NUTRIENT DYNAMICS UNDER DRIP FERTIGATION IN COTTON

Thesis submitted in part fulfillment of the requirements for the Degree of

MASTER OF SCIENCE (AGRICULTURE) IN

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

to the Tamil Nadu Agricultural University, Coimbatore-3

By

N. JAYAPRAKASH
(I.D. No. 06-617-002)

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE

TAMIL NADU AGRICULTURAL UNIVERSITY

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ABSTRACT

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By

N. JAYAPRAKASH

Degree : **Master of Science (Agriculture) in Soil Science and Agricultural Chemistry**

Chairman : **Dr. K. APPAVU**
Professor
Department of Soil Science and Agricultural Chemistry
Water Technology Center
Tamil Nadu Agricultural University
Coimbatore – 641 003.

2008

A field experiment was carried out at Agricultural College and Research Institute, Coimbatore during September 2007 to March 2008 to study the nutrient dynamics under drip fertigation with straight and water soluble fertilizers on the growth and yield of hybrid cotton (RCH 2Bt). The experiment was conducted in a randomized block design with three replications. The data on soil moisture distribution, nutrient distribution, growth parameters, yield attribute and quality of cotton were recorded at different stages. The uptake of nutrients by different plant growth stages was also computed.

The soil moisture content at the point of dripper from increasing with vertical distance from the emitter, similarly lower in the surface layer and followed by increasing trend with the depth. It implies that the drip system could maintain an ideal soil moisture regime for optimum crop growth condition.

The distribution of ammoniacal, nitrate, available nitrogen, phosphorus and potassium were distributed higher near the root zone (0-30 cm) except nitrate, because its leaches beyond the root zone. The higher available nutrients distributed under drip fertigation with water soluble fertilizers at all the levels then compared to drip fertigation with straight fertilizers and surface irrigation with soil application of fertilizer. The treatments under water soluble fertilizer the availability of nutrient distribution is higher, which ensures the availability and nutrient uptake by the crop. The soil pH was decrease in distance to the dripper from vertically and horizontally, which helps to lower pH in root zone for favorable root growth. The EC was increase in distance to the dripper from

vertically and horizontally with the increasing the levels of fertilizer it's also ensures the nutrient exchanges and availability to crop.

Application of surface irrigation with soil application of 100 per cent RDF as straight fertilizer produced significantly taller plants as compared to other treatments. Drip fertigation with 75 per cent RDF as water soluble fertilizer had significant influence on the yield attributes *viz.,* sympodial branches per plant, number of bolls per plant and boll weight found to be higher over other treatments. Drip fertigation with 75 per cent recommended dose of NPK as water soluble fertilizer recorded the highest seed cotton yield of 3324.0.kg ha^{-1}, which was statistically on par with the treatments having drip fertigation with 100 per cent recommended dose of NPK as straight and water soluble fertilizer *viz.,* 3062.8 and 3062.2 kg ha^{-1}. Surface irrigation with soil application of 100 per cent recommended dose of NPK as straight fertilizer produced inferior over other treatments. Nutrient uptake was favourably increased with drip fertigation with 75 percent RDF as water soluble fertilizer compared to drip fertigation with straight fertilizer and surface irrigation with soil application of fertilizer at all the stages of crop growth.

Drip fertigation with 75 per cent recommended dose of NPK as water soluble fertilizer recorded superior fibre length of 32.40 mm it was on par with the treatment drip fertigation with 100 per cent recommended dose of NPK as straight fertilizer 32.40. Drip fertigation with 100 per cent recommended dose of NPK as water soluble fertilizer recorded maximum bundle strength of 22.20 g tex^{-1}, while drip fertigation with 100 per cent recommended dose of NPK as straight fertilizer recorded higher micronaire value (4.2) as compared to other treatments and uniformity ratio of 47.0 were increased significantly in drip fertigation with 150 per cent recommended dose of NPK as water soluble fertilizer.

The highest benefit cost ratio of 2.14 recorded with drip fertigation with 100 per cent RDF as straight fertilizer with the net return of Rs. 40,760.20 ha^{-1}. The next best B: C ratio of 1.99 with the highest net return of Rs. 41,374.15 ha^{-1} was noticed in drip fertigation with 75 per cent RDF as water soluble fertilizer. Surface irrigation with soil application of 100 per cent RDF as straight fertilizer recorded the least value of net return and B: C ratio of Rs. 3244.00 and 1.13 respectively.

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CHAPTER I

INTRODUCTION

The existence, endurance and exuberance of human life in this universe chiefly depends on the nutritious food for a healthy survival, safer place for dwelling and if not the least to ignore, a decent dress to mark the level of a civilized social environment. Garments rule the roost in the present day world where the human beings have experienced a giant leap or a paradigm shift from the status of a barbarian to a much civilized explorer of life's mysteries and secrets. Cloth is an external indicator of one's level of civilization, education, status, respect, comfort and fashion. Even as umpteen raw materials are emerging, cotton, the '**white gold**' remains neither shaken nor stirred of its top position in garment making and allied fields such as medical aids.

Cotton enjoys a predominant position amongst all cash crops in India. Cotton is an important raw material for the Indian textile industry, constituting about 65 per cent of its requirements. The Indian textile industry occupies a significant place in the country's economy with over 1500 mills, 4 million handlooms, 1.7 million power looms and thousands of garment, hosiery and processing units, providing employment directly or indirectly around 35 million people.

In India, cotton occupies an area of nearly 91.42 lakh hectares, with a production of 280.00 lakh bales during 2006-2007, ranking third in the world. The lint productivity of cotton is 521 kg ha^{-1}, which is the lowest and far below that of the world average of 627 kg ha^{-1} (Anon, 2008)

In Tamil Nadu, as a predominant commercial crop, different varieties and hybrids of cotton are grown to an extent of 1.22 lakh ha, with a production of 5.00 lakh bales and productivity of 697 kg of lint ha^{-1}(Anon, 2008). The major cotton growing districts are Virudhunagar, Salem, Madurai and Coimbatore which together accounted for 43.3 per cent of the total area of the state during 2004-05 (Anon, 2005). With advancement in evolving superior hybrids and production technologies, the cotton cultivation is gaining momentum and there exists potential scope for enhancing its productivity.

Efficient management of water is of utmost importance for sustaining and enhancing agricultural production. While there is demand to bring more area under assured irrigation, availability of water for irrigation is expected to diminish in coming years due to the competing demand for other uses. As compared to surface water, greater proportion of irrigation water comes from the ground water and this source is increasingly being exploited in an unscientific manner. Thus the importance of scientific water management and the need to adopt advanced techniques like drip irrigation to enhance productivity and water use efficiency of field crops became imperative. It has been proved over time and space that drip irrigation can result in more than 50 per cent saving in water application with high levels of water use efficiencies for a wide range of crops.

In irrigated agriculture, low fertilizer use efficiency primarily of nitrogenous fertilizer is a consequence of existing poor water use efficiency. Any strategy that focuses on improving fertilizer use efficiency will have to consider the linkage between fertilizer and water. Applying fertilizers through irrigation water particularly through drip termed as fertigation provides the most effective way of supplying nutrients at the vicinity of plant roots. Drip irrigation has the added advantage because it can also be used to apply any water soluble fertilizer or chemical in precise amounts, as and when required to match the plant needs or any other agronomic management (Bar-Yosef and Sagiv, 1982; Bafna *et al*., 1993).

Considerable amount of work has been done on drip irrigation in recent years but information on the conjunctive use of water and nutrient and the resultant nutrient movement and distribution using drip irrigation is scanty. The information on the nutrient dynamics under drip fertigation would be very useful in designing efficient fertigation systems. In addition to nitrogen, the single most important plant nutrient, potassium, a nutrient considered adequate in soils all over the world, has now been reported to be deficit in vast areas in recent years. This necessitates the addition of potassium based on the crop need and drip fertigation is a viable option for balanced use of this quality element.

Sustainability of any system requires optimal utilization of resources such as water, fertilizer or soil. Apart from the economic considerations, the adverse effect on injudicious use of water and fertilizers on the environment can have far reaching implications. There is a need to develop agro technology, which will help in sustaining the precious resources and maximizing crop production without any detrimental impact on the environment. Efficient and judicious use of both water and fertilizer is the key weapon for boosting up the production and productivity of crop lands. Fertigation is one of such technologies where any water-soluble fertilizer or chemical can be applied in precise amounts in synchrony with the plant needs, directly into the root zone of the crop. This not only economizes the water use, but also improves nutrient use efficiency, as the fertilizer applied remains confined to the root zone of the crop. Information on the moisture and nutrient distribution under fertigation is rather scanty. Very little work has been done on the spatial distribution of fertilizer nutrients applied through fertigation to cotton. Hence, an attempt was made to investigate the moisture and nutrient dynamics in the soil under drip fertigation systems in cotton.

The present investigation was carried out to study the effect of drip fertigation with straight fertilizer and water soluble fertilizer on the feasibility, productivity and economics of Bt cotton hybrid. The specific objectives contemplated on these aspects are outlined as follows.

1. To study the wetting pattern, nutrient distribution under drip fertigation in cotton
2. To study the growth parameters, yield and quality of cotton under drip fertigation
3. To study the nutrient uptake at different stage of plant growth under drip fertigation

CHAPTER II

REVIEW OF LITERATURE

Water and nutrient are the two key inputs in cotton production. However, their use efficiency is low and their injudicious use leads to wastage of inputs and environmental degradation. Among the various techniques, drip fertigation is the most efficient method for enhancing the use efficiency of both water and nutrients. Drip fertigation with straight fertilizers and water soluble fertilizers significantly influences the crop yield. The research findings related to nutrient dynamics under drip fertigation with different levels of straight and water soluble fertilizers on cotton are reviewed here under.

2.1. Drip irrigation

As water is becoming a scarce commodity now-a-days, it is necessary to find ways and means of using the available water resources in a judicious manner to attain maximum productivity per unit quantity of water. In drip irrigation, water is provided most efficiently at right time and practically near the root zone of the crop. Only a fraction of soil is wetted, generally between 15 to 60 per cent. It enables precise application of water and nutrient at root zone avoiding soil erosion and drain of water by deep percolation (Herman, 1982). Selvaraj *et al*. (1997) revealed that drip irrigation could also be used for close spaced row crops of high return wherever water scarcity is the major constraint. Though the initial cost would be more, the pay back period for many commercial crops like sugarcane, banana, vegetables, cotton, etc., was within two years. .

Sivanappan (2004) found that the advancement in designing and reduced cost of material, drip irrigation is becoming popular and acceptable for most of the field crops. In cotton, drip irrigation is one of the suitable methods of irrigation which is now being practiced in major cotton growing areas. It is realized that drip irrigation not only boost up the production but also reduce the water requirement, when it is practiced along with fertigation.

Shock *et al*. (2005) reported that drip irrigation provides control and precision of irrigation timing, as well as the amount of water applied, while assuring high yield. As a result, drip irrigation causes significantly less erosion, less deep percolation and less leaching than furrow irrigation. Drip irrigation can be managed to protect the environment, avoiding off-site losses of fertilizer and water and can be maintained as wed free environment.

2.2. Fertigation

Fertigation is the application of fertilizers through irrigation. By definition, fertigation is the precise application of soluble fertilizers through sprinkler and drip irrigation (Bill, 2003). When fertilizers were applied along with water through drip irrigation system, there was a considerable saving of fertilizers besides increased yield, quality and saving of water compared to surface method of irrigation. It helps to achieve higher fertilizer and water use efficiency.

Drip fertigation provides an efficient method of fertilizer delivery and if properly managed, it reduces overall fertilizer application rate and minimize the adverse environmental impact (Hochmuth, 1994).

Fertigation is the technique that provides the means to add N and other plant nutrients and chemicals at right time and right place and increases the application frequency and, therefore, increases N recovery. Application of N fertilizer with irrigation water improves crop yield and N recovery and provides better timing to meet crop demand throughout the growing season. The drip fertigation technique dictated better understanding of N uptake, concentration, partitioning among plant tissues, recovery, equivalent N fertilizer uptake and equivalent total N uptake. Improved N management of cotton crop might lead to higher yield, N recovery and better environmental protection. Excess N application can cause excessive vegetative growth, reduced N recovery and increased NO_3 percolation and leaching beyond the root zone and into the groundwater. Insufficient nitrogen can reduce the vegetative growth, limits the fruiting site and consequently decrease the yield which was stated by Janat, 2004.

2.3. Fertigation on cotton

Fertigation gives flexibility of fertilization which enables the specific nutritional requirement of the crop to be met at different stages of its growth. Split application of fertilizer ensures adequate supply of required nutrients in right time and in right quantity for getting higher yields with minimum loss of nutrients.

Lint yield as a function of N input under drip fertigation has consistently and significantly increased the yield, ranging between 1852 and 2221 kg ha^{-1}. While, for surface-irrigated treatment, the lint yield was much lower (1585 kg ha^{-1}) and was only comparative with the drip irrigated control (Janat, 2004).

2.4. Moisture distribution under drip irrigation

Water movement and distribution in the soil largely varies depending upon several parameters such as soil type, rate of infiltration, rate of discharge, quantity of water applied, antecedent moisture content, depth to water table and certain climatic factors.

The wetting front depth with 1.5 lph emitter was at 40 cm. For 4 lph and 4 hours application time, it was at 52.5 cm. After redistribution, wetting front depth will be certainly greater than these values. Accordingly, with crop root depth, emitter and lateral spacing, discharge choice can be obtained and consequently application time optimization prevents water loss neither by deep percolation nor by under irrigation (Thabet and Zayan, 2008). Drip irrigation resulted in reduced nitrate loss from deep percolation and reduced water use without negatively affecting yield and quality of products (Sharmasarkar *et al*., 2001).

Li *et al*. (2004) reported that increasing application rate allows more water to distribute in the horizontal direction, while decreasing the rate allows more water to distribute in the vertical direction. Shirahatti *et al*. (2007) pointed out that vertical distribution, soil moisture content increased with depth. While in the lateral distribution, the maximum soil moisture was observed just below the trickle source (0-10 cm) and decreased as the distance from the water source increased.

Suresh Kumar (2000) also established that available soil moisture was almost consistent and nearer to field capacity under drip irrigation system as against wide fluctuation under surface irrigation.

Adequate soil moisture availability ensures successful cotton production under any type of cultivation. Higher available soil moisture (ASM) was observed in drip irrigation plots as compared to furrow irrigation in two soil depths of 0-15 cm and 15-30 cm (Veeraputhiran, 2000).

2.5. Interaction of water and nutrients

Interaction is the differential response of one production input in combination with varying levels of the second input applied simultaneously. There exists a positive interaction between water and fertilizer, the two key production inputs. Synergistic interaction between these two critical inputs has been researched extensively for harvesting maximum benefits out of such an association. The nitrogen significantly interacts with the moisture, increases vegetative growth considerably even during the maturity phase.

In cotton, the interaction of moisture and nitrogen was well defined. Cotton responded to all levels of N (0, 60, 120 and 240 lb ac^{-1}) whereas at low and intermediate moisture level, the response to N was only upto 120 lb ac^{-1}. Nitrogen increased the efficiency of water utilization (Scarsbrook *et al*., 1959). The growth of cotton increased with more frequent irrigation and the increase was greater with higher N doses (Lashin and Sorour, 1976). Increasing N supply within water regime (50 and 100 per cent ET level) resulted in a positive response in boll number per plant (Morrow and Krieg, 1990).

The yield of cotton was found to increase with increase in drip irrigation regimes of 100, 75 and 50 per cent and it had positive response with increasing fertilizer levels of 50, 75 and 100 per cent of nitrogen (Anon, 2005).

2.6. Nutrient distribution under drip fertigation

2.6.1. Nitrogen distribution

Hue *et al.* (2007) reported that the distribution of residual NO_3-N in the soil with depth differed significantly due to the interaction between treatment and soil depth, although residual NO_3-N concentrations were generally higher in the 0.4-0.5 m than in the 0.3-0.4 m, with the least residual NO_3-N concentrations in the 0.1-0.2 m. Increased in N_2O emissions or NO_3 leaching associated with changes in dynamics and distribution of water, C and N in soil was reported by Six *et al*. (2002) and Ball *et al*. (1999).

Darwish *et al.* (2003) stated that the fertigated treatment indicated a restriction of the nitrate within the root zone (40 cm), whereas a significant movement beyond the root zone occurred under the sprinkler treatment. Based on the average NO_3 concentration of the soil solution N leached beyond the potato root zone was less than 3 kg ha^{-1} season in the drip irrigation compared to 55 kg ha in the macro sprinkler.

Boswell *et al*. (1985) reported that nitrate-N is relatively unreactive and, therefore, susceptible to movement through diffusion and mass transport in the soil water because 1. Nitrate compounds are readily soluble in water, and 2. They are not usually adsorbed on the negatively charged soil clay particles. Since nitrate-N is highly soluble and non adsorbing, it is more likely to be lost through surface water runoff and deep percolation of water.

Ajdary *et al*. (2007) reported the highest and lowest N concentration was observed for sandy loam and silt soils, respectively. This implies that more permeable soils are prone to leaching when compared to the less permeable soils. Lateral spreading of N in second layer is more for silt clay loam and silt soils. This might have been due to poor intake rate and increased pounding time. However, it may be mentioned that N concentration in active root zone is adequate in all soils considered. Simulated N distributions in the vertical direction under various soils at the end of simulation period can be explained with the difference in N concentration is more at the depth of 10-15 cm, which is classified as active root zone. N concentration increased with depth up to 10-15 cm there after decreased and became almost constant in all soils except sandy loam. In case of sandy loam soil, it was still showing decreasing trend. For all soils, concentration of N was more at the vertical plane located at 15 cm from emitter. It may be mentioned that plant is located at 15 cm from the emitter.

Water flow and solute transport experiments involving relatively long furrows/borders is the change in solute concentration and application time as water flows along the field and ways to specify overland solute concentrations with distance and time. For instance, fertigation (applying fertilizers with irrigation water) in long borders or furrows can result in considerable fertilizer non-uniformity along the field according to Abbasi *et al*. (2003).

Janat (2004) stated that the nitrate leaching beyond the root zone causing most economical losses for farmers, the major source of groundwater and water-table pollution. Optimizing N fertilizer application by reducing NO_3 losses from the rhizosphere area and monitoring the nitrate level in the root zone are necessary steps for N fertilizer optimization as well as higher economical return for farmers. To reduce the nutrient leaching, it is necessary to have the right diagnostic tool that can simply and reasonably be used in the field drip-fertigated treatments, as well as the subsurface (25-50 cm) of the 180 kg N ha^{-1} drip-fertigation treatment contained the largest amount of NO_3-N when compared with the control plots. The differences were highest for the drip-fertigated treatments, 120,180 and 240 kg N ha^{-1} and lowest for the surface-irrigated treatment.

Findeling *et al*. (2007) reported that, the consequence of gaseous losses by nitrification and denitrification (N_2, N_2O and NO) and/or a preferential downward convective transport of nitrate during the rain, which the model could not account for NH_4 -N content in soil as always smaller than 1 mg N kg^{-1} soil, which was negligible when compared with the NO_3-N content. Consequently, they only considered nitrate as inorganic nitrogen. Measurements of NO_3-N amounts in the topsoil layer (0-5 cm) are presented in ends of each drying period. An increase in nitrate content over time was observed for both residues. This increase can result from mineralization of humified soil organic matter, nitrate leaching from the mulch and convective transport of nitrate by capillary rise of water in the soil during evaporation stages.

Li *et al.* (2004) investigated the influence of emitter discharge rate, input nutrient concentration and applied volume on water movement and nitrogen distribution, when nutrients were applied continuously at a constant concentration from a surface point source and found that nitrate (NO_3-N) accumulated towards the boundary of the wetted volume for any combination of discharge rate, input concentration and volume applied, suggests that the nitrate is susceptible to move out of the root zone by mismanagement of fertigation, leads to nitrate contamination of surface and ground water sources and soil.

Under drip irrigation, highest reduction in soil NO_3-N was observed in 30 to 60 cm depth (18 mg per kg) (Nightingale *et al*., 1985). The concentration of non-reacting nutrient was increased with increasing distance from the point source under drip fertigation towards the soil wetting front and the concentration gradient in the wetted zone are greater in the loamy soil than in the sandy soil (Bar-Yosef, 1995).

Cook and Sanders (1991) studied the effect of N application frequency (daily, weekly, biweekly, monthly or before planting) through drip irrigation on soil NO_3-N movement in the bed profile and on yield and N uptake by tomato plants. NO_3-N concentration within the raised bed decreased with time due to plant uptake and leaching. Nitrogen levels declined most rapidly in the area closest to the drip line. Cotton uses only inorganic form of N either as nitrate nitrogen (NO_3-N), or ammonical nitrogen (NH_4-N).

Chakraborthy *et al*. (1998) reported the distribution of NO_3-N throughout the soil profile under fertigation varied both horizontally and vertically below from the emitter point. The peak nitrate nitrogen concentration below the emitter was found to be in 30 to 50 cm depth, whereas from location 15, 30 and 45 cm away from the emitter, peak was within 10 to 20 cm depth. Below the emitter NO_3-N distribution at first decreased steadily upto a depth of 25 cm followed by sudden increase in peak concentration at 30-50 cm depth of soil whereas the peak concentration of ammoniacal nitrogen was confined to 0-15 cm soil depth.

Singh *et al*. (2002) reported that, under drip irrigation the ammoniacal form of nitrogen dominated in the upper soil layer as compared to surface irrigation, whereas NO_3-N dominated in lower soil layers and significant amount leached away to deeper layers of soil. The study conducted by Singh *et al*. (2002) reported that potassium was confined to root zone in fertigation. In case of furrow irrigation, significant quantity of potassium moved beyond the root zone. Suganya *et al*. (2007) also reported that higher concentration of ammoniacal nitrogen was observed closer to the emitter and as well as in the top layer while, nitrate concentration increased with distance from the emitter. Available N content was maximum closer to the emitter and concentration decreased with distance and depth.

Laher and Avinmelech (1980) reported that, before fertigation both NH_4 and NO_3 form of nitrogen were uniformly distributed in the soil up to 80 cm, but after fertigation NH_4 was more concentrated on the surface soil than sub surface whereas, NO_3 was uniformly distributed. Even after fertigation indicating that NO_3 is more mobile and NH_4 very less mobile. Stanley *et al*. (1990) reported that N movement in soil applied through drip with 3 N rates (17.8, 9.4 and 6.0 kg N $ha^{-1}wk^{-1}$), in non cropped treatment high NH_4 concentration accumulated at all depths for 22 weeks after sugarcane planting.

Haynes (1990) reported that after 5 hours of fertigation more urea N than NH_4 and NO_4 in 4 days almost all urea was hydrolyzed. But even after 4 weeks subsequent nitrification of NH_4 was not observed this is because of anaerobic condition inhibits the nitrification but after 8 days onwards significant amount of NO_3-N was noticed. Haynes and Swift (1987) reported that, in both urea and (NH_4) $ZnSO_4$ treatment more amount of NH_4-N was noticed in the top soil and it decreased away from the emitter indicates the less mobile nature of NH_4-N. However, NO_3-N increases up to 20 cm from emitter because of its more mobile nature.

Papadopoulos (1986) observed that residual NO_3 concentration in soil was high for higher fertigation rate. But in 17.8 m/mol N per treatment NO_3 noticed more than the required it even continued over on long period and is subsequently lost in leaching leading to loss of nutrients (NO_3-N) and affect the soil properties (Ec) which has reflected in the yield of the cucumber the higher fruits/plant and yield of cucumber as recorded with 11.8 m.mol N litre^{-1}. The author also observed in clay soil that, with increase in N levels more residues NO_3-N was observed with 230 mg N/liter fertigation in the same way as mentioned above. Significant amount of NO_3-N was noticed below the root zone depth, which will be lost in leaching and not useful for crop. The tomato yield produced by 230 mg N liter^{-1} was on par with 180 mg N litre^{-1} which suggests that 180 mg N litre^{-1} are optimum fertigation rate.

Cook and Sanders (1991) observed that more amount soil NO_3-N was noticed with daily application of N through drip than monthly or weekly etc., and this more NO_3-N reflected in more yield of tomatoes. This is because of poorly buffered sandy soil low in organic carbon when nitrogen was applied daily not much was lost in leaching but by monthly or pre plant application leaching occurs. It suggests that in light soil number of application of same nutrient quantity should be more.

Haynes (1990) observed that vertical movement of Urea was more in discharge rate of 21/hr than 41/hr, however with 41/hr more horizontal movement of urea was observed. Thompson and Doerge (1996) observed that more amount of residual N at 0-90 cm soil depth when higher N rates and irrigated at high soil moisture tension. But when irrigated at low soil moisture tension nitrogen was lost beyond root zone. Urea was not used by crop and this has reflected in the highest net returns obtained with 340 kg ha^{-1} and irrigated at 17.5 kg pascal (Pa). In the same manner more predicted amounts of residual soil inorganic N occurred under condition of high soil moisture tension and high N application rates and lowest predicted amount were under condition of low soil moisture tension and low N applications.

Bharambe *et al*. 1997, observed that 100 kg N ha^{-1} fertigation significant amount of nitrogen was noticed beyond the root zone which will be lost and this suggests that this rate is more than required for crop, which reflects in the yield. The yield obtained with 100 kg N ha^{-1} was on par with 75 kg N ha^{-1} so about 25 per cent N can be reduced by fertigation.

2.6.2. Phosphorous distribution

Rauschkolb *et al*. (1976) studied P movement in clay loam soil. They found that increase in P rates, its movement in horizontal and vertical direction was increased. Also glycerophosphate was more mobile than ortho phosphoric acid however for both source and rate, higher P was observed on surface soil it suggests its immobile nature. With 24 days of irrigation, vertical movement of P observed than that with 3 days irrigation at the same rate of P application. However, orthophosphoric acid moved both in horizontal and vertical direction and super phosphate moved more in vertical direction (Neill *et al*., 1979). Mikkelsen and Jarrell (1987) found that with increase in P fertigation rate increase P movement down ward but lateral movement was negligible and P applied through triple super phosphate moved more than urea phosphate (20 kg P /ha) has shown optimum P concentration in root zone and increased rate showed more than required P content in root zone which affected nutrient balance and hence affects yield. So 20 kg P/ha gave higher fruit weight of tomatoes than higher and lower rate than the recommended one.

Martinez *et al,* (1991) studied effect of emitter placement on P content in soil. They found that, for surface placement of emitter higher P content was found on top 10 cm soil from all distance from the emitter whereas for subsurface higher P content was in 20-40 cm depth, this is due to less mobile nature of P and this different in P content in soil led to yield difference so subsurface placement has produced higher yield. Papadopoulos (1992) studied the P concentration in soil for 3 years using four phosphorus (i.e. 0, 20, 40 and 60 mg lt^{-1}) fertigation rates. It was observed that for initial two years on much difference was observed with respect to P concentration in soil however in 3rd year a significant amount of P movement below the root zone was observed in higher fertigation rate (60 mg P L^{-1}). This suggests that rate is more than crop requirement. And this variation in P content in soil is very well depicted in yield of potato. 60 mg P L^{-1} rate produced yield on par with 40 mg P/L fertigation rate.

2. 6. 3. Potassium disribution

Parchomchuk *et al*. (1993) analysed K distribution in soil before and after fertigation. He found that K content in soil decreased from top to 25 cm soil depth before fertigation but after fertigation reverse head observed, i.e. K content increased up to 25 cm depth, this is because of after fertigation with nitrogen K was displaced by NH_4 and was subsequently was leached down. Belton and Goh (1992) found with increase in urea fertigation increased the exchangeable Fe and Mn and reduced the exchangeable Ca and Mg and this is mainly because of acidification effect of urea.

2. 7. 1. Nutrient management in cotton

2. 7. 1. 1. Nitrogen

Nitrogen is a constituent of protoplasm, chlorophyll, nucleic acid and aminoacids. It sustains the physiological functions of the crop and essential for establishment of root and vegetative growth as well as seed cotton yield. Nitrogen application in excess delays crop maturity by promoting the vegetative growth and extending the period of flower production. In contrast, inadequate N supply particularly at boll formation and development phase leads to shedding of fruiting parts.

Studies conducted at Coimbatore, showed that application of N, P and K and their availability in soil was increased with higher N levels at 160 kg ha^{-1} in winter irrigated TCHB 213 hybrid cotton. (Alagudurai, 1999). Drip fertigation at 120 kg N ha^{-1} recorded significantly higher N uptake compared to furrow band application of 120 kg N ha^{-1} (Veeraputhiran, 2000).

2. 7. 1. 2. Phosphorus

Phosphorus is known to stimulate early and extensive development of root system, which enables the cotton plant to grow rapidly and to mature early. Even though phosphorus is essential for many processes such as photosynthesis, carbohydrate metabolism and formation of seed and fibre, no direct effect on the size of boll, weight of seeds, percentage of lint, length of fibre etc has been observed. Response of P application has been inconsistent (Nehra *et al*., 2004).

2.7.1.3. Potassium

Potassium is required in substantial quantity to produce an optimum yield of cotton. Where the soil is deficit in potassium, application of potassium may result in higher yield, improved quality and increased resistance to pest and diseases. Application of potasic fertilizer at the rate of 30 kg ha^{-1} at sowing resulted in higher seed cotton yield of 1.879 kg ha^{-1} than control (Nehra *et al*., 2004).

Potassium is an important nutrient in crop management, which contributes to the production of high quality cotton. Shanmugham and Bhat (1991) observed that application of one third of total K through foliage during flowering and remaining through soil application at sowing maintained 3.0 to 3.6 per cent K in the leaves during the reproductive phase resulting in improved span length, uniformity ratio, fineness, maturity co efficient and fibre strength.

Pettigrew *et al*. (1999) observed that deficit soil K levels compromised the quality of fibre produced. Fibre micronaire and fibre maturity were reduced by 5.0 and 2.0 per cent respectively in K deficient plants. The overall effect K deficiency appears to be a reduction in the amount of photosynthate available for the reproductive sinks which promotes the yield and fibre quality reductions associated with production under K deficiency.

Nitrogen fertilization prolongs the crop maturity and invites the problems of pest and diseases. Whereas phosphorus and potash application hasten the crop maturity, increases the efficiency of available soil moisture in crop production and help the crop to escape from the stress condition in the later period of the crop growth. It is therefore, essential to adopt a balanced nutrient schedule for higher efficiency and profitability.

2.7.2. Effect of drip irrigation on growth of cotton

Constable and Hodgson (1990) reported higher DMP under buried and surface drip irrigation than under furrow irrigation in vertisols of Narrabri, Australia. Irrigation through drip favourably influenced the growth parameters viz., plant height, and DMP and number of monopodial branches compared to furrow irrigation in hybrid cotton TCHB 213 grown under Coimbatore conditions (Veeraputhiran 2000).

Studies conducted at Bangalore in red sandy loam soil showed that plant height and sympodial branches were significantly higher in emitter and turbo tape drip irrigation compared to furrow irrigation in both main and ratoon crops of hybrid DCH 32 (Reddy and Gowda, 1997)

Sampathkumar (2003) concluded that drip irrigation in cotton significantly enhanced the growth characters viz., plant height and DMP compared with that of furrow irrigation.

2.7.2.1. Effect of drip irrigation on cotton yield

Drip irrigation has been proved as one of the effective method in achieving the potential yield in cotton. In sodic soil conditions of Tamil Nadu, Muthuchamy *et al*. (1993) recorded 10 per cent more cotton yield in drip method than surface method of irrigation. Reddy and Gowda (1997) observed that plant and ratoon yield of cotton DCH 32 was increased by 13 and 3 per cent under turbo drip and 12 and 6 percent under emitter drip respectively over furrow irrigation. Experimental results from Turkey indicated that the maximum seed cotton yield of 4380 kg ha^{-1} was registered under drip irrigation against 3630 kg ha^{-1} under furrow irrigation and 3380 kg ha^{-1} under sprinkler method of irrigation (Cetin and Bilgel, 2002).

Jadhav *et al*. (2002) reported that the seed cotton yield was enhanced by 44 per cent under drip compared to surface irrigation in hybrid cotton.

Patil *et al*. (2004 a) reported that 10 per cent increased seed cotton yield (1329 kg ha^{-1}) under drip irrigation over surface irrigation (1210 kg ha^{-1}) at Dharward.

2.7.2.2. Drip fertigation on fibre quality

In cotton, water deficit treatments induced earliness in both drip and furrow irrigation (Mateos *et al.*, 1991). Carmi (1986) observed that drip irrigation induced earliness by restricting root zone to a small volume in cotton. Nawar *et al.* (1995) reported that drip irrigation increased the fibre maturity compared to traditional irrigation system. Lint index, maturity co-efficient and seed index were higher with drip irrigation as compared to traditional surface irrigation methods (Reddy and Gowda, 1997). Field studies conducted at Syria revealed that drip fertigation improved earliness and lint properties of cotton cv. Aleppo 33/1 (Janat and Somi, 2000). Fertigation to cotton improved the quality of cotton lint by increasing the 2.5 per cent span length and fineness of cotton fibre and decreasing the short fibre content in comparison to flood irrigation (Shelke, 2005).

2.7.2.3. Drip irrigation in high value crops

Ahlwalia *et al.* (1993) stated that tomato and cauliflower with drip irrigation yielded on an average 6 and 56 per cent higher yield and saved upto 37 and 57 per cent irrigation respectively as compared to conventional method, resulting in tremendous increase in water use efficiency.

Drip irrigation in banana at 60 per cent ET resulted in significant water saving of 63.07 per cent and increase of 19.43 per cent in fruit yield in poovan and dwarf cavendish varieties(29.5 and 29.0 t ha^{-1} respectively) as compared to ring basin irrigation (Kumathe *et al.,* 2001).

In brinjal, drip irrigation at 75 per cent of surface irrigation recorded the maximum yield of 30.28 and 37.81 t ha^{-1} in summer and kharif season respectively as compared to furrow irrigation (Bobade, 1999). Drip irrigation at 100 per cent CPE recorded significantly higher growth characters viz., plant height, number of branches, root length, etc., and higher yield of 99.97 t ha^{-1} compared to surface irrigation in capsicum (Antony and Singandhupe, 2004).

2.7.3. Effect of fertigation on growth characters

Fertigation studies in cotton at Akola showed that application of 100 per cent recommended dose with liquid fertilizer (8:8:8 NPK + urea) through drip increased the plant height, number of primary and secondary branches and boll per plant as compared to 25 and 50 per cent recommended N dose with liquid fertilizer as well as 100 per cent recommended solid fertilizer (Benke, 1996). Bharambe *et al*. (1997) indicated that application of 100 kg N as urea through drip irrigation recorded higher number of bolls per plant and boll weight as compared to 75 kg ha^{-1} through drip and 100 kg N ha^{-1} as soil application.

Drip fertigation and drip band application of nitrogen registered enhanced growth attributes viz., plant height, DMP and monopodial branches over the furrow band application (Veeraputhiran, 2000).

Nalayini and Shanmugham (2002) reported that drip irrigation with 80 ha cm of water and fertigation with 75 per cent recommended dose of NPK (60:30:30 kg ha^{-1}) recorded increased plant height and dry matter production per plant as compared to surface irrigation. Shanmugham *et al*.(2007) also reported that drip fertigation with 125 per cent recommended dose of NPK ha^{-1} recorded significantly higher plant height of cotton at 30, 60 and 90 DAS than surface irrigation and soil application of 100 per cent recommended fertilizer.

2. 7. 4. Effect of drip fertigation on nutrient uptake

Nitrogen uptake was significantly increased with the use of the drip fertigation
method and with the increase in N input relative to surface irrigation. N uptake ranged between 28 g for the surface-irrigated treatment and 47.5 g for the comparative drip-fertigated treatment according to (Janat, 2004).

Sampathkumar *et al*, (2006) reported that drip irrigation recorded higher N, P and K uptake when compared to other surface irrigation methods. Ravankar *et al*. (2003) stated that the N, P_2O_5 and K_2O accumulation in the cotton with lint yield of 3000 kg ha^{-1} were 385.8, 244.7 and 340.3 kg ha^{-1}, respectively.

2. 7. 5. Effect of drip fertigation on cotton yield

Vaishnava *et al*. (1995) reported that application of 100 kg N ha^{-1} through drip in six equal splits increased seed cotton yield by 16 per cent as compared to soil application in hybrid cotton NHH-44 in a medium deep clay soil at Parbhani, Maharastra state. At Akola, drip fertigation with liquid fertilizers at recommended dose increased seed cotton yield by 28 per cent in addition to 50 per cent fertilizer saving as compared to soil application, while the fibre qualities were not affected by fertigation according to Benke, (1996).

Bharambe *et al*. (1997) reported that application of 100 kg N ha^{-1} as urea through drip irrigation produced significantly higher seed cotton yield over soil application of 100 kg N as well as 75 kg and 50 kg N ha^{-1}. The yield obtained with 75 kg N ha^{-1} through fertigation was on par with soil application of 100 kg N ha^{-1}, thereby indicating a saving of 25 kg N ha^{-1}. Further N application through drip improved the ginning percentage, micronaire value and bundle strength of lint over soil application in hybrid cotton NHH 44.

Veeraputhiran (2000) observed that drip fertigation and drip band application of 100 per cent recommended dose of NPK kg ha^{-1} (120:60:60) increased the seed cotton yield by 10.8 and 9.7 per cent during winter and 15.0 and 10.9 per cent during summer seasons respectively as against furrow band application. Adoption of drip fertigation saved 60 kg N ha^{-1} over furrow band application during both the seasons. Enhanced cotton quality parameters viz., ginning percentage, lint index and Bartlett's index was also observed with drip fertigation and drip band application as compared to furrow irrigation.

Nalayini and Shanmugham (2002) conducted Field experiment at Coimbatore during summer indicated that 75 per cent recommended NPK kg ha^{-1} (60:30:30) through drip fertigation recorded higher seed cotton yield (1639 kg ha^{-1}) as compared to soil application of recommended fertilizer (782 kg ha^{-1}). Jadhav *et al*., (2002) revealed that drip fertigation with 75 per cent recommended dose of NPK kg ha^{-1} (100:50:50) in four or six equal splits enhanced seed cotton yield by 30 per cent as compared to soil application of recommended dose of fertilizer in two equal splits.

Patil *et al*., (2004c) reported that maximum seed cotton yield of 2475 kg ha^{-1} was registered under drip fertigation with recommended dose of N, P_2O_5 and K_2O (150:75:75 kg ha^{-1}) in the form of water soluble fertilizer and the yield was 9 and 98 per cent higher than the yield obtained at recommended dose of straight fertilizer as urea, DAP and muriate of potash and no fertilizer application respectively.

Patil *et al*, (2004b) also reported that split application of 90 per cent recommended dose of fertilizer (150:75:75 kg NPK ha^{-1}) in 19 equal splits at 5 days interval commencing from 30 DAS upto 120 DAS through fertigation and remaining 10 per cent as basal application recorded higher seed cotton yield of 2718 kg ha^{-1} over the control with no fertilizer (1380 kg ha^{-1}). However split application of recommended dose of fertilizer through drip fertigation in 19 equal splits had no significant influence on fibre quality parameters.

Higher seed cotton yield was recorded with 100 per cent recommended dose of N and K through fertigation in six equal splits than 100 per cent recommended dose of fertilizer through soil application under drip method of irrigation at Dharwad (Anon, 2003).

Shelke (2005) observed that fertigation significantly influenced the seed cotton yield. Application of 100 per cent RDF (N & K levels) through drip in six splits recorded maximum seed cotton yield (3374 kg/ha). It was on par with 100 per cent recommended dose of N and K in four splits and 75 per cent recommended dose of N and K in six splits.

The increase in seed cotton yield under drip irrigation was 23.7, 35, 45 and 53 per cent over all furrows, skip furrow, alternate furrow and check basin method of irrigation respectively. This might be due to production of more vegetative biomass, more flowers and conversion into better bolls and more retention in plants under drip irrigation (Sampathkumar *et al*, 2006). Drip fertigation with 75 percent recommended dose of fertilizer (120:60:60 kg NPK ha^{-1}) enhanced the number of bolls per plant by 22.5 and seed cotton yield by 1.33 t ha^{-1} respectively compared to flood irrigation and soil application of recommended fertilizer (Muthuchamy and Subramanian, 2004).

Shanmugham *et al*., (2007) reported that higher seed cotton yield of 2099 kg ha^{-1} was recorded in drip fertigation with 125 per cent recommended dose of NPK which was comparable with drip fertigation at 100 per cent recommended dose of NPK (2073 kg ha^{-1}) but significantly superior over 100 per cent recommended NPK through soil application under drip irrigation (1979 kg ha^{-1}).

2. 7. 6. Fertigation studies in high value crops

Fertigation reduces the nutrient losses that would normally occur with conventional method of fertilizer application and thus permits better availability and uptake of nutrients by crops. Studies conducted at Rahuri in vertisol by Bafna *et al*. (1993) showed that drip fertigation of nitrogen as urea produced 42 per cent higher fruit yield over band placement in hybrid tomato Rupali.

Muralidhar (1998) reported that capsicum growth was superior with fertigation as the growth components viz., plant height, leaf area, number of leaves and branches were improved by fertigation, which eventually resulted in significantly higher DMP at all growth stages of the crop. Green fruit yield was maximum with fertigation as compared to drip and furrow irrigation methods.

Shivashankar (1999) conducted drip fertigation studies in capsicum and reported an yield increase of 25.0, 11.9 and 20.2 per cent in capsicum, maize and sunflower respectively in addition to economizing 20 per cent fertilizer requirement when compared to conventional method of fertilizer application. Higher cane and sugar yields were registered in drip at 100 per cent ETc with fertigation and comparable with drip at 75 per cent ETc with fertigation and both these effects were significantly superior to furrow irrigation with soil application of nutrients (Dhanalakshmi, 1999).

Bhanu Rekha *et al*. (2005) reported that drip fertigation with 120 kg N ha^{-1} significantly increased yield by 54 per cent as compared to furrow irrigation in bhendi. Singandhupe *et al*. (2003) reported that application of nitrogen through drip irrigation in 10 equal splits increased the fruit yield by 3.7 - 12.5 per cent and also saved 31 to 37 per cent irrigation water in tomato.

2. 8. Effect of different fertilizer levels on the growth and yield of hybrids cotton under fertigation

Application of 120:60:60 kg NPK ha^{-1} recorded the tallest plants and was superior to lower levels in MECH – 162 Bt hybrid (Anon, 2004). A fertilizer level of 100:50:50 kg NPK ha^{-1} recorded significantly higher seed cotton yield (1521 kg ha^{-1}) and 1421 kg ha^{-1}with 120:60:60 kg NPK ha^{-1} (Anon, 2006) and further added that no significant difference was noticed on the number of bolls per plant. A negative correlation was observed with boll weight and fertilizer levels, heaviest boll was recorded with 80:40:40 kg NPK ha^{-1}. Fertilizer response observed up to the levels of 135:67.5:67.5 kg NPK ha^{-1} for the Bt cotton hybrids in the summer irrigated cotton at Srivilliputhur (Anon, 2005). Application of 150 per cent of recommended level of fertilizers registered significantly the highest number of burst bolls per plant (24.8) with a seed cotton yield of 3090 kg ha^{-1} and it was on par with 125 per cent of recommended dose of fertilizers at Coimbatore (Sankaranarayananan *et al*., 2004)

Patil *et al*., (2004c) investigated the performance of Rasi Bt cotton hybrids (RCH 2, RCH 20 and RCH 144) at different levels of fertilizers and found that Rasi Bt cotton hybrids recorded significantly higher yield with the application of 120:60:60 kg NPK ha^{-1} than their non –Bt hybrids as well as the local check non –Bt hybrids. Among the Rasi Bt cotton hybrids tested RCH 2 Bt was the top yielder (2857 kg ha^{-1}) followed by RCH 144 Bt (2794 kg ha^{-1}) and it was significantly superior to RCH 20 Bt cotton hybrid (2585 kg ha^{-1}) as well as MECH 184 Bt cotton hybrid (2575 kg ha^{-1}).

2. 9. Water use efficiency in cotton

It was well established that seasonal evapotranspiration is highly correlated with dry matter accumulation and yield of cotton. In cotton the interaction of moisture and nitrogen was well defined. Higher moisture levels of cotton respond to all levels of N, where as at low moisture and intermediate levels, the response was for 120 lb acre^{-1} only. Nitrogen applied increased the efficiency of water utilization (Scarsbrook *et al*., 1959).

Many researchers have reported higher yields and water use efficiency (WUE) of drip irrigation system over the conventional irrigation methods throughout the world. In drip irrigation the volume of wetted soil at a particular water application is controlled by the volume of water added, the discharge rate of dripper and the soil water content (Bresler, 1977).

Morrow and Krieg (1990) showed that increased N supply from 0 to 100 kg N ha^{-1} at peak flowering increased the yield irrespective of irrigation intensity. Maximum cotton yields were obtained when N and water were applied in the ratio of 0.25 kg N ha^{-1} mm^{-1} of water. It was also reported that lint production was increased (0. 016 kg lint mm^{-1}) for each additional kg N ha^{-1}.

Veeraputhiran (2000) concluded that increasing the N application level under drip fertigation increased the WUE progressively. Higher water use efficiency of 5.50 kg ha^{-1} mm^{-1} under drip irrigation was observed as against 4.19 kg ha^{-1} mm^{-1} under furrow irrigation.

The water use efficiency increased from 17.6 to 22.1 kg ha^{-1} cm^{-1} (26 per cent) under drip fertigation as compared with check basin irrigation as reported by Aujla *et al*. (2005).

Higher water use efficiency was registered under drip irrigation (3.98 to 4.60 kg^{-1} ha^{-1} $mm^{`-1}$) as compared to surface irrigation (2.80 kg^{-1} ha^{-1} mm^{-1}) in cotton cv MCU 12 (Shanmugam *et al*., 2007).

2. 10. Economics

One of the main objectives of fertigation is to reduce the cost of cultivation and to increase the economic product as high as possible. Therefore getting maximum benefits from each unit of water and nutrient applied to crop are important. A technically feasible different level of fertigation with straight and water soluble fertilizer through drip would be economically viable for its successful adoption.

Drip irrigation with 1.5 litre day^{-1} $hill^{-1}$ recorded maximum gross return (Rs 16,085 ha^{-1}), net return (Rs 8,159 ha^{-1}) and return on net rupee invested (2.02) as compared to low level of drip fertigation at 0.5 litre day^{-1} $hill^{-1}$ in cotton (Narkhede *et al*., 1996).

Veeraputhiran (2000) reported that drip fertigation with 120 kg N ha^{-1} registered higher net income of Rs 48,886 ha^{-1} as compared to furrow irrigation. It was also reported that even though higher cost was involved for drip unit, benefit cost ratio for drip fertigation was lowest when compared to furrow irrigation. The monetary investment on drip irrigation unit could be realised within two years under Coimbatore conditions.

Higher net return of Rs 30,105 ha^{-1} and B:C ratio of 2.75 were registered under drip irrigation as compared to furrow irrigation (Rs 21,750 ha^{-1} and 2.04 respectively) (Sampath Kumar, 2003). Drip irrigation at 100 per cent PE once in 3 days interval with coir pith mulching registered higher net profit of Rs 30939 ha^{-1} and B:C ratio of 2.34 than drip irrigation at 60 per cent PE once in 7 days (Ramesh, 2003).

Patil *et al*. (2004b) stated that paired row planting (60/120 cm x 60 cm) was better than single row planting (90 x 60 cm) with considerable saving of cost of drip system due to reduced cost of laterals. Drip fertigation with 100 per cent recommended dose of NPK recorded higher B: C ratio (1.79) followed by drip fertigation with 125 per cent NPK (1.77). Lowest B: C ratio was observed with drip fertigation with 75 per cent recommended dose of NPK (1.60) (Shanmugham *et al*., 2007).

CHAPTER III

MATERIALS AND METHODS

A field experiment was carried out at Agricultural College and Research Institute, Coimbatore during September 2007 to March 2008 to study the nutrient dynamics under drip fertigation with straight and water soluble fertilizers on the growth and yield of cotton. The details of materials used and methods adopted in the experiment are presented in this chapter.

3.1. Materials

3.1.1. Location

The field experiment was conducted in field No.76 of Eastern block, Agricultural College and Research Institute, Coimbatore as winter irrigated crop during 2007 - 08. The experimental site is geographically situated at 11°N latitude and 77°E longitude at an altitude of 427 m above MSL

3.1.2. Climate and weather

The mean annual rainfall of Coimbatore is 640 mm distributed in 47 rainy days. The mean maximum and minimum temperature were 31.4°C and 21.2° C respectively. The meteorological data on maximum, minimum temperatures, relative humidity, rainfall and solar radiation that prevailed during the cropping period are given in Appendix I.

3.1.3. Soil

The soil of the experimental field is sandy clay loam of Periyanaicken palayam series (*vertic ustropept*) with low available nitrogen (256.1 kg ha^{-1}), low available phosphorus (12.0 kg ha^{-1}) and high available potassium (491.6 kg ha^{-1}). The physio - chemical characters of the soil are presented in Table 1.

3. 1. 4. Crop and variety

Intraspecific cotton hybrid RCH-2Bt released from Rasi seeds (P) limited, Tamil Nadu was used as the test variety. The salient features of the hybrid are given in Appendix II.

3. 1 .5. Irrigation water

The source of irrigation water was from a bore well. The analytical data of the irrigation water are presented in Table 2.

3. 2. Methods

3. 2. 1. Experimental design and layout

The experiment was laid out in a randomized block design and replicated thrice. The different levels of fertilizer in combination with straight fertilizer and water soluble fertilizer were allotted in a randomized manner. The layout of the experiment is given in Fig. 1.

3. 2. 2. Treatments

The treatment details are as follows

T_1 : Drip fertigation with 75 per cent recommended dose of N&K as straight fertilizer (P as Basal)

T_2 : Drip fertigation with 100 per cent recommended dose of N&K as straight fertilizer (P as Basal)

T_3 : Drip fertigation with 125 per cent recommended dose of N&K as straight fertilizer (P as Basal)

T_4 : Drip fertigation with 150 per cent recommended dose of N&K as straight fertilizer (P as Basal)

T_5 : Drip fertigation with 75 per cent recommended dose of NPK as straight fertilizer

T_6 : Drip fertigation with 100 per cent recommended dose of NPK as straight fertilizer

T_7 : Drip fertigation with 125 per cent recommended dose of NPK as straight fertilizer

T_8 : Drip fertigation with 150 per cent recommended dose of NPK as straight fertilizer

T_9 : Drip fertigation with 75 per cent recommended dose of NPK as water soluble fertilizer

T_{10} : Drip fertigation with 100 per cent recommended dose of NPK as water soluble fertilizer

T_{11} : Drip fertigation with 125 per cent recommended dose of NPK as water soluble fertilizer

T_{12} : Drip fertigation with 150 per cent recommended dose of NPK as water soluble fertilizer

T_{13} : Soil application of 100 per cent recommended dose of NPK as straight fertilizer under drip irrigation

T_{14} : Soil application of 100 per cent recommended dose of NPK as straight fertilizer under surface irrigation

The recommended dose of fertilizer for test variety of cotton is 120:60:60 kg of NPK ha^{-1}.

3. 2. 2. 1. Plot size

Gross plot : 7.5 m x 4.5 m = 33.75 m^2

3. 2. 2. 2. Installation of drip irrigation system

Water from the bore well was pumped through 7.5 HP motor and conveyed to the field using PVC pipe (63 mm OD) after filtering through the screen filter. By-pass arrangement was provided and used for maintaining a pressure head of 1.2 ksc in the system for irrigation. From sub main, online laterals were laid at a spacing of 1.5 m with 4 lph emitters spaced at 1.5 m such that one lateral could cover one row and one emitter could cover one plant. A control tap was fixed at the entry point of each lateral to regulate fertigation for individual plot. The gross plot size was 33.75 m^2 (7.5 m $\times$ 4.5 m). Each plot had 3 rows and each row had 5 plants thus there were 15 plants per plot.

3. 2. 3. Cultivation details

3. 2. 3. 1. Field Preparation

The experimental field was ploughed using tractor drawn disc plough followed by tiller and levelled. Raised beds of 1.2 m width with furrows of 30 cm width and 15 cm depth were formed for drip fertigation treatments. Beds and channels were formed for flood irrigation. The individual plot was formed with ridge plough and later rectified manually.

3. 2. 4. Crop culture

3. 2. 4. 1. Sowing

Good viable seeds of hybrid RCH-2Bt as delinted seed were dibbled at one seed per hill.

3. 2. 4. 2. Cultural operations

Gap filling was done at 10 DAS. Pendimethilin was applied @ 3.3 litres per hectare as pre emergence herbicide. Weeding and hoeing was done on 20, 40 and 60 DAS in all plots. Monocrotophos @ 2 ml per litre was sprayed thrice to control leaf hopper and aphids. Earthing up was done at 45 DAS along with second split application of recommended fertilizers as per the treatment.

3. 2. 4. 3. Irrigation scheduling

Under surface irrigation treatment, irrigation was scheduled at 7 days interval to 5.0 cm depth throughout the crop growth. First irrigation was given immediately after sowing; life irrigation on 3 DAS and subsequent irrigation was given at 7 days interval.

In the case of drip fertigation plots, initial soaking irrigation was given immediately after sowing and subsequent irrigation was scheduled once in four days.

3. 2. 4. 4. Fertigation

The entire quantity of phosphorus was applied as basal as per treatments T_1, T_2, T_3, T_4, T_{13} and T_{14} in the form of single super phosphate at the time of sowing. In the treatments T_5, T_6, T_7, and T_8, phosphorus was applied in 14 splits in the form of single super phosphate. Overnight soaked and decanted solution was applied through drip. T_{13} and T_{14} involving recommended dose of straight fertilizers to soil application through nitrogen in the form of urea and potassium in the form of muriate of potash were applied in three equal splits as basal, 45 and 65 DAS.

The treatments T_9, T_{10}, T_{11} and $T_{12,}$ the water soluble fertilizer sources for supplying NPK were urea (46 per cent N), mono ammonium phosphate (12 per cent N and 61 per cent P_2O_5) and sulphate of potash (50 per cent K_2O), respectively. The details of split application of fertilizers are given in table 3.

Nitrogen and potassium were applied as per the treatment through fertigation in 19 splits for all treatments except T_{13} and T_{14} at seven days interval commencing from 14 DAS upto 140 DAS. Phosphorus was applied as per the treatment through fertigation in 14 splits for all treatments except T_1, T_2, T_3, T_4, T_{13} and T_{14} at seven days interval commencing from 14 DAS up to 105 DAS. The fertigation schedule indicating the nutrient requirement at different pheonological stages and quantity of nutrients to be applied for 100 per cent recommended dose is given in Table 3.

The fertilizer solution was prepared by dissolving the required quantity of fertilizer with water in 1:5 ratios and injected into the irrigation system through ventury assembly.

3. 2. 4. 5. Harvest

The seed cotton was harvested as kapas in three pickings at an interval of 10 - 12 days. One border row on all the sides was harvested first before each picking. Then, the net plot was harvested separately. The harvested seed cotton was shade dried and weighed at uniform moisture content.

3. 3. Observations

3. 3. 1. Growth characters of cotton

Five plants were selected at random from net area of each plot and tagged. The following growth and yield parameters were recorded on 40, 70, 105, and 140 DAS.

3. 3. 1. 1. Plant height

The plant height was measured from the cotyledonary node to the top of last fully opened leaf of the tagged plants and the mean height was expressed in cm. (Latha, 1988).

3. 3. 1. 2. Monopodial branches per plant

The number of monopodial branches per plant was counted from the randomly tagged 5 plants in each plot at 140 DAS and mean worked out and expressed in number per plant.

3. 3. 1. 3. Dry matter production

Dry matter production (DMP) was estimated at 40, 70, 105 and 140 DAS. Three plants from the outs of each plot were cut at the cotyledonary node, air dried and oven dried at 65 ^{o}C till a constant weight was obtained. From the dried moisture free samples, dry matter production was computed and expressed in kg ha^{-1}

3. 3. 2. Yield attributes

3. 3. 2. 1. Number of sympodial branches per plant

The number of reproductive branches (sympodial branches) arising from extra auxiliary buds was counted on 140 DAS from the tagged plants in each plot and the mean was expressed in number per plant.

3. 3. 2. 2. Number of bolls per plant

From the tagged plants in each plot, number of bolls per plant was counted on 105 and 140 DAS and mean number of bolls per plant was worked out.

3. 3. 2. 3. Boll weight per plant

The seed cotton weights from one fully opened boll at random from the tagged plants per plot was recorded and mean boll weight was expressed in g boll^{-1}.

3. 3. 3. Seed cotton yield

The seed cotton obtained from each harvest was weighed and the yield of all pickings were added and expressed as kg ha^{-1}.

3. 4. Quality parameters

3. 4. 1. Fibre length

The mean fibre length was determined by using Balls Sledger Sorter instrument and expressed in mm (Sundaram, 1974).

3. 4. 2. Fibre fineness (micronaire value)

Weight (g) per unit length (cm) of the fibre is generally taken as a measure of fineness. This was determined by air flow method using Micronaire instrument (Sundaram, 1974).

3. 4. 3. Bundle strength

It is the ratio of the breaking strength of a bundle of fibre to its own weight. Duplicate rings of fibre weighing 1 mg were fed into the "Pressley strength tester" which gives the reading. The value is expressed as gram per tex by multiplying the Pressley Strength Index (PSI) with 5.36 (Sundaram, 1974).

3. 5. Chemical analysis

3. 5. 1. Plant analysis

3. 5. 1. 1. Preparation of plant samples

The plant samples collected for estimating nutrient content at 40, 70, 105, and 140 DAS. The oven dried samples were powdered and utilized for estimating the content of N, P and K of crop as per standard procedure. The uptake values were calculated and computed to kg ha^{-1} by multiplying nutrient content with corresponding total dry matter production.

3. 5. 1. 2. Plant analysis

3. 5. 1. 3. Total nitrogen

The nitrogen content of the plant samples was estimated by micro kjeldahl method (Humphries, 1956) and uptake was obtained by multiplying the nutrient content with dry matter yield and expressed in kg ha^{-1}.

3. 5. 1. 4. Total phosphorus

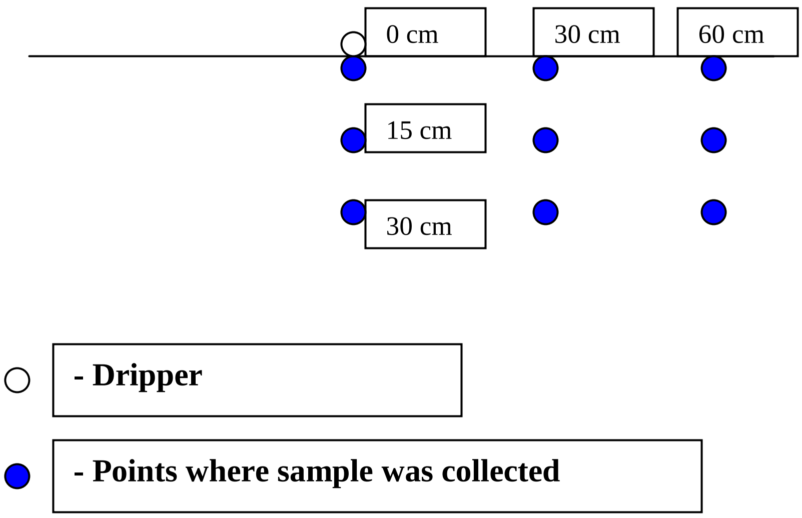
The estimation of P_2O_5 content in plant sample was done by using calorimeter method as proposed by Jackson (1973) and expressed in kg ha^{-1}.

3. 5. 1. 5. Total potassium

The K_2O content in plant samples was estimated using flame photometer (Jackson, 1973**)** and uptake calculated in kg ha^{-1}.

3. 5. 2. Soil analysis

Soil samples were collected at 0, 30 and 60 cm distance horizontally away from the dripper point and at 0-15 and 15-30 cm depth using augur. Horizontal distance between 2 samples was fixed based on the spacing between two crops. Soil samples were collected at 40, 70, 105, and 140 DAS around the crop. Samples were analysed for moisture content by gravimetric method.



3. 5. 2. 1. Soil moisture distribution

Soil moisture content was estimated by gravimetric method. Soil samples were collected at 0, 30 and 60 cm distance horizontally away from the emitting point and at 0-15 and 15-30 cm depth using core sampler for studying soil moisture distribution pattern. This observation was done in one rain free period. The values were expressed in per cent soil moisture by weight.

3. 5. 2. 2. Preparation of extract

10 gram of soil was treated with 100 ml of 2M KCl, solution shaken for 1 hr and filtered through Whatman No.1 filter paper.

3. 5. 2. 3. Exchangeable NH_4 - N

An aliquot of 20 ml of the above filtrate was distilled with freshly ignited MgO with Bremner distillation apparatus and the distillate was collected in 2 per cent boric acid containing mixed indicator titrated with standard sulphuricacid (Bremner and Keeney, 1966).

3. 5. 2. 4. Nitrate - N

On removal of exchangeable NH_4^+ ions from the sample, a pinch of Devarda alloy was added and steam distillation continued the upon. The amount of NO_3-N was determined as described for exchangeable ammonium (Bremner and Keeney, 1966).

3. 5. 2. 5. Available soil nitrogen

Available nitrogen was determined by the method proposed by Subbiah and Asija (1956) and expressed in kg ha^{-1}.

3. 5. 2. 6. Available phosphorus

Available phosphorus was estimated by the procedure the outlined by Olsen *et al*. (1954) and expressed in kg ha^{-1}.

3. 5. 2. 7. Available potassium

Available potassium was estimated by the method proposed by Stanford and English (1949) and expressed in kg ha^{-1}.

3. 6. Economics

The net return per hectare was worked out for each treatment by subtracting the cost of cultivation from the gross return. Benefit-cost ratio was worked out by dividing the gross income by cost of cultivation. In case of drip ferigation, economics was calculated by discounted benefit cost ratio analysis.

3. 7. Statistical analysis

The data pertaining to the experiment were subjected to statistical analysis by Analysis of Variance method as suggested by Gomez and Gomez (1984). Wherever the treatment differences were found significant ('F' test), critical difference was worked out at five per cent probability level and the values furnished. The treatment difference that were non significant are denoted by 'NS'

CHAPTER IV

RESULTS

The results of the experiment to study the effect of drip fertigation on moisture distribution, nutrient dynamics and growth and yield of hybrid cotton with different levels of straight and water soluble fertilizers are presented in this chapter.

4. 1. Soil moisture distribution

The data on soil moisture content are presented in table 4.

The soil moisture content was estimated in three depths up to 30 cm *viz*., 0, 15 and 30 cm vertically and along the lateral at 0, 30 and 60 cm to emitter point from horizontal distance. The moisture content was estimated at 40, 70, 105 DAS and post harvest stages of drip fertigation. The soil moisture content at the point of dripper increasing in the vertical distance from the emitter similarly lower in the surface layer, followed by increasing trend with depth. This uniform soil water content represented soil water near the field capacity, its indicating optimum soil water availability condition for the crop. It implies that the drip system could maintain an ideal soil moisture regime for optimum crop growth condition.

4. 2. Nutrient distribution

The mobility of nutrients had been assessed from soil samples taken at 0, 0-15, 15-30 cm depth of the profile at the emitting points and 0, 30 and 60 cm from the lateral at 0, 30 and 60 cm horizontally from the emitter.

4. 2. 1. Nitrogen

4. 2. 2. Ammoniacal nitrogen

Ammoniacal - N distribution in soil is presented in Table 5, 6, 7 and 8.

The Ammoniacal nitrogen concentration was increased with the increasing level of fertilizer doses *viz.*, 28 to 210 mg kg^{-1} soil. Concentration of Ammoniacal nitrogen was higher in drip fertigation with water soluble fertilizers at all levels when compared to drip fertigation with straight fertilizers and surface irrigation with soil application of fertilizer. At the point of 15 and 30 cm from the emitter the vertical (0, 15, 30 cm) and horizontal (0, 30, 60 cm) distribution of NH_4-N is varying in concentration from top to bottom layer of the profile was less than that at the point immediately closer to the source.

4. 2. 3. Nitrate nitrogen

Nitrate - N content distribution in soil is presented in Table 9, 10, 11 and 12.

The nitrate nitrogen concentration was increased with the increasing levels of fertilizer doses *viz*., 28 to 168 mg kg^{-1} soil. Nitrate nitrogen concentration was higher in drip fertigation with water soluble fertilizers at all levels when compared to drip fertigation with straight fertilizers and surface irrigation with soil application of fertilizer. At the point of 15 and 30 cm from the emitter the vertical (0, 15, 30 cm) and horizontal (0, 30, 60 cm) of NO_3-N varied in concentration from top to bottom layer of the profile was higher than that at the point immediately closer to the source.

4. 2. 4. Available nitrogen

Available - N distribution in soil is presented in Table 13, 14, 15 and 16.

The available nitrogen was increased steadily with increase in distance from the dripper both vertically and horizontally. The available nitrogen was increased with the increasing level of fertilizer doses *viz*., 238 to 276 kg ha^{-1}. Available nitrogen was higher in drip fertigation with water soluble fertilizers at all levels when compared to drip fertigation with straight fertilizers and surface irrigation with soil application of fertilizer. At the point of 15 and 30 cm from the emitter the vertical (0, 15, 30 cm) and horizontal (0, 30, 60 cm) distribution of available nitrogen was changes in concentration from top to bottom layer of the profile, which was less than that at the point immediately closer to the source.

4. 2. 5. Available phosphorus

Available - P distribution in soil is presented in Table 17, 18, 19 and 20.

The available phosphorus was increased steadily with increase in distance to the dripper both vertically and horizontally. The available phosphorus was increasing with increasing levels of fertilizer doses *viz*., 13.9 to 29.4 mg kg^{-1} soil. Available phosphorus was higher in drip fertigation with water soluble fertilizers at all levels when compared to drip fertigation with straight fertilizers and surface irrigation with soil application of fertilizer. At the point of 15 and 30 cm from the emitter the vertical (0, 15, 30 cm) and horizontal (0, 30, 60 cm) distribution of available phosphorus is varied in concentration from top to bottom layer of the profile was less than that at the point immediately closer to the source.

4. 2. 6. Available potassium distribution

Available - K distribution in soil is presented in Table 21, 22, 23 and 24.

The available potassium was increased steadily with increase in distance to the dripper both vertically and horizontally. The available potassium was increased with the increasing the levels of fertilizer doses *viz*., 512 to 528 kg ha^{-1}. Available potassium was higher in drip fertigation with water soluble fertilizers at all levels than compared to drip fertigation with straight fertilizers and surface irrigation with soil application of fertilizer. At the point of 15 and 30 cm from emitter, vertical (0, 15, 30 cm) and horizontal (0, 30, 60 cm) distance from dripper, the available potassium distribution changed in concentration from top to bottom layer of the profile, which was less than that of point immediately closer to the source.

4. 3. Soil pH

Soil pH is presented in Table 25, 26, 27 and 28.

The soil pH was decreased in distance to the dripper both vertically and horizontally. The soil pH was decreased with the increased the levels of fertilizer doses *viz*., 8.69 to 8.33. Soil pH was higher in drip fertigation with straight fertilizers and surface irrigation with soil application of fertilizer at all levels as compared to drip fertigation with water soluble fertilizers. At the point of 15 and 30 cm from the emitter the vertical (0, 15, 30 cm) and horizontal (0, 30, 60 cm) distribution of soil pH was difference from top to bottom layer of the profile, which was less than that at the point immediately closer to the source.

4. 4. Soil EC

Soil EC is presented in Table 29, 30, 31 and 32.

The soil EC was increased with distance to the dripper both vertically and horizontally. The soil EC was increased with the increasing levels of fertilizer doses viz., 0.25 to 0.31 d Sm^{-1}.Soil EC was higher in drip fertigation with water soluble fertilizers at all levels than compared to drip fertigation with straight fertilizers and surface irrigation with soil application of fertilizer. At the point of 15 and 30 cm from the emitter the vertical (0, 15, 30 cm) and horizontal (0, 30, 60 cm) distribution of soil EC was slight changes in concentration from top to bottom layer of the profile, which was higher than that at the point immediately closer to the source.

4. 6. Growth characters

4. 6. 1. Plant height

The data on plant height recoded at 40, 70, 105 and 140 DAS are presented in table 33.

The results clearly indicated that there was significant difference in plant height as influenced by the treatments at all stages of crop growth except 40 DAS.

Among the treatments, soil application of 100 per cent recommended dose of NPK as straight fertilizer under surface irrigation (T_{14}) registered significantly the highest plant height of 69.8, 123.2 and 178.12 cm at later stages (70, 105 and 140 DAS). In 70 DAS soil application of 100 per cent recommended dose of NPK as straight fertilizer under surface irrigation (T_{14}) is on par with Drip fertigation with 150 per cent recommended dose of N&K as straight fertilizer (P as Basal) (T_4), drip fertigation with 100 per cent recommended dose of NPK as water soluble fertilizer (T_{10}), drip fertigation with 100 per cent recommended dose of NPK as straight fertilizer (P as basal) (T_2), Drip fertigation with 100 per cent recommended dose of NPK as straight fertilizer (T_6), drip fertigation with 75 per cent recommended dose of NPK as water soluble fertilizer (T_9), drip fertigation with 75 per cent recommended dose of NPK as straight fertilizer (T_5), drip fertigation with 125 per cent recommended dose of NPK as water soluble fertilizer (T_{11}), Drip fertigation with 150 per cent recommended dose of NPK as straight fertilizer (T_8), drip fertigation with 125 per cent recommended dose of N and K as straight fertilizer (P as Basal) (T_3) and drip fertigation with 150 per cent recommended dose of NPK as water soluble fertilizer (T_{12}). At 105 DAS T_{14} is on par with T_{12}, T_{10}, T_4 and T_8. At 140 DAS T14 is on par with T_{11}, T_6, T_8, T_4, T_2 and T_{10}.

The plant height under the treatments drip fertigation with 125 per cent recommended dose of NPK as straight fertilizer (T_7), soil application of 100 per cent recommended dose of NPK as straight fertilizer under drip irrigation (T_{13}) were comparable and were significantly inferior over the rest of the treatments.

Significant variation in plant height was also observed between straight and water soluble fertilizers with the same level of fertilizer at 75, 100 and 125 per cent of recommended NPK.

4. 6. 2. Dry matter production

The data on total DMP recorded at 40, 70, 105 and 140 DAS are presented in table 34.

The treatments had not significantly influences the DMP at all crop growth stages. Adoption of drip fertigation with 75 per cent recommended dose of N and K as straight fertilizer (P as Basal) (T_1) produced higher DMP of 279.2, 2791.0, 5274.7 and 6592.7 kg ha^{-1} at 40, 70, 105 and 140 DAS respectively. T_4 produced lower DMP at all the stages of crop growth.

4. 7. Yield components

4. 7. 1. Monopodial branches per plant

The data on monopodial branches recorded at 140 DAS are presented in table 35. The monopodial branches per plant were significantly influenced by the different levels of drip fertigation treatments.

However, adoption of drip fertigation with 75 per cent recommended dose of NPK as water soluble fertilizer (T_9) recorded numerically more (5.7) number of monopodial branches per plant, which was on par with $T_{4,}$ $T_{5,}$ and T_{14}. T_1 T_2 and, T_3 recorded least number of (4.3, 4.7, and 4.3) monopodial branches per plant.

4. 7. 2. Sympodial branches per plant

The data on sympodial branches per plant recorded at 140 DAS are presented in table 35.

Application of different levels of drip fertigation with straight and water soluble fertilizers had a significant effect on the number of sympodial branches per plant. Higher number of sympodial branches 72.7 was registered with the treatment receiving drip fertigation with 75 per cent recommended dose of NPK as water soluble fertilizer (T_9), which was on par with the treatment drip fertigation with 100 per cent recommended dose of N and K as straight fertilizer (P as Basal) (T_2). The minimum number of sympodial branches per plant was recorded in the treatment soil application of 100 per cent recommended dose of NPK as straight fertilizer under drip irrigation (T_{13}) 48.3.

4. 7. 3. Number of bolls per plant

The data on number of bolls per plant are presented in table 35.

Drip fertigation with 75 per cent recommended dose of NPK as water soluble fertilizer (T_9) produced significantly more number of bolls $plant^{-1}$(247.0) and it was significantly superior to other treatments, which was comparable (230.0) with treatment drip fertigation with 100 per cent recommended dose of N and K as straight fertilizer (P as Basal) (T_2). The least number of bolls plant^{-1} (113.3) was observed in the treatment involving soil application of 100 per cent recommended dose of NPK as straight fertilizer under surface irrigation (T_{14})

4. 7. 4. Boll weight

The data on boll weight are presented in table 35.

The maximum boll weight of 6.7 g^{-1} was recorded in drip fertigation with 75 per cent recommended dose of NPK as water soluble fertilizer (T_9), and it was on par with (6.4 and 5.8) the treatments T_2 and T_3. The least boll weight of 4.8 and 4.9 g^{-1}was recorded in the treatment involving soil application of 100 per cent recommended dose of NPK as straight fertilizer under surface irrigation (T_{14}) and soil application of 100 per cent recommended dose of NPK as straight fertilizer under drip irrigation (T_{13}).

4. 7. 5. Seed cotton yield

The data pertaining to the seed cotton yield under different treatments are presented in table 35.

Application of varying levels of fertilizer as drip fertigation in combination with straight and water soluble fertilizers had positively influenced on seed cotton yield. Drip fertigation with 75 per cent recommended dose of NPK as water soluble fertilizer (T_9) recorded the highest seed cotton yield of 3324.0.kg ha^{-1}, which was statistically on par with seed cotton yield of 3062.8, 3062.2 and 2819.7 kg ha^{-1} (T_2, T_{10} and T_{11}) respectively. Soil application of 100 per cent recommended dose of NPK as straight fertilizer under surface irrigation (T_{14}) produced inferior (1111.6 kg ha^{-1}) over other treatments.

4. 8. Nutrient Uptake

The nutrient content of the plant samples was estimated and uptake was obtained by multiplying the nutrient content (Table 36, 37 and 38) with dry matter yield and expressed in kg ha^{-1}.

4. 8. 1. Nitrogen

The data on N uptake at 40, 70, 105 and 140 DAS are presented in table 39.

Nitrogen uptake was steadily increased with the advancement of age of the crop. There was significant increase in N uptake by fertigation levels and its combination with straight and water soluble fertilizers at 40, 70, 105 and 140 DAS. In all the stages of crop growth, highest nitrogen uptake of 4.80, 39.91, 74.84 and 115.36 kg ha^{-1} was observed in the treatment of drip fertigation with 75 per cent recommended dose of NPK as water soluble fertilizer (T_9). Followed by drip fertigation with 100 per cent recommended dose of NPK as water soluble fertilizer (T_{10}) 3.78 and 37.15 at 40 and 70 DAS respectively, in the later stages of 105 and 140 DAS the N uptake of 66.41 and 102.35 kg ha^{-1} which was on par with T_3. Drip fertigation with water soluble fertilizers significantly influenced the N uptake at the fertigation levels of 75 and 100 per cent recommended NPK.

4. 8. 2. Phosphorus

The data pertaining to P uptake at 40, 70, 105 and 140 DAS are presented in table 40.

Drip fertigation and its combination with straight and water soluble fertilizer had a positive effect on P uptake during all the stages of observation. Drip fertigation with 75 per cent recommended dose of NPK as water soluble fertilizer (T_9) was significantly superior with the highest P uptake of 2.60, 13.25, 24.84 and 49.44 kg ha^{-1} at 40, 70, 105 and 140 DAS. The next best under T_3 (2.47 and 12.84 at 40 and 70 DAS) respectively, at later stages of 105 and 140 DAS the P uptake of 23.61 and 45.41 kg ha^{-1}. In the initial stages, the P uptake was significantly lower in (T_7) 1.76 kg ha^{-1} at 40 DAS and later sages 70, 105 and 140 DAS the lower P uptake were observed in the treatments under soil application of 100 per cent recommended dose of NPK as straight fertilizer under drip irrigation T_{13}.

4. 8. 3. Potassium

The data on K uptake at 40, 70, 105 and 140 DAS are presented in table 41.

Potassium uptake followed a similar trend as that of N and P uptake and the highest values was recorded at Drip fertigation with 75 per cent recommended dose of NPK as water soluble fertilizer (T_9) 4.24, 41.12, 84.71 and 120.51 kg ha^{-1} respectively. Followed by the higher K uptake of 4.06, 39.63, 78.07 and 107.77 kg ha^{-1} were T_6 at 40 DAS, T_1 at 70 and 105 DAS and T_3 at 140 DAS respectively. Drip fertigation with 125 per cent recommended dose of NPK as water soluble fertilizer (T_{11}) found to have the lowest K uptake of 3.04, 24.15, 56.17 and 72.87 kg ha^{-1} at 40, 70, 105 and 140 DAS respectively.

4. 9. Quality parameters

4. 9. 1. Fibre fineness (micronaire value)

The data on micronaire value are presented in table 42.

Drip fertigation with 100 per cent recommended dose of NPK as straight fertilizer (T_6) recorded higher micronaire value (4.2) as compared to other treatments. Minimum micronaire value (3.0, 3.0 and 3.0) was obtained in T_7, T_8 and T_{11}.

4. 9. 2. Fibre length

The data pertaining to fibre length are presented in table 42.

The treatments significantly influenced the fibre length of cotton. Among the treatments, drip fertigation with 75 per cent recommended dose of NPK as water soluble fertilizer (T_9) recorded superior fibre length of 32.40 mm, which was on par with (T_6). The treatment of drip irrigation with soil application of 100 per cent recommended dose of NPK as straight fertilizer (T_{13}) recorded the lowest fibre length of 29.80 mm.

4. 9. 3. Uniformity ratio

The data on uniformity ratio was computed and presented in table 42.

Significant difference in uniformity ratio was observed among the treatments. Higher uniformity ratio (47.0) was observed in drip fertigation with 150 per cent recommended dose of NPK as water soluble fertilizer (T_{12}). The least uniformity ratio (44.0) was recorded in drip fertigation with 100 per cent recommended dose of N and K as straight fertilizer (P as Basal) T_2.

4. 9. 4. Bundle strength

The data observed on bundle strength are presented in table 42.

Drip fertigation with 100 per cent recommended dose of NPK as water soluble fertilizer (T_{10}) recorded maximum bundle strength of 22.20 g tex^{-1}. Minimum bundle strength of 19.20 g tex^{-1} was noticed in drip fertigation with 100 per cent recommended dose of N and K as straight fertilizer (P as Basal) T_2, which was on par with the treatment drip fertigation with 150 per cent recommended dose of NPK as water soluble fertilizer (T_{12}) 19.20 g tex^{-1}.

4. 10. Economics

The economics in terms of cost of cultivation, gross return, net return and B: C ratio were worked out and presented hereunder.

The highest benefit cost ratio of 2.14 recorded with drip fertigation with 100 per cent RDF as straight fertilizer (T_2) with the net return of Rs. 40,760.20 ha^{-1} (Table 43). The next best B: C ratio of 1.99 with the highest net return of Rs. 41,374.15 ha^{-1} was noticed in drip fertigation with 75 per cent RDF as water soluble fertilizer (T_9). Surface irrigation with soil application of 100 per cent RDF as straight fertilizer (T_{14}) recorded the least value of net return and B: C ratio of Rs. 3,244.00 and 1.13 respectively.

CHAPTER V
DISCUSSION

A field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore, during September 2007, to study the wetting pattern, nutrient dynamics and the effect of drip fertigation with different levels of straight and water soluble fertilizers on growth and yield of hybrid cotton.

5. 1. Effect of drip fertigation on soil moisture distribution (Table 4 and plate 2)

Data on soil moisture content showed that in general, the moisture content was higher near the dripper (0-30 cm) and it decreased with the increase in lateral distance from the emitter. Similarly it was higher in the surface layer (0-15 cm) and followed a decreasing trend with the depth. This uniform soil water distribution represented soil water near the field capacity indicating optimum soil water availability conditions for the crop. It implies that the drip system could maintain an ideal moisture regime for optimum crop growth condition and thus ensures water saving or increase in the water use efficiency. Similar results have been reported by Haynes (1990), Prabhakar and Hebber (1996), Chakraborty *et al.* (1999) and Bharambe *et al.* (2001).

5. 2. Effect of drip fertigation on nutrient dynamics in soil

Plant nutrient availability in the soil is a very important factor for obtaining higher yield. Leaching, volatilization and fixation of nutrients in the soil are some of the factors that affect the availability of soil nutrients.

5. 3. Nutrient distribution

5. 3. 1. Ammoniacal nitrogen (Table 5, 6, 7 & 8 and plate 3&4).

Data on ammoniacal nitrogen content showed that in general, At the point of 0, 30 and 60 cm from the emitter, the variation in concentration of NH_4-N from top to bottom layer of the profile was less than that at the point immediately closer to the source. The increase in NH_4-N concentration immediately in the vicinity of the emitter is a consequence of the hydrolysis of urea. The wet condition around the emitter also ensures that the conversion of NH_4-N to NO_3-N occurs at some distance away from the emitter in a relatively drier zone, where more oxygen is available (Focht and Verstraete, 1977). The NH_4-N is adsorbed by the soil matrix and therefore the maximum concentration changes are confined to the top layer and around the emitter (Haynes and Swift, 1987; Chakraborty *et al.*, 1999; Suganya *et al*., 2007).

5. 3. 2. Nitrate nitrogen (Table 9, 10, 11 & 12 and plate 5&6)

The peak nitrate nitrogen concentrations were found at deeper depth in the profile. Nitrate ion being mobile has a tendency to move away from the emitter to the periphery of the water front (Chakraborty *et al.,* 1999), Hue *et al.* (2007), Darwish *et al.* (2003), Janat (2004) and findling *et al.* (2007) and does not become available to the plant. The distribution of NO_3-N in the soil profile has shown that it neither accumulates at the periphery of the wetting front nor is leached out from the root zone under drip systems.

5. 3. 3. Available nitrogen (Table 13, 14, 15 & 16 and plate 7 &8)

The mobility of nutrients was well prounded under drip fertigation system. An understanding of such transformation on nutrient mobility is very important in elucidating the soil fertility interactions. The available nitrogen content in the soil was maximum just beneath the dripper and the concentration decreases with distance and depth. The N mobility in the soil was due to the concentration gradient created on account of mass flow which has rendered nutrients to move from higher concentration to the lower one. The water available in the root zone plays a vital role in the mobility of nutrients. As more quantum of water was available just beneath the dripper, was corresponding increase in available N in the soil (Bangar and Chaudhari, 2004).

5. 4. Available phosphorus (Table 17, 18, 19 & 20 and plate 9 & 10)

A spectacular movement of phosphorus in the soil was found under drip fertigation. The extend of movement of orthophosphate from the emitter is very much dependent upon the phosphate adsorption of the soil. Rauschkolb *et al*. (1976) observed considerable vertical and horizontal movement of phosphate in clay loam soil. However, the distance of phosphate movement was proportional to the application rate, since movement resulted from saturation of adsorption sites on the soil near the point of application and subsequent mass flow with the soil water. Generally, the applied orthophosphate is confined to the soil volume directly surrounding the emitter. The movement of P in this experiment appeared to be directed downward as it moved with the irrigation water. There was little lateral movement of P under these conditions expecting at the soil surface and this was probably due to surface flow of liquid. The extend of P movement in soil is dependent on saturation of reaction sites in soil.

Unlike nitrogen, the higher concentration of phosphorus was seen at 0-15 cm soil layer than at 15-30 cm at all the distance from the emitter. The restricted mobility of phosphorus might be due to its strong reaction as stated by Harjinder singh *et al.* (2004) and Suresh Kumar (2000). Phosphorus is less mobile in the soil and tends to accumulate near the point of application *i.e.,* under the dripper, with little being leached downward or moved laterally (Alva and Sysertsen, 1991). Kelin and Spieler (1987) Veeranna *et al*., (2007) also reported a decrease in P concentration at 15 cm from the drippers in all directions.

5. 5. Available potassium (Table 21, 22, 23 & 24 and plate 11 & 12)

The levels of soil solution K will depend upon equilibrium and kinetic reactions that occur between different forms of soil potassium, the soil moisture content concentration of bivalent cations in solution and exchange phase (Sparks and Huang, 1985). Potassium is less mobile than nitrate but distribution in the wetted volume may be uniform due to interactions with binding sites (Kafkafi *et al*., 1988). After the fertigation the highest K concentration was found in 0-15 cm soil depth than at the lower layer *i.e.,* 15-30 cm depth. The peak quantity of K was recorded in 0-15 cm depth under emitter. This falls in line with findings of Singh *et al*. (2002).

Potassium availability in the surface soil may change rapidly due to fluctuating soil moisture in response to wetting and drying during summers, a process that may enhance soil K fixation. In this experiment soil K content was significantly higher in the surface soil than in the subsoil, this might be due to majority of applied K was held in the surface soil and the downward movement was slow. Slow downward movement of applied K may be partially attributed to net upward flux of soil water in the soil profile as a result of high evapotranspiration. This is in line with the findings of Zeng *et al*. (2000). Molawa and Or (2000), Veeranna *et al*., (2007) who also reported similar findings, that potassium (K) distribution in the soil profile is characterized by decreasing soil K content with depth. K content increased significantly throughout the 0-15 cm soil profile even though movement of surface applied K in the soil profile was slow.

5. 6. Soil reaction - *pH* (Table 25, 26, 27 & 28 and plate 13 & 14)

The salt concentration represented as the soil reaction expressed as pH was recorded as 9.25 and the electrical conductivity was found as 0.17 dS m^{-1} in the experimental field before planting the crop. The results of the pH values recorded horizontal and vertical distance from the lateral. In all the treatments higher value of pH was observed at the point of nearer to dripper, if distance increased the pH was also decreased. This was due to the increased salinity in the outer zone, the similar findings was reported by Sharmiladevi *et al*. (2007)

5. 7. Salt Concentration (Table 29, 30, 31 & 32 and plate 15 & 16)

The EC values recorded at the different stages of crop growth was showed that the frequency of drip fertigation affected the salt distribution. Effect of different levels of drip fertigation along with straight and water soluble fertilizers on electrical conductivity distribution at the point of 10 cm away from the dripper point, the salt concentration at all depths (0, 10 and 30 cm) showed an increased EC value than nearer to point of dripper. Similar trend of salt concentration was observed at 0, 30 and 60 cm away from the emitter, the similar findings was reported by Sharmiladevi *et al*. (2007)

5. 8. Effect of drip fertigation on growth and development of hybrid cotton

Growth of the plant is manifested in many ways through plant height, DMP. Even though the plant height is genetically controlled, it can be modified by environment factors.

Drip fertigation levels studied in the experiment did not have any significant influence on plant height of cotton at 40 DAS. At later stages, marked differences were found among the treatments. (Fig. 2.) the plants were taller when the fertilizers were applied through drip fertigation along with water soluble fertilizers as compared to that of drip fertigation with straight fertilizers.

The plant height under drip fertigation along with straight fertilizers was inferior compared to that of drip fertigation along with water soluble fertilizers. The favorable increasing growth attributes in terms of plant height due to drip fertigation was reported by Sampathkumar (2003) and Veeraputhiran *et al*., (2002).

Higher dry matter production was recorded under drip fertigation along with straight fertilizers (N and K) over drip fertigation along with water soluble fertilizers and drip irrigation with soil application of fertilizers.

The favourable increase in growth attributes was mainly due to enhanced availability of nutrients by continuous supply of N, P and K through fertigation up to 140 DAS along with 19 split and adequate quantity of water needed for biochemical activities of the crop. Better performance of drip fertigation along with soluble fertilizers over drip fertigation along with straight fertilizer.

5. 9. Effect of drip fertigation on yield attributes, yield and quality of cotton

The yield attributes of hybrid cotton as influenced by drip fertigation along with water soluble fertilizers on number of sympodial branches, number of bolls per plant and boll weight (Fig. 3). The increase in yield attributes under drip fertigation with water soluble fertilizer might be due to enhanced availability and uptake of nutrients leading to enhanced photosynthesis, expansion of leaves and translocation of nutrients to reproductive parts compared to conventional method of soil application of nutrients.

Drip fertigation resulted in more growth in terms of plant height and biomass production which resulted in higher fruiting points and number of bolls compared to drip irrigation with soil application of fertilizers and surface irrigation combined with soil application of fertilizer. The results corroborates with the findings of Bharambe *et al*. (1997). Grieesha (2003) observed significantly higher values of yield attributes due to drip fertigation than conventional method of fertilizer application.

Application of nutrients through drip fertigation with 75 per cent RDF as water soluble fertilizer improved seed cotton yield by 33.44 per cent compared to conventional surface irrigation with soil application of fertilizer. (Fig.4.) Comparatively lower seed cotton yield under surface irrigation with soil application of fertilizers. The results are in conformity with the findings of Bharambe *et al*. (1997), Veeraputhiran *et al*. (2002), Nalayini and Shanmugham (2002), Jadhav *et al*. (2002) and Patil *et al*. (2004c).

The seed cotton yield under drip irrigation and soil application of recommended NPK was significantly lower and inferior over drip fertigation.

The quality parameters of seed cotton are by and large heritable. However, environmental and crop management practices can influence the quality parameters to some extent. Drip fertigation had a significant influence on fibre quality parameters viz., Micronaire, fibre length and uniformity ratio over surface irrigation and soil application of fertilizer. Bharambe *et al*. (1997) observed close association of fibre qualities with drip fertigation than surface irrigation with soil application of fertilizer.

5. 10. Effect of drip fertigation on nutrient uptake by cotton

The nutrient uptake was higher under drip fertigation compared to surface irrigation with soil application of fertilizers. The N uptake was significantly higher under drip fertigation with 75 per cent recommended dose of fertilizer as water soluble fertilizer compared to surface irrigation at all the stages of crop growth. The P and K uptake values followed more or less the similar trend as that of N uptake at different crop growth stages (Fig. 5, 6 and 7.). The difference in absorption rate between high-yield fields and the control increased gradually from the crop growth stages. It was indicated that nitrogen absorption capacity was obviously higher in the plants from high-yield fields than in those from the control, from budding stage to boll forming stage, and after that the difference was reduced. Compared with N absorption rate, the duration of the highest rate for P absorption lasted relatively shorter period. The accumulation peak of N, P and K in high-yield cotton occurred at the 90 to 105 DAS. (Ravankar *et al*., 2003)

The concentration and availability of various nutrients in the soil for plant uptake depends on the soil solution phase which is mainly determined by soil moisture availability. The higher available soil moisture provided due to continuous water supply under drip fertigation had led to higher availability of nutrients in the soil and thereby increased the nutrient uptake by the crop. The increased nutrient uptake under drip fertigation was the result of increased biomass production due to continuous availability of water and nutrients to the crop. The increased uptake may also be due split application of NP and K under drip fertigation that resulted in minimal loss of nutrients thereby making them available continuously to the crop. Similar findings of higher nutrient uptake with drip fertigation has been reported by Bharambe *et al*. (1997) and Veeraputhiran (2000).

Supply of water at shorter intervals and N, P and K supply through drip irrigation created a favourable condition rendering more nutrients available in the soil. Increasing the soil nutrient availability with drip fertigation as compared to soil application was reported by Malik *et al*. (1994), and Bharambe *et al*. (1997).

5.11. Effect of drip fertigation levels on economics of cotton

The cost of installing drip fertigation system for cotton was high (Rs. 70,269 ha^{-1}). Considering longer life period of drip fertigation system (5 years or 10 seasons), the benefit accrued out of drip fertigation will be for longer period.

Higher gross return, net return and B: C ratio was observed under drip fertigation with 75 per cent recommended NPK as straight fertilizer against surface irrigation with soil application of 100 per cent RDF, due to yield advantage. The next best B: C ratio and highest net return was noticed in drip fertigation with 75 per cent RDF as water soluble fertilizer, even though the gross returns were comparable because of higher initial investment, the benefit cost ratio was lower with surface irrigation with soil application of 100 pr cent RDF . The increase in gross return and net return and net income and B:C ratio, per unit of nutrient applied were attributed to increased seed cotton yield due to better uptake of nutrients and resultant overall improvement in the crop performance under the treatments. Economic feasibility of adopting drip fertigation has been reported by Benke (1996) and Veeraputhiran (2000).

CHAPTER VI

SUMMARY AND CONCLUSION

Field experiment was conducted during winter season 2007-08 at Agricultural College and Research Institute, Coimbatore with an objective to study the effect of drip fertigation with different levels of straight and water soluble fertilizer on wetting pattern, nutrient distribution, growth, yield and quality of hybrid cotton. The experiment was laid out in randomized block design and replicated thrice.

Observations were made on wetting pattern, nutrient distribution, growth, yield, and quality. The important findings emanated from the results of the experiment are summarized in this chapter.

The soil moisture content at the point of dripper from increasing with the vertical distance from the emitter, similarly lower in the surface layer and followed by increased trend with the depth. This uniform soil water content represented soil water near the field capacity indicating optimum soil water availability for the crop. It implies that the drip system could maintain an ideal soil moisture regime for optimum crop growth condition.

The distribution of ammoniacal, nitrate, available nitrogen, phosphorus and potassium were distributed higher near the root zone (0-30 cm) except nitrate, because of its leaching beyond the root zone. The higher available nutrients distributed under drip fertigation with water soluble fertilizers at all the levels than compared to drip fertigation with straight fertilizers and surface irrigation with soil application of fertilizer. The treatments under water soluble fertilizer the availability of nutrient distribution is higher, which ensures the availability and nutrient uptake by the crop.

The soil pH was decreased in distance to the dripper from vertically and horizontally. The soil pH was decreased with the increasing the levels of water soluble fertilizers doses which helps to lower pH in root zone for favorable root growth. The EC was increase in distance to the dripper from vertically and horizontally with the increasing the levels of fertilizer doses. The soil EC was increasing with the increasing the level of fertilizer doses, it's also ensures the nutrient exchanges and availability to crop.

Application of surface irrigation with soil application of 100 per cent RDF as straight fertilizer produced significantly taller plants as compared to other treatments. Significant variation in plant height was also observed between drip fertigation with higher levels of straight and water soluble fertilizers.

Drip fertigation with 75 per cent RDF as water soluble fertilizer had significant influence on the yield attributes *viz.*, sympodial branches per plant, number of bolls per plant and boll weight found to be higher over other treatments.

Application of varying levels of fertilizer as fertigation in combination with straight and water soluble fertilizers had positive influence on seed cotton yield. Drip fertigation with 75 per cent recommended dose of NPK as water soluble fertilizer recorded the highest seed cotton yield of 3324.0 kg ha^{-1}, which was statistically on par with the treatments having drip fertigation with 100 per cent recommended dose of NPK as straight and water soluble fertilizer *viz.*, 3062.8 and 3062.2 kg ha^{-1}. Surface irrigation with soil application of 100 per cent recommended dose of NPK as straight fertilizer produced inferior over other treatments.

Nutrient uptake was favourably increased with drip fertigation with 75 percent RDF as water soluble fertilizer compared to drip fertigation with straight fertilizer and surface irrigation with soil application of fertilizer at all the stages of crop growth.

Drip fertigation with 75 per cent recommended dose and of NPK as water soluble fertilizer recorded superior fibre length of 32.40 mm was on par with the treatment of drip fertigation with 100 per cent recommended dose of NPK as straight fertilizer (32.40). Drip fertigation with 100 per cent recommended dose of NPK as water soluble fertilizer recorded maximum bundle strength of 22.20 g tex^{-1}, while drip fertigation with 100 per cent recommended dose of NPK as straight fertilizer recorded higher micronaire value (4.2) as compared to other treatments and uniformity ratio of 47.0 were increased significantly in drip fertigation with 150 per cent recommended dose of NPK as water soluble fertilizer.

The highest benefit cost ratio of 2.14 recorded with drip fertigation with 100 per cent RDF as straight fertilizer with the net return of Rs. 40,760.20 ha^{-1}. The next best B: C ratio of 1.99 with the highest net return of Rs. 41,374.15 ha^{-1} was noticed in drip fertigation with 75 per cent RDF as water soluble fertilizer. Surface irrigation with soil application of 100 per cent RDF as straight fertilizer recorded the least value of net return and B: C ratio of Rs. 3244.00 and 1.13 respectively

Conclusions

Adoption of drip fertigation for hybrid cotton exerted a positive response and produced superior yield attributes, seed cotton yield and quality as compared to the conventional method of surface irrigation and soil application of nutrients. Besides drip fertigation also fetched higher revenue.

- Application of 100 per cent recommended dose of NPK as drip fertigation produced higher seed cotton yield, net return and B: C ratio.
- Higher net return and B: C ratio were associated with drip fertigation with 100 per cent recommended dose of NPK as straight fertilizer.

From the above conclusions it is recommended that drip fertigation with 100 per cent of recommended NPK (120:60:60 kg ha^{-1}) as straight fertilizer was found to be the viable agro technique to realize the yield potential of hybrid cotton and to fetched higher returns.

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RESEARCH FINDINGS

NUTRIENT DYNAMICS UNDER DRIP FERTIGATION IN COTTON

Student **Chairman**

N. Jayaprakash. Dr. K. Appavu,

06-617-002 Professor (SS & AC)

A field experiment was carried out at Agricultural College and Research Institute, Coimbatore during September 2007 to March 2008 to study the nutrient dynamics under drip fertigation with straight and water soluble fertilizers on the growth and yield of hybrid cotton.The treatments comprised of four levels of drip fertigation *viz.*, 75, 100, 125 and 150 per cent recommended doses of NPK combined with straight, water soluble fertilizers and soil applications of 100 per cent recommended dose of NPK under drip irrigation and surface irrigation and the findings are.,

- The soil moisture content at the point of dripper increases at the vertical distance from the emitter similarly lower in the surface layer and followed by increasing trend with the depth. The distribution of ammoniacal, nitrate, available nitrogen, phosphorus potassium, pH and EC were distributed more near the root zone (0-30 cm) but pH and nitrate leached beyond the root zone.
- The higher available nutrients was distributed under drip fertigation with water soluble fertilizers at all the levels and then compared to drip fertigation with straight fertilizers and surface irrigation with soil application of fertilizer.
- Application of surface irrigation with soil application of 100 per cent RDF as straight fertilizer produced significantly taller plants as compared to other treatments.
- Drip fertigation with 75 per cent RDF as water soluble fertilizer had significant influence on the yield attributes *viz.*, sympodial branches per plant, number of bolls per plant boll weight and seed cotton yield found to be higher over other treatments. The quality parameters *viz.*, fibre length, bundle strength, micronaire and uniformity ratio found to be higher in water soluble fertilizers.

- The highest benefit cost ratio of 2.14 was recorded with drip fertigation of 100 per cent RDF as straight fertilizer followed by 1.99 in drip fertigation with 75 per cent RDF as water soluble fertilizer. Application of straight fertilizers seems to be more cost effective than drip fertigation with water soluble fertilizers.

Table 1. Soil characteristics of the experimental field

SI. No.	Characters	Value	Methods employed
Mechanical composition			
1.	Coarse sand (%)	30.81	Robinson's International Pipette method (Piper, 1966)
2.	Fine sand (%)	23.05	
3.	Silt (%)	15.75	
4.	Clay (%)	29.40	
5.	Textural class	Sandy clay loam	
Physical properties			
1.	Bulk density (g cc^{-1})	1.52	Core method (Blake and Hartge, 1986)
Chemical properties			
1.	Organic carbon (%)	0.37	rapid titration method (Walkley and Black, 1934)
2.	Available nitrogen (kg ha^{-1})	256.1	Alkaline permanganate method (Subbiah and Asija, 1956)
3.	Available phosphorus (kg ha^{-1})	12.0	Olsen *et al*. (1954)
4.	Available potassium (kg ha^{-1})	491.6	Flame photometry, Neutral normal ammonium acetate method (Jackson, 1973)
5.	pH	8.6	1:2.5 soil : water suspension using pH meter (Jackson, 1973)
6.	Electrical conductivity (dSm^{-1})	0.25	1:2.5 Soil : water suspension using EC bridge (Jackson, 1973)

Table 2. Quality of irrigation water in F. No. 76 Bore well

S. No	Properties	Value	Methods employed
1	pH	8.1	Jackson, 1973
2	EC (dS m^{-1})	1.53	Jackson, 1973
3.	**Cations (m eq l^{-1})**		
	Carbonate	Trace	Jackson, 1973
	Bicarbonate	11.73	Jackson, 1973
	Sulphate	5.0	Jackson, 1973
	Chloride	6.4	Jackson, 1973
4.	**Anions (m eq l^{-1})**		
	Calcium	8.6	Schwarzenbach *et al*, (1946)
	Magnesium	17.4	Schwarzenbach *et al*, (1946)
	Sodium	3.8	Jackson, 1973
	Potassium	Trace	Jackson, 1973

Table 3. Fertigation schedule for cotton

Recommended dose of fertilizer- 120: 60: 60 NPK kg ha^{-1}

Stage	No. of Split	Days	N (per cent)	P (per cent)	K (per cent)
Seedling	**1**	14	5	12.5	2.5
	2	21	5	12.5	2.5
Vegetative	**3**	28	2.85	12.5	3.57
	4	35	2.85	12.5	3.57
	5	42	2.85	5	3.57
	6	49	2.85	5	3.57
	7	56	2.85	5	3.57
	8	63	2.85	5	3.57
	9	70	2.85	5	3.57
Boll formation	**10**	77	9	5	6
	11	84	9	5	6
	12	91	9	5	6
	13	98	9	5	6
	14	105	9	5	6
Maturity	**15**	112	5		8
	16	119	5		8
	17	126	5		8
	18	133	5		8
	19	140	5		8

Note: 60 kg of phosphorus was soil applied basally for T_1, T_2, T_3, T_4, T_{13} and T_{14}.

Table 4. Effect of drip fertigation on distribution of moisture at different levels of fertigation (per cent)

Depth (cm)	**Horizontal distance** (cm)	**Stages**			
		I	**II**	**III**	**IV**
0	**0**	26.4	26.1	24.5	25.6
	30	31.0	33.4	27.7	30.7
	60	38.8	36.8	32.4	36.3
15	**0**	23.4	22.1	15.7	20.0
	30	26.2	26.0	19.2	20.8
	60	30.7	29.9	25.4	26.9
30	**0**	21.3	21.0	15.5	18.9
	30	21.9	23.0	17.1	20.0
	60	26.3	26.0	22.3	23.3

Table 5. NH_4-N (mg kg^{-1}) distribution in soil under drip fertigation at different levels of straight fertilizers N and K

Depth (cm)	**Horizontal distance** (cm)	**75 per cent RDF**				**100 per cent RDF**				**125 per cent RDF**				**150 per cent RDF**			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	84	112	70	84	84	112	84	98	112	140	98	112	126	154	126	140
	30	56	112	56	70	56	112	70	84	84	126	84	98	98	154	112	112
	60	42	70	56	42	56	84	70	56	70	98	84	70	98	126	112	98
-15	**0**	98	140	98	98	98	154	98	112	126	168	126	126	140	196	140	154
	30	84	126	84	84	84	126	98	98	112	154	112	112	126	168	140	140
	60	70	98	70	70	84	112	84	70	98	126	98	98	112	140	126	112
-30	**0**	56	84	56	70	70	84	70	70	84	112	84	98	112	126	112	112
	30	42	98	56	56	42	98	70	70	70	126	84	84	84	140	112	112
	60	42	56	56	42	42	70	56	42	56	84	84	70	84	112	98	84

Table 6. NH_4-N (mg kg^{-1}) distribution in soil under drip fertigation at different levels of straight fertilizers N P K

Depth (cm)	**Horizontal distance** (cm)	**75 per cent RDF**				**100 per cent RDF**				**125 per cent RDF**				**150 per cent RDF**			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	84	112	84	98	84	112	84	98	112	140	98	126	126	154	126	140
	30	56	112	70	70	56	112	70	84	84	140	98	98	98	154	112	126
	60	42	84	70	56	56	84	70	56	70	112	98	84	98	126	112	98
-15	**0**	98	140	98	112	112	154	112	112	126	168	126	140	154	196	140	154
	30	84	126	84	98	98	126	98	98	112	154	112	126	140	168	140	140
	60	70	98	84	70	84	112	84	84	98	126	98	98	126	154	126	126
-30	**0**	70	84	70	70	70	84	70	70	98	112	98	98	112	126	112	112
	30	42	98	56	56	56	112	70	70	70	126	84	84	98	154	112	112
	60	42	70	56	42	42	70	56	56	70	98	84	70	84	112	98	98

Table 7. NH_4-N (mg kg^{-1}) distribution in soil under drip fertigation at different levels of water soluble fertilizers N P K

Depth (cm)	**Horizontal distance** (cm)	**75 per cent RDF**				**100 per cent RDF**				**125 per cent RDF**				**150 per cent RDF**			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	98	126	84	98	98	126	98	112	126	154	112	126	140	168	140	154
	30	70	126	70	84	70	126	84	98	98	154	98	112	112	168	126	140
	60	56	98	70	70	70	98	84	70	84	112	98	84	112	140	126	112
-15	**0**	112	154	112	112	126	168	112	126	140	182	140	140	168	210	154	168
	30	98	140	98	98	98	140	112	112	126	168	126	126	140	182	154	154
	60	84	112	84	84	98	126	98	84	112	140	112	112	140	168	140	126
-30	**0**	70	98	84	84	84	98	84	84	98	126	98	112	126	140	126	126
	30	56	112	70	70	70	112	84	84	84	140	98	98	112	154	126	126
	60	56	70	70	56	56	84	70	70	84	98	98	84	98	126	112	98

Table 8. NH_4-N (mg kg^{-1}) distribution in soil under drip irrigation at soil application of 100 per cent RDF and surface irrigation

Depth (cm)	**Horizontal distance** (cm)	**Drip irrigation at100% RDF**				**Surface irrigation at100% RDF**			
		Stages of sampling							
		I	II	III	IV	I	II	III	IV
0	**0**	56	70	42	70	56	70	42	70
	30	52	70	28	56	38	56	28	42
	60	48	42	28	28	32	28	32	42
-15	**0**	70	98	70	84	70	98	56	84
	30	56	84	56	70	56	70	56	70
	60	42	56	42	42	42	56	42	28
-30	**0**	42	42	28	42	28	28	28	42
	30	42	56	28	42	38	56	28	28
	60	32	28	28	28	28	28	28	28

Table 9. NO_3 -N (mg kg^{-1}) distribution in soil under drip fertigation at different levels of straight fertilizers N and K

Depth (cm)	**Horizontal distance** (cm)	**75 per cent RDF**				**100 per cent RDF**				**125 per cent RDF**				**150 per cent RDF**			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	26	56	56	70	28	56	70	84	42	70	84	98	56	84	84	112
	30	22	56	70	84	28	70	70	98	42	84	98	112	56	98	98	126
	60	42	70	70	98	42	84	84	98	56	98	98	112	70	112	112	126
-15	**0**	28	56	70	84	28	70	70	98	42	84	84	112	56	98	98	126
	30	28	70	84	98	28	84	84	98	42	98	98	112	56	112	112	126
	60	56	98	84	112	70	98	84	112	84	112	98	126	84	126	112	140
-30	**0**	42	84	84	98	42	84	84	98	56	98	98	112	70	112	112	126
	30	56	98	84	98	56	112	84	112	70	126	112	126	84	126	112	140
	60	70	112	84	112	84	112	98	126	98	126	112	140	112	140	126	154

Table 10. NO_3 -N (mg kg^{-1}) distribution in soil under drip fertigation at different levels of straight fertilizers N P K

Depth (cm)	**Horizontal distance** (cm)	**75 per cent RDF**				**100 per cent RDF**				**125 per cent RDF**				**150 per cent RDF**			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	28	56	56	84	42	70	56	84	56	84	70	98	56	84	84	112
	30	28	56	70	84	28	70	84	98	42	84	98	112	42	84	112	126
	60	42	84	70	98	42	84	84	98	56	98	98	112	56	112	112	126
-15	**0**	28	70	56	84	42	70	70	98	56	84	84	112	70	98	98	126
	30	28	70	84	98	28	84	84	98	42	98	112	112	56	112	112	126
	60	56	98	84	98	56	112	98	112	70	112	112	126	84	126	112	140
-30	**0**	42	84	70	98	56	98	84	98	70	112	98	112	84	112	112	126
	30	56	98	84	98	56	98	98	112	70	112	112	126	70	126	126	140
	60	84	112	84	112	84	112	98	126	98	126	112	140	98	140	126	154

Table 11. NO_3-N (mg kg^{-1}) distribution in soil under drip fertigation at different levels of water soluble fertilizers N P K

Depth (cm)	Horizontal distance (cm)	75 per cent RDF				100 per cent RDF				125 per cent RDF				150 per cent RDF			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	28	70	70	84	42	70	70	98	56	84	98	112	70	98	98	126
	30	28	70	84	98	42	84	84	112	56	98	98	126	70	112	112	126
	60	56	84	84	112	56	98	98	112	70	112	112	126	84	126	112	140
-15	**0**	42	70	84	98	42	84	84	112	56	98	98	126	70	112	112	126
	30	42	84	84	98	42	98	98	112	56	112	112	126	70	112	126	140
	60	70	98	98	112	84	112	98	126	98	126	112	140	98	126	126	154
-30	**0**	56	98	98	98	56	98	98	112	84	112	112	126	98	126	126	140
	30	56	112	98	112	70	126	98	126	84	140	112	140	98	140	126	140
	60	84	126	98	126	98	126	112	140	112	140	126	154	126	154	126	168

Table 12. NO_3-N (mg kg^{-1}) distribution in soil under drip irrigation at soil application of 100 per cent RDF and surface Irrigation

Depth (cm)	Horizontal distance (cm)	Drip irrigation at100% RDF				Surface irrigation at100% RDF			
		Stages of sampling							
		I	II	III	IV	I	II	III	IV
0	**0**	28	28	42	56	26	28	28	42
	30	24	42	42	70	28	28	42	56
	60	36	56	56	70	28	42	42	70
-15	**0**	32	42	42	56	28	28	42	56
	30	30	56	56	70	34	42	56	70
	60	42	70	56	84	30	70	56	84
-30	**0**	36	56	56	70	32	56	56	70
	30	24	84	56	84	36	70	56	70
	60	56	84	70	98	42	84	56	84

Table 13. Available -N (kg ha^{-1}) distribution in soil under drip fertigation at different levels of straight fertilizers N and K

Depth (cm)	Horizontal distance (cm)	75 per cent RDF				100 per cent RDF				125 per cent RDF				150 per cent RDF			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	237	254	259	246	241	259	264	251	249	269	274	261	253	271	276	264
	30	235	254	258	246	239	258	262	250	246	266	270	258	252	270	275	262
	60	234	253	257	245	238	257	261	249	248	266	271	259	251	269	274	262
-15	**0**	236	255	259	247	240	260	264	252	250	269	273	261	252	271	275	263
	30	235	254	259	246	239	258	263	250	248	267	272	259	251	270	275	262
	60	235	253	258	245	239	257	262	249	247	268	273	260	250	269	273	261
-30	**0**	235	253	258	245	239	257	262	249	251	269	274	261	252	272	276	264
	30	235	252	257	244	239	256	261	248	249	267	272	259	250	270	274	262
	60	235	253	258	245	239	257	262	249	247	265	270	257	250	268	273	261

Table 14. Available -N (kg ha^{-1}) distribution in soil under drip fertigation at different levels of straight fertilizers N P K

Depth (cm)	Horizontal distance (cm)	75 per cent RDF				100 per cent RDF				125 per cent RDF				150 per cent RDF			
		Stages sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	235	253	255	242	238	256	261	248	245	263	268	255	250	268	273	260
	30	235	253	258	245	237	256	261	248	243	262	267	254	248	267	271	259
	60	231	249	254	242	237	256	260	248	244	262	267	254	248	266	271	258
-15	**0**	234	253	255	242	239	258	262	250	245	264	268	256	251	269	274	261
	30	233	252	256	244	239	255	260	247	244	263	267	255	249	267	272	260
	60	232	250	255	243	238	256	261	248	245	263	268	255	247	265	270	258
-30	**0**	233	253	257	245	240	258	263	250	246	264	269	257	253	271	276	264
	30	233	252	256	244	238	257	262	249	244	263	268	255	248	268	272	260
	60	233	251	256	243	237	255	260	248	244	263	267	255	247	265	270	257

Table 15. Available -N (kg ha^{-1}) distribution in soil under drip fertigation at different levels of water soluble fertilizers N P K

Depth (cm)	**Horizontal distance** (cm)	**75 per cent RDF**				**100 per cent RDF**				**125 per cent RDF**				**150 per cent RDF**			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	237	256	261	248	241	259	264	251	247	266	271	258	253	271	276	263
	30	238	256	261	248	240	259	263	251	246	265	270	257	251	270	275	263
	60	234	252	257	245	240	259	263	251	247	265	270	257	251	269	274	261
-15	**0**	237	256	261	248	240	259	263	251	248	267	271	259	254	272	277	264
	30	236	255	259	247	242	260	265	252	247	266	270	258	252	270	275	262
	60	235	253	258	246	240	259	264	251	248	266	271	258	250	268	273	261
-30	**0**	236	254	259	247	241	259	264	251	249	266	271	258	256	274	277	264
	30	236	255	259	247	241	260	265	252	247	266	270	258	251	270	274	262
	60	236	254	259	246	240	257	262	249	247	267	271	259	250	268	273	260

Table 16. Available -N (kg ha^{-1}) distribution in soil under drip irrigation at soil application of 100 per cent RDF and surface irrigation

Depth (cm)	**Horizontal distance** (cm)	**Drip irrigation at100% RDF**				**Surface irrigation at100% RDF**			
		Stages of sampling							
		I	II	III	IV	I	II	III	IV
0	**0**	235	253	247	241	232	250	245	239
	30	235	253	247	241	231	250	246	239
	60	233	252	248	241	231	250	245	238
-15	**0**	235	254	249	242	232	250	245	239
	30	234	253	249	242	232	250	244	238
	60	233	251	248	241	232	250	244	238
-30	**0**	235	254	249	242	231	249	245	238
	30	232	251	247	240	230	249	244	238
	60	232	251	247	240	230	249	245	238

Table 17. Available -P (kg ha^{-1}) distribution in soil under drip fertigation at different levels of straight fertilizers N and K

Depth (cm)	Horizontal distance (cm)	75 per cent RDF				100 per cent RDF				125 per cent RDF				150 per cent RDF			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	16.3	19.3	21.5	17.6	17.6	20.5	22.7	18.9	17.9	20.8	23.0	19.1	19.3	22.2	24.4	20.5
	30	14.4	17.4	19.6	15.7	16.7	19.6	21.8	17.9	17.4	20.3	22.5	18.6	18.4	21.3	23.5	19.6
	60	14.5	17.5	19.7	15.8	13.7	16.6	18.8	14.9	14.9	17.8	20.0	16.2	17.9	20.8	23.0	19.1
-15	**0**	16.3	19.2	21.4	17.5	15.8	18.7	20.9	17.0	18.1	21.0	23.2	19.3	18.9	21.9	24.0	20.2
	30	15.8	18.7	20.9	17.0	16.8	19.7	21.9	18.1	17.0	19.9	22.1	18.2	18.4	21.3	23.5	19.6
	60	15.2	18.1	20.3	16.4	13.9	16.8	19.0	15.1	14.7	17.6	19.8	15.9	17.8	20.7	22.9	19.0
-30	**0**	13.9	16.8	19.0	15.1	15.5	18.4	20.6	16.8	16.9	19.8	22.0	18.1	18.9	21.8	24.0	20.1
	30	14.6	17.5	19.7	15.9	16.2	19.1	21.3	17.4	16.7	19.6	21.8	18.0	18.8	21.7	23.9	20.0
	60	16.3	19.2	21.4	17.5	14.4	17.3	19.5	15.6	15.0	17.9	20.1	16.2	17.6	20.5	22.7	18.8

Table 18. Available -P (kg ha^{-1}) distribution in soil under drip fertigation at different levels of straight fertilizers N P K

Depth (cm)	Horizontal distance (cm)	75 per cent RDF				100 per cent RDF				125 per cent RDF				150 per cent RDF			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	17.4	20.3	22.5	18.6	18.7	21.6	23.8	19.9	19.0	21.9	24.1	20.2	20.4	23.3	25.5	21.6
	30	15.5	18.4	20.6	16.7	17.7	20.7	22.8	19.0	18.4	21.3	23.5	19.6	19.4	22.3	24.5	20.6
	60	15.6	18.5	20.7	16.8	14.7	17.6	19.8	15.9	16.0	18.9	21.1	17.2	18.9	21.8	24.0	20.2
-15	**0**	17.3	20.2	22.4	18.5	16.8	19.7	21.9	18.1	19.1	22.0	24.2	20.3	20.0	22.9	25.1	21.2
	30	16.8	19.7	21.9	18.0	17.9	20.8	23.0	19.1	18.1	21.0	23.2	19.3	19.5	22.4	24.6	20.7
	60	16.2	19.1	21.3	17.5	14.9	17.9	20.0	16.2	15.7	18.6	20.9	17.0	18.9	21.8	24.0	20.1
-30	**0**	14.9	17.8	20.0	16.2	16.6	19.5	21.7	17.8	17.9	20.9	23.0	19.2	19.9	22.8	25.0	21.1
	30	15.7	18.6	20.8	16.9	17.2	20.2	22.3	18.5	17.8	20.7	22.9	19.0	19.8	22.7	24.9	21.0
	60	17.3	20.2	22.4	18.5	15.4	18.3	20.5	16.6	16.1	19.0	21.2	17.3	18.6	21.5	23.7	19.8

Table 19. Available -P (kg ha^{-1}) distribution in soil under drip fertigation at different levels of water soluble fertilizers N P K

Depth (cm)	Horizontal distance (cm)	75 per cent RDF				100 per cent RDF				125 per cent RDF				150 per cent RDF			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	21.3	24.2	26.4	22.6	22.6	25.5	27.7	23.8	22.9	25.8	28.0	24.1	24.3	27.2	29.4	25.5
	30	19.4	22.3	24.5	20.7	21.7	24.6	26.7	22.9	22.3	25.2	27.4	23.5	23.3	26.3	28.4	24.6
	60	19.5	22.4	24.6	20.8	18.6	21.6	23.7	19.9	19.9	22.8	25.0	21.1	22.9	25.8	28.0	24.1
-15	**0**	21.2	24.1	26.3	22.4	20.8	23.7	25.8	22.0	23.0	25.9	28.1	24.2	23.9	26.8	29.0	25.1
	30	20.7	23.6	25.8	21.9	21.8	24.7	26.8	23.0	22.0	24.9	27.1	23.2	23.4	26.3	28.5	24.6
	60	20.2	23.1	25.2	21.4	18.9	21.8	23.9	20.1	19.7	22.6	24.8	20.8	22.8	25.7	27.9	24.0
-30	**0**	18.9	21.8	24	20.1	20.5	23.4	25.6	21.7	21.9	24.8	27.0	23.1	23.8	26.8	28.9	25.1
	30	19.6	22.5	24.7	20.8	21.2	24.1	26.2	22.4	21.7	24.6	26.8	22.9	23.8	26.7	28.9	25.0
	60	21.2	24.1	26.3	22.4	19.3	22.2	24.4	20.5	20.0	22.9	25.1	21.2	22.5	25.4	27.6	23.8

Table 20. Available -P (kg ha^{-1}) distribution in soil under drip irrigation at soil application of 100 per cent RDF and surface irrigation

Depth (cm)	Horizontal distance (cm)	Drip irrigation at100% RDF				Surface irrigation at100% RDF			
		Stages of sampling							
		I	II	III	IV	I	II	III	IV
0	**0**	17.8	20.7	22.9	19.0	15.7	18.6	20.8	16.9
	30	16.2	19.1	21.4	17.5	14.7	17.6	19.8	15.9
	60	16.7	19.6	21.8	17.9	14.5	17.5	19.7	15.8
-15	**0**	17.8	20.7	22.9	19.0	16.1	19.1	21.2	17.4
	30	15.9	18.8	21.0	17.1	15.7	18.6	20.8	16.9
	60	14.7	17.6	19.8	15.9	15.1	18.0	20.2	16.3
-30	**0**	16.9	19.8	22.0	18.1	13.5	16.5	18.7	14.8
	30	16.7	19.6	21.8	18.0	14.6	17.5	19.7	15.8
	60	15.0	17.9	20.1	16.2	15.7	18.6	20.8	16.9

Table 21. Available -K (kg ha^{-1}) distribution in soil under drip fertigation at different levels of straight fertilizers N and K

Depth (cm)	Horizontal distance (cm)	75 per cent RDF				100 per cent RDF				125 per cent RDF				150 per cent RDF			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	500	509	516	505	502	512	519	508	504	514	521	511	505	515	523	512
	30	498	507	514	503	500	509	517	506	502	511	519	508	503	514	521	510
	60	499	508	515	503	501	510	518	506	502	511	519	508	504	513	521	511
-15	**0**	498	507	516	505	500	510	517	508	502	512	519	511	503	515	522	511
	30	496	505	513	504	500	510	516	504	500	510	517	506	503	512	520	509
	60	497	507	514	503	500	509	516	509	502	511	518	507	503	512	520	510
-30	**0**	497	506	510	505	500	510	517	505	501	511	516	509	502	512	519	508
	30	496	505	509	498	498	508	514	502	502	512	516	505	501	511	518	507
	60	496	506	513	493	498	507	514	503	501	510	517	507	502	511	518	507

Table 22. Available -K (kg ha^{-1}) distribution in soil under drip fertigation at different levels of straight fertilizers N P K

Depth (cm)	Horizontal distance (cm)	75 per cent RDF				100 per cent RDF				125 per cent RDF				150 per cent RDF			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	500	509	517	505	502	511	519	507	505	514	522	510	506	513	525	514
	30	498	508	513	501	500	509	517	505	503	512	519	508	504	513	521	510
	60	499	508	516	504	501	510	515	504	504	513	520	509	505	514	519	508
-15	**0**	500	510	517	505	500	510	517	506	504	513	520	509	504	514	525	513
	30	498	507	515	503	498	507	515	503	502	512	518	507	503	513	520	509
	60	497	507	514	503	499	509	516	505	502	512	519	508	504	513	519	508
-30	**0**	497	506	514	502	499	508	516	505	502	511	520	509	503	513	520	509
	30	496	505	513	504	498	507	515	504	501	510	518	506	502	512	519	508
	60	497	506	513	502	496	506	513	502	501	511	518	507	503	512	519	508

Table 23. Available -K (kg ha^{-1}) distribution in soil under drip fertigation at different levels of water soluble fertilizers N P K

Depth (cm)	**Horizontal distance** (cm)	**75 per cent RDF**				**100 per cent RDF**				**125 per cent RDF**				**150 per cent RDF**			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	504	513	520	511	505	515	522	512	508	518	525	515	510	521	528	518
	30	501	511	518	508	503	513	520	510	507	516	524	514	508	517	524	515
	60	502	512	519	509	504	514	521	511	507	517	524	514	509	518	525	516
-15	**0**	503	512	520	510	505	514	522	512	508	517	525	515	511	521	527	517
	30	499	509	516	506	503	512	519	510	507	516	523	514	508	517	522	513
	60	502	512	519	509	503	513	520	510	506	515	523	513	507	517	524	514
-30	**0**	500	510	517	507	503	512	519	510	505	515	522	512	507	518	526	516
	30	500	509	516	507	503	512	519	510	504	514	521	511	506	515	523	513
	60	500	510	517	507	502	512	519	509	505	515	522	512	506	516	523	513

Table 24. Available -K (kg ha^{-1}) distribution in soil under drip irrigation at soil application of 100 per cent RDF and surface irrigation

Depth (cm)	**Horizontal distance** (cm)	**Drip irrigation at100% RDF**				**Surface irrigation at100% RDF**			
		Stages of sampling							
		I	II	III	IV	I	II	III	IV
0	**0**	516	526	522	510	513	522	507	502
	30	514	524	520	508	511	520	505	501
	60	515	524	521	509	512	521	506	501
-15	**0**	514	524	520	509	511	521	505	501
	30	512	522	518	506	509	518	514	503
	60	514	523	519	508	510	520	505	501
-30	**0**	513	523	519	508	510	519	504	502
	30	512	522	518	507	509	518	514	500
	60	513	522	518	507	509	519	515	499

Table 25. Soil pH under drip fertigation at different levels of straight fertilizers N and K

Depth (cm)	**Horizontal distance** (cm)	**75 per cent RDF**				**100 per cent RDF**				**125 per cent RDF**				**150 per cent RDF**			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	8.60	8.57	8.54	8.52	8.60	8.58	8.54	8.52	8.60	8.57	8.55	8.53	8.60	8.57	8.54	8.52
	30	8.60	8.58	8.54	8.52	8.60	8.54	8.53	8.51	8.61	8.57	8.55	8.53	8.61	8.57	8.54	8.52
	60	8.60	8.57	8.54	8.52	8.60	8.55	8.53	8.51	8.60	8.58	8.54	8.52	8.62	8.58	8.55	8.53
-15	**0**	8.61	8.55	8.53	8.51	8.61	8.56	8.53	8.51	8.61	8.55	8.54	8.52	8.61	8.56	8.53	8.51
	30	8.61	8.56	8.53	8.51	8.60	8.53	8.52	8.50	8.60	8.56	8.54	8.52	8.62	8.55	8.52	8.52
	60	8.61	8.56	8.53	8.51	8.61	8.52	8.52	8.50	8.60	8.57	8.53	8.51	8.62	8.55	8.52	8.50
-30	**0**	8.61	8.53	8.53	8.50	8.61	8.54	8.53	8.51	8.61	8.52	8.54	8.52	8.62	8.56	8.53	8.51
	30	8.62	8.56	8.52	8.50	8.61	8.58	8.52	8.52	8.60	8.56	8.53	8.51	8.62	8.55	8.52	8.50
	60	8.60	8.56	8.52	8.50	8.61	8.51	8.52	8.50	8.60	8.55	8.52	8.50	8.61	8.54	8.54	8.52

Table 26. Soil pH under drip fertigation at different levels of straight fertilizers N P K

Depth (cm)	**Distance (cm)**	**75 per cent RDF**				**100 per cent RDF**				**125 per cent RDF**				**150 per cent RDF**			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	
0	**0**	8.61	8.57	8.55	8.53	8.60	8.56	8.54	8.52	8.61	8.55	8.55	8.53	8.60	8.55	8.56	8.54
	30	8.69	8.57	8.55	8.53	8.61	8.57	8.54	8.52	8.63	8.55	8.53	8.51	8.61	8.55	8.55	8.53
	60	8.62	8.56	8.55	8.53	8.62	8.57	8.54	8.52	8.61	8.56	8.54	8.52	8.63	8.55	8.54	8.52
-15	**0**	8.61	8.55	8.54	8.52	8.63	8.55	8.54	8.52	8.61	8.55	8.55	8.53	8.60	8.53	8.53	8.51
	30	8.60	8.56	8.53	8.51	8.61	8.56	8.53	8.51	8.63	8.53	8.53	8.51	8.62	8.54	8.53	8.51
	60	8.62	8.56	8.54	8.52	8.61	8.55	8.52	8.50	8.65	8.54	8.52	8.50	8.61	8.54	8.53	8.51
-30	**0**	8.60	8.55	8.54	8.52	8.62	8.55	8.53	8.51	8.63	8.53	8.52	8.50	8.62	8.53	8.53	8.51
	30	8.62	8.56	8.53	8.50	8.62	8.55	8.53	8.51	8.62	8.53	8.51	8.49	8.65	8.53	8.52	8.50
	60	8.62	8.55	8.54	8.52	8.61	8.54	8.5	8.48	8.63	8.54	8.52	8.50	8.62	8.53	8.51	8.49

Table 27. Soil pH under drip fertigation at different levels of water soluble fertilizers N P K

Depth (cm)	Horizontal distance (cm)	75 per cent RDF				100 per cent RDF				125 per cent RDF				150 per cent RDF			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	8.60	8.55	8.52	8.50	8.60	8.55	8.49	8.47	8.60	8.54	8.48	8.46	8.60	8.53	8.48	8.46
	30	8.62	8.54	8.52	8.50	8.61	8.55	8.48	8.46	8.69	8.55	8.48	8.46	8.69	8.54	8.48	8.46
	60	8.60	8.55	8.53	8.51	8.63	8.54	8.48	8.46	8.83	8.54	8.47	8.45	8.63	8.57	8.48	8.46
-15	**0**	8.62	8.54	8.51	8.49	8.65	8.54	8.48	8.46	8.65	8.54	8.47	8.45	8.65	8.54	8.46	8.42
	30	8.60	8.54	8.5	8.47	8.62	8.53	8.46	8.44	8.63	8.52	8.46	8.44	8.63	8.52	8.46	8.42
	60	8.60	8.54	8.52	8.50	8.61	8.53	8.47	8.45	8.81	8.54	8.48	8.46	8.61	8.53	8.47	8.43
-30	**0**	8.65	8.54	8.53	8.51	8.68	8.53	8.48	8.36	8.68	8.53	8.47	8.35	8.68	8.54	8.46	8.32
	30	8.60	8.52	8.51	8.47	8.62	8.53	8.46	8.34	8.66	8.52	8.46	8.34	8.66	8.52	8.46	8.42
	60	8.64	8.54	8.52	8.48	8.57	8.53	8.47	8.35	8.67	8.52	8.48	8.46	8.60	8.53	8.47	8.33

Table 28. Soil pH under drip irrigation at soil application of 100 per cent RDF and surface irrigation

Depth (cm)	**Horizontal distance** (cm)	**Drip irrigation at100% RDF**				**Surface irrigation at100% RDF**			
		Stages of sampling							
		I	II	III	IV	I	II	III	IV
0	**0**	8.60	8.57	8.54	8.52	8.60	8.58	8.58	8.58
	30	8.61	8.57	8.54	8.52	8.64	8.57	8.57	8.57
	60	8.62	8.57	8.55	8.53	8.65	8.57	8.57	8.57
-15	**0**	8.60	8.55	8.53	8.51	8.62	8.56	8.58	8.58
	30	8.65	8.55	8.53	8.51	8.61	8.56	8.56	8.54
	60	8.65	8.55	8.53	8.52	8.64	8.56	8.58	8.58
-30	**0**	8.64	8.54	8.52	8.52	8.61	8.56	8.57	8.57
	30	8.69	8.55	8.53	8.51	8.62	8.55	8.57	8.57
	60	8.61	8.54	8.53	8.54	8.63	8.56	8.58	8.57

Table 29. Soil EC (d S^{-1}) under drip fertigation at different levels of straight fertilizers N and K

Depth (cm)	Distance (cm)	75 per cent RDF				100 per cent RDF				125 per cent RDF				150 per cent RDF			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	0.25	0.25	0.25	0.25	0.26	0.26	0.25	0.25	0.25	0.25	0.26	0.26	0.25	0.25	0.25	0.25
	30	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.26	0.26	0.25	0.25	0.26	0.26
	60	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.26	0.26
-15	**0**	0.26	0.28	0.28	0.28	0.26	0.28	0.27	0.27	0.26	0.28	0.29	0.27	0.27	0.29	0.25	0.27
	30	0.26	0.27	0.26	0.26	0.28	0.29	0.27	0.28	0.28	0.29	0.29	0.29	0.26	0.27	0.28	0.28
	60	0.25	0.25	0.27	0.27	0.26	0.26	0.26	0.29	0.29	0.29	0.28	0.27	0.28	0.28	0.29	0.28
-30	**0**	0.26	0.28	0.29	0.28	0.28	0.28	0.29	0.29	0.28	0.29	0.29	0.29	0.28	0.29	0.27	0.29
	30	0.27	0.28	0.38	0.29	0.28	0.29	0.28	0.29	0.29	0.28	0.29	0.29	0.29	0.29	0.29	0.29
	60	0.27	0.27	0.29	0.28	0.28	0.28	0.26	0.29	0.29	0.29	0.29	0.29	0.28	0.28	0.31	0.28

Table 30. Soil EC (d S^{-1}) under drip fertigation at different levels of straight fertilizers N P K

Depth (cm)	**Horizontal distance** (cm)	75 per cent RDF				100 per cent RDF				125 per cent RDF				150 per cent RDF			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	0.25	0.25	0.26	0.26	0.25	0.25	0.26	0.25	0.25	0.25	0.26	0.26	0.25	0.25	0.26	0.26
	30	0.25	0.25	0.25	0.26	0.25	0.25	0.26	0.25	0.25	0.25	0.26	0.26	0.25	0.25	0.26	0.26
	60	0.25	0.25	0.26	0.26	0.25	0.25	0.25	0.27	0.25	0.25	0.25	0.25	0.25	0.25	0.27	0.26
-15	**0**	0.29	0.27	0.28	0.29	0.27	0.29	0.31	0.28	0.27	0.29	0.28	0.31	0.25	0.27	0.27	0.27
	30	0.27	0.28	0.29	0.29	0.27	0.28	0.25	0.27	0.77	0.28	0.27	0.28	0.28	0.29	0.27	0.28
	60	0.28	0.28	0.26	0.28	0.27	0.27	0.27	0.31	0.28	0.28	0.29	0.28	0.27	0.27	0.26	0.28
-30	**0**	0.25	0.27	0.29	0.30	0.28	0.29	0.32	0.29	0.27	0.29	0.29	0.31	0.28	0.29	0.29	0.28
	30	0.26	0.27	0.31	0.31	0.29	0.29	0.27	0.31	0.29	0.29	0.29	0.31	0.29	0.30	0.29	0.31
	60	0.28	0.28	0.28	0.31	0.28	0.29	0.29	0.31	0.28	0.28	0.29	0.29	0.28	0.28	0.29	0.31

Table 31. Soil EC (d S^{-1}) under drip fertigation at different levels of water soluble fertilizers N P K

Depth (cm)	**Horizontal distance** (cm)	**75 per cent RDF**				**100 per cent RDF**				**125 per cent RDF**				**150 per cent RDF**			
		Stages of sampling															
		I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	**0**	0.25	0.25	0.26	0.26	0.25	0.25	0.26	0.25	0.25	0.25	0.25	0.26	0.25	0.25	0.26	0.26
	30	0.25	0.25	0.25	0.26	0.25	0.25	0.26	0.26	0.25	0.25	0.27	0.27	0.25	0.25	0.26	0.26
	60	0.25	0.25	0.28	0.27	0.25	0.25	0.26	0.27	0.25	0.25	0.26	0.26	0.25	0.25	0.25	0.25
-15	**0**	0.27	0.29	0.27	0.29	0.28	0.30	0.28	0.31	0.27	0.29	0.26	0.31	0.28	0.29	0.29	0.29
	30	0.26	0.27	0.27	0.29	0.28	0.28	0.27	0.28	0.27	0.28	0.29	0.26	0.29	0.27	0.28	0.29
	60	0.26	0.27	0.28	0.29	0.27	0.27	0.28	0.28	0.28	0.28	0.30	0.29	0.29	0.28	0.27	0.27
-30	**0**	0.29	0.31	0.29	0.31	0.28	0.30	0.29	0.31	0.31	0.30	0.28	0.31	0.29	0.29	0.31	0.31
	30	0.26	0.27	0.29	0.30	0.29	0.29	0.30	0.31	0.29	0.28	0.31	0.29	0.29	0.28	0.29	0.31
	60	0.29	0.29	0.28	0.31	0.28	0.29	0.29	0.29	0.29	0.29	0.31	0.29	0.29	0.29	0.29	0.29

Table 32. Soil EC (d S^{-1}) under drip irrigation at soil application of 100 per cent RDF and surface irrigation

Depth (cm)	**Horizontal distance** (cm)	**Drip irrigation at100% RDF**				**Surface irrigation at100% RDF**			
		Stages of sampling							
		I	II	III	IV	I	II	III	IV
0	**0**	0.25	0.25	0.26	0.25	0.25	0.25	0.25	0.25
	30	0.25	0.25	0.26	0.25	0.25	0.25	0.25	0.26
	60	0.25	0.25	0.25	0.26	0.25	0.25	0.26	0.25
-15	**0**	0.28	0.27	0.29	0.27	0.28	0.26	0.26	0.27
	30	0.29	0.29	0.26	0.31	0.27	0.26	0.27	0.27
	60	0.28	0.28	0.26	0.27	0.27	0.27	0.29	0.26
-30	**0**	0.28	0.27	0.31	0.29	0.26	0.27	0.28	0.28
	30	0.29	0.30	0.28	0.31	0.27	0.28	0.28	0.27
	60	0.29	0.28	0.29	0.31	0.27	0.28	0.29	0.26

Table 33. Effect of different levels of drip fertigation on plant height (cm) of cotton

Treatments	25 DAS	70 DAS	105 DAS	140 DAS
T_1	25.33	62.14	98.60	157.07
T_2	25.68	67.46	106.10	162.51
T_3	25.10	63.33	107.30	157.23
T_4	25.59	69.80	114.10	166.51
T_5	26.05	65.74	95.50	157.07
T_6	26.33	67.32	106.10	167.41
T_7	24.21	55.50	98.60	144.41
T_8	26.61	64.25	112.32	166.51
T_9	26.58	67.12	97.90	146.47
T_{10}	25.83	68.36	114.10	151.38
T_{11}	25.33	65.21	107.30	170.87
T_{12}	25.68	63.07	123.30	162.78
T_{13}	24.10	54.13	109.71	157.23
T_{14}	25.59	69.80	123.20	178.12
SEd	1.40	3.51	5.90	8.85
CD (P=0.05)	NS	7.21	12.12	18.19

Table 34. Effect of different levels of drip fertigation on DMP (kg ha^{-1})

Treatments	40 DAS	70 DAS	105 DAS	140 DAS
T_1	279.2	2791.0	5274.7	6592.7
T_2	234.3	2228.4	4294.7	5332.8
T_3	251.4	2437.2	4717.9	5838.5
T_4	222.5	2221.0	4252.6	5239.3
T_5	227.8	2301.1	4408.3	5475.5
T_6	244.4	2476.9	4752.7	5897.9
T_7	213.0	2223.8	4133.8	5230.7
T_8	218.6	2307.5	4205.2	5367.5
T_9	257.2	2631.7	4934.6	6179.8
T_{10}	249.2	2449.4	4743.7	5848.7
T_{11}	220.9	2154.5	4253.5	5159.0
T_{12}	223.5	2174.4	4307.1	5355.2
T_{13}	230.9	2308.2	4526.4	5648.5
T_{14}	229.9	2357.1	4528.3	5679.6
SEd	22.79	235.06	438.85	535.43
CD (P=0.05)	NS	NS	NS	NS

Table 35. Effect of different levels of drip fertigation on mono podial branches, sympodial branches, boll weight, No. of bolls plant^{-1} and seed cotton yield

Treatments	Mono podial branches (Nos)	Sympodial branches (Nos)	Boll weight g boll^{-1}	No. of bolls per plant (Nos)	Seed cotton yield (kg ha^{-1})
T_1	4.3	60.0	5.4	197.7	2748.9
T_2	4.7	67.7	6.4	230.0	3062.8
T_3	4.3	57.7	5.8	194.7	2361.2
T_4	5.0	60.3	5.4	185.7	2712.7
T_5	5.3	60.3	5.1	198.7	2710.2
T_6	5.0	58.0	5.2	190.3	2802.3
T_7	4.7	49.3	5.3	195.3	2682.4
T_8	5.7	60.0	5.2	193.7	2544.9
T_9	5.7	72.7	6.7	247.0	3324.0
T_{10}	5.3	62.7	5.7	214.0	3062.2
T_{11}	5.3	55.7	5.6	198.3	2819.7
T_{12}	5.7	61.3	5.5	199.0	2517.5
T_{13}	4.0	48.3	4.9	190.0	2138.6
T_{14}	5.3	60.0	4.8	133.3	1111.6
SEd	0.46	4.12	0.51	11.34	262.5
CD (P=0.05)	0.96	8.47	1.04	23.32	539.7

Table. 36. Effect of different levels of drip fertigation on potassium content in cotton (per cent)

Treatments	40 DAS	70 DAS	105 DAS	140 DAS
T_1	1.41	1.42	1.48	1.59
T_2	1.30	1.37	1.49	1.70
T_3	1.48	1.48	1.58	1.85
T_4	1.38	1.29	1.41	1.60
T_5	1.56	1.29	1.53	1.63
T_6	1.66	1.31	1.71	1.68
T_7	1.53	1.19	1.55	1.67
T_8	1.51	1.32	1.58	1.73
T_9	1.65	1.56	1.72	1.95
T_{10}	1.59	1.35	1.54	1.59
T_{11}	1.38	1.12	1.35	1.41
T_{12}	1.39	1.12	1.30	1.38
T_{13}	1.47	1.23	1.41	1.50
T_{14}	1.43	1.31	1.47	1.68

Table 37. Effect of different levels of drip fertigation on nitrogen content in cotton (per cent)

Treatments	40 DAS	70 DAS	105 DAS	140 DAS
T_1	1.25	1.33	1.15	1.75
T_2	1.40	1.28	1.28	1.52
T_3	1.43	1.40	1.52	1.75
T_4	1.52	1.28	1.28	1.52
T_5	1.52	1.28	1.28	1.63
T_6	1.40	1.28	1.40	1.63
T_7	1.40	1.28	1.28	1.40
T_8	1.52	1.17	1.40	1.52
T_9	1.87	1.52	1.52	1.87
T_{10}	1.52	1.52	1.40	1.75
T_{11}	1.40	1.28	1.17	1.52
T_{12}	1.40	1.40	1.05	1.28
T_{13}	1.40	1.28	1.28	1.40
T_{14}	1.40	1.28	1.17	1.40

Table. 38. Effect of different levels of drip fertigation on phosphorus content in cotton (per cent)

Treatments	40 DAS	70 DAS	105 DAS	140 DAS
T_1	0.84	0.38	0.42	0.59
T_2	0.90	0.41	0.49	0.73
T_3	0.97	0.53	0.44	0.68
T_4	0.87	0.47	0.48	0.72
T_5	0.88	0.46	0.47	0.72
T_6	0.96	0.49	0.50	0.77
T_7	0.83	0.44	0.44	0.69
T_8	0.88	0.47	0.47	0.73
T_9	1.01	0.50	0.50	0.80
T_{10}	0.99	0.47	0.48	0.75
T_{11}	0.85	0.58	0.41	0.63
T_{12}	0.85	0.48	0.40	0.62
T_{13}	0.88	0.37	0.43	0.66
T_{14}	0.94	0.39	0.44	0.48

Table 39. Effect of different levels of drip fertigation on N uptake by cotton (kg/ha)

Treatments	40 DAS	70 DAS	105 DAS	140 DAS
T_1	3.49	37.12	60.66	113.37
T_2	3.28	28.60	55.12	80.88
T_3	3.60	34.12	71.55	102.17
T_4	3.37	28.50	54.58	79.46
T_5	3.46	29.53	56.57	89.43
T_6	3.42	31.79	66.54	96.33
T_7	2.98	28.54	53.05	73.23
T_8	3.32	26.92	58.87	81.41
T_9	4.80	39.91	74.84	115.36
T_{10}	3.78	37.15	66.41	102.35
T_{11}	3.09	27.65	49.62	78.25
T_{12}	3.13	30.44	45.22	68.72
T_{13}	3.23	29.62	58.09	79.08
T_{14}	3.22	30.25	52.83	79.51
SEd	0.01	0.12	0.25	0.45
CD (P=0.05)	0.02	0.24	0.51	0.91

Table 40. Effect of different levels of drip fertigation on P uptake by cotton (kg/ha)

Treatments	40 DAS	70 DAS	105 DAS	140 DAS
T_1	2.35	10.61	22.15	38.90
T_2	2.10	9.14	20.90	38.75
T_3	2.44	12.84	20.76	39.70
T_4	1.94	10.36	20.41	37.90
T_5	2.00	10.51	20.72	39.61
T_6	2.35	12.14	23.61	45.41
T_7	1.76	9.71	18.19	36.09
T_8	1.93	10.77	19.90	39.18
T_9	2.60	13.25	24.84	49.44
T_{10}	2.47	11.43	22.61	43.87
T_{11}	1.88	12.50	17.58	32.33
T_{12}	1.91	10.36	17.08	33.20
T_{13}	2.04	8.46	19.31	37.28
T_{14}	2.16	9.19	19.92	27.26
SEd	0.01	0.04	0.07	0.16
CD (P=0.05)	0.02	0.09	0.13	0.34

Table 41. Effect of different levels of drip fertigation on K uptake by cotton (kg/ha)

Treatments	40 DAS	70 DAS	105 DAS	140 DAS
T_1	3.94	39.63	78.07	104.82
T_2	3.06	30.45	63.88	90.66
T_3	3.72	35.95	74.31	107.77
T_4	3.08	28.69	60.07	83.61
T_5	3.56	29.63	67.23	88.98
T_6	4.06	32.41	81.39	99.04
T_7	3.25	26.41	64.25	87.18
T_8	3.31	30.38	66.41	92.59
T_9	4.24	41.12	84.71	120.51
T_1	3.97	32.96	73.13	93.09
T_2	3.04	24.15	57.60	72.87
T_3	3.11	24.37	56.17	73.86
T_4	3.39	28.47	63.93	84.49
T_5	3.29	30.94	66.60	95.61
SEd	0.01	0.15	0.26	0.38
CD (P=0.05)	0.02	0.31	0.53	0.78

Table 42. Effect of different levels of drip fertigation on Quality of cotton

Treatments	MIC	2.5% Staple length	Uniformity ratio (per cent)	Tancity 3.2mm g/tex
T_1	3.40	30.60	46.00	20.10
T_2	3.20	30.50	44.00	19.20
T_3	3.70	30.30	46.00	20.50
T_4	4.10	31.60	45.00	20.10
T_5	3.40	30.90	46.00	21.90
T_6	4.20	32.40	46.00	21.10
T_7	3.00	31.20	45.00	19.90
T_8	3.00	29.90	46.00	20.90
T_9	3.40	32.40	45.00	20.50
T_{10}	3.20	30.40	45.00	22.20
T_{11}	3.00	31.50	46.00	21.00
T_{12}	3.60	31.10	47.00	19.20
T_{13}	3.40	29.80	45.00	21.00
T_{14}	3.20	30.30	46.00	21.70
SEd	0.01	0.02	0.02	0.02
CD (P=0.05)	0.02	0.04	0.03	0.04

APPENDIX 1

WEEKLY WEATHER DATA (STANDARD WEEK) DURING THE CROPPING PERIOD

Period	Standard week	Mean Temperature		Mean RH (%) 722 hrs	Mean RH% 1422 hrs	Mean Evaporation (mm)	Total Rainfall (mm)	Total Rainy days	Mean Sunshine hrs	Wind velocity (km hr^{-1})	Solar radiation
		Max.	Min.								
Aug 31 - Sep 6	36	31.3	22.8	84	52	5.6	0.2	-	4.7	9.2	359.9
Sep 7 - 13	37	32.1	23	91	56	4.1	7.6	1	6.1	4.4	328.9
Sep 14 - 21	38	30.5	23.9	80	58	5.9	4.2	-	3.3	14.6	321.3
Sep 22 - 28	39	31.2	22.8	86	54	5.1	2.4	-	5	9.7	341.8
Sep 29 - Oct 5	40	32.2	21.4	80	45	5.6	-	-	7.4	7.3	410.3
Oct 6 - 12	41	33	22.2	91	49	5	10.2	1	7.2	4.6	348.7
Oct 13 - 1 9	42	30	22	94	65	3.2	87.6	3	3	4.3	262.9
Oct 20 - 26	43	28	22	96	70	2.5	156.1	4	2.7	4.7	237.5
Oct 27 - Nov 2	44	28.9	22.1	94	68	3.3	72.2	5	4	4.1	250.6
Nov 3 - 9	45	29.8	22.1	93	58	3.8	8.6	1	6.3	2.8	411.6
Nov 10 - 16	46	25.7	16.4	90	39	3.8	-	-	9.9	2.9	464.4
Nov 17 - 23	47	29.5	20.5	87	54	3.5	0.6	-	7.4	4.8	382.9
Nov 24 - 30	48	29.4	19.5	87	53	4	-	-	5.2	3.9	406.9
Dec 1 - 7	49	28.4	19.9	86	54	4	1	-	7	7.1	394.7
Dec 8 - 14	50	28.5	20.9	87	53	3.4	0.5	-	3.9	6.9	315

Period	Standard week	Mean Temperature		Mean RH (%) 722 hrs	Mean RH% 1422 hrs	Mean Evaporation (mm)	Total Rainfall (mm)	Total Rainy days	Mean Sunshine hrs	Wind velocity (km hr^{-1})	Solar radiation
		Max.	Min.								
Dec 15 - 21	51	26.9	20.5	91	71	3.1	113.4	3	3.1	7.5	271.3
Dec 22 - 28	52	29.7	16.3	92	39	3.4	-	-	9.2	3	459
Dec 29- Jan 4	1	26.6	17.7	91	49	3.8	-	-	8.1	4.9	379.2
Jan 5 - 11	2	28.3	17.5	91	49	3.6	0.2	-	8.2	4.9	281.5
Jan 12 - 18	3	25	16.9	93	29	4.2	0.2	-	9.1	5.2	405.9
Jan 19 - 25	4	30.2	17.3	90	42	3.8	-	-	8.8	3.3	500.7
Jan 26 - Feb 1	5	32	19.8	91	47	4.2	-	-	7.6	3.1	420.6
Feb 2 - 8	6	31.3	21.8	86	51	3.9	-	-	4.9	3.6	406.6
Feb 9 - 15	7	29.9	22.5	90	59	3.3	49.2	3	5.7	4.1	425.7
Feb 16 - 22	8	31.7	19.8	86	37	4.9	-	-	9.6	4.6	366.2
Feb 23 - 29	9	32.5	17.1	84	27	5.6	-	-	9.9	4.6	383.7
Mar 1 - 7	10	32.7	18.5	82	26	6.1	-	-	9.7	5.3	418
Mar 8 - 14	11	31.8	19.7	77	38	6.5	4	2	6.3	6	425.7
Mar 15 - 21	12	29.7	22.5	93	65	3.2	52.3	6	2.6	5.4	451.9
Mar 22 - 28	13	30.6	21.3	91	53	3.9	3.8	2	7	4.9	391.8

APPENDIX II

CHARACTERISTICS OF COTTON HYBRID RCH 2Bt

S. No.	Characters	Description
1.	Year of release	2005
2.	State from which released	Rasi seeds (P) Ltd, Attur, Salem Tamilnadu.
4.	Duration (days)	155-165
5.	Potential seed cotton yield (q ha^{-1})	35-40
6.	Ginning percentage	35
7.	Fiber strength (G/tex)	23-24
8.	Average boll weight (gm)	4.5-5.00
9.	Span length (2.5%) mm	29-31

APPENDIX – III

COST OF CULTIVATION FOR COTTON (Hectare^{-1})

S. No.	Particulars	Inputs	Rate Rs. /unit	Furrow	Drip
1	**Preparatory cultivation**				
a	Tractor ploughing twice	Four hrs	250 hr^{-1}	1000	1000
b	Ridges and furrow formation	2 bullock pair	150 hr^{-1}	300	
c	Broad bed formation	1 bullock pair	150 hr^{-1}		150
d	Rectification of ridges and furrow formation	5 A type	80 day^{-1}	400	
e	Rectification of raised bed	2 A type	80 day^{-1}		160
2	**Seed and sowing**				
a	Cost of seed	450 g	750	750	750
b	sowing	8 B type	80 day^{-1}	640	640
c	Gap filling	2 B type	80 day^{-1}	160	160
3	**Manures and fertilizers**				
a	FYM	12.5 tonnes	500 t^{-1}	6250	6250
b	Application charges	5 A type	80 day^{-1}	400	400

S. No.	Particulars	Inputs	Rate Rs. /unit	Furrow	Drip
4	**Weeding**				
a	Herbicide	1 litre	405	405	405
b	Manual weeding	45 B type	80 day^{-1}	3600	
		25 B type	80 day^{-1}		2000
c	Herbicide application charges	1A and 1B type	80 day^{-1}	160	160
d	Earthing up	15 A type	80 day^{-1}	1200	
5	**Plant protection**				
a	Monocrotophos	2 lit	450 lit^{-1}	900	900
b	Application charges	3A type+2 B type	80 day^{-1}	400	400
6	**Harvesting**	45 B type	80 day^{-1}	3600	3600
7	**Irrigation charges**	15 A type	80 day^{-1}	1200	1200
			Total	**21,365**	**18,175**

APPENDIX IV

Cost of drip irrigation unit ha^{-1} for hybrid cotton RCH 2Bt

Lateral spacing : 1.5 m
Dripper spacing : 1.5 m
Number of plants : 4,444
Number of dripper / plant : 1

Sl. no.	**Particulars**	**Quantity needed**	**Unit**	**Unit cost (Rs.)**	**Cost (Rs.)**
Cost of drip irrigation unit					
1	Main line PVC (63mm)	50	m	38.00	1900.00
2	Submain – PVC (40 mm)	100	m	25.00	2500.00
3	Lateral (16 mm) drippers (4 lph).	6670 4,444	m nos	7.20 2.75	48024.00 12221.00
4	GTO(53 x 2)	106	nos	2.00	212.00
5	End cap (53 x 2)	106	nos	2.00	212.00
6	Filter	1	nos	2200	2200.00
				Total	67269.00
	Cost of drip irrigation unit with fertigation system				
1	Cost of drip irrigation unit				67269.00
2	Cost of fertigation unit including other accessories			3000	3000.00
				Total	70269.00
	Drip fertigation				
1	Drip system per year				
2	Assuming 5 years/ 10 season	70269.00	10	Season	7026.90
3	Intrest 10 %per year	70269.00	10	Season	7026.90
4	Repair and maintainance				1000.00
5	Drip irrigation				15053.80
	Drip system per year				
1	Assuming 5 years/ 10 season	70269.00	10		6726.90
2	Intrest 10 %per year	70269.00	10		6726.90
3	Repair and maintainance				1000.00
				Total	14453.80

APPENDIX V

Cost of straight and water soluble fertilizer and cost of seed cotton

1	**Fertilizer**	**Cost per kg**
2	Urea	5.00
3	Muriate of potash	4.75
4	Single super phosphate	3.75
5	Mono ammonium phosphate (12:61:0)	65.00
6	Sulphate of potash (0:0:50)	38.00
7	Seed cotton	25.00

Figure 1. Layout of the experimental field

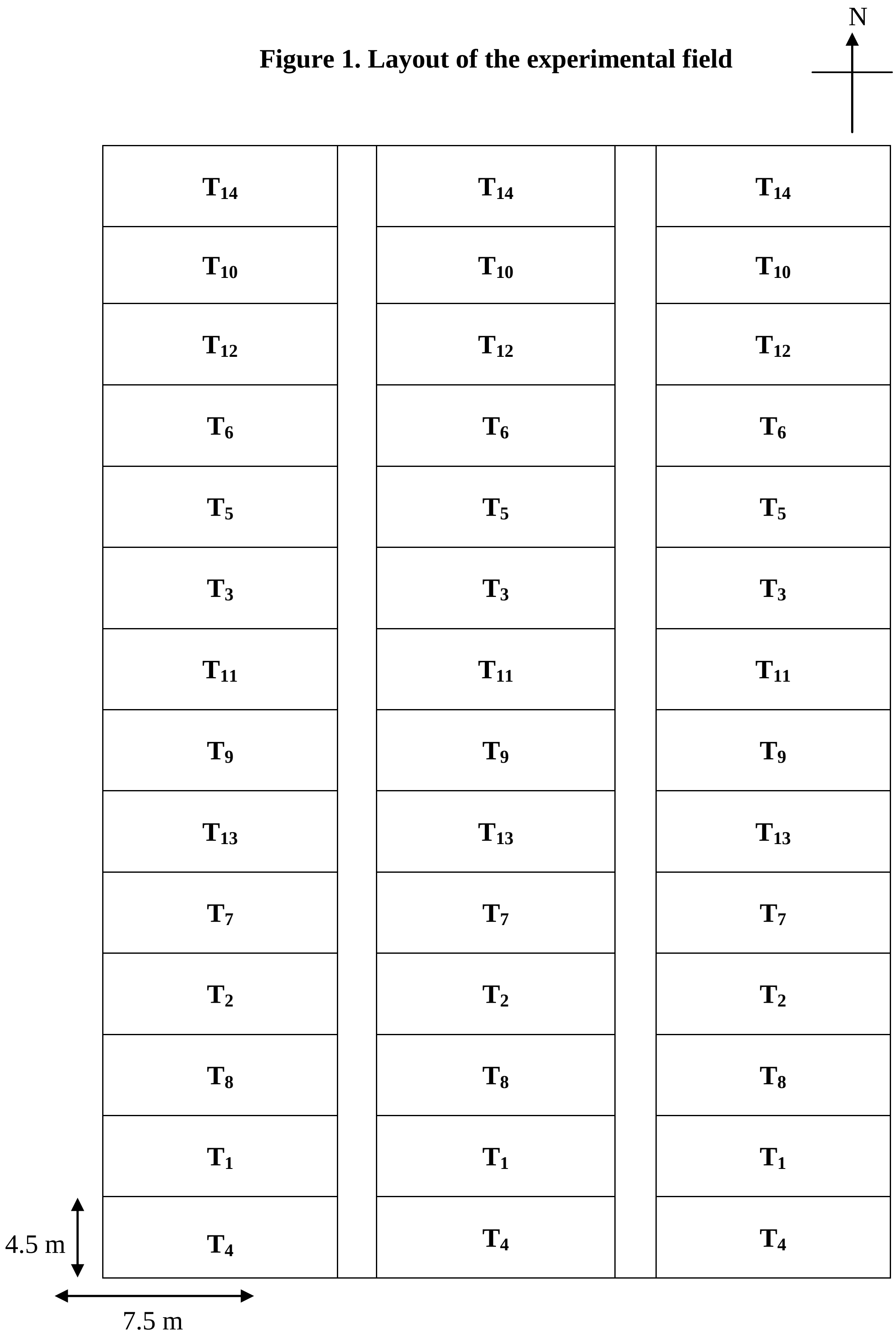


Fig. 4. Effect of drip fertigation at different levels of straight and water soluble fertilizers on seed cotton yield (kg ha^{-1})

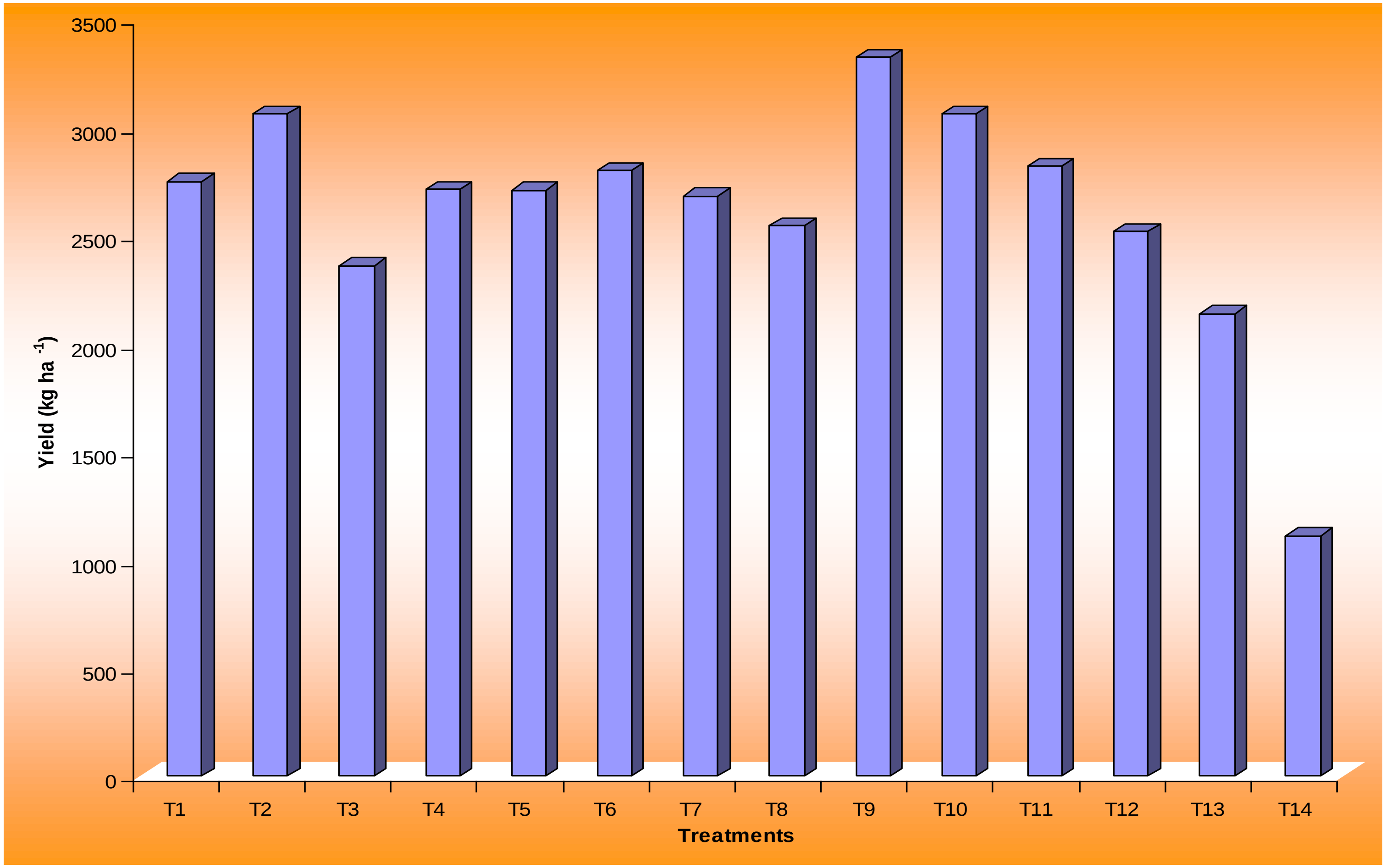


Fig. 2. Effect of drip fertigation at different levels of straight and water soluble fertilizers on plant height (cm) of cotton

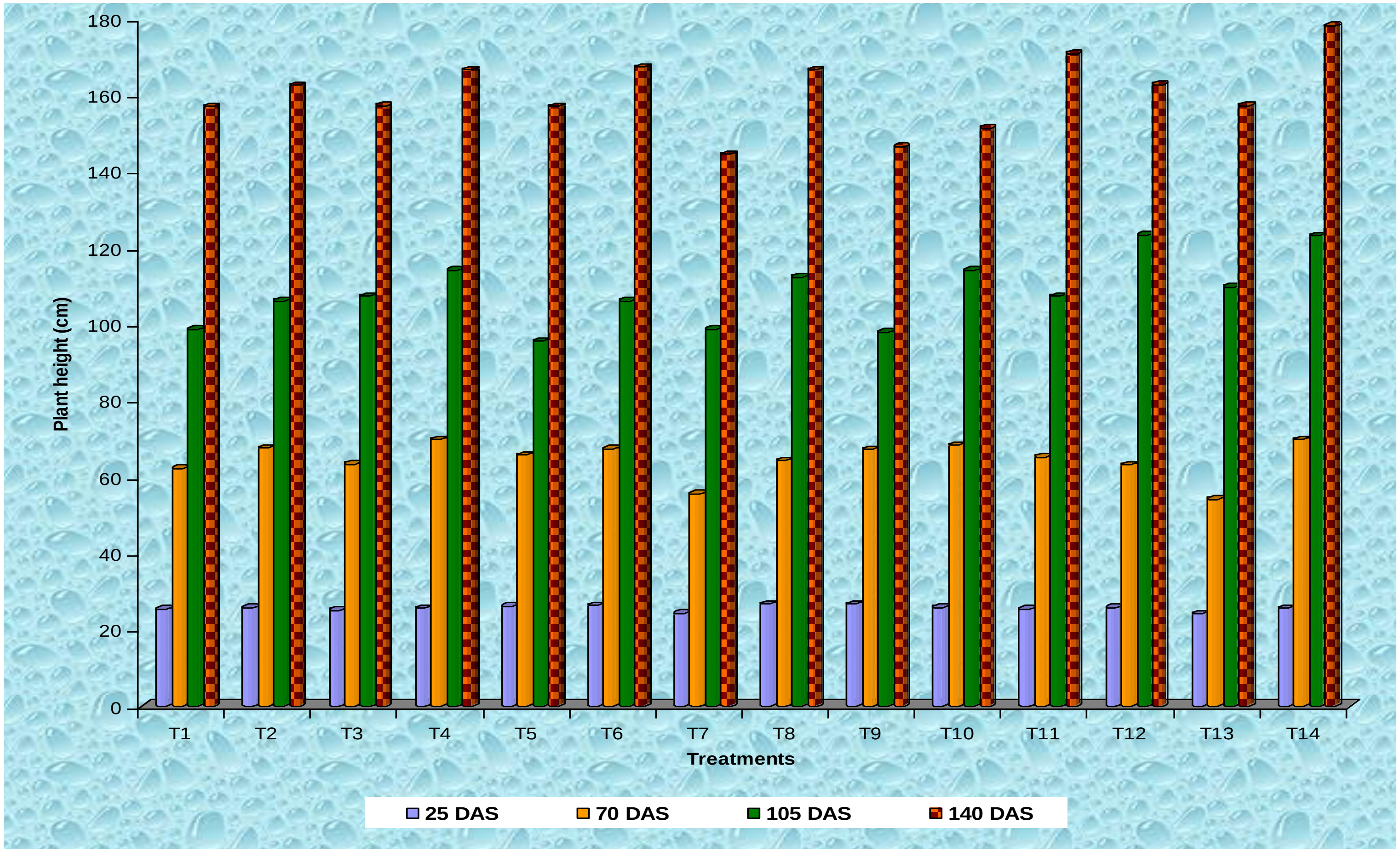


Fig. 3. Effect of drip fertigation at different levels of straight and water soluble fertilizers on monopodial and sympodial branches plant^{-1}

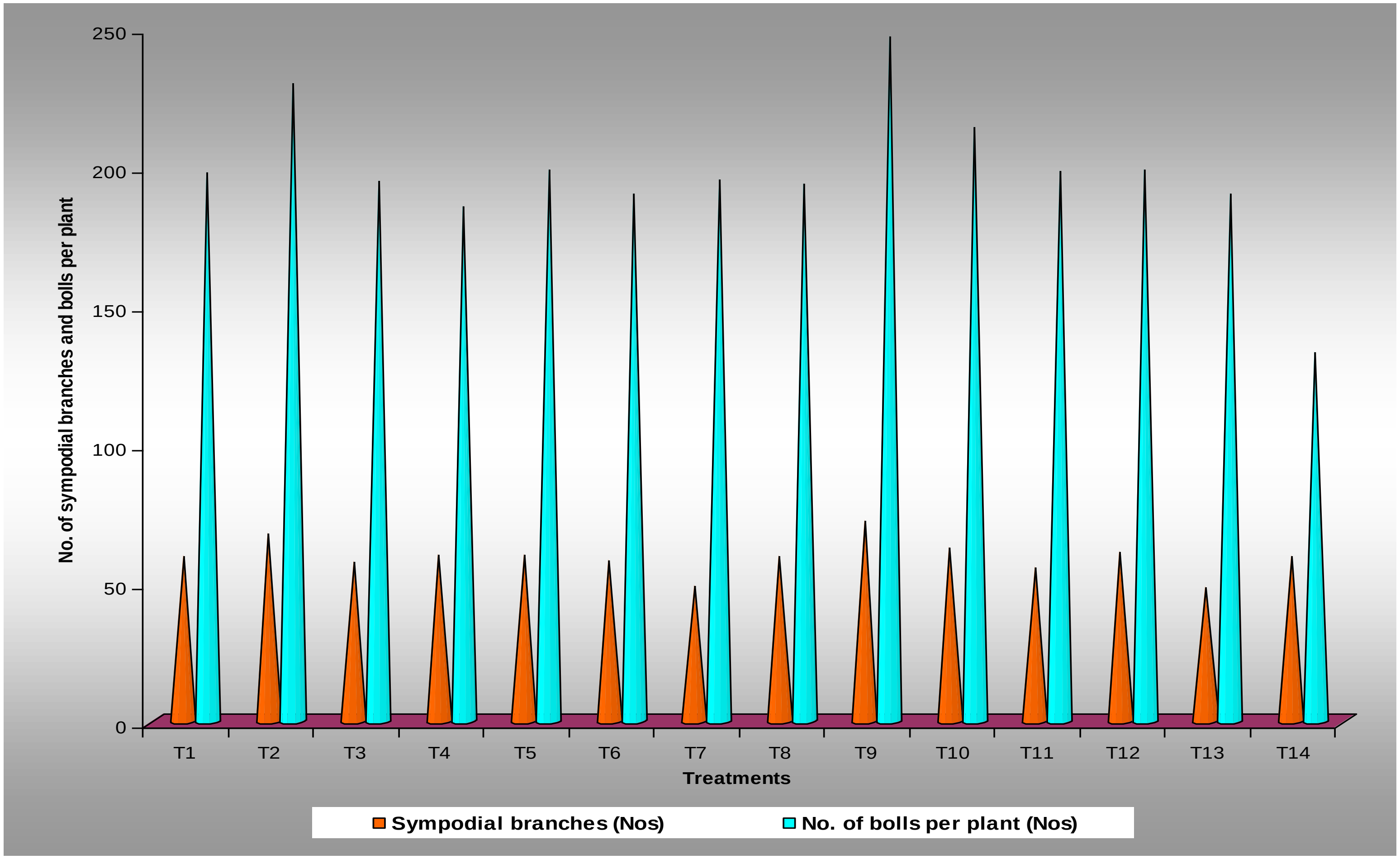


Fig. 8. Effect of drip fertigation at different levels of straight and water soluble fertilizers on quality of cotton

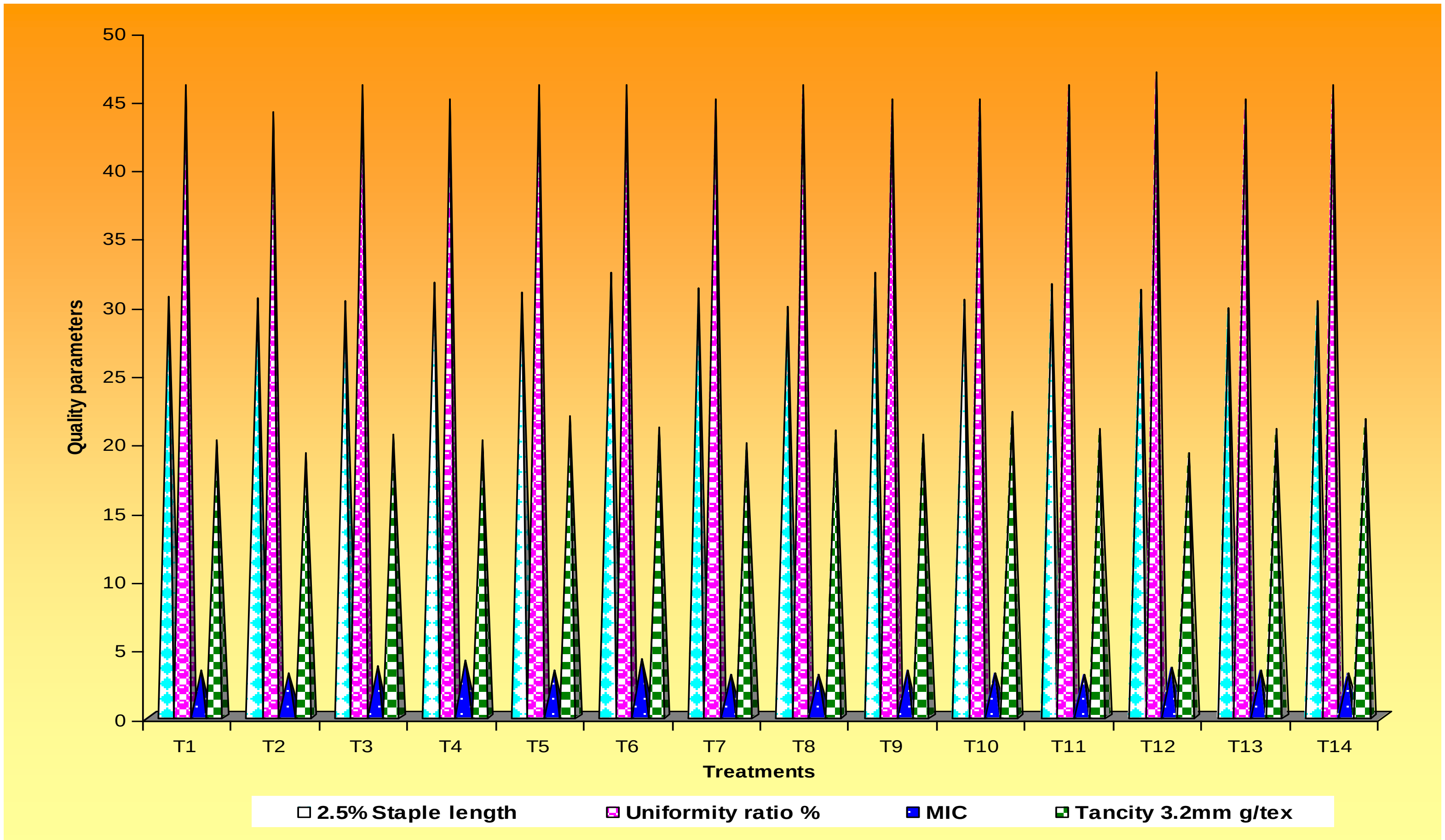


Fig. 5. Effect of drip fertigation at different levels of straight and water soluble fertilizers on N uptake by cotton (kg ha^{-1})

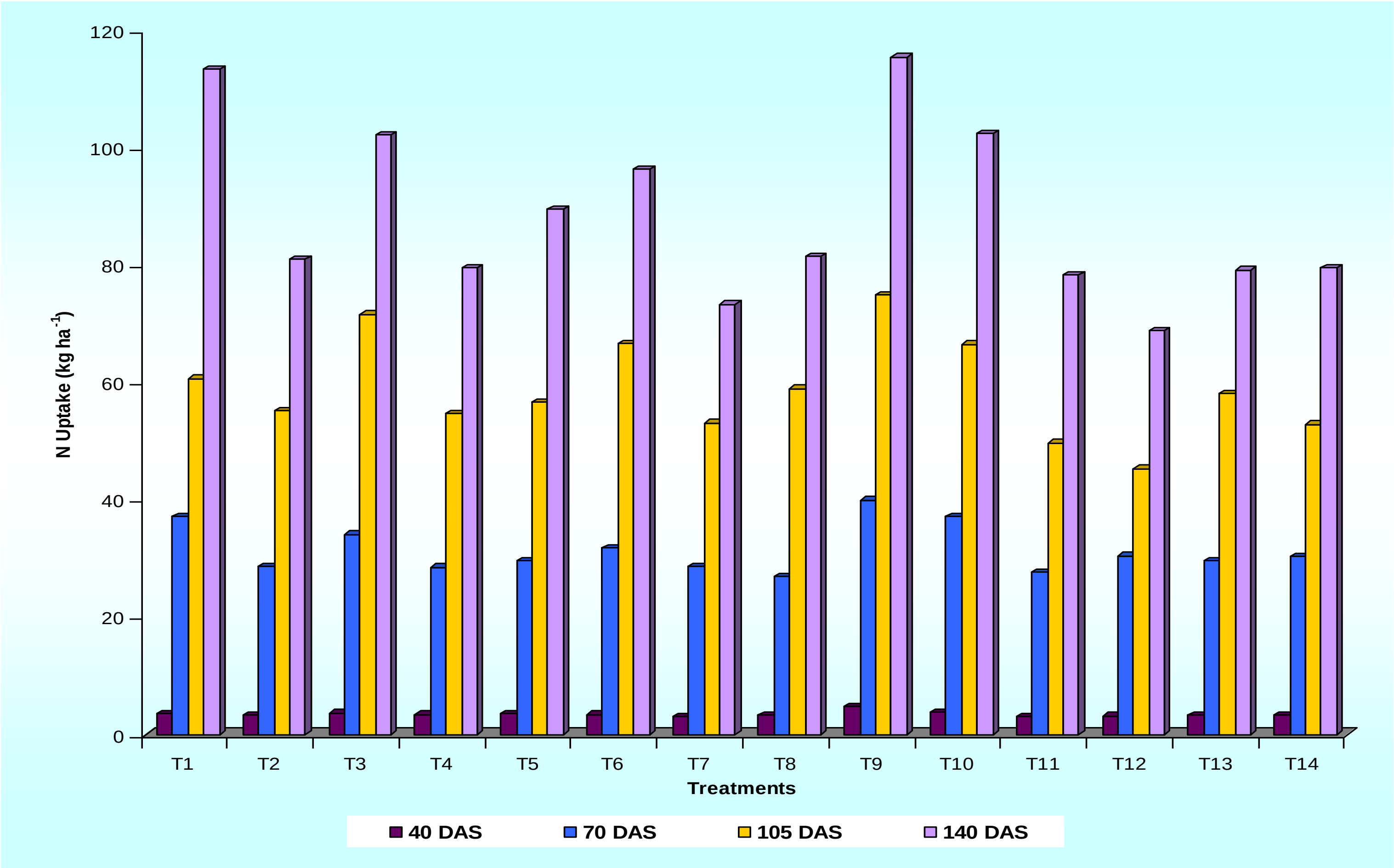


Fig. 6. Effect of drip fertigation at different levels of straight and water soluble fertilizers on P uptake by cotton (kg ha^{-1})

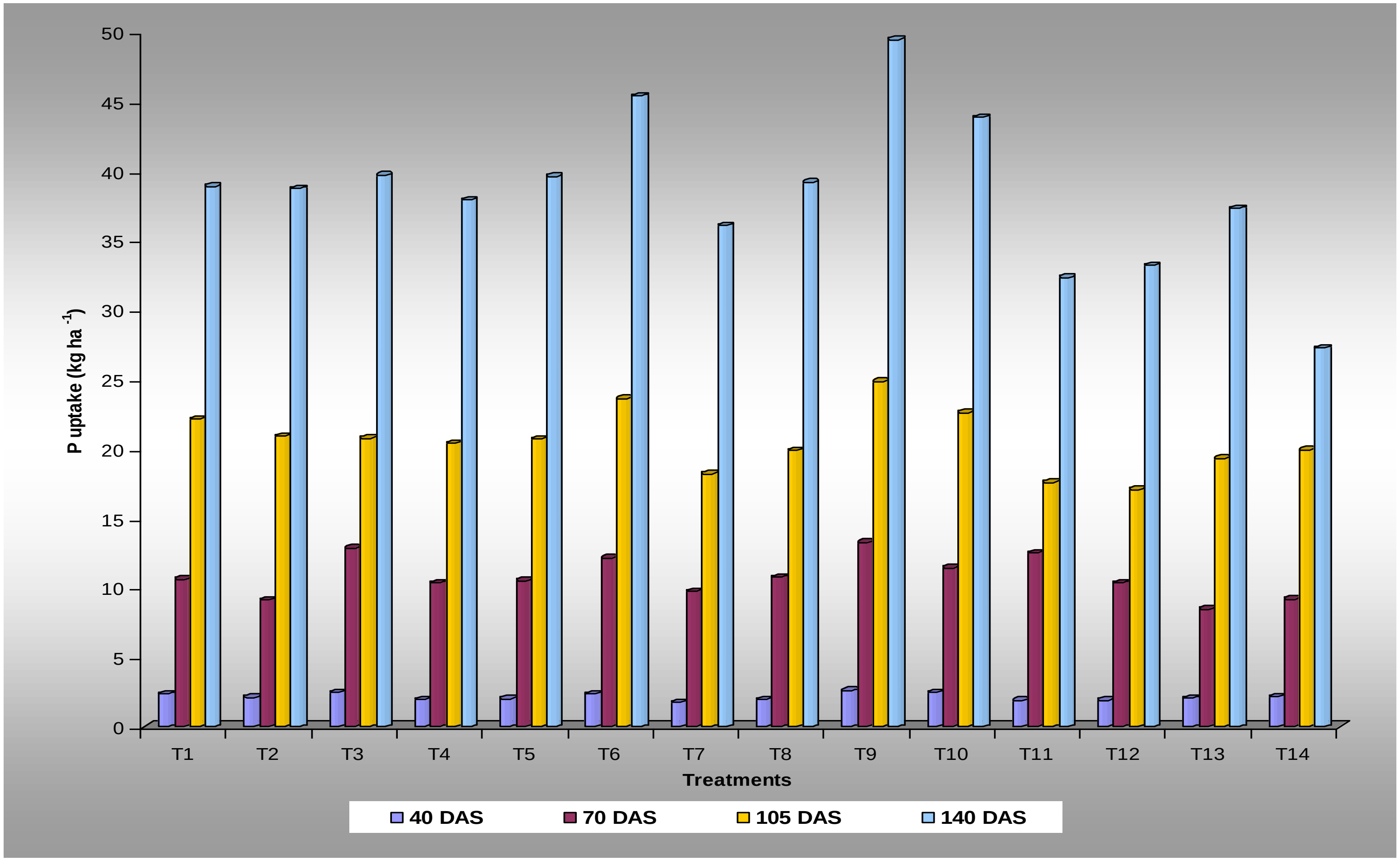


Fig. 7. Effect of drip fertigation at different levels of straight and water soluble fertilizers on K uptake by cotton (kg ha^{-1})

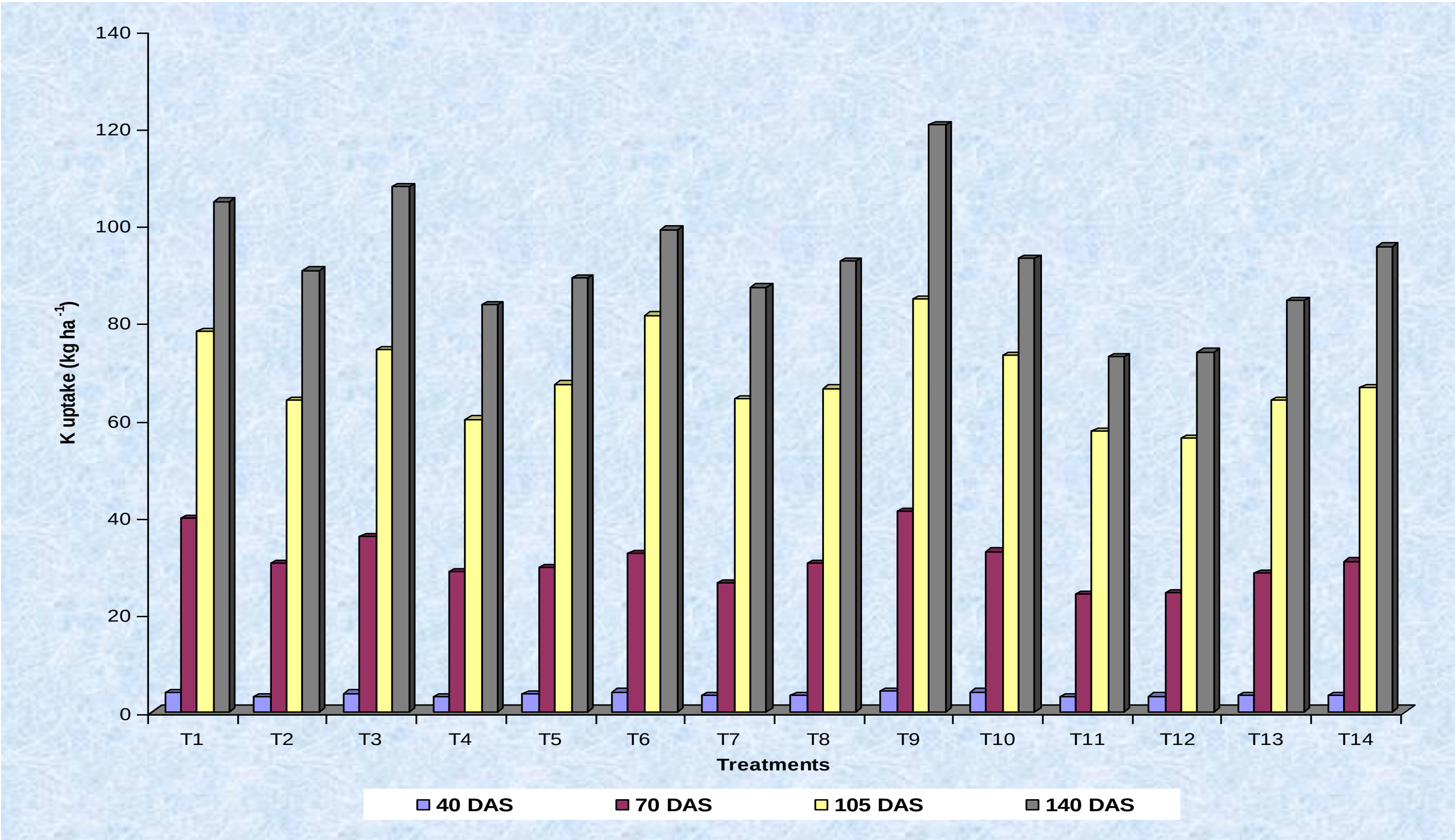


Fig. 9. Effect of drip fertigation at different levels of straight and water soluble fertilizers on B: C ratio of cottton

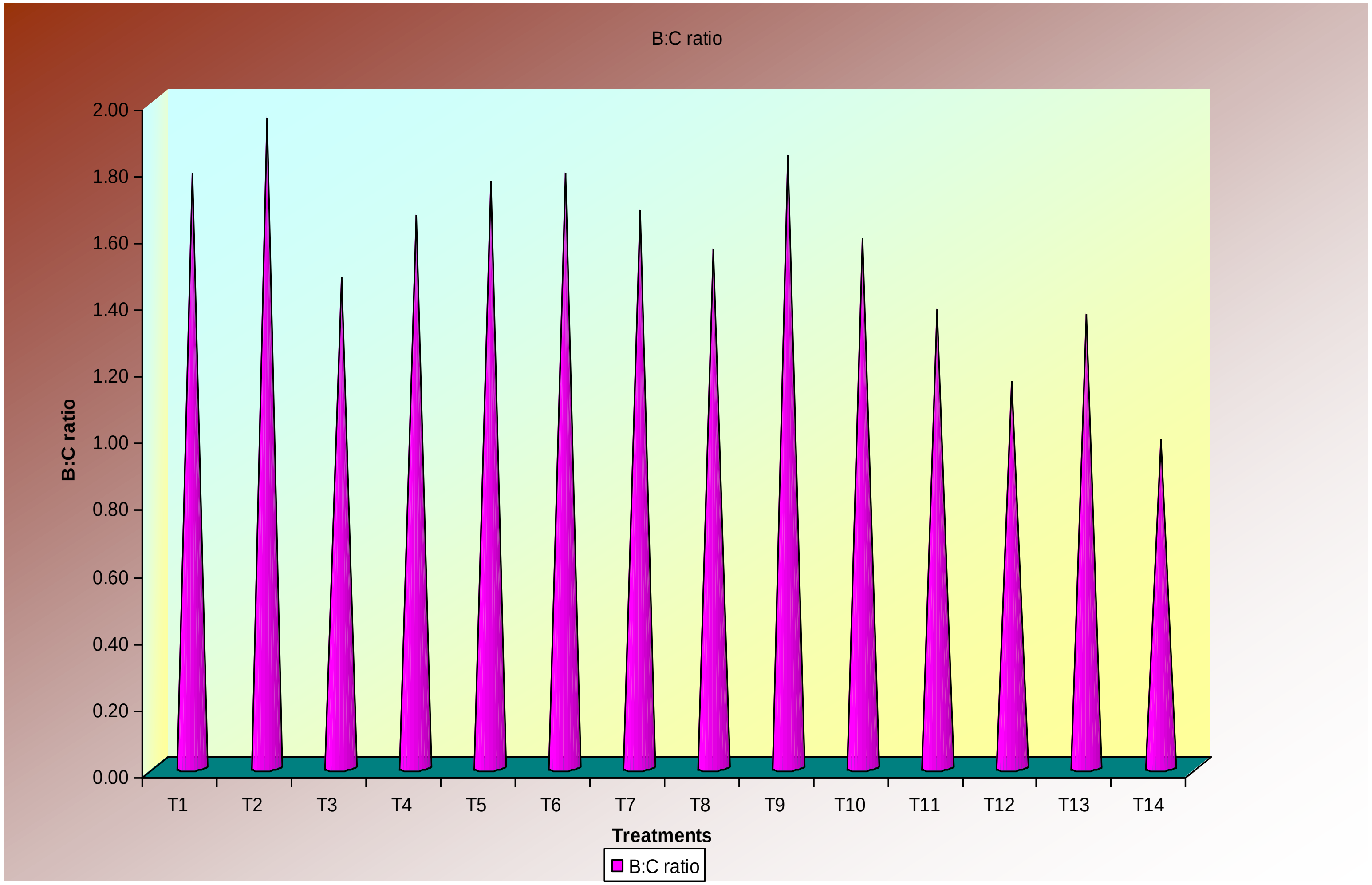
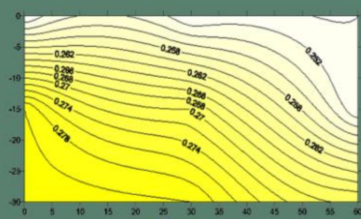
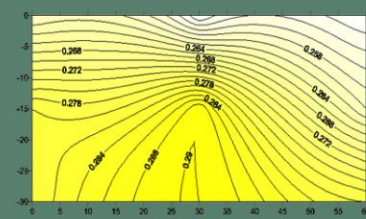


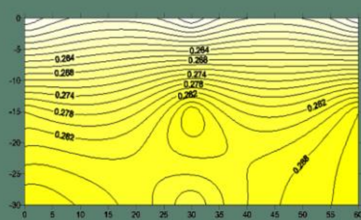
Plate 15. Soil EC distribution under drip fertigation with straight fertilizer



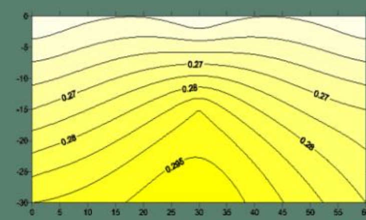
75% RDF



100% RDF

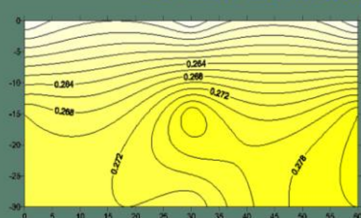


125% RDF

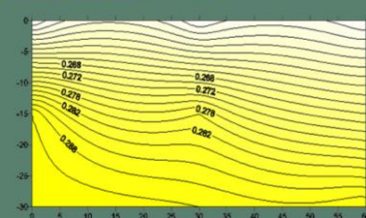


150% RDF

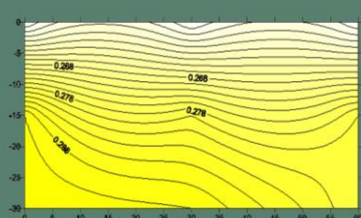
EC under drip fertigation with straight fertilizer NPK



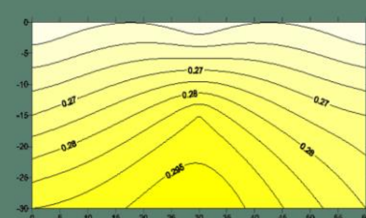
75% RDF



100% RDF

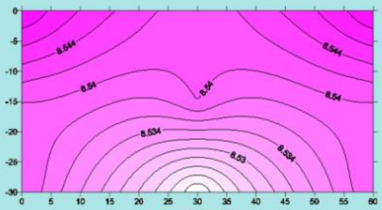


125% RDF

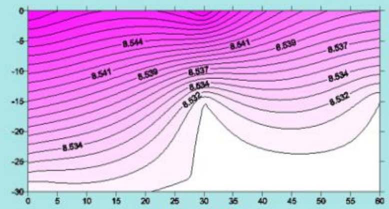


150% RDF

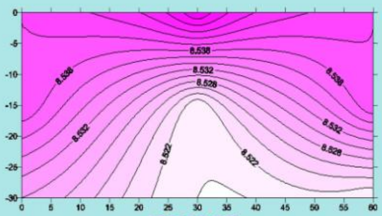
Plate 14. Soil pH distribution under drip fertigaion with water soluble ferttilizer and control



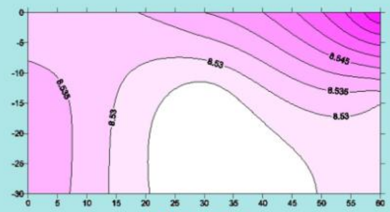
75% RDF



100% RDF

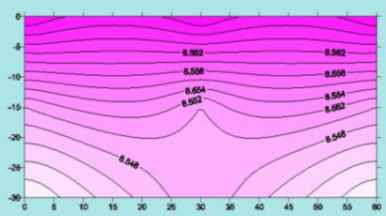


125% RDF



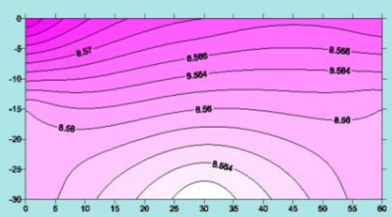
150% RDF

Soil pH under drip irrigation with soil application of straight fertilizer



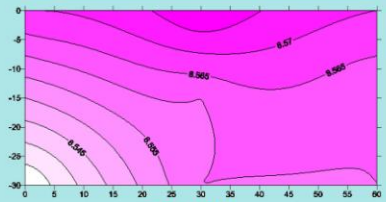
100% RDF

Soil pH under surface irrigation with soil application of straight fertilizer

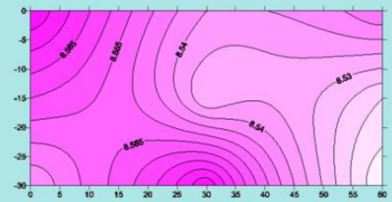


100% RDF (Control)

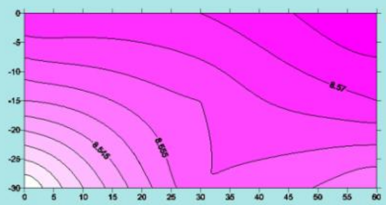
Plate 13. Soil pH distribution under drip fertigation with straight fertilizer



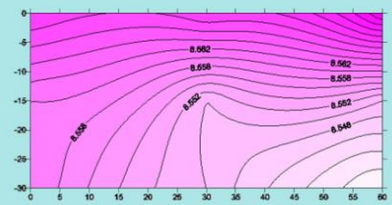
75% RDF



100% RDF

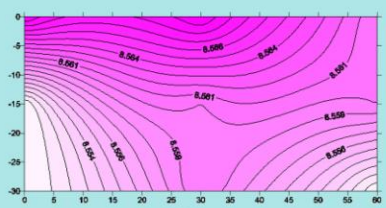


125% RDF

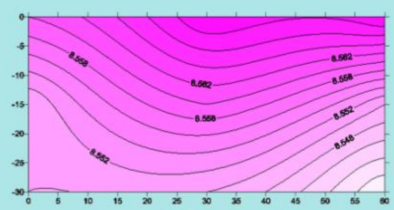


150% RDF

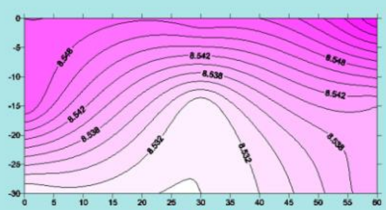
Soil pH under drip fertigation with straight fertilizer NPK



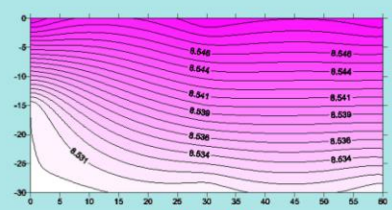
75% RDF



100% RDF



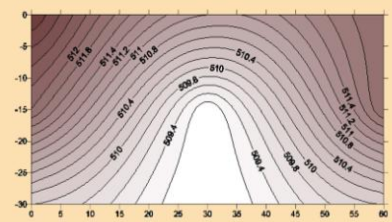
125% RDF



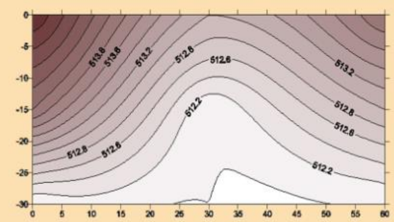
150% RDF

Stage - II

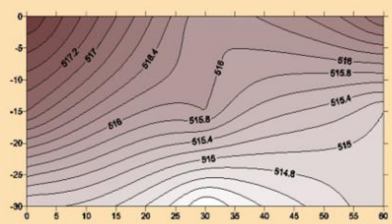
Plate 12. Available potassium distribution under drip fertigation with water soluble fertilizer and control



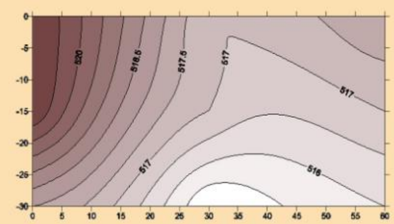
75% RDF



100% RDF

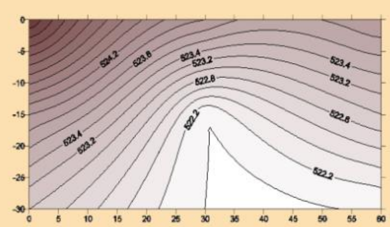


125% RDF



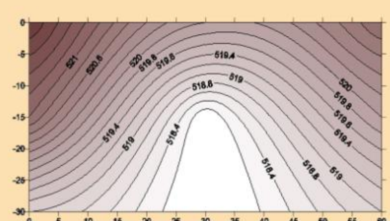
150% RDF

Drip irrigation with soil application of straight fertilizer



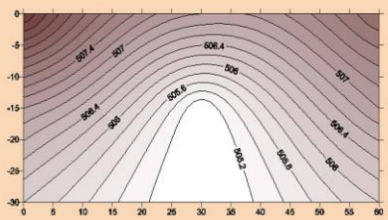
100% RDF

Surface irrigation with soil application of straight fertilizer

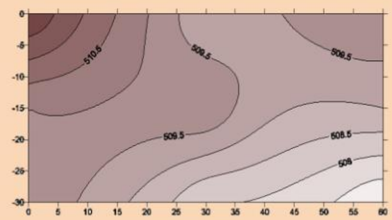


100% RDF (Control)

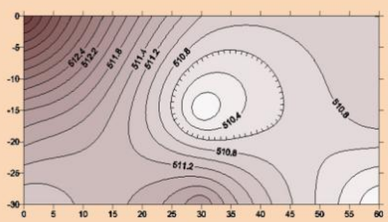
Plate 11. Available potassium distribution under drip fertigation with straight fertilizer



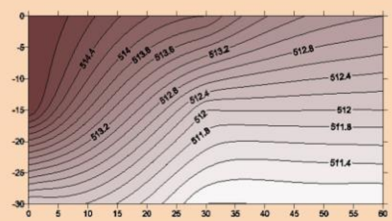
75% RDF



100% RDF

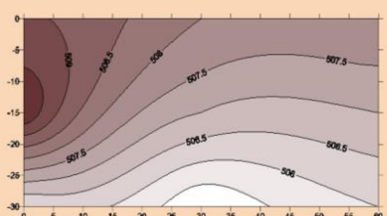


125% RDF

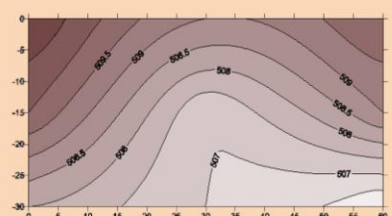


150% RDF

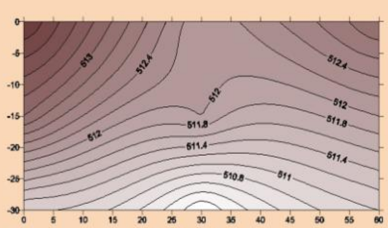
Available potassium under drip fertigation with straight fertilizer NPK



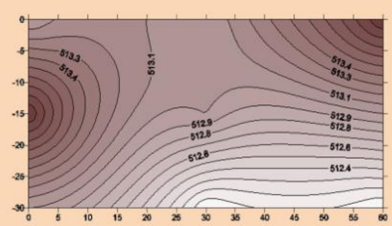
75% RDF



100% RDF



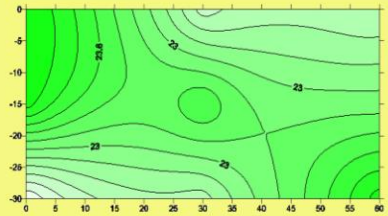
125% RDF



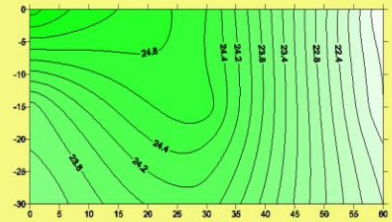
150% RDF

Stage - II

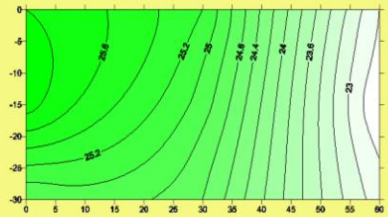
Plate 10. Available phosphours distributiion under drip fertigation with water soluble ferilizer and control



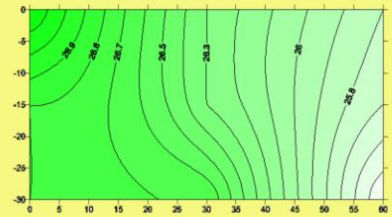
75% RDF



100% RDF

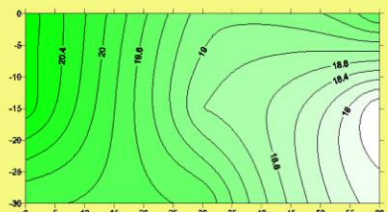


125% RDF



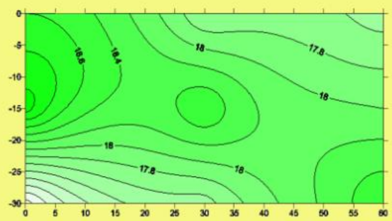
150% RDF

Drip irrigation with soil application of straight fertilizer



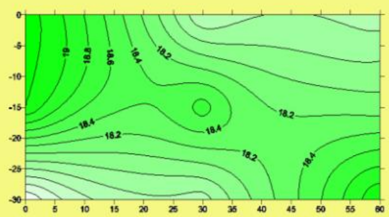
100% RDF

Surface irrigation with soil application of straight fertilizer

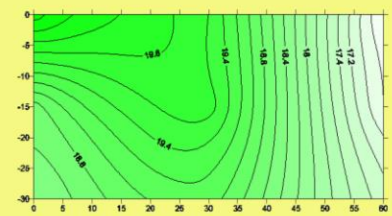


100% RDF (Control)

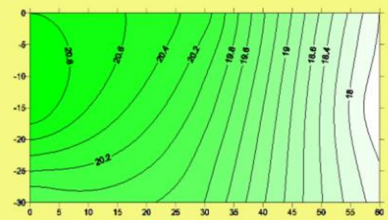
Plate 9. Available phoaphorus distribution under drip fertigation with straight fertilizer



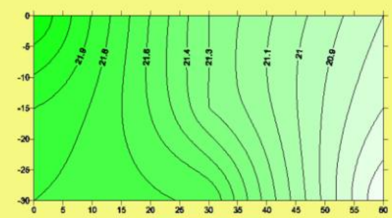
75% RDF



100% RDF

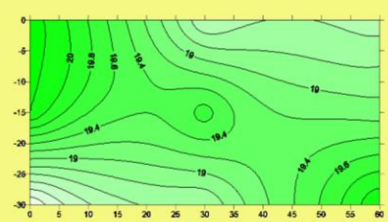


125% RDF

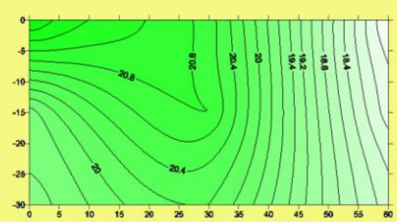


150% RDF

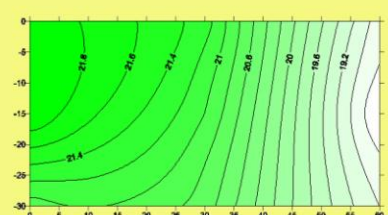
Available phosphorus under drip fertigation with straight fertilizer NPK



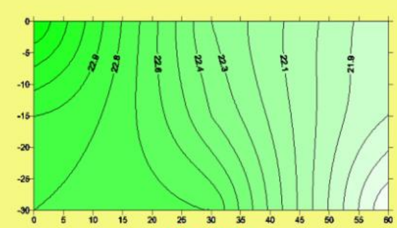
75% RDF



100% RDF

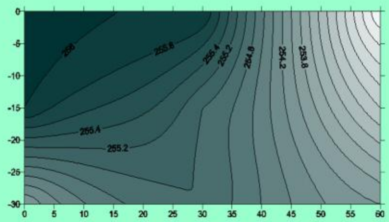


125% RDF

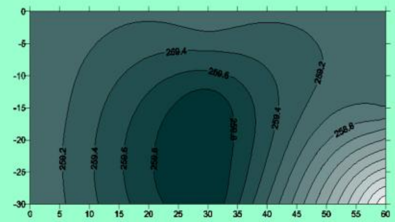


150% RDF

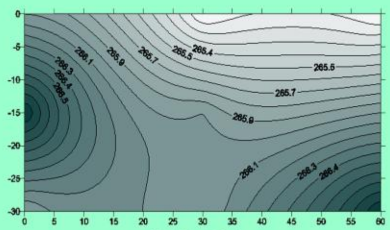
Plate 8. Available nitrogen distribution under drip ferigation with water soluble ferilizer and control



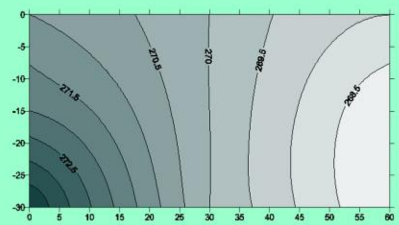
75% RDF



100% RDF

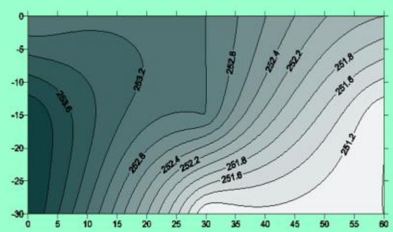


125% RDF



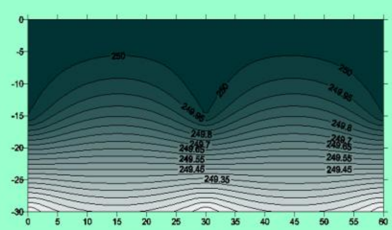
150% RDF

Drip irrigation with soil application of straight fertilizer



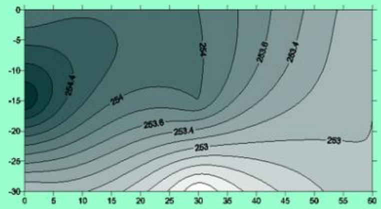
100% RDF

Surface irrigation with soil application of straight fertilizer

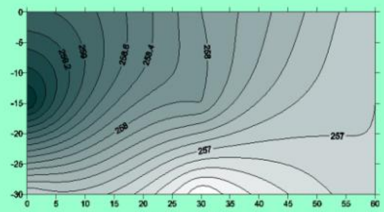


100% RDF (Conrol)

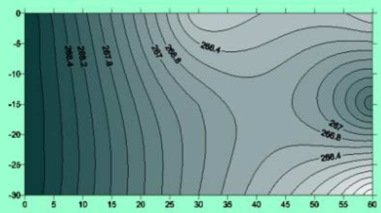
Plate 7. Available nitrogen distribution under drip fertigation with straight fertilizer



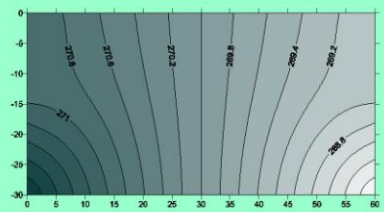
75% RDF



100% RDF

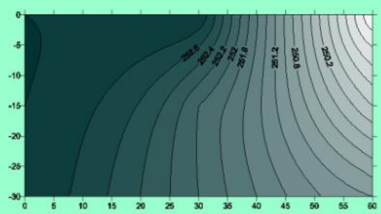


125% RDF

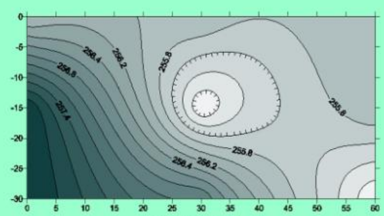


150% RDF

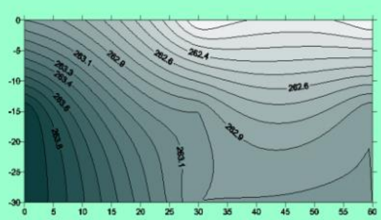
Available nitrogen under drip fertigation with straight fertilizer NPK



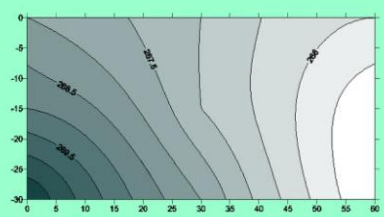
75% RDF



100% RDF

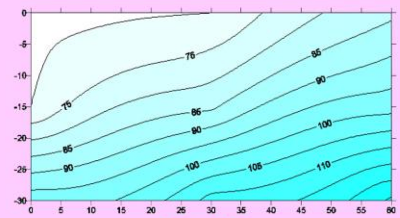


125% RDF

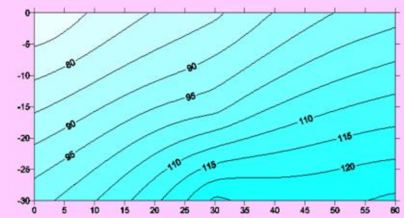


150% RDF

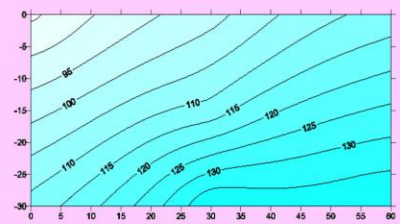
Plate 6. Nitrate nitrogen distribution under drip fertigation with water soluble fertilizer and control



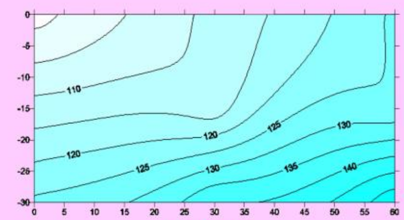
75% RDF



100% RDF

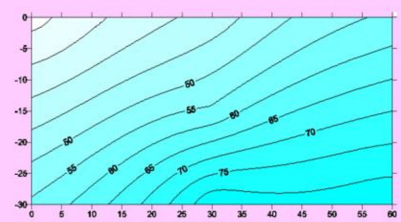


125% RDF



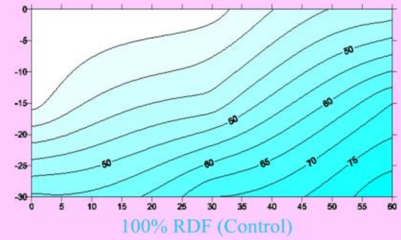
150% RDF

Drip irrigation with soil application of straight fertilizer



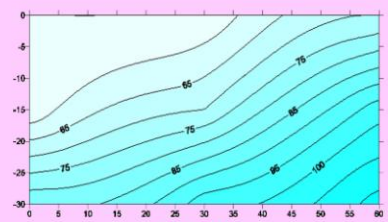
100% RDF

Surface irrigation with soil application of straight fertilizer

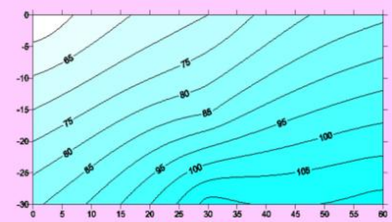


100% RDF (Control)

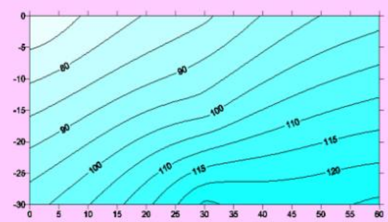
Plate 5. Nitrate nitrogen distribution under drip fertigation with straight fertilizer



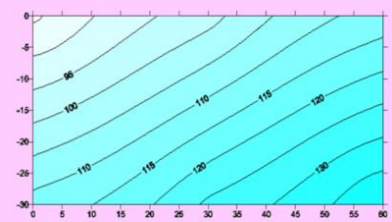
75% RDF



100% RDF

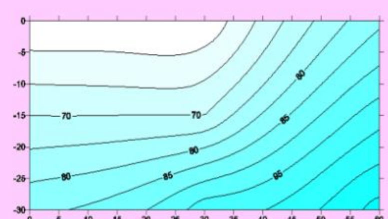


125% RDF

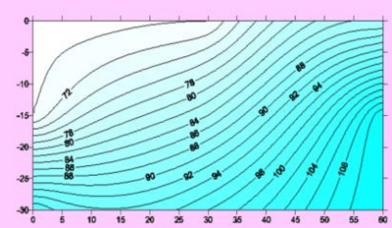


150% RDF

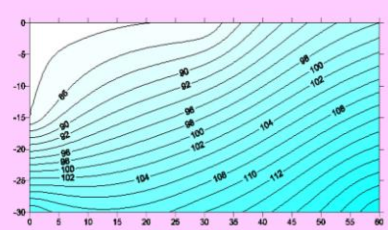
Nitrate nitrogen under drip fertigation with straight fertilizer NPK



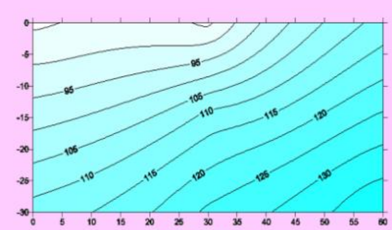
75% RDF



100% RDF

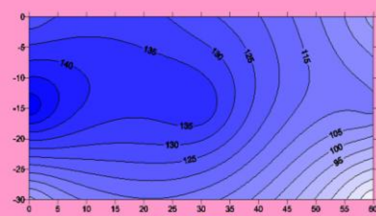


125% RDF

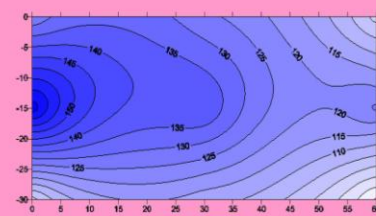


150% RDF

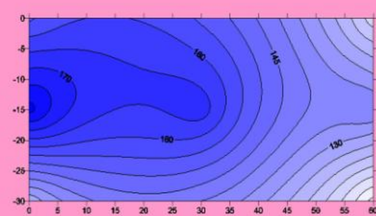
Plate 4. Ammoniacal nitrogrn distribution under drip ferigation with water soluble fertilizer and control



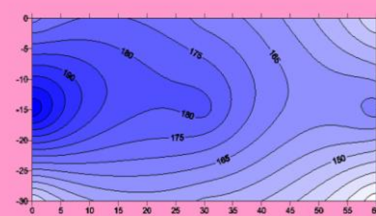
75% RDF



100% RDF

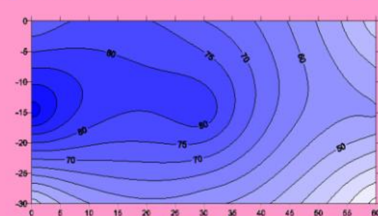


125% RDF



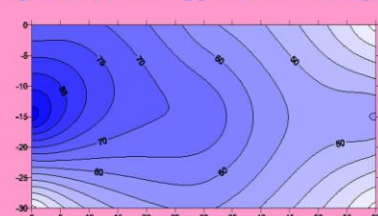
150% RDF

Drip irrigation with soil application of straight fertilizer



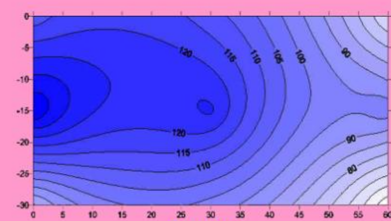
100% RDF

Surface irrigation with soil application of straight fertilizer

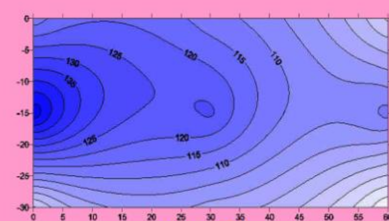


100% RDF (Control)

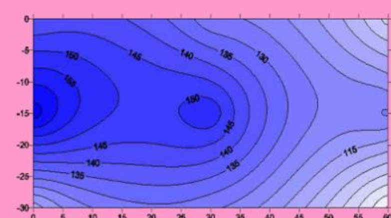
Plate 3. Ammoniacal nitrogen distribution under drip fertigation with straight fertilizer



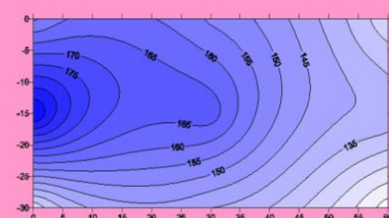
75% RDF



100% RDF

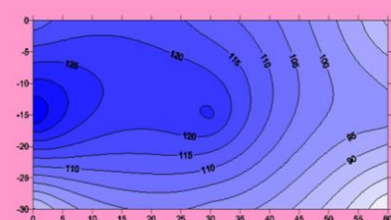


125% RDF

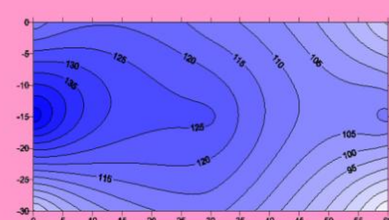


150% RDF

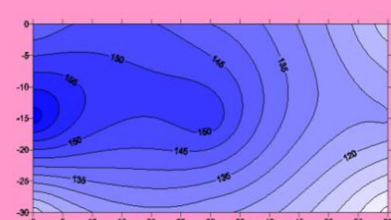
Ammoniacal nirogen under drip fertigation with straight fertilizer NPK



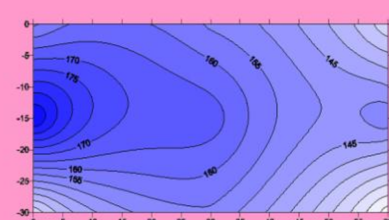
75% RDF



100% RDF



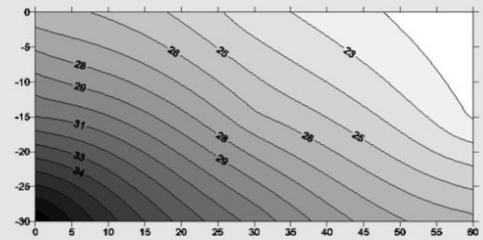
125% RDF



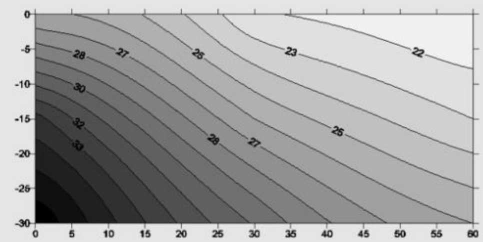
150% RDF

Stage - II

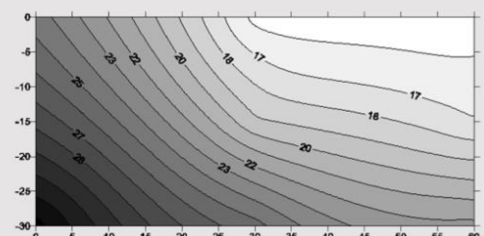
Plate 2. Moisture disrtibution under drip fertigation in cotton at different stages



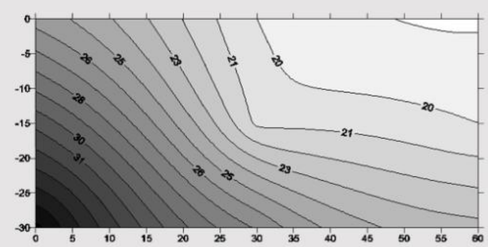
Stage - I



Stage - II



Stage - III



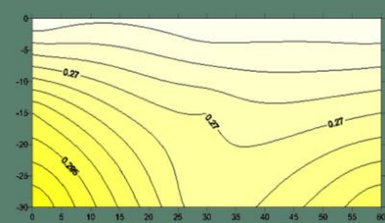
Stage - IV

Plate 1. Overview of Experimental plot

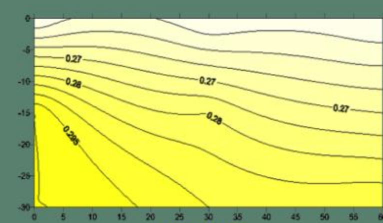
Field view

Treatments

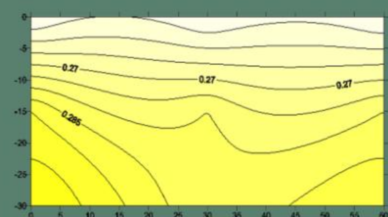
Plate 16. Soil EC distribution under drip fertigation with water soluble fertilizer and control



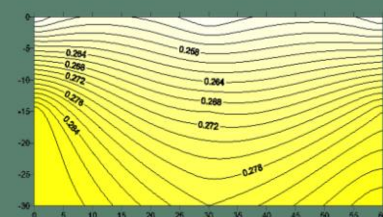
75% RDF



100% RDF

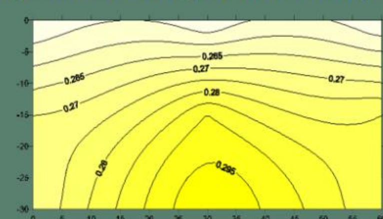


125% RDF



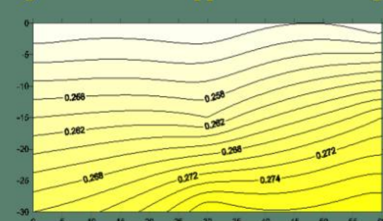
150% RDF

Drip irrigation with soil application of straight fertilizer



100% RDF

Surface irrigation with soil application of straight fertilizer



100% RDF (Control)