour

From the Table 4.14, it was clear that treatment T_1 (8.3) was superior in case of flavour as compared to other treatments. Treatment T_8 and T_9 fruits was given the lowest grade.

4.5.4.3 Texture

From the Table 4.14, it was observed that T_1 (8.2) treatment gave the highest grade in texture as compared to other treatments. The fruits from fertigation treatment were very soft in

Table 4.14 Organoleptic test of different treatmentss in ratoon banana

Treatment	Colour and appearance	Flavour	Texture	Taste	Overall acceptability
T_1	8.1	8.3	8.2	8.0	8.1
T_2	7.9	8.1	8.1	7.9	7.9
T_3	7.8	7.9	7.8	7.7	7.6
T_4	7.9	8.0	8.0	7.8	7.8
T_5	7.7	7.8	7.7	7.6	7.6
T_6	8.0	8.2	8.1	8.0	8.0
T_7	7.8	8.0	7.9	7.7	7.7
T_8	7.6	7.7	7.8	7.5	7.4
T_9	7.4	7.5	7.6	7.2	6.9

texture and uniform in ripening, whereas fingers from CF treatment were rough in texture and ripened ununiformily.

4.5.4.4 Taste

With refrence to above data and acidity of fruit it can be stated that T_1 (8.1) treatment fingers were sweeter than all other treatments and T_8 (6.9) treatment fruits had a little acidic taste.

4.5.4.5 Overall acceptability

From the Table 4.14 it was clear that fruits from T_1 (8.1) treatment was superior to over all other treatments in case of overall acceptability. Fruit from CF (T_8) (7.4) had less overall acceptability followed by fruits of T_9 treatment (DI with no fertilizer) due to rough texture, acidic flavour and non uniform colour.

4.6 Water management studies

The total seasonal water requirement of the ratoon banana crop for both conventional and drip system was worked out considering 12 months as a crop period. The data regarding the water applied, effective rainfall, total water use, water use efficiency, water saving and increase in yield are presented in Table 4.15 and Fig 4.12.

4.6.1 Water use

The total water used by ratoon banana under drip method was 98.56 cm. The fertigation with 100 per cent WSF applied in 18 splits as per crop growth stages resulting into 36.72 per cent increase in yield over conventional fertilizer applied through soil (T_8).

4.6.2 Water use efficiency

From the table, it was observed that Treatment T_1 (100% WSF) recorded highest WUE (83.60 kg/ha-mm) followed by treatment T_6 (80.87 kg/ha-mm). Lower WUE (48.81 kg/ha-mm) was recorded in T_9 (No fertilizer).

Table 4.15 Water use and water use efficiency under different treatments in ratoon banana

Treatment	Depth of water applied (mm)	Effective Rainfall (mm)	Total Water use (mm)	Yield (t/ha)	FWUE, (kg/ha-mm)	% increase in yield over CF
T_1	913.10	72.50	985.60	82.35	83.60	36.72
T_2	913.10	72.50	985.60	77.21	78.39	28.19
T_3	913.10	72.50	985.60	67.89	68.92	12.71
T_4	913.10	72.50	985.60	72.96	74.09	21.13
T_5	913.10	72.50	985.60	65.52	66.52	8.78
T_6	913.10	72.50	985.60	79.66	80.87	32.25
T_7	913.10	72.50	985.60	70.84	71.91	17.61
T_8	913.10	72.50	985.60	60.23	64.75	-
T_9	913.10	72.50	985.60	48.08	48.81	-

From the data, it was clear that drip with 100 % WSF recorded significantly higher yield as compared to drip with conventional fertilizer applied through soil.

4.6.3 Soil moisture status

Data presented in appendix III and in Fig. 4.12 indicated that, the moisture content was higher and very close to field capacity in all drip irrigated treatments at all growth stage. Those might be due to irrigations were applied at every alternate day based on pan evaporation data through drip.

The moisture content observed at optimum level in all treatments upto 40 cm distance vertically from the dripper as compared to 40-60 and 60-80 cm depth. Whereas the moisture content was higher at the dripper there after it was decreased as distance from dripper increased horizontally.

4.7 Periodical NPK status of soil

The data pertaining to the NPK status of soil before and after harvest is given in Table 4.16

Periodical nutrient availability in soil was found to be influenced significantly by different treatmentss. The N, P and K availability increased with period and maximum availability was observed at 9 months after ratoon in treatment T_1 (N, P and K as 313, 49.2 and 599 kg/ha). The lowest N, P and K availability was observed in T_9 *i.e.* no fertilizer treatment (150, 10.6 and 457 kg/ha) at 9 months after ratoon.

Table 16 Periodical soil nutrient availability in ratoon banana

Treatment	Nutrient availability in soil (3 month after ratoon)			Nutrient availability in soil (6 month after ratoon)			Nutrient availability in soil (9 month after ratoon)			Nutrient availability in soil (at harvest)		
	N	P	K	N	P	K	N	P	K	N	P	K
T_1	245.5	31.4	545	266.4	39.3	588	313.0	49.2	599	155.0	14.7	460
T_2	232.2	27.2	528	249	33.2	570	286	42	579	150.0	13.5	454
T_3	213.2	24.5	523	227	27.5	538	251	34.5	562	146.0	12.3	453
T_4	226.2	25.2	527	246	29.5	569	284	41.5	577	149.0	12.8	454
T_5	175.2	22.5	522	196	23.2	535	204	34	561	145.0	11.5	452.5
T_6	230.5	28.7	539	252	35.5	571	287	43.2	580	151.7	13.7	456
T_7	218.0	24.9	525	227	29.2	566	254	36.7	575	146.0	13.1	453
T_8	169.0	20.4	518	184	22.2	534	190	31.2	561	143.0	13.5	450
T_9	151.0	11.0	464	145	14.8	459	150	10.6	457	142.0	10.3	447
SE	3.39	1.37	2.67	2.07	1.10	5.3	4.13	1.90	2.89	1.11	0.40	2.00
CD at 5%	11.16	4.45	8.62	7.10	4.4	N.S	12.0	5.3	8.78	3.86	1.20	6.00

4.7.1 Availability of Nitrogen

The data regarding soil available nitrogen at 3, 6, 9 month after ratoon and at harvest of ratoon banana as influenced by different fertigation treatments are presented in Table 4.16.

The N availability in soil increased with time from ratoon in all treatments up to 9 months after ratoon expect T_9 (No fertilizer) and decreased at harvesting stage in all treatments. The decreased soil N availability at harvesting stage may be due to higher uptake of N by plants at reproductive stage. The level of fertilizer had influenced the N availability in soil up to some extent.

At 3 month after ratoon, the maximum nitrogen availability in soil was observed in treatment T_1 and decreased with decreasing fertilizer levels. Lowest value of N availability was observed in treatment T_9 (245.5 kg/ha) at all stages.

At 9 months after ratoon, the significantly maximum N availability was observed in treatment T_1 (313.0 kg/ha) and it was significantly superior over all other treatments. Treatment T_9 at all stages recorded lowest value of N availability. At 6 month after ratoon same trend of nutrient availability was observed.

At harvest the maximum N availability in soil was observed in treatment T_1 and was decreased with decreasing fertilizer levels.

The treatment T_8 where fertilizers applied through soil resulted into less availability of nutrients at all stages compared to fertigation treatments. It might have resulted into more leaching of fertilizers and in turn would have made less fertilizer available.

The sources of fertilizer also resulted into moderate change in N availability in the root zone soil of banana at all the stages. The water soluble fertilizers resulted into more availability of N in soil, it is due to more number of splits than compared to conventional fertilizers .

As optimum quantity of water was available just beneath the dripper in drip irrigated treatments, there was corresponding increase in available N in the soil. It has been inferred a direct association between N availability and presence of in-situ irrigation water. These results are in close conformity with those reported by Bangar *et al.* (1998), Bangar and Chaudhary (2000).

4.7.2 Availability of phosphorus

The data pertaining to soil available phosphorus at 3, 6, 9 month after ratoon and at harvest as influenced by different fertigation treatments are presented in Table 4.16.

The P availability in soil was increased with period from ratoon in all the treatments up to 9 months and decreased at harvesting stage. The decreased P availability at harvesting stage may be due to higher uptake of P by plants at reproductive stage.

The level of fertilizer influenced the P availability in soil up to some extent. The maximum P availability in soil was observed in treatment T_1 and was decreased with decreasing fertilizer levels. Lowest value of availability was in treatment T_9 at all stages.

At 3 months after ratoon, the maximum P availability in soil was observed in treatment T_1 (39.3 kg/ha) and it was significantly superior over all the treatments. At 6 and 9 month after ratoon the significantly maximum P availability in soil was observed in treatment T_1 (31.4 and 49.2 kg/ha) over all other treatments. At harvest, the same trend of P availability in soil was observed.

The drip fertigation treatments, where P was applied through drip irrigation in the form of water soluble fertilizer resulted into more availability of P in soil at all stages compared to fertilizer applied through soil.

The sources of fertilizers also resulted into moderate change in P availability in the root zone soil of banana at all the stages. The water soluble fertilizers resulted into more availability of P in soil when 100 % RD of P was applied through drip in the form of mono ammonium phosphate (12:61) as compared to conventional fertilizers where P was applied through di ammonium phosphate. It resulted into increased P availability in T_1 up to the extent 4.4 kg/ha as compared to T_9 (DI with 0 % RD of WSF) at harvest.

As optimum water was available just beneath the dripper, there was corresponding increase in availability of P in the soil. It has been inferred a direct association between P availability and presence of in-situ irrigation water. These results are in close conformity with those reported by, Bangar *et al.* (1998) and Bangar and Chaudhary (2000).

4.7.3 Availability of potassium

The data regarding soil available potassium at 3, 6, 9 month after ratoon and at harvest as influenced by different fertigation treatments are presented in Table 4.16.

The K availability in soil was increased with period from ratoon in all treatments up to 9 month after ratoon and decreased at harvesting stage. The decreased K availability at harvesting stage may be due to higher uptake of K by plants at reproductive stage. The highest availability was found in treatment T_1 and decreased with decreased fertilizer levels. Lowest value of availability was in treatment T_9.

At 3 months after ratoon, the maximum K availability in soil was observed in treatment T_1 significantly superior over all other treatment except T_8.

At 6 month after ratoon, the maximum K availability in soil was observed in treatment T_1 (588.0 kg/ha). However the treatments differences were non significant .

At 9 month after ratoon the significantaly maximum K availability in soil was observed in treatment T_1 (599 kg/ha) over all other treatment.

The treatment T_8, where fertilizer was applied through soil resulted into less K availability in soil at all stages compared to fertigation treatments. The treatment T_8 might have resulted into more leaching of fertilizers and in turn would have made less fertilizer available.

The sources of fertilizer also resulted into moderate change in K availability in the root zone soil of banana at all the stages. The water soluble fertilizers resulted into more availability of K in soil, when 100 per cent RD of K applied through drip in the form of sulphate of potash as compared to conventional fertilizers. These results are in close conformity with those reported by Bangar *et al.* (1998) and Bangar and Chaudhary (2000).

4.8 Nutrient uptake

4.8.1 Nutrient uptake by banana shoot

The data pertaining to the NPK uptake by banana shoot in kg/ha are given in Table 4.17 and fig 4.13. From the table, it could be observed that the N uptake by banana shoot was improved significantly due to fertigation as compared to conventional fertilizer application. Treatment T_1 (47.46 kg/ha) recorded significantly high uptake of N (47.46 kg/ha) over other treatment but it was at par with the treatments T_6 (46.23 kg/ha) and T_2 (43.83 kg/ha). Treatment T_9 (35.11) recorded lowest N uptake and was significantly low.

In case of P uptake, it was increased with increasing dose of fertilizers. Treatment T_1 recorded significantly higher P uptake (15.7kg/ha) over other treatments, however it was at par with T_6 and T_2. The P uptake by banana shoot was improved in fertigation treatments as compared to application of conventional fertilizers through soil applied at planting only. No fertilizer treatment recorded lowest P uptake (11.36 kg/ha).

Table 4.17 Nutrient uptake by banana shoot as influenced by various treatment in ratoon banana

Treatment	Nutrient uptake (kg/ha)		
	Nitrogen	Phosphorus	Potassium
T_1	47.46	15.77	294.41
T_2	43.83	15.00	292.15
T_3	40.63	13.30	291.16
T_4	43.20	14.78	291.47
T_5	39.31	12.94	290.62
T_6	45.23	15.47	293.90
T_7	40.41	13.88	291.55
T_8	38.27	12.59	288.13
T_9	35.11	11.36	285.81
S.E. $\pm$	1.23	0.27	0.75
CD at 5 %	3.70	0.80	2.26
Mean	41.49	13.92	291.11

In case of K uptake, treatment T_1 (294.41 kg ha^{-1}) recorded significantly higher K uptake over all other treatments except T_6 (293.9 kg ha^{-1}) and T_2 (292.15 kg ha^{-1}). The K uptake by banana shoot was improved significantly in fertigation treatments as compared to application of conventional fertilizers through soil. This might be due to loss of conventional fertilizer through leaching and less uptake due to less availability of nutrients. Treatment T_9 (291.11 kg ha^{-1}) showed the lowest value of K uptake.

This indicates that level of fertilizer and application of fertilizer as per growth stages had a positive effect on uptake.

4.8.2 Nutrient uptake by banana leaves

The data pertaining to the NPK uptake by banana leaves (kg ha^{-1}) are given in Table 4.18 and Fig 4.14. From the table it could be observed that the N uptake by leaves increased with increasing levels of fertilizer. The N uptake by banana leaves was improved in fertigation treatment as compared to application of conventional fertilizers. Treatment T_1 recorded significantly higher N uptake (242.53 kg/ha) over all other treatments except T_6 (240.0 kg/ha) and T_2 (238.45 kg/ha). This indicated that there was significant effect of fertilizer levels on uptake of N.

In case of P uptake, treatment T_1 (DI with 100 % RD of WSF through urea, MAP and SOP in 18 splits as per schedule) recorded significantly higher P uptake over other treatments, however it was at par with T_6 and T_2. The P uptake by banana leaves was improved in fertigation treatments as compared to application of conventional fertilizers through soil applied at

Table 4.18 Nutrient uptake by banana leaves as influenced by various treatment in ratoon banana

Treatment	Nutrient uptake (kg/ha)		
	Nitrogen	Phosphorus	Potassium
T_1	242.53	50.05	291.90
T_2	238.45	46.10	288.65
T_3	228.89	40.41	284.15
T_4	235.51	43.59	287.67
T_5	226.61	37.97	283.01
T_6	240.00	48.64	291.48
T_7	232.89	42.37	285.48
T_8	221.43	36.89	278.83
T_9	219.77	33.35	269.59
S.E. $\pm$	1.38	1.32	1.35
CD at 5 %	4.15	3.95	4.07
Mean	231.79	42.14	284.42

ratooning only. No fertilizer treatment recorded lowest P uptake (33.35 kg/ha).

In case of K uptake, T_1 (291.90 kg ha^{-1}) recorded significantly higher values overall other treatments except T_6 (291.48 kg ha^{-1}) and T_2 (288.65 kg ha^{-1}). Lowest K uptake was recorded in treatment T_9 (269.59 kg ha^{-1}) followed by T_8 (278.83 kg ha^{-1}). It indicated that different fertilizer levels had significant effect on nutrient uptake by leaves.

4.8.3 Nutrient uptake by ratoon banana fruit

The results pertaining to the NPK uptake by banana fruit (kg/ha) are given in Table 4.19 and Fig 4.15. From the table, it could be observed that the N uptake by fruit increased with increasing levels of fertilizer. The N uptake by banana fruit was improved in fertigation treatment as compared to application of conventional fertilizers. Treatment T_1 recorded significantly higher N uptake (105.83 kg/ha) over all other treatments except T_6 (104.12 kg/ha) and T_2 (102.34 kg/ha). This indicated that there was significant effect of different fertilizer levels on uptake of N.

In case of P uptake, treatment T_1 (22.23 kg/ha) recorded significantly higher P uptake (22.23 kg/ha) over other treatments, however it was at par with T_6 (22.83 kg/ha) and T_2 (21.56 kg/ha). The P uptake by banana fruit was improved in fertigation treatments as compared to application of conventional fertilizers through soil at ratooning only. No fertilizer treatment recorded lowest P uptake (16.56 kg/ha).

Table 4.19 Nutrient uptake by banana fruit as influenced by various treatment in ratoon banana

Treatment	Nutrient uptake (kg/ha)		
	Nitrogen	Phosphorus	Potassium
T_1	105.83	22.23	355.9
T_2	102.34	21.56	350.36
T_3	96.66	19.95	344.26
T_4	99.36	20.41	348.00
T_5	95.4	19.34	340.88
T_6	104.12	21.83	353.38
T_7	97.34	20.26	347.48
T_8	94.99	18.40	337.6
T_9	91.61	16.56	330.86
S.E. $\pm$	1.20	0.61	1.87
CD at 5 %	3.60	1.83	5.60
Mean	98.63	20.06	345.41

In case of K uptake, T_1 (355.9 kg/ha) was recorded significantly higher over all other treatments except T_6 (353.38 kg/ha) and T_2 (350.36 kg/ha). Lowest K uptake was recorded in treatment T_9 (330.86 kg/ha) followed by T_8 (DI with CF 337.6 kg/ha). It indicated that different fertilizer levels had significant effect on nutrient uptake by fruit.

4.8.4 Total nutrient uptake by ratoon banana

The data pertaining to total NPK uptake of banana in kg/ha is given in Table 4.20 and graphically depicted in Fig 4.16. The total nutrient uptake is the summation of shoot, leaves, and fruit uptake. Over all T_1 treatment recorded significantly higher nutrient uptake (395.8, 88.05 and 941.21 NPK kg/ha respectively) over other treatments except $T_{6.}$ T_9 treatment recorded lowest nutrient uptake (346.49, 61.27 and 886.26 NPK kg/ha). Water soluble fertilizers recorded significant increase in uptake of nutrients over conventional fertilizer applied through soil. These results are in confirmation with research findings of Patil (2008) and Jadhav (2008).

4.9 Correlation studies

The relationship among different forms of potassium, morphological character, crop yield, NPK availability in soil were studied.

4.9.1 Correlation coefficient between different forms potassium, and morphological character, crop yield, NPK uptake by ratoon banana and available NPK in soil

The simple correlation coefficient between different forms of potassium and morphological character, crop yield, NPK uptake and available NPK are presented in Table 4.21 and 4.22.

Table 4.20 Total nutrient uptake by ratoon banana

Treatment	Nutrient uptake (kg/ha)		
	N	P	K
T_1	395.82	88.05	941.21
T_2	383.99	82.73	931.48
T_3	368.18	73.66	919.57
T_4	377.70	78.78	927.10
T_5	361.32	70.25	914.51
T_6	390.35	85.94	938.76
T_7	370.64	76.51	924.51
T_8	354.69	67.88	904.56
T_9	346.49	61.27	886.26
S.E. $\pm$	2.00	0.73	1.28
CD at 5 %	6.00	2.20	4.25
Mean	327.13	76.19	920.8

Table 4. 21. Correlation coefficient between the fractions of K, crop yield and NPK uptake by ratoon banana at 9 month

	Water soluble K	Exchange able K	Non exchange able K	Availabl e K	Lattice K	Total K
Yield	0.82**	0.925**	0.844**	0.829**	0.892**	0.889**
Number of hands	0.66**	0.691**	0.604**	0.643**	0.642**	0.646**
Number of fingers	0.794**	0.9**	0.808**	0.8**	0.864**	0.853**
Plant height	0.931**	0.948**	0.995**	0.779**	0.975**	0.969**
Plant girth	0.704**	0.748**	0.65**	0.726**	0.688**	0.693**
Number of leaves	0.268	0.356	0.285	0.384*	0.322	0.33
Shoot N uptake	0.696**	0.824**	0.706**	0.775**	0.778**	0.777**
Shoot P uptake	0.609**	0.744**	0.633**	0.704**	0.705**	0.709**
Shoot K uptake	0.746**	0.758**	0.695**	0.756**	0.728**	0.738**
Leaves N uptake	0.71**	0.832**	0.689**	0.863**	0.771**	0.785**
Leaves P uptake	0.738**	0.857**	0.716**	0.825**	0.801**	0.805**
Leaves K uptake	0.828**	0.938**	0.876**	0.885**	0.91**	0.918**
Fruit N uptake	0.698**	0.805**	0.666**	0.752**	0.746**	0.742**
Fruit P uptake	0.781**	0.828**	0.748**	0.795**	0.799**	0.805**
Fruit K uptake	0.781**	0.912**	0.802**	0.884**	0.869**	0.877**
Available N	0.881**	0.789**	0.876**	0.786**	0.867**	0.768**
Available P	0.864**	0.868**	0.897**	0.879**	0.789**	0.876**
Available K	0.897**	0.687**	0.789**	1.00**	0.783**	0.862**

Table 4.22. Correlation coefficient between the fractions of K in ratoon banana

	Water soluble K	Exchange able K	Non exchange able K	Available K	Lattice K	Total K
3 months						
Water soluble K	1.000**					
Exchangeable K	0.827**	1.000**				
Non exch.K	0.698**	0.921**	1.000**			
Available K	0.830**	0.972**	0.895**	1.000**		
Lattice K	0.820**	0.968**	0.936**	0.982**	1.000**	
Total K	0.810**	0.974**	0.937**	0.986**	0.998**	1.000**
6 months						
Water soluble K	1.000**					
Exchangeable K	0.915**	1.000**				
Non exch.K	0.896**	0.956**	1.000**			
Available K	0.922**	0.989**	0.959**	1.000**		
Lattice K	0.909**	0.991**	0.963**	0.990**	1.000**	
Total K	0.911**	0.987**	0.982**	0.987**	0.995**	1.000**
9 months						
Water soluble K	1**					
Exchangeable K	0.939**	1**				
Non exch.K	0.941**	0.964**	1**			
Available K	0.819**	0.886**	0.826**	1**		
Lattice K	0.940**	0.988**	0.981**	0.836**	1**	
Total K	0.944**	0.991**	0.980**	0.871**	0.996**	1**
At harvest						
Water soluble K	1.000**					
Exchangeable K	0.827**	1.000**				
Non exch.K	0.698**	0.921**	1.000**			
Available K	0.830**	0.972**	0.895**	1.000**		
Lattice K	0.820**	0.968**	0.936**	0.982**	1.000**	
Total K	0.810**	0.974**	0.937**	0.986**	0.998**	1.000**

The data clearly indicated that there was significantly positive correlation between water soluble K and yield (0.82**), number of hands (0.66**), number of fingers (0.794**), plant height (0.931**), girth of pseudostem (0.704**), number of leaves (0.268*), shoot N uptake (0.696**), shoot P uptake (0.609**), shoot K uptake (0.746**), leaves N uptake (0.71**), leaves P uptake (0.738**), leaves K uptake (0.828**), fruit N uptake (0.698**), fruit P uptake (0.781**), fruit K uptake (0.781**) and soil available N (0.881**), soil available P (0.864**), soil available K (0.897**),

The positive correlation coefficient between periodical fractions of K with yield and yield attributes shows that as period of crop increase the availability of these forms in soil also increased.

4.9.2 Correlation among various K fractions

The value of various K fractions were correlated. Total K had positive and significant correlation with all the fractions of K. Water soluble K showed significant and positive correlation with exchangeable K (0.939**), non exchangeable (0.941**), lattice K (0.940**), indicating rapid equilibrium establishment between various forms.

4.10. Economic studies

The data regarding the cost of cultivation, gross and net monetary returns and benefit : cost ratio from cultivation of banana as influenced by different treatmentss are presented Table 4.23.

4.10.1 Cost of cultivation

With reference to the data given in the Table 4.23 the maximum cost of cultivation was observed in treatment T_6 (Rs. 2,91,358 per ha) and T_4 (Rs. 2,71,398) and was lowest in treatment T_9 (Rs. 66242.00).

4.10.2 Gross monetary returns

The data (Table 4.23) computed for gross monetary returns differed due to various treatments under study. Amongst the treatments of different fertilizer levels, the maximum gross monetary returns (Rs. 6,17,625 per ha) was recorded in T_1 treatment due to maximum yield. In all treatments minimum gross returns (Rs. 3,38,100 per ha) were obtained from T_9 followed by T_8 (Rs.4,51,125). Similar trend of results were obtained by Berad (1998) and Kode (2001).

4.10.3 Net monetary returns

The data regarding net monetary returns from various treatments are reported in Table 4.23. The maximum net monetary returns (Rs. 427798 per ha) was obtained in T_2 followed by T_3 (Rs 379179 per ha). The lowest net monetary returns (Rs. 271390 per ha) was obtained in T_9 treatment which was due to lower yield may be due to lower availability of nutrients. These results are in conformity to those reported by Berad (1998) and Kode (2001).

Table 4.23. Economics of ratoon banana

Treatment	Cost of cultivation (Rs/ha)	Gross monetary Return (Rs/ha)	Net monetary Return (Rs/ha)	B:C ratio	Water productivity (Rs/ha)
T_1	252758	617625	364867	2.44	370
T_2	151277	579075	427798	3.83	434
T_3	129996	509175	379179	3.91	385
T_4	271398	547200	275802	2.02	280
T_5	219990	491400	271410	2.23	275
T_6	291358	604950	313592	2.08	318
T_7	235351	531300	295949	2.26	300
T_8	118903	451125	332222	3.79	337
T_9	66242	338100	271390	5.10	275

4.10.4 Water productivity

The treatment T_2 recorded maximum water productivity (Rs. 434 per cm) as compared to other treatments. Treatment T_8 i.e conventional fertilizer applied through soil recorded water productivity of Rs. 337 per cm of water used. The lowest water productivity was observed in no fertilizer treatment (Rs. 275 per cm).

4.10.5 Benefit : Cost ratio

The B : C (Table 4.23) ratio in various treatments were in range of 2.02 to 5.10. Amongst all the treatments the highest B: C ratio was obtained in treatment T_9 (5.10) followed by T_8 (3.79). The fertigation treatments resulted into B : C ratio of 2.02 to 3.91 which were lower than other treatment. Treatment T_9 (no fertilizer) resulted into higher B:C ratio than all other treatments. In fact, the higher market prices of water soluble fertilizers applied through drip masked the positive effects of fertigation such as improvement in yield and quality and in turn resulted into lower B:C ratio.

5. SUMMARY AND CONCLUSIONS

5.1 Summary

The field experiment was conducted at Instructional Farm of Inter-faculty Department of Irrigation Water Management, M.P.K.V., Rahuri during 2014-2015 to study the "Studies on potassium fractions in soil and yield of ratoon banana as influenced by fertigation". The experiment was laid out in randomized block design with 9 treatments and 3 replications. The soil of experimental field was clayey in texture, containing 8.0, 14.0, 26.8, and 50.5 % fine sand, coarse sand, silt and clay, respectively. The per cent moisture content at field capacity and permanent wilting point and available water were 39.2 and 17.9, 21.3 %, respectively. The bulk density of soil was 1.27 Mg m^{-3}. The available nitrogen, phosphorus and potassium content in soil were 157.0 kg ha^{-1}, 14.20 kg ha^{-1} and 465.0 kg ha^{-1}, respectively. The recommended dose of fertilizer (200:40:200 N, P_2O_5 and K_2O g $plant^{-1}$) was applied to ratoon banana as per schedule. In fertigation treatments, different grades of fertilizer *viz*; urea (46:00:00), monoammonium phosphate (12:61:00), muriate of potash (00:00:60), special grade (9:5:33) and sulphate of potash (0:0:50) were applied with the help of injection pump in 18 splits fortnightly as per schedule to all treatments.

The data in respect of growth and yield attributes of banana were recorded. The most important findings emerging from this investigation are summarized as below.

5.1.1 Forms of potassium

The treatment T_1 (drip with 100% WSF in 18 weekly splits as per growth stages through urea, MAP and SOP) recorded significantly higher water soluble K (31.5 mg kg^{-1}), exchangeable K (191.3 mg kg^{-1}), non exchangeable K (761.60 mg kg^{-1}), available K (221.50 mg kg^{-1}), lattice K (4591 mg kg^{-1}) and total K (5600.00 mg kg^{-1}) over other treatments. However, it was at par with treatments T_6, T_2, and T_4. The lowest K fractions were recorded in no fertilizer treatment *i.e.* water soluble K (15.6 mg kg^{-1}), exchangeable K (103.5 mg kg^{-1}), non exchangeable K (555.6 mg kg^{-1}), available K (132.2 mg kg^{-1}), lattice K (3010.4 mg kg^{-1}) and total K (3501.4 mg kg^{-1}).

5.1.2 Growth studies

The growth attributes *viz.,* plant height, pseudostem girth, number of leaves per plant were significantly influenced by fertigation. Among the different treatmentss, T_1 treatment recorded maximum plant height (3.16 m), pseudostem girth (59.13 cm), number of leaves (17.00). However, it was at par with T_6, T_2 and T_4.

5.1.3 Yield contributing characters

The yield attributes *viz.,* number of hands/bunch (9.07), number of fingers per bunch (156.33) and weight of bunch (18.03 kg) were found to be the highest in treatment T_1. Which was directly reflected on fruit yield of banana. However, it was at par with treatment T_6 and T_2. The lower number of hands/bunch (6.4), number of fingers per bunch (112.33), weight of bunch (11.31 kg) were found in no fertilizer treatment (T_9).

5.1.4 Yield

Drip with 100% RD of WSF as per growth stages (T_1) recorded significantly higher yield (82.35 t ha^{-1}) over all other treatments except T_6 (79.66 t ha^{-1}) and T_2 (77.21 t ha^{-1}). The banana yield obtained under T_3 (60 % RD of WSF) was 67.89 t/ha which was at par with T_8 where 100 % RD of CF (60.23 t/ha) applied through soil. This showed that fertilizer application as per growth stages resulted more yield. It indicated that 40 % fertilizers can be saved through application of water soluble fertilizers through drip as compared to conventional fertilizers applied through soil with increase in yield.

5.1.5 Water use

The total water requirement in drip was 985.60 mm. Treatment T_1 recorded maximum water use efficiency (83.60 kg/ ha mm), whereas the lowest water use efficiency was observed in treatment T_9, (48.08 kg /ha mm).

5.1.7 Nutrient availability

The NPK availability in soil was increased with period from ratoon in all treatments up to 9 months and decreased at harvesting stage. The decreased NPK availability at harvesting stage may be due to higher uptake of NPK by plants at reproductive stage. The maximum availability was observed in treatment T_1 where 100% RD of WSF was applied through drip through urea, MAP and SOP and was decreased with decreasing fertilizer levels. The treatment T_8, where NPK was applied through soil resulted into less availability in soil at all stages compared to fertigation treatments.

5.1.8 Total nutrient uptake

The treatment T_1 recorded significantly higher total uptake of nitrogen (395.82 kg ha^{-1}), phosphorus (88.05 kg ha^{-1}) and potassium (941.21 kg ha^{-1}) over other treatments. The lower nutrient uptake of nitrogen (346.49 kg ha^{-1}), phosphorus (61.27 kg ha^{-1}) and potassium (886.26 kg ha^{-1}) was found in T_9.

5.1.9 Correlation studies

The positive correlation between periodical fractions of K with yield and yield attributes showed that as period of crop increases the availability of fractions of K in soil also increased.

5.1.10 Economics

The net monetary income was influenced by the various doses of fertigation. Maximum net monetary income of Rs.427798/ha was obtained in treatment T_2 (DI with 80% RD of WSF through urea, MAP and SOP in 18 splits as per schedule).The T_9 (DI with no fertilizer of WSF) recorded lowest net monetary income than other treatments (Rs.271390/ha). Maximum B : C ratio of 5.10 and 3.91 were recorded in T_9 and T_3.The maximum net profit per mm of water used (Rs.434/ha) was in treatment T_2 which was maximum amongst all the treatment.

5.2 Conclusions

Based on the findings emerged out from this investigation the following conclusions could be drawn.

1. The higher availability of K fractions in soil were observed significantly in WSF as compared to conventional fertilizer treatment. The T_1 treatment (drip with 100 % WSF in 18

equal fortnight splits) recorded the significantly the highest K fractions over other treatments except T_6 (80 % RDF of 9:5:33) and T_2 (80 % RDF of MAP) and T_4.

2. The drip with 100 % RD of WSF (T_1) resulted into higher growth and yield contributing characters as compared to other treatments and recorded significantly higher yield (82.35 t ha^{-1}) over other treatments except T_6 and T_2. The banana yield obtained under treatment T_3 (60 % RD of WSF) was (67.89 t ha^{-1}) higher than T_8 (drip with CF) (60.23 t ha^{-1}).
3. Nutrient uptake and residual fertility in soil after harvest of ratoon banana was significantly increased due to application of WSF through drip as compared to CF. Treatment T_1 recorded significantly higher NPK availability in soil (313, 49.2, 599 NPK kg/ha) at 9 month after ratoon.
4. The higher net monetary return (4,27,798 Rs/ha) was recorded in T_2 followed by T_3 (3,79,179 Rs/ha).The higher water productivity per mm of water used was recorded in T_1 followed by T_6.
5. The moisture content was observed at optimum level and close to the field capacity in all drip irrigated treatments. It was increased upto 40 cm vertically from the dripper and then decreased upto 80 cm depth.
6. The positive correlation was found between different forms of potassium and morphological character, crop yield, NPK uptake and availability in soil.

7. The values of various K fractions were correlated to identify their interdependence. Total K had positive and significant correlation with all the fractions of K.

The available and water soluble K fractions were found to increase to larger extent in fertigation treatments as compared to conventional fertilizer applied through soil, which has improved the growth and yield of ratoon banana. In view of this, application of water soluble fertilizers in splits as per growth stages is recommended for improving productivity, efficient nutrient and water use from ratoon banana cultivated in medium deep soils.

The results of present investigation are of one crop study hence needs the more field trials for the confirmation.

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* Original are not seen.

7. APPENDICES

Appendix-I : Details of meterological data during experimental period.

Meterologicla week	Temperature (^0C)		Relative humidity (%)		Wind velocity (km hr^{-1})	Mean evaporation (mm day^{-1})	Rainfall (mm)	No. of rainy days
	Max.	Min.	Morning	Evening				
October 2013								
40	34.1	22.2	70	40	07.5	01.2	0.0	-
41	34.0	19.6	64	33	8.0	2.5	7.4	1
42	33.7	20.9	72	43	8.1	1.1	13.4	2
43	29.4	16.1	72	57	4.9	1.4	1.0	-
44	32.0	14.0	56	36	9.8	1.9	0.0	-
November								
45	31.8	15.9	57	33	9.1	1.2	0.0	-
46	29.7	20.1	81	63	5.3	1.0	95.6	2
47	29.8	15.2	69	41	9.1	0.4	0.0	-
48	29.6	12.1	57	29	9.1	0.5	0.0	-
December								
49	29.1	10.9	55	32	9.5	0.5	0.0	-
50	29.2	14.6	67	47	7.0	1.3	0.0	-
51	25.7	7.5	52	34	8.6	1.0	0.0	-
52	29.7	20.1	81	63	5.3	1.0	0.0	-
January, 2014								
1	28.8	12.2	66	37	8.2	1.7	-	-
2	29.5	12.3	59	34	9.1	1.5	-	-
3	29.7	13.5	54	34	7.9	2.5	-	-
4	29.0	14.8	67	39	6.2	2.0	-	-
5	28.5	11.2	59	31	9.3	1.4	-	-
February								
6	31.8	11.2	54	20	10.1	01.6	-	-
7	28.0	10.3	54	27	10.2	3.4	-	-
8	31.1	15.2	56	30	9.4	2.0	-	-
9	30.8	13.6	51	33	9.3	3.4	0.06	-

Appendix-I contd....

Meterolo gicla week	Temperature (^{0}C)		Relative humidity (%)		Wind velocity (km hr^{-1})	Mean evaporation (mm day^{-1})	Rainf all (mm)	No. of rainy days
	Max.	Min.	Morning	Evening				
March								
10	29.4	16.6	77	45	6.7	3.3	32.8	3
11	33.7	18.7	59	30	7.4	2.0	00.8	-
12	36.0	17.0	41	20	9.0	1.8	-	-
13	36.9	18.7	39	20	8.9	1.6	-	-
April								
14	37.5	18.4	36	19	8.5	1.8	-	-
15	37.2	17.9	46	17	9.4	2.0	-	-
16	37.8	21.1	59	26	9.6	1.9	-	-
17	38.7	21.6	46	20	9.4	1.9	-	-
18	39.1	22.5	52	21	9.7	2.3	3.6	1
May								
19	37.7	22.7	65	22	8.2	3.1	-	-
20	36.9	2.3	65	25	7.8	3.7	-	-
21	39.3	23.1	61	23	8.9	4.7	-	-
22	40.2	23.6	58	26	8.4	4.6	-	-
June								
23	38.7	24.5	71	33	7.2	5.7	2.6	-
24	36.7	24.7	65	36	9.8	7.8	18.8	-
25	33.4	24.7	66	46	3.6	10.3	22.4	-
26	35.9	22.5	66	35	8.1	6.1	-	-
July								
27	34.4	23.3	72	52	5.2	4.7	11.8	1
28	32.7	23.4	73	52	3.8	6.0	16.8	2
29	30.8	24.0	72	64	1.1	9.8	0.0	-
30	29.1	22.3	76	63	4.1	5.5	23.4	3
31	29.0	22.6	75	68	2.2	7.0	13.2	2
August								
32	30.5	21.9	72	57	5.1	5.6	1.6	-
33	31.7	21.9	70	50	4.8	5.6	34.0	1
34	32.7	22.6	79	51	5.3	2.0	44.4	2
35	28.6	21.8	81	72	1.4	2.3	130.0	5
September								
36	29.5	22.2	75	66	3.7	5.9	15.8	1
37	30.7	21.0	71	57	5.2	3.0	0.0	-
38	31.9	21.0	71	71	8.0	2.9	4.0	1
39	33.6	20.0	70	70	8.7	0.5	-	-

Appendix-II : Per cent nutrient concentration in ratoon banana as influenced by various treatments

At 3 months

Treatment	Shoot			Leaves		
	N	P	K	N	P	K
T_1	0.7	0.42	3.5	2.3	0.51	3.6
T_2	0.66	0.42	3.47	2.22	0.48	3.52
T_3	0.63	0.40	3.43	2.16	0.46	3.47
T_4	0.65	0.41	3.45	2.21	0.48	3.51
T_5	0.62	0.40	3.42	2.13	0.45	3.44
T_6	0.68	0.42	3.48	2.25	0.51	3.56
T_7	0.64	0.40	3.44	2.18	0.46	3.49
T_8	0.6	0.33	3.41	2.12	0.45	3.42
T_9	0.57	0.33	3.40	2.00	0.437	3.397
Mean	0.639	0.392	3.445	2.174	0.471	3.490
S.E. $\pm$	0.003	0.002	0.001	0.023	0.001	0.001
CD at 5 %	0.010	0.005	0.003	0.069	0.003	0.003

At 6 months

Treatment	Shoot			Leaves		
	N	P	K	N	P	K
T_1	0.65	0.25	3.6	2.20	0.45	3.5
T_2	0.63	0.24	3.57	2.16	0.42	3.43
T_3	0.61	0.23	3.53	2.14	0.39	3.36
T_4	0.62	0.24	3.56	2.15	0.42	3.4
T_5	0.6	0.23	3.53	2.13	0.38	3.35
T_6	0.64	0.24	3.58	2.18	0.45	3.46
T_7	0.61	0.24	3.54	2.14	0.4	3.38
T_8	0.59	0.23	3.52	2.13	0.37	3.33
T_9	0.563	0.233	3.493	2.00	0.347	3.287
Mean	0.613	0.237	3.547	2.136	0.403	3.389
S.E. $\pm$	0.001	0.002	0.003	0.010	0.001	0.001
CD at 5 %	0.003	0.005	0.009	0.030	0.003	0.003

At 9 months

Treatment	Shoot			Leaves		
	N	P	K	N	P	K
T_1	0.60	0.20	3.80	2.10	0.43	3.08
T_2	0.58	0.20	3.72	2.00	0.39	2.93
T_3	0.54	0.19	3.51	1.93	0.32	2.88
T_4	0.56	0.20	3.63	1.98	0.36	2.90
T_5	0.54	0.19	3.44	1.90	0.31	2.87
T_6	0.59	0.20	3.78	2.09	0.42	3.08
T_7	0.55	0.20	3.55	1.91	0.34	2.90
T_8	0.53	0.18	3.40	1.89	0.30	2.85
T_9	0.52	0.18	3.34	1.88	0.28	2.79
Mean	0.556	0.1933	3.575	1.964	0.350	2.92
S.E. $\pm$	0.002	0.0001	0.005	0.013	0.001	0.011
CD at 5 %	0.007	0.0004	0.016	0.039	0.003	0.032

At harvest

Treatment	Shoot			Leaves			Fruit		
	N	P	K	N	P	K	N	P	K
T_1	0.81	0.17	2.73	0.55	0.19	4.15	2.03	0.41	2.94
T_2	0.80	0.17	2.72	0.54	0.18	3.84	1.9	0.37	2.81
T_3	0.76	0.16	2.70	0.52	0.17	3.6	1.85	0.33	2.76
T_4	0.78	0.16	2.71	0.53	0.18	3.82	1.9	0.35	2.79
T_5	0.75	0.15	2.68	0.52	0.17	3.58	1.82	0.3	2.76
T_6	0.80	0.17	2.72	0.55	0.18	3.84	2.01	0.41	2.93
T_7	0.76	0.16	2.71	0.53	0.18	3.73	1.85	0.34	2.78
T_8	0.74	0.14	2.65	0.51	0.17	3.57	1.81	0.3	2.74
T_9	0.73	0.13	2.64	0.50	0.17	3.40	1.79	0.267	2.69
Mean	0.77	0.16	2.70	0.53	0.18	3.73	1.884	0.342	2.800
S.E. $\pm$	0.01	0.01	0.01	0.002	0.001	0.002	0.008	0.001	0.001
CD at 5 %	0.02	NS	0.04	0.007	0.003	0.007	0.024	0.003	0.003

Appendix-III : Depth of irrigation applied under different treatmentss (banana)

Date	Alternate CPE (mm)	Rainfall (mm)	Kc	Kp	WA %	Water applied(mm) CPE×Kp×Kc×WA ------------------ 0.909(Eu)
1	2	3	4	5	6	7
2/10/2013	6.7	-	1.1	0.7	0.6	5.16
4	7.8	4.0	1.1	0.7	0.6	6.01
6	5.4	24.2	1.1	0.7	0.6	4.16
8	3.8	-	1.1	0.7	0.6	2.93
10	7.8	1.2	1.1	0.7	0.6	6.01
12	7.4	14.6	1.1	0.7	0.6	5.70
14	7.8	4.00	1.1	0.7	0.6	6.01
16	7	-	1.1	0.7	0.6	5.39
18	7.4	-	1.1	0.7	0.6	5.70
20	8.2	-	1.1	0.7	0.6	6.31
22	8.8	-	1.1	0.7	0.6	6.78
24	9.4	-	1.1	0.7	0.6	7.24
26	8.7	-	1.1	0.7	0.6	6.70
28	8.7	-	1.1	0.7	0.6	6.70
30	8	-	1.1	0.7	0.6	6.16
1/11/2013	8.6	-	1.075	0.7	0.6	6.47
3	8.6	-	1.075	0.7	0.6	6.47
5	8.5	-	1.075	0.7	0.6	6.40
7	6.8	-	0.5	0.7	0.6	2.38
9	6.4	-	0.5	0.7	0.6	2.24
11	6.5	-	0.5	0.7	0.6	2.28
13	7.2	-	0.5	0.7	0.6	2.52
15	7.2	-	0.5	0.7	0.6	2.52
17	6.5	-	0.5	0.7	0.6	2.28
19	6.9	-	0.5	0.7	0.6	2.42
21	6.6	-	0.5	0.7	0.6	2.31
23	6.6	41.8	0.5	0.7	0.6	2.31
25	7.5	-	0.5	0.7	0.6	2.63
27	6.3	-	0.5	0.7	0.6	2.21
29	6.7	-	0.5	0.7	0.6	2.35
1/12/2013						
2	5.6	-	0.5	0.7	0.6	1.96
4	5.5	-	0.5	0.7	0.6	1.93
6	5.4	-	0.5	0.7	0.6	1.89
8	5.7	-	0.5	0.7	0.6	2.00
10	6.7	-	0.5	0.7	0.6	2.35
12	5	-	0.5	0.7	0.6	1.75
14	4.6	-	0.5	0.7	0.6	1.61
16	4.6	-	0.5	0.7	0.6	1.61
18	4.5	-	0.5	0.7	0.6	1.58
20	4.4	-	0.5	0.7	0.6	1.54
22	6.6	-	0.5	0.7	0.6	2.31
24	7.2	-	0.5	0.7	0.6	2.52
26	6.8	-	0.5	0.7	0.6	2.38
28	6.8	-	0.5	0.7	0.6	2.38
30	6.8	-	0.5	0.7	0.6	2.38

Appendix-III contd....

Date	Alternate CPE (mm)	Rainfall (mm)	Kc	Kp	WA %	Water applied(mm) CPE×Kp×Kc×WA ------------------ 0.909(Eu)
1/1/2014						
3	7.3	-	0.5	0.7	0.6	2.56
5	7.1	-	0.5	0.7	0.6	2.49
7	6.8	-	0.5	0.7	0.6	2.38
9	6.4	-	0.5	0.7	0.6	2.24
11	6.5	-	0.5	0.7	0.6	2.28
13	7.2	-	0.5	0.7	0.6	2.52
15	7.2	-	0.5	0.7	0.6	2.52
17	6.5	-	0.5	0.7	0.6	2.28
19	6.9	-	0.5	0.7	0.6	2.42
21	6.6	-	0.5	0.7	0.6	2.31
23	6.6	-	0.5	0.7	0.6	2.31
25	7.5	-	0.5	0.7	0.6	2.63
27	6.3	-	0.5	0.7	0.6	2.21
2/2/2014	7.1	-	0.5	0.7	0.6	2.49
4	7.7	-	0.5	0.7	0.6	2.70
6	7	-	0.5	0.7	0.6	2.45
8	6.7	-	0.5	0.7	0.6	2.35
10	6.9	-	0.5	0.7	0.6	2.42
12	8	-	0.5	0.7	0.6	2.80
14	9	-	0.5	0.7	0.6	3.15
16	9.5	-	0.5	0.7	0.6	3.33
18	9.7	-	0.5	0.7	0.6	3.40
20	9.3	-	0.5	0.7	0.6	3.26
22	9.3	-	0.5	0.7	0.6	3.26
24	10.2	-	0.5	0.7	0.6	3.57
26	9.8	-	0.5	0.7	0.6	3.43
28	9.9	-	0.5	0.7	0.6	3.47
2/3/2014	9.8	-	0.5	0.7	0.6	3.43
3	10.3	-	0.5	0.7	0.6	3.61
5	9.9	-	0.5	0.7	0.6	3.47
7	10.3	-	0.5	0.7	0.6	3.61
9	11	-	0.5	0.7	0.6	3.85
11	11.3	-	0.5	0.7	0.6	3.96
13	11.9	-	0.5	0.7	0.6	4.17
15	13.1	-	0.5	0.7	0.6	4.59
17	12.9	-	0.5	0.7	0.6	4.52
19	13.5	-	0.5	0.7	0.6	4.73
21	14.2	-	0.5	0.7	0.6	4.97
23	5	12.2	0.5	0.7	0.6	1.75
25	8.6	3	0.5	0.7	0.6	3.01
27	8.3	-	0.5	0.7	0.6	2.91
29	10.8	-	0.5	0.7	0.6	3.78
31	13.9	-	0.5	0.7	0.6	4.87
2/4/2014	14.6	-	0.6	0.7	0.6	6.13
4	13.5	-	0.6	0.7	0.6	5.67
6	10.7	-	0.6	0.7	0.6	4.49
8	10.4	-	0.6	0.7	0.6	4.37
10	14.3	-	0.6	0.7	0.6	6.01

Appendix-III contd....

Date	Alternate CPE (mm)	Rainfall (mm)	Kc	Kp	WA %	Water applied(mm) CPE×Kp×Kc×WA ------------------ 0.909(Eu)
12	14.4	-	0.6	0.7	0.6	6.05
14	14.7	-	0.6	0.7	0.6	6.17
16	15.2	-	0.6	0.7	0.6	6.38
18	14.7	-	0.6	0.7	0.6	6.17
20	16.1	3.8	0.6	0.7	0.6	6.76
22	15.2	-	0.6	0.7	0.6	6.38
24	15.3	-	0.6	0.7	0.6	6.43
26	16.1	-	0.6	0.7	0.6	6.76
28	16.3	-	0.6	0.7	0.6	6.85
30	15.9	-	0.6	0.7	0.6	6.68
2/5/2014	15.6	-	0.8	0.7	0.6	8.74
4	16.3	-	0.8	0.7	0.6	9.13
6	16.7	-	0.8	0.7	0.6	9.35
8	17	-	0.8	0.7	0.6	9.52
10	16.9	-	0.8	0.7	0.6	9.46
12	16.5	-	0.8	0.7	0.6	9.24
14	15.7	-	0.8	0.7	0.6	8.79
16	14.5	-	0.8	0.7	0.6	8.12
18	17.4	-	0.8	0.7	0.6	9.74
20	18.6	-	0.8	0.7	0.6	10.42
22	16.5	-	0.8	0.7	0.6	9.24
24	16.3	-	0.8	0.7	0.6	9.13
26	16.5	-	0.8	0.7	0.6	9.24
28	16.4	-	0.8	0.7	0.6	9.18
30	16.6	-	0.8	0.7	0.6	9.30
1/6/2014	16.5	-	1	0.7	0.6	11.55
3	16.3	5.4	1	0.7	0.6	11.41
5	9	2.1	1	0.7	0.6	6.30
7	9.3	12.0	1	0.7	0.6	6.51
9	8.5	24.2	1	0.7	0.6	5.95
11	9.5	-	1	0.7	0.6	6.65
13	10.8	-	1	0.7	0.6	7.56
15	13.5	0.4	1	0.7	0.6	9.45
17	13.9	8.6	1	0.7	0.6	9.73
19	15.8	2.8	1	0.7	0.6	11.06
21	14.3	6.6	1	0.7	0.6	10.01
23	13.7	4.6	1	0.7	0.6	9.59
25	14	18.6	1	0.7	0.6	9.80
27	9.7	-	1	0.7	0.6	6.79
29	12.5	-	1	0.7	0.6	8.75
1/7/2014	4.5	16.0	1.1	0.7	0.6	3.47
3	9.7	4.2	1.1	0.7	0.6	7.47
5	10.9	1.0	1.1	0.7	0.6	8.39
7	12.4	-	1.1	0.7	0.6	9.55
9	12.5	-	1.1	0.7	0.6	9.63
11	11.9	1.00	1.1	0.7	0.6	9.16
13	11.8	-	1.1	0.7	0.6	9.09
15	11.4	2.6	1.1	0.7	0.6	8.78
17	11.6	-	1.1	0.7	0.6	8.93

Appendix-III contd....

Date	Alternate CPE (mm)	Rainfall (mm)	Kc	Kp	WA %	Water applied(mm) CPE×Kp×Kc×WA ------------------ 0.909(Eu)
19	12.4	-	1.1	0.7	0.6	9.55
21	12.3	-	1.1	0.7	0.6	9.47
23	12.4	-	1.1	0.7	0.6	9.55
25	2.4	-	1.1	0.7	0.6	1.85
27	2.5	11.6	1.1	0.7	0.6	1.93
29	4.9	-	1.1	0.7	0.6	3.77
31	7.6	-	1.1	0.7	0.6	5.85
2/8/2014	7.6	-	1.1	0.7	0.6	5.85
4	6	11.8	1.1	0.7	0.6	4.62
6	3.1	-	1.1	0.7	0.6	2.39
8	5	-	1.1	0.7	0.6	3.85
10	2.5	-	1.1	0.7	0.6	1.93
12	1.6	1.4	1.1	0.7	0.6	1.23
14	4.2	5.8	1.1	0.7	0.6	3.23
16	5.1	12.8	1.1	0.7	0.6	3.93
18	6.1	44.6	1.1	0.7	0.6	4.70
20	7	3.2	1.1	0.7	0.6	5.39
22	7.2	9.0	1.1	0.7	0.6	5.54
24	8.5	-	1.1	0.7	0.6	6.55
26	6	13.1	1.1	0.7	0.6	4.62
28	6	-	1.1	0.7	0.6	4.62
30	6.7	-	1.1	0.7	0.6	5.16
1/9/2014	3.8	-	1.1	0.7	0.6	2.93
3	3.7	-	1.1	0.7	0.6	2.85
5	9.12	-	1.1	0.7	0.6	7.02
7	3.9	-	1.1	0.7	0.6	3.00
9	0.3	54.00	1.1	0.7	0.6	0.23
11	4.1	8.4	1.1	0.7	0.6	3.16
13	1.4	12.0	1.1	0.7	0.6	1.08
15	4.2	6.10	1.1	0.7	0.6	3.23
17	6	2.8	1.1	0.7	0.6	4.62
19	7.8	16.4	1.1	0.7	0.6	6.01
21	3.1	2.0	1.1	0.7	0.6	2.39
23	6.1	12.6	1.1	0.7	0.6	4.70
25	6.8	31.2	1.1	0.7	0.6	5.24
27	8.3	-	1.1	0.7	0.6	6.39
29	8	-	1.1	0.7	0.6	6.16
Harvesting	**1611.26**					**985.60**

Appendix-IV : Actual soil moisture per cent influenced by different treatmentss

Treat.	Depth	Sample collected from respective distance and depth									
		3 Month after ratoon					6 Month after ratoon				
		0 cm	20 cm	40 cm	60 cm	80 cm	0 cm	20 cm	40 cm	60 cm	80 cm
T1	0 cm	38.23	36.5	36.8	36.5	35.22	39.23	38.69	37.78	36.72	36.12
	20 cm	40.11	38.33	37.54	37.1	36.35	40.43	40.11	38.74	37.64	37.05
	40 cm	42.35	39.46	38.64	38.23	37.65	41.19	39.56	39.32	38.46	38.12
	60 cm	38.2	37.67	36.8	36.63	35.1	39.45	38.65	38.12	37.58	37.13
	80 cm	37.1	36.4	35.31	35.2	34.3	38.14	37.77	37.34	36.48	36
T_2	0 cm	38.45	37.34	37.10	36.58	35.70	39.67	39.32	38.68	38.02	37.34
	20 cm	41.23	39.25	38.23	37.35	36.56	40.13	39.78	39.13	39	38.46
	40 cm	42.67	41.56	40.46	39.59	38.75	41.67	40.16	40.10	40	39.56
	60 cm	39.64	38.11	37.68	36.37	36.67	39.56	39.23	39.02	38.45	38.23
	80 cm	37.06	36.87	35.34	35.23	35.10	38.69	38.32	37.68	37.24	36.12
T_3	0 cm	36.78	36.21	35.67	35.23	34.56	37.89	37.34	36.68	36.21	35.25
	20 cm	39.67	39.34	38.78	38.04	36.78	38.68	38.45	37.58	37.15	36.43
	40 cm	41.43	40.23	39.46	38.90	37.68	39.46	39.21	38.43	38.23	37.48
	60 cm	38.88	38.68	38.34	37.67	36.64	38.49	38.34	37.33	37.02	36.37
	80 cm	37.59	37.12	37	36.47	35.25	37.65	37.34	36.68	36.23	35.56
T_4	0 cm	36.67	36.12	35.88	35.21	34.54	37.89	37.46	36.68	36.03	35.55
	20 cm	38.73	37.78	37.02	36.57	35.76	38.65	38.34	37.56	37.32	36.47
	40 cm	40.27	39.56	38.21	37.38	36.46	40.25	39.47	38.54	38.56	37.49
	60 cm	38.89	37.46	36.34	35.48	34.67	38.69	38.23	37.69	37.34	36.56
	80 cm	36.53	35.78	35.11	35.03	34.35	37.78	37.26	36.49	36.14	35.28
T_5	0 cm	38.23	37.78	37.23	37	36.67	39.56	39.14	38.68	37.45	36.56
	20 cm	39.12	38.79	38.31	37.68	37.05	40.25	39.80	39.23	38.69	37.88
	40 cm	41.34	39.41	39.03	38.57	38.23	42.36	41.67	40.45	39.79	38.89
	60 cm	39.27	38.12	37.68	37.03	36.47	40.46	39.49	39.23	38.74	37.56
	80 cm	37.78	37.02	36.48	36.04	35.69	38.68	38.36	37.78	37.23	36.57

Appendix- IV contd……

Treat.	Depth	Sample collected from respective distance and depth									
		3 Month after ratoon					6 Month after ratoon				
		0 cm	20 cm	40 cm	60 cm	80 cm	0 cm	20 cm	40 cm	60 cm	80 cm
T_6	0 cm	37.68	37.34	36.59	36.02	35.67	38.67	38.12	37.78	37.25	36.49
	20 cm	38.89	38.23	37.65	37.23	36.58	39.47	39.42	38.59	38.21	37.38
	40 cm	40.35	39.69	38.58	38.14	37.69	41.04	40.49	39.69	39.2	38.47
	60 cm	38.46	38.03	37.69	37.34	36.79	38.69	38.21	37.48	37.32	37.03
	80 cm	37.23	36.68	36.38	36.02	35.58	38.02	37.67	36.59	36.22	35.45
T_7	0 cm	38.46	38.12	37.57	37.02	36.45	39.23	38.79	38.23	37.47	37.23
	20 cm	39.68	39.34	38.68	38.23	37.45	40.38	39.69	39.24	38.79	38.23
	40 cm	41.75	40.22	39.59	39.04	38.79	42.56	40.73	40.32	39.45	39.32
	60 cm	39.69	39.35	38.59	38.61	38.31	39.34	39	38.46	38.03	37.77
	80 cm	38.54	38.23	37.43	37.04	36.76	37.59	37.32	36.79	36.34	36.13
T_8	0 cm	39.23	39.03	38.67	38.23	37.45	39.45	38.69	37.59	37.04	36.43
	20 cm	40.34	40.07	39.79	39.65	38.75	40.34	39.68	38.59	38.04	37.56
	40 cm	42.45	41.15	40.36	39.69	39.34	41.58	40.43	39.65	39.34	38.50
	60 cm	39.68	39.34	38.69	38.04	37.68	39.47	38.78	38.23	37.89	37.15
	80 cm	38.56	38.35	37.69	37.45	37.03	38.61	37.68	37.25	36.34	36.02
T_9	0 cm	37.57	37.34	36.48	35.56	34.45	38.68	38.24	37.69	37.23	36.34
	20 cm	38.78	38.36	37.78	36.58	35.47	39.53	39.12	38.59	38.34	37.65
	40 cm	39.56	39.13	38.68	37.72	36.42	40.23	39.69	39.32	38.89	38.26
	60 cm	38.49	38.24	37.78	36.61	35.24	39.47	38.48	37.49	37.04	36.68
	80 cm	37.69	37.23	36.56	35.31	34.36	38.34	37.59	36.54	36.16	35.34

Appendix-IV contd.....

Treat.	Depth	Sample collected from respective distance and depth									
		9 Month after ratoon					At harvest				
		0 cm	20 cm	40 cm	60 cm	80 cm	0 cm	20 cm	40 cm	60 cm	80 cm
T1	0 cm	37.5	37.3	37.1	36.8	36.6	37.2	37.1	37.0	36.8	36.6
	20 cm	39.1	39	38.8	38.6	38.5	38.8	38.7	38.5	38.4	38.1
	40 cm	42.4	42.2	42.0	41.7	41.5	42.1	42.0	41.9	41.7	41.5
	60 cm	40.9	40.7	40.4	40.2	40.1	40.4	40.2	40.1	39.9	39.7
	80 cm	38.8	38.6	38.5	38.3	38.2	37.6	37.5	37.2	37.0	36.9
T_2	0 cm	37.6	37.4	37.2	37	36.8	37.3	37.1	36.8	36.7	36.4
	20 cm	39.5	39.3	39.2	39.1	38.8	39.3	39.1	38.9	38.7	38.6
	40 cm	42.8	42.6	42.5	42.3	42.1	41.9	41.7	41.6	41.4	41.1
	60 cm	41.3	41.1	40.9	40.7	40.6	40.1	39.8	39.7	39.5	39.3
	80 cm	39.3	39.1	38.9	38.6	38.5	38.9	38.6	38.5	38.4	38.2
T_3	0 cm	36.9	36.7	36.5	36.4	36.2	36.5	36.3	36.2	36.0	35.8
	20 cm	38.7	38.6	38.4	38.3	38.1	38.3	38.1	38.0	37.8	37.6
	40 cm	41.8	41.7	41.5	41.3	41.1	41.6	41.4	41.2	41.0	40.9
	60 cm	39.5	39.3	39.1	38.9	38.7	39.2	39.0	38.8	38.6	38.4
	80 cm	37.8	37.6	37.5	37.3	37.1	37.3	37.1	37.0	36.8	36.5
T_4	0 cm	37.8	37.7	37.3	37.2	37	37.4	37.2	37.0	36.8	36.5
	20 cm	39.9	39.8	39.6	39.4	39.2	39.6	39.4	39.2	39.0	38.9
	40 cm	43.1	42.8	42.7	42.5	42.4	42.8	42.7	42.5	42.3	42.1
	60 cm	40.6	40.4	40.2	39	39.8	40.2	40.1	40.0	39.8	39.6
	80 cm	38.4	38.2	38	37.8	37.6	38.1	37.9	37.7	37.6	37.3
T_5	0 cm	37.1	36.7	36.5	36.3	36.2	36.7	36.5	36.3	36.2	36.0
	20 cm	39.1	38.9	38.7	38.6	38.5	38.9	38.6	38.5	38.3	38.1
	40 cm	42.8	42.7	42.5	42.3	42.1	42.5	42.2	42.1	42.0	41.8
	60 cm	40.6	40.4	40.3	40.1	39.9	40.2	40.0	39.9	39.6	39.4
	80 cm	38.4	38.3	38.1	37.9	37.7	38.1	37.8	37.6	37.5	37.3

Appendix-IV contd…..

Treat.	Depth	Sample collected from respective distance and depth									
		9 Month after ratoon					At harvest				
		0 cm	20 cm	40 cm	60 cm	80 cm	0 cm	20 cm	40 cm	60 cm	80 cm
T_6	0 cm	37.2	37	36.9	36.7	36.6	36.8	36.6	36.4	36.2	36.1
	20 cm	38.8	38.6	38.5	38.3	38.2	38.2	38.1	37.9	37.7	37.5
	40 cm	41.8	41.7	41.5	41.3	41.1	41.7	41.6	41.5	41.3	41.2
	60 cm	40.3	40.1	39.9	39.7	39.5	39.9	39.6	39.5	39.3	39.1
	80 cm	37.5	37.3	37.2	37	36.8	37.5	37.3	37.1	37.0	36.8
T_7	0 cm	36.9	36.7	36.5	36.3	36.1	36.5	36.4	36.3	36.1	36.0
	20 cm	38.6	38.5	38.3	38.1	37.9	38.1	37.9	37.8	37.6	37.4
	40 cm	42.7	42.6	42.4	42.2	42	40.8	40.7	40.5	40.3	40.1
	60 cm	40.6	40.4	40.2	40.1	40	39.7	39.6	39.4	39.2	39.1
	80 cm	38.4	38.2	38	37.8	37.7	37.4	37.3	37.1	36.8	36.6
T_8	0 cm	36.9	36.8	36.5	36.4	36.2	36.4	36.2	36.1	35.8	35.7
	20 cm	39.2	38.6	38.4	38.3	38.1	38.9	38.7	38.6	38.4	38.2
	40 cm	43.2	42.9	42.7	42.6	42.4	42.5	42.3	42.2	42.0	41.8
	60 cm	40.1	39.8	39.6	39.4	39.3	40.0	39.8	39.7	39.5	39.3
	80 cm	37.7	37.5	37.3	37.2	37	38.1	37.9	37.7	37.6	37.4
T_9	0 cm	36.4	36.2	36.1	36	35.8	35.2	36.0	35.8	35.6	35.4
	20 cm	38.6	38.5	38.3	38.2	38.1	38.4	38.3	38.2	38.1	38.0
	40 cm	41.8	41.7	41.6	41.5	41.3	40.7	40.6	40.4	40.2	40.1
	60 cm	39.3	39.1	38.9	38.6	38.5	38.9	38.7	38.5	38.4	38.2
	80 cm	37.2	37	36.8	36.6	36.5	36.9	36.6	36.4	36.3	36.2

Appendix-V (A) : Economics of drip-irrigation systems for banana

Sr. No,	Items	Cost (Rs.)	Life year	Depreciation =OC- JV/L	Interest@ 12% p.a.Rs.	Repair and maintenance @ 2 % p.a.(Rs.)
I.	**Drip irrigation**					
1.	Centrifugal pump set (5 HP) and accessories	8000	20	360	960	80
2.	Screen filter with pressure guage	3000	6	450	360	60
3.	Bypass	1000	6	150	120	20
4.	PVC pipe, 63 mm diameter (150m) @32 Rs./m	4800	6	720	576	96
5.	PVC pipe, 50 mm diameter (200m) @ 30 Rs/m	6000	6	900	720	120
6.	LDPE lateral,16 mm diameter 6667 m @ Rs. 6.40/m	42668.8	6	6541.82	5320.26	868.38
	GTO for LDPE lateral 16 mm diameter @ Rs. 2.5/unit (133 Nos.)	332.5	6	49.88	39.9	6.65
7.	PVC end caps (133) @ Rs. 2.50/m	332.5	6	49.88	39.9	6.65
8.	Drippers for LDPE lateral 16 mm 8889 No. @ 2 /unit	17778	6	2715.92	2318.64	370.56
9.	PVC fitting	2000	6	300	36	40
10.	Pressure guage	1000	6	150	120	20
11.	Valves	1000	6	150	120	20
13.	Total investment	87910	-	12573.5	10730.8	1708.47
14.	**Total annual cost**	-	-	**25012.77**		

OC = Original cost,
L = Life span
JV = Junk value = 10 % of OC.

Appendix –V(B) : Cost of cultivation for drip- irrigation systems per hectare for cultivation of ratoon banana

Sr. No.	Particulars	T1		T2		T3		T4	
		Qty	Cost(Rs.)	Qty	Cost(Rs.)	Qty	Cost(Rs.)	Qty	Cost(Rs.)
1	Labour charges@120/day	60	7200	60	7200	60	7200	60	7200
2	Water charges		826		826		826		826
3	Earthing up	2	7200	2	7200	2	7200	2	7200
4	Weeding	1	4800	1	4800	1	4800	1	4800
5	Insecticide/pesticide	1	2000	1	2000	1	2000	1	2000
6	Fertlizer								
	Special grade @ 85/kg	0	0					2155	183175
	Urea @ 6 /kg	1833	10998	1466.4	8798.4	1099.8	6598.8	0	0
	MAP @ 82 /kg	378.76	31058	303	24846	227	18614	0	0
	SOP @ 70 /kg	1778	124460	604	42280	453	31710	0	0
	MOP @ 14.5/kg	0	0	0	0	0	0	0	0
	DAP @ 25 /kg	0	0	0	0	0	0	0	0
7	Electricity charges		2100		2100		2100		2100
8	Harvesting and marketing		10900		10900		10900		10900
9	A. Working capital (3 to 11)		201542		110950		91948.8		218201
10	B. Interest on working capital @ 12 % p. a.		24185		13314		11034		26184
11	C. Rental value of land		2000		2000		2000		2000
12	Total (A+B+C)		**227727**		**126264**		**104953**		**246385**

Appendix-V(B) contd....

sr. no	Particulars	T5		T6		T7		T8		T9	
		Qty	Cost Rs.)	Qty	Cost Rs.)	Qty	Cost Rs.)	Qty	Cost Rs.)	Qty	Cost Rs.)
1	Labour charges@120/day	60	7200	60	7200	60	7200	60	7200	60	7200
2	Water charges		826		826		826		826		826
3	Earthing up	2	7200	2	7200	2	7200	2	7200	2	7200
4	Weeding	1	4800	1	4800	1	4800	1	4800	1	4800
5	Insecticide/pesticide	1	2000	1	2000	1	2000	1	2000	1	2000
6	Fertlizer										
	Special grade @ 85/kg	1615	137275	2155	183175	1616	137360	0	0	0	0
	Urea @ 6 /kg	0	0	1152	6912	864	5184	1778	10668	0	0
	MAP @ 82 /kg	0	0	137	11234	103	8446	0	0	0	0
	SOP @ 70 /kg	0	0	0	0	0	0	0	0	0	0
	MOP @ 14.5/kg	0	0	0	0	0	0	1482	26676	0	0
	DAP @ 25 /kg	0	0	0	0	0	0	387	9675	0	0
7	Electricity charges		2100		2100		2100		2100		2100
8	Harvesting and marketing		10900		10900		10900		10900		10900
9	A. Working capital (3 to 11)		17230 1		23634 7		18601 6		82045		35026
10	B. Interest on working capital @ 12 % p. a.		20676		27998		22322		9845		4203
11	C. Rental value of land		2000		2000		2000		2000		2000
12	Total (A+B+C)		**194977**		**266345**		**210338**		**93890**		**41229**

Appendix-V C : Cost economics of ratoon banana fertigation under different treatmentss

	T_1 : 100 % RDWSF	T_2 : 80 % RDWSF	T_3: 60 % RDWSF	T_4 : 80 % RDWSF	T_5 : 60 % RDWSF	T_6 : 80 % RDWSF	T_7 : 60 % RDWSF	T_8 : 100 % RD CF	T_9 : No fertilizer
Fixed cost	25031	25013	25013	25013	25013	25013	25013	25013	25013
Operational Cost	227727	126264	105030	246385	194977	266345	210338	93890	41229
Seasonal Cost	252758	151277	129996	271398	219990	291358	235351	118903	66242
Water used cm	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.6
Yield of banana t/ha	82.35	77.21	67.89	72.96	65.52	80.66	70.84	60.15	45.08
Selling price, Rs./t	7500	7500	7500	7500	7500	7500	7500	7500	7500
Income from Produce,Rs/ha	617625	579075	509175	547200	491400	604950	531300	451125	338100
Net seasonal Income ,Rs/ha	372700	424759	379132	275802	271410	316624	304764	332222	271390
B:C Ratio	2.44	3.83	3.91	2.02	2.23	2.08	2.26	3.79	5.10
Net profit/mm water use	370	434	385	280	275	318	300	337	275

8. VITA

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of

MASTER OF SCIENCE (AGRICULTURE)

in

IFD-IRRIGATION WATER MANAGEMENT

2015

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