



Impact of fertigation frequency on growth and yield parameters of baby corn (*Zea mays*) under drip irrigation

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ABSTRACT

The experiments were conducted at the research farm of Water Technology Centre, Indian Agricultural Research Institute, New Delhi during 2010–2011 for three consecutive seasons (October 2010–February 2011, April– July 2011 and August– November 2011) to study the impact of different fertigation frequencies and dripper discharge at different system operating pressures on growth parameters, corn yield and fodder yield of baby corn (*Zea mays* L.) crop. The study was planned with nine treatments which included dripper discharges at three system operating pressures (0.5 kg/cm², 1.0 kg/cm² and 1.5 kg/cm²) and three fertigation frequencies (biweekly, weekly and fortnightly). Growth parameters, viz. number of leaves per plant, plant girth, plant height, leaf area and Leaf Area Index (LAI) of baby corn during different growth stages were measured and recorded. There was a significant ($P < 0.05$) effect of drip fertigation on number of leaves/plant, plant height, leaf area and leaf area index. Maximum number of leaves/plant (15.67), plant girth (57.29 mm), plant height (176.29 cm) and LAI (5.94) were observed under treatment T₄ (biweekly fertigation with 1.41 l/h dripper discharge at 1.0 kg/cm² system operating pressure) at 80 days after sowing (DAS) during second season whereas lower values of number of leaves/plant (11.33), plant height (150.40 cm), plant girth (41.07 mm) and LAI (4.90) were observed at 120 DAS under treatment T₉ (fortnightly fertigation frequency with 1.71 l/h dripper discharge at system operating pressure of 1.5 kg/cm²) during third season fortnightly fertigation frequency at system operating pressure of 1.5 kg/cm² during third season. Yield components of baby corn were not significantly affected by fertigation at different system operating pressures. However, different yield attributes of baby corn were significantly ($P < 0.05$) affected by fertigation frequencies. Biweekly fertigation frequency at par with weekly fertigation schedule while a trend of significantly lower yields were recorded under fortnightly fertigation frequency. Highest yield of baby corn and fodder was recorded in biweekly fertigation schedule with 1.41 l/h dripper discharge at system operating pressure of 1.0 kg/cm² (22.5 and 633.3 q/ha) followed by weekly fertigation schedule at system operating pressure of 1.0 kg/cm² (22.0, 619.4 q/ha), respectively during second season. The lowest yields of baby corn and fodder (11.2 q/ha and 454.6 q/ha) were recorded in fortnightly fertigation frequency with 1.71 l/h dripper discharge at system operating pressure of 1.5 kg/cm² during third season.

Key words: Baby corn yield, Drip irrigation, Fertigation, Fodder yield, Growth parameters

Drip irrigation ensures high water use efficiency by applying small amount of water more frequently to the crop root zone as and when required. Improved water use efficiency under drip irrigation, by reducing percolation and evaporation losses, provides for environmentally safer water and fertilizer application through drip irrigation water (Mmolawa and Or 2000). Several research reports have indicated that drip irrigation enhances the crop growth and development of maize (Lamm *et al.* 2001, O Briesn *et al.* 2001). Zhu *et al.* (2007) suggested that corn is one of the suitable crops for drip irrigation system with a line source as it is grown in rows on ridges. Application of fertilizer with irrigation water in drip irrigation is known as fertigation. Fertigation can be done through any of the injection devices

such as venturi, fertilizer tank or fertigation pump. Fertigation aims at providing required amount of nutrients to the crop at the time of their need that result in better and high quality produce. Fertigation enables the application of soluble fertilizers and other chemicals along with irrigation water in the vicinity of the root zone (Patel and Rajput 2000, Narda and Chawla 2002). The application of water and nutrients in small doses at frequent intervals in the crop root zone ensures their availability to the plants optimally. Muthukumar *et al.* (2005) observed that the application of N in split doses influence the cob yield and other plant growth parameters of baby corn. Rajput and Patel (2006) found that yield of onion was not significantly affected in daily, alternate day and weekly fertigation though there was a significant reduction of yields in case of monthly fertigation. The highest yield was recorded in daily fertigation (28.74 tonnes/ha) followed by alternate day fertigation (28.4 tonnes/ha), however lowest onion yield

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was reported in monthly fertigation (21.4 tonnes/ha). Badr *et al.* (2007) found the high total tomato yields of 67.75, 65.13 and 63.29 tonnes/ha with the fertigation frequencies of 1, 3 and 7 days respectively. Yield with the fertigation biweekly frequency were significantly lower (54.32 tonnes/ha) than these values. Sampathkumar *et al.* (2010) reported higher corn grain yield at once in 6 days fertigation which was at par with fertigation once in the 9, 12 and 15 days.

Maize (*Zea mays* L.) is an important food crop among all cereals in the world. Maize grown as vegetable and consumed in the form of dehusked corn ear harvested within 2-3 days of silk emergence is known as baby corn. Presently, baby corn is grown as a high value vegetable, comparatively a new concept for Indian market, has huge potential for commercial production. Baby corn production is gaining popularity among the farmers as it gives more returns within a short span of time as compared to the other crops. There is a huge demand for high quality baby corn in the national and international market (Thavaprakash *et al.* 2005). Cultivation of baby corn generates employment for the rural poor as 3-4 crops can be raised in year and giving good profit per unit area per unit time, besides high fodder yields. The productivity of baby corn largely depends on the essential nutrients application and their management.

A considerable amount of work has been done on drip irrigation however, a very few studies have been conducted on baby corn with drip irrigation in India. The information on baby corn crop under drip fertigation along with the

fertigation schedule would be very useful to the farmers. Therefore, the present field investigation was conducted to study the impact of different fertigation frequencies on crop growth parameters and baby corn and fodder yields.

MATERIALS AND METHODS

The experiments were conducted at the research farm of Water Technology Centre, Indian Agricultural Research Institute, New Delhi, India (Latitude 28°37'23.303" N, Longitude 77°82'45.3" E and AMSL 228.61 m) for three consecutive seasons, i.e. October 2010–February 2011, April–July 2011 and August–November 2011.

Soil samples were collected with the help of pipe auger from soil surface up to a depth of 60.0 cm at 15.0 cm interval. Hydrometer method was followed to determine the soil texture, i.e. sand, silt and clay percentage of soil. The soil of the experimental field was classified as loam comprising 37.57% sand, 40.67% silt and 21.59% clay. The bulk density of soil was 1.53 g/cm³, field capacity 20% and saturated hydraulic conductivity 1.17 cm/h, respectively. The pH and EC were determined with the help of digital pH and EC meters. Average values of pH and EC of the soil of experimental area was 8.01 and 0.49 dS/m.

Field experiments were designed to study the effect of dripper discharges at different system operating pressures and fertigation frequencies on growth parameters and yield attributes of baby corn. The experiment was planned with factorial 3² Randomized Complete Block Design (RCBD)

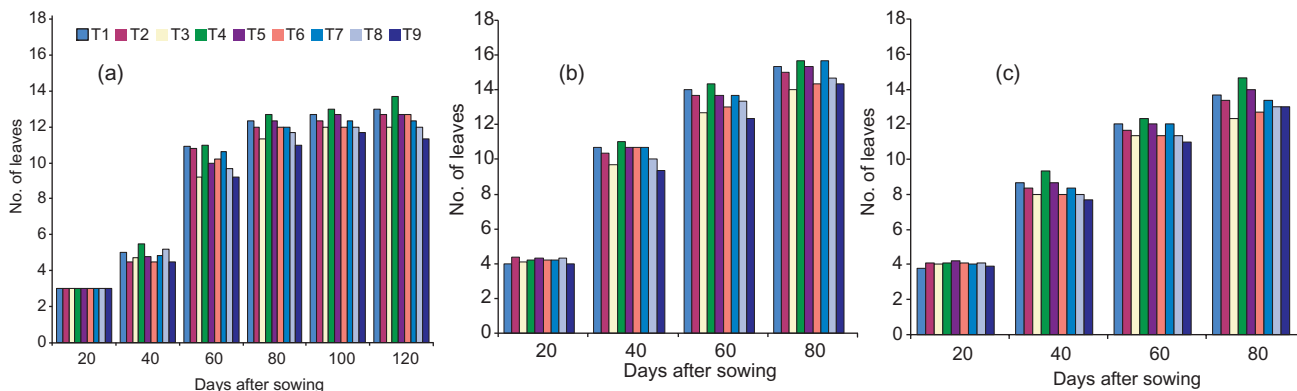


Fig 1 Number of leaves/plant in baby corn during different crop growth stages under different seasons (a) season 1 (b) season 2 and (c) season 3

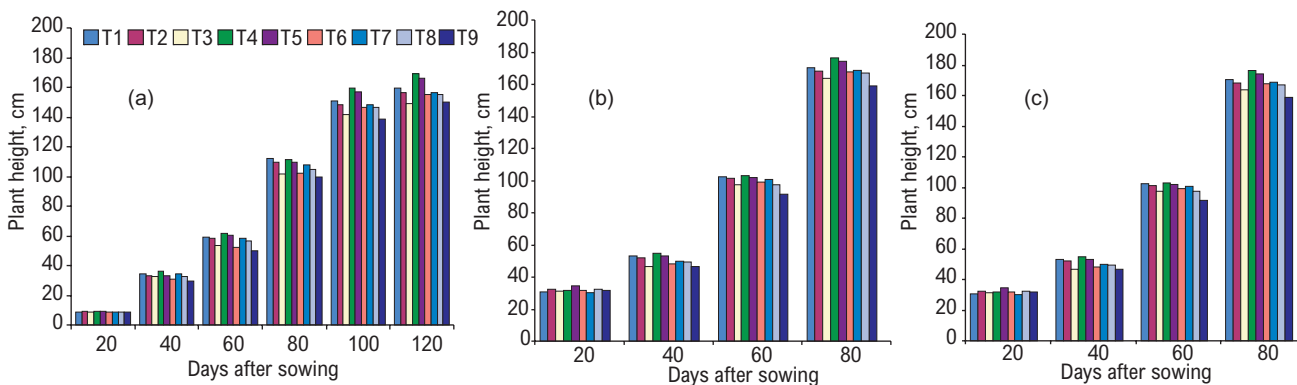


Fig 2 Plant height of baby corn during different crop growth stages under different seasons (a) season 1, (b) season 2 and (c) season 3

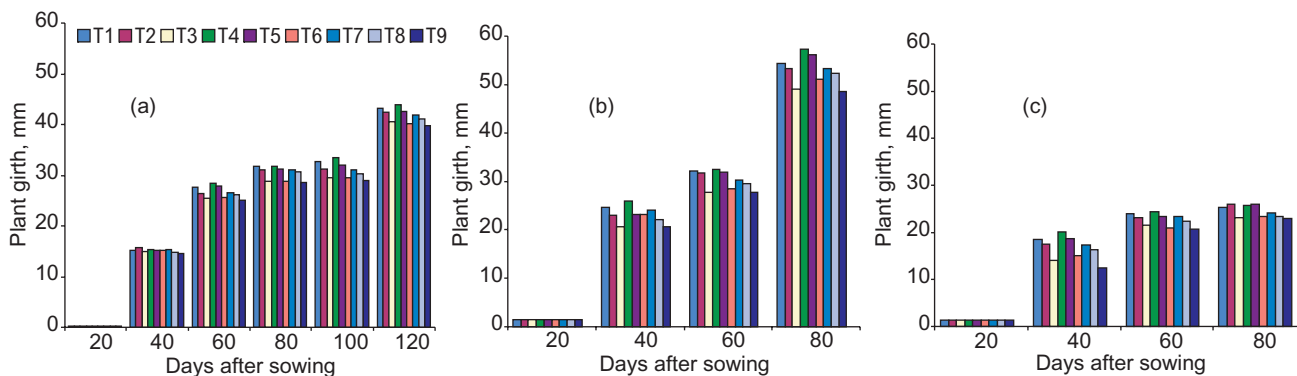


Fig 3 Plant girth of baby corn during different crop growth stages under different seasons (a) season 1, (b) season 2 and (c) season 3

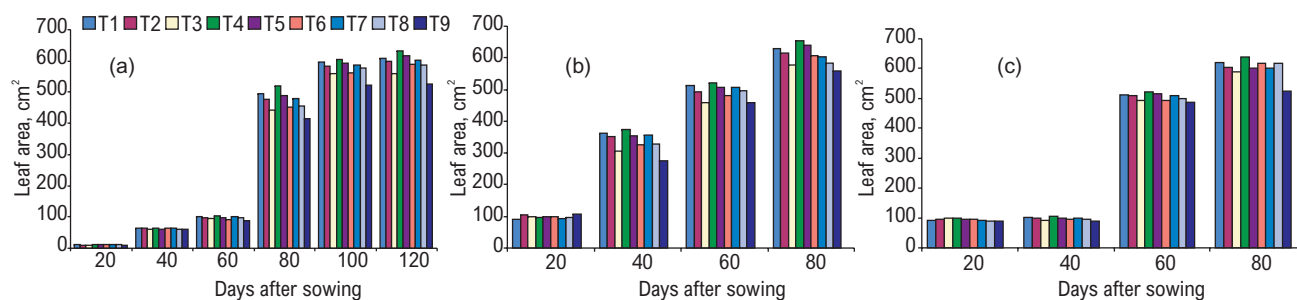


Fig 4 Leaf area of baby corn plant during different crop growth stages under different seasons (a) season 1, (b) season 2 and (c) season 3

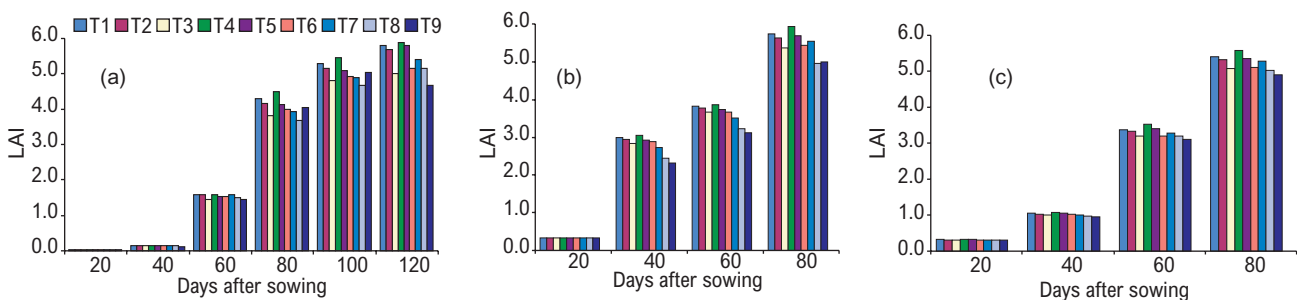


Fig 5 Leaf area index in baby corn plant during different crop growth stages under different in (a) season 1, (b) season 2 and (c) season 3

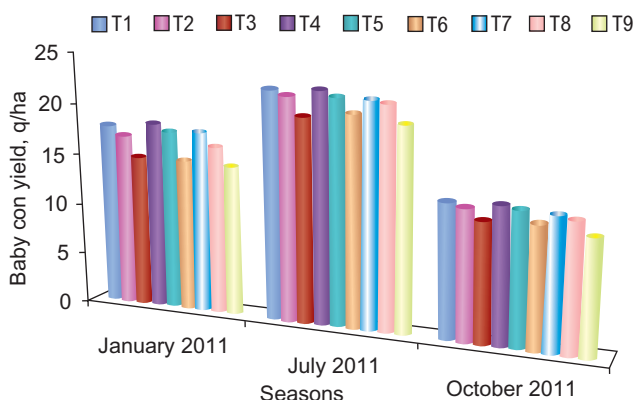


Fig 6 Baby corn yield under different treatments

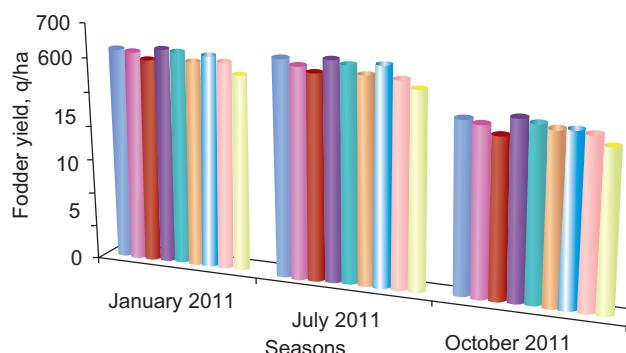


Fig 7 Fodder yield under different treatments

with three replications. Three equal size (7 m × 50 m) plots were selected and 1 m isolation distance between two was provided. Each plot of 7 m × 50 m size was further divided into 9 lines of size of 0.6 m × 50 m. Each line represented

a single treatment. Drip irrigation system was installed in the month of October 2010 with the head work, which included hydro-cyclone filter (flow rate 27 m³/h, 75 mm size), sand media

filter (flow rate 25 m³/h, 50 mm size, silica sand 0.7 mm), back flush mechanism and a control panel (Model Pro-C, Hunter). The venturi injector was attached to the drip system for fertigation. Main line (PVC pipes of 60 mm diameter) was connected to sub-mains (PVC pipes of 40 mm diameter) with a gate valve connected for each plot having 9 rows. Each line provided with solenoid valve, ball valve connector and pressure release valve. Flush manifolds were connected at the lower end of each block. Each row of baby corn was irrigated through thin-walled one inline drip tape (12 mil (304.8 micron) thickness with 30 cm dripper spacing and dripper discharge 1.4 l/h) systems. A gate valve was connected to each drip line to enable adjustment of the operation time as per requirement of treatments.

Baby corn, HM 4 variety was selected for the present study. The seeds were sown during three consecutive seasons at a spacing of 60 cm × 20 cm on 10 October 2010, 21 April 2011 and 30 August 2011. The baby corn harvesting was done during 27 December 2010 to 4 February 2011, 17 June 2011 to 27 July 2011 and 24 October 2011 to 18 November 2011, respectively.

Nine treatments were selected including three dripper discharge at three system operating pressures (0.5, 1.0 and 1.5 kg/cm²) and three fertigation frequencies (biweekly, weekly and fortnightly). The specific treatments selected for the study were as follows: T₁, Fertigation biweekly and dripper discharge 0.94 l/h at 0.5 kg/cm² system operating pressure; T₂, fertigation weekly and dripper discharge 0.94 l/h at 0.5 kg/cm² system operating pressure; T₃, fertigation fortnightly and dripper discharge 0.94 l/h at 0.5 kg/cm² system operating pressure; T₄, fertigation biweekly and dripper discharge 1.41 l/h at 1.0 kg/cm² system operating pressure; T₅, fertigation weekly and dripper discharge 1.41 l/h at 1.0 kg/cm² system operating pressure; T₆, fertigation fortnightly and dripper discharge 1.41 l/h at 1.0 kg/cm² system operating pressure; T₇, fertigation biweekly and dripper discharge 1.71 l/h at 1.5 kg/cm² system operating pressure; T₈, fertigation weekly and dripper discharge 1.71 l/h at 1.5 kg/cm² system operating pressure; T₉, Fertigation fortnightly and dripper discharge 1.71 l/h at 1.5 kg/cm² system operating pressure.

Soil nutrients status before crop was determined and found 123.49, 31.9 and 119.3 kg/ha of nitrogen, phosphorus and potassium, respectively. To meet the crop nutritional requirement, 8 tonnes/ha of Farmyard, 150 kg N/ha, 60 kg P/ha and 60 kg K/ha was applied as suggested by Dass *et al.* (2009). N, K and P were applied in form of urea, muriate of potash and phosphoric acid, respectively. In sandy loam soils, where potassium may be lost due to leaching, K was applied in split doses. Recommended quantity of nutrients (N, P and K) was applied through fertigation in biweekly, weekly and fortnightly. Fertigation started 15 days after sowing of crop and stopped 15 days before the harvest of crop. During fertigation, the solutions of different fertilizers were applied separately and not mixed, to avoid precipitation due to non-compatibility of two chemicals. Drip irrigation system was operated for the desired duration at three

operating pressures of a 0.5, 1.0 and 1.5 kg/cm² and the fertilizer solution placed in the bucket was applied through a venturi injector.

Reference crop evapotranspiration (ET_o) was computed on a daily basis by using Penman–Monteith's semi-empirical formula (Smith 1991). The necessary weather data were collected from weather station located at IARI. The actual crop evapotranspiration 'ET_c' was estimated by multiplying reference evapotranspiration with crop coefficient 'K_c' (ET_c = ET_o × K_c) for different months based on crop growth stages. The crop coefficient adopted at initial, crop developmental, mid season and maturity stages was 0.5, 1.2, 1.05 and 0.9, respectively during all three crop seasons (October 2010-February 2011, April 2011-July 2011 and August-November 2011) (Allen *et al.*, 1998).

The required amount of water was applied on alternate days through drip irrigation system at pre-determined system operating pressures. The duration of operation of drip system was worked out for different treatments based on the dripper discharge at different system operating pressures. The duration of irrigation in each treatment was controlled with the help of control valves.

The water requirement of baby corn ranged from 0.1 to 3.5, 1.2 to 8.7 and 0.6 to 5.8 mm/day from early stage to peak demand period during October 2010-February 2011, April 2011-July 2011 and August-November 2011, respectively.

Total rainfall during the crop seasons of October 2010-February 2011, April 2011-July 2011 and August-November 2011 were 33.3, 138.4 and 163.6 mm, respectively. Irrigation efficiency of drip irrigation system was assumed as 95% (Rajput and Patel 2001).

Six plants were selected randomly from each treatment and tagged. All biometric observations were recorded from the tagged plants. The growth attributing characters of the crop, viz. number of leaves/plant; plant height; stem girth; and leaf area index were measured under different treatments in all the seasons during different growth stages. The plant growth parameters were measured starting from 20 days after sowing with 20 days interval till the end of the crop season. Plant height was recorded from base of the plant to tip of the terminal leaf on main stem with an ordinary scale and expressed in cm. The stem girth was measured with the help of Digital Vernier Caliper (Mitutoyo Absolute Digimatic). The stem girth of plant was measured with the help of Digital Vernier Caliper (Mitutoyo Absolute Digimatic). The leaf area was measured by 203 laser area meter. Then leaf area index was calculated using the following equation:

$$LAI = \frac{LA}{SA}$$

where, LAI, Leaf area index; LA, leaf area, cm²; SA, area covered by the plant, cm².

Picking of fresh baby was done manually during 27 December 2010 to 4 February 2011, 17 June 2011 to 27

July 2011 and 24 October 2011 to 8 November 2011, respectively. The fresh baby corn weight (unhusked baby corn) yield and fresh weight of fodder was taken under each treatment at the harvest. Digital weighing balance was used to weigh different components of produce. Statistical analysis was done by using standard analysis of variance (ANOVA). Probability level 0.05 was considered for determination of significance. Analysis of variance was conducted for baby corn and fodder yields by SPSS (Statistical Product and Service Solution Version 16.0).

RESULTS AND DISCUSSION

The effect of fertigation schedule and dripper discharges at different system operating pressures on biometric parameters of baby corn such as number of leaves/plant, plant height, stem girth of plant, Leaf Area Index (LAI) and baby corn yield and fodder yield were analysed statistically.

Effect of fertigation on biometric parameters of baby corn

The experimental results of these biometric observations under all treatments during different seasons are presented in Fig 1-5. The variation among fertigation frequencies were found to be statistically significant at 5% level of significance. The replications for all the treatments and dripper discharges at different system operating pressures were found to be non-significant.

Fertigation frequency schedules had a significant ($P < 0.05$) effect on number of leaves/plant however; number of leaves/plant was not significantly affected by dripper discharge at different system operating pressures. The interaction of fertigation frequency and dripper discharge at different system operating pressures did not affect number of leaves/plant significantly. Fig 9 shows that the maximum number of leaves/plant (15.67) was under treatment T_4 (biweekly fertigation frequency and dripper discharge 1.41 l/h at 1.0 kg/cm² operating pressure) at 80 DAS while minimum number of leaves/plant (11.33) was under treatment T_9 (fortnightly fertigation frequency and dripper discharge 1.71 l/h at 1.5 kg/cm² operating pressure) at 120 DAS in second season and first season, respectively. Higher values of number of leaves/plant was recorded in all the treatments during second season, however, slightly lower values were observed during first season during different crop growth stages.

The plant height responded significantly with different fertigation schedules, however, plant height at biweekly fertigation frequency was statistically at par with weekly fertigation frequency but was statistically ($P < 0.05$) different in case of fortnightly fertigation frequency. Fig 2 (a), (b) and (c) shows the similar trends in all three seasons. Biweekly fertigation frequency schedule with dripper discharge of 1.41 l/h at 1.0 kg/cm² system operating pressure (T_4) produced significantly ($P < 0.05$) higher plant height (176.29 cm) at 80 DAS, during the second season. Statistically significantly ($P < 0.05$) lower plant height (143.20 cm) was registered under fortnightly fertigation frequency with 1.71 l/h dripper discharge at 1.5 kg/cm²

system operating pressure treatment at 120 DAS, during the third season. Average values of plant height in different crops growth stages ranged from 7.83 to 169.40, 30.62 to 176.29 and 29.63 to 165.03 were recorded during October-February, April- July and August- November, respectively. Similar trends for plant height were recorded all in the three seasons. Similar trends for plant height were recorded during all three seasons. The trends were in agreement with the results reported by Sampathkumar *et al.* (2010).

Taller plants under fertigation scheduled biweekly with 100 % recommended dose of fertilizer were observed which was mainly because of good response of baby corn crop to the frequent application of nutrients through fertigation.

Plant girth was observed at different growth stages under different treatments. Maximum plant girth (57.29 mm) was observed under treatment T_4 at 80 DAS, in second season while minimum (23.37 mm) under T_9 treatment irrigation at 70 DAS, in third season. However, the plant girth was almost same under all the treatments up to 20 days during first, second and third seasons, respectively (Fig 3). Fig 3 (a, b and c) shows that nutrients were not properly utilized by the crop during initial stage in winter season while the effect of nutrients use by the crop under fertigation was visible in the summer season just after 20 DAS.

Fig 4 present the LAI during different crop growth stages for all the three seasons. The highest value of LAI (5.94) was observed under treatment T_4 at 80 DAS during the second season however, lowest value of LAI (4.68) was recorded under treatment T_9 at 120 DAS during first season.

Highest values of number of leaves/plant, plant height, stem girth of plant and LAI during the whole crop growth period in different seasons were recorded under biweekly fertigation schedule. Small quantities of nutrients were applied in frequent doses (biweekly fertigation) through drip fertigation as per requirement of corn plants and were effectively utilized by the plants, however, lower values of all the growth parameters of baby corn plants were recorded under fortnightly fertigation frequency treatment during all the seasons. This shows that under treatment of fortnightly fertigation schedule, the plants were not able to utilize the applied nutrients properly as higher quantity of fertilizers applied in one dose, i.e. lower frequency resulting in loss of nutrients either by leaching or lateral movement away from the crop root zone. These findings are in line with the findings of Sampathkumar *et al.* (2010).

Effect of fertigation on growth and yield of baby corn

The highest yields of baby corn and fodder were recorded during 2nd season (April-July) in all the ten treatments as compared to 1st and 3rd season. The lowest value of baby corn and fodder yields were recorded during 3rd season. Baby corn and fodder yields were significantly affected by fertigation through drip fertigation. Yield components of baby corn were significantly different during different seasons. The variation in yields component during

different seasons could be attributed to the variation in weather parameters. Weather conditions were best suited to the baby corn crop during 2nd season, i.e. April to July. Baby corn and fodder yield obtained under different treatment are presented in Fig 6-7. Irrigation treatments at different system operating pressures did not show any significant impact on yield parameters. Fertigation frequency schedule was significantly different at 0.05% level of significance. Yield attributes of baby corn were not significantly affected in biweekly and weekly fertigation schedules, however, it was significantly different statistically at 0.05% level with fortnightly fertigation frequency schedule. Yield parameters with interaction of season with fertigation frequency and irrigation at different system operating pressures were not statistically significant. During 1st season, 19.7% less baby corn yield was observed, whereas, 40.3% less baby corn yield was recorded during 3rd season as compared to 2nd season. During 2nd season (April– July), the average highest yields of baby corn and fodder were recorded in treatment T₄, i.e. biweekly fertigation schedule with 1.41 l/h dripper discharge at system operating pressure of 1.0 kg/cm² (22.5 q/ha and 633.3 q/ha, respectively) followed by treatment T₅ i.e. weekly fertigation schedule with 1.41 l/h dripper discharge at system operating pressure of 1.0 kg/cm² (22.0 q/ha and 619.4 q/ha, respectively) during second season while average lowest baby corn and fodder yield were recorded in third season under treatment T₉, i.e. fortnightly fertigation frequency with 1.71 l/h dripper discharge at system operating pressure of 1.5 kg/cm² (11.2 q/ha and 454.6 q/ha, respectively) during third season. The CD values at 5% significant level for yield attributes of baby corn for all three seasons are presented in Table 1. The fertigation frequency schedules had statistical significant effect on yield attributes of baby corn. Fertilizers applied through fertigation in biweekly and weekly fertigation schedule resulted in higher yield as compared to fortnightly fertigation schedule with same quantity of fertilizers applied. Reasons for lower yield in fortnightly fertigation schedule may be attributed to non-availability of nutrients to the plants at the time of need that leading to nutrient stress, result in poor plant growth and lower crop yield. In case of frequent nutrient application, the plants were not subjected to nutrient stress and hence good plant growth and higher crop yields.

Table 1 CD values at 5% significant level for different yield attributes of baby corn during different seasons

Yield Attributes	Season 1		Season 2		Season 3	
	(P<0.01)	(P<0.05)	(P<0.01)	(P<0.05)	(P<0.01)	(P<0.05)
Baby corn yield	12.69	5.14	9.33	3.77	7.68	3.11
Fodder yield	11.68	4.85	6.70	2.71	6.91	2.79

Crop season 1: October, 2010–February, 2011; Season 2: April 2011- July 2011 and Season 3: August, 2011- November, 2011.

CONCLUSION

Drip fertigation is an advance and innovative technology for applying the optimum quantity of water and fertilizer to the crop in small and frequent doses. Frequent fertigation results in good crop growth and high yield of produce. Higher values of all the growth parameters of the baby corn plant, viz. number of leaves/plant, plant height, plant girth, leaf area and leaf area index were recorded in biweekly fertigation with 1.41 l/h dripper discharge at 1.0 kg/cm² operating pressure during second season however, lower values of these parameters were recorded in fortnightly fertigation with 1.71 l/h dripper discharge at 1.5 kg/cm² operating pressure treatment. Yield attributes of baby corn was at par in biweekly and weekly fertigation frequency, although, a decreasing trend of yield in fortnightly fertigation frequency schedule was observed. The fertigation frequencies significantly influence plant growth parameters and yield of baby corn irrespective of the quantity of fertilizer used.

REFERENCES

- Allen R G, Percira L S, Raes D and Smith M. 1998. Crop evapotranspiration. Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper No. 56, FAO, Rome, Italy, 300 p.
- Badr M A and Abou El-Yazied A A. 2007. Effect of fertigation frequency from subsurface drip irrigation on tomato yield growth on sandy soil. *Australian Journal of Basic and Applied Sciences* 1 (3): 279–85.
- Binder D L, Sander D H and Walters D T 2000. Corn response to time of nitrogen application as affected by level of nitrogen deficiency. *Agronomy Journal* 92: 1 228–36.
- Cox, W J, Kalonge S, Cherney D J R and Reid W S. 1993. Growth, yield, and quality of forage maize under different nitrogen management practices. *Agronomy Journal* 85: 341–7.
- H D. 2001. Nitrogen fertilization for subsurface drip irrigated corn. *Transactions ASAE* 44: 533–42.
- Dass Sain, Yadav V K, Kwatra Asha, Sekhar J C, Yadav Yogendra. 2009. Baby corn production technology and value addition. Directorate of Maize Research, Pusa Campus, New Delhi, p 44.
- Lamm F R, Trooien T P, Manges H L and Sunderman H D. 2001. Nitrogen fertilization for subsurface drip irrigated corn. *Transactions ASAE* 44: 533–42.
- Mmolawa K, and Or D, 2000. Water and solute dynamics under a drip-irrigated crop: experiments and analytical model. *Transactions ASAE* 43 (6): 1 597–1 608.
- Muthukumar V B, Velayudham K and Thavaprakash N. 2005. Effect of plant growth regulators and time of nitrogen application on quality and green cob yield of baby corn (*Zea mays* L.). *Madras Agricultural Journal* 92 (7-9): 545–8.
- Mugalkhod A S, Shivamurthy D, Kumar Anil and Biradar M S. 2011. Yield components of baby corn (*Zea mays* L.) as affected by planting methods and irrigation schedule under drip. *Plant Archives* 11 (1): 379–81.
- Narda N K and Chawla J K. 2002. A simple nitrate sub-model for trickle fertigated potatoes. *Irrigation and Drainage* 51:361–71.

- O'Brien D M, Lamm F R, Stone L R and Rogers D H. 2001. Corn yields and profitability for low-capacity irrigation systems. *Applied Engineering in Agriculture* **17**: 315–21.
- Patel N, Rajput T B S. 2000. Effect of fertigation on growth and yield of onion. (In) *Micro Irrigation*, pp 451–4. CBIP publication no. 282.
- Pandey A K, Prakash V and Gupta H S. 2002. Effect of integrated weed management practices on yield and economics of baby corn. *Indian Journal of Agricultural Science* **72**: 206–9.
- Paul J C, Mishra J N and Pradhan P L. 2011. Effect of drip irrigation and plastic mulch on growth, yield and economics of tomato in coastal Odisha. *Journal of Soil and Water Conservation* **10** (4): 310–5.
- Rajput T B S and Patel N. 2006. Water and nitrate movement in drip-irrigated onion under fertigation and irrigation treatments. *Agricultural Water Management*, **79**: 293–311.
- Sampathkumar T and Pandian B J. 2010. Effect of fertigation frequencies and levels on growth and yield of maize. *Madras Agricultural Journal* **97** (7-9): 245–8.
- Singandhupe R B, Rao G G S N, Patil N G and Brahmanand P S. 2003. Fertigation studies and irrigation scheduling in drip irrigation system in tomato crop (*Lycopersicon esculentum L.*). *European Journal of Agronomy* **19**: 327–40.
- Sivannapan R K. 2009. Development of micro-irrigation in India. Lecture note delivered in Winter School on Micro Irrigation, 4-24 March 2009, WTC, IARI, New Delhi.
- Sivanappan R K and Padmakumari O. 1980. Drip irrigation. Tamil Nadu Agricultural University, Coimbatore, India, SVNP Report, p 15.
- Thavaprakash N, Velayudham K and Muthukumar V B. 2005. Effect of crop geometry, intercropping systems and integrated nutrient management practices on productivity of baby corn (*Zea mays L.*) based intercropping systems. *Research Journal of Agricultural and Biological Sciences* **1**(4): 295–302.
- Tiwari K N, Mal P K, Singh R M and Chattopadhyaya A. 1998. Response of okra to drip irrigation under mulch and non-mulch conditions. *Agricultural Water Management* **38**:91–102.