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Studies on drip fertigation under different planting geometry in maize (*Zea mays* L.)

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Abstract
A field experiment was conducted during *kharif* 2014, College of Agriculture, VC Farm, Mandya in red sandy loam soil. The experiment was laid out in RCBD with ten treatments and replicated thrice. The treatments comprised of two paired rows under drip *viz.*, 30/60 and 30/90 cm with two irrigation levels (80 and 100 per cent CPE) along with two fertilizer combinations *viz.*, conventional fertilizer nitrogen (Urea), potassium (MOP) fertigation with water soluble phosphorus (MAP) or soil application of phosphorus (SSP). The results revealed that paired row planting of maize (NAH-1137) at 30/90 cm with irrigation at 80 or 100 per cent CPE and conventional fertilizer nitrogen, potassium fertigation and soil applied or water soluble phosphorus recorded significantly higher growth parameters, yield parameters and kernel (7505 to 7732 kg ha^{-1}) yield of maize over planting of maize at 45 or 60 cm row spacing with furrow irrigation and conventional fertilizer application. Similarly, the former treatments recorded higher total nutrient uptake at harvest, NUE and WUE and also B:C ratio (2.34 to 2.77). However, paired row planting of maize at 30/60 cm with similar drip fertigation recorded significantly lower values for above parameters.

Keywords: Fertigation under, planting geometry, maize (*Zea mays* L.)

Introduction
Maize (*Zea mays* L.) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because of the highest genetic yield potential and there is no cereal crop on the earth that has so immense potential as that of maize. The crop is mainly cultivated for commercial purpose with various uses *viz.*, food, feed for livestock and also used as a raw material in starch, ethanol, paper industries, etc. Improper management of water has contributed extensively to the current water scarcity and pollution problems in many parts of the world and is also a serious challenge to future food security and environmental safety. This issue requires an integrated approach to soil-water-plant nutrient management at the plant rooting zone. Some of these technologies are drip irrigation and fertigation. These are modern agro-techniques, provide an excellent opportunity to maximize yield and minimize environmental pollution (Hagin and Lowengart, 2002) [3] by increasing water and fertilizer use efficiencies through drip irrigation. Introduction of simultaneous drip fertigation opens new possibilities for controlling water and nutrient supplies to crops besides maintaining the desired concentration and distribution of nutrient and water into the soil. The production potential of hybrid maize is not fully harnessed even under irrigated conditions due to improper water and nutrient management. The optimum and precise use of these inputs are of most importance because of they are costly and scarce. Generally, maize is grown as a surface irrigated crop and cost consideration generally limits its cultivation under drip irrigation. But the response of maize to drip irrigation has shown convincingly superior results under varied agro climatic situations. Further, proper planting geometry plays an important role in overcoming high cost on drip laterals by bringing two rows of the maize crop sown close together and the large space left before the next paired row. Hence it is necessary to exploit the crop under different planting geometry with the highly evolved drip fertigation system for higher productivity and to increase efficiency of various inputs used.

Material and Methods
A field experiment was conducted during *Kharif* 2014 at College of Agriculture, Vishweshwaraiah Canal Farm, Mandya (Karnataka). The soil of the experimental site is red sandy loam in texture, having neutral in reaction (pH 7.55), organic carbon content was medium (0.66%) with low available nitrogen (238.90 kg ha^{-1}), medium in available phosphorous (29.37 kg ha^{-1}) and high in available potassium (349.40 kg ha^{-1}) and experiment

was laid out in RCBD with ten treatments and replicated thrice. The treatments combinations consisted of two paired rows under drip *viz.*, 30/60 and 30/90 cm with two irrigation levels *viz.*, 80 and 100% CPE along with two fertilizer combinations *viz.*, conventional fertilizer nitrogen (Urea), potassium (MOP) fertigation with water soluble phosphorus (MAP) or soil application of phosphorus (SSP). These combinations were compared with 45 or 60 cm row spacing with recommended practices and surface irrigation. The variety used was NAH-1137 (HEMA).The recommended dose of fertilizer (150-75-40 kg NPK ha^{-1}) given in ten schedules at four days interval from ten days after sowing to 46 days after sowing for fertigation treatments and basal application of half dose of nitrogen, entire dose of phosphorus and potassium along with top dressing of nitrogen at 15 and 30 days after sowing for the conventional farmer practices. Irrigations were scheduled as per the treatments by taking decennial average evaporation data obtained from Agro met cell of College of Agriculture, Vishweshwaraiah Canal Farm, Mandya (Karnataka). Irrigation was scheduled at 2 days interval in drip and 6 to 8 days interval in ridge and furrow method of irrigation. The quantity of water discharged for the individual treatments were measured with water meters fixed to the system. The recommended agronomic practices and plant protection measures were adopted as and when required. Data on yield, total nutrient uptake at 60 DAS and at harvest, nutrient use efficiency and nutrient status of soil after harvest of the maize crop were documented and analyzed statistically and presented in Tables 1 to 4.

Results and Discussion

Kernel yield

Planting of maize at 30 cm between rows and 90 cm between paired row with irrigation at 80% CPE and conventional fertilizer nitrogen, potassium and water soluble phosphorus recorded statistically higher kernel yield (7732 kg ha^{-1}) as compared to planting of maize at 45 or 60 cm row spacing with recommended practices (5654 to 5942 kgha^{-1}) and was on par with rest of the drip fertigation treatments. The extent of increase in yield in above treatments was 24.33 to 33.19 percent as compared to regular planting of maize at 45 or 60 cm row with recommended practices (Table 1). The similar trend was also observed for stover yield. The significant improvement in the yield was due to application of water in accordance with plant need (80% CPE) to the root zone with optimum quantity and frequency through drip in combination with water soluble fertilizers favoured higher uptake of nutrients which resulted in better growth and yield parameters and final yield of maize plant. The results obtained are in conformity with the findings of Ramulu *et al*. (2010) [6] and Chris o' Neil *et al.* (2006) [2].

Table 1: Kernel yield (kg ha^{-1}) of maize at harvest as influenced by drip fertigation under different planting geometry

Treatments		Kernel yield
T_1 :	PR at 30 /60 cm with 100% CPE and conventional fertilizer N & K fertigation.	7091
T_2 :	PR at 30 /60 cm with 100% CPE and fertigation by conventional fertilizer N & K and water soluble P.	7531
T_3 :	PR at 30 /60 cm with 80% CPE and conventional fertilizer N & K fertigation.	7030
T_4 :	PR at 30 /60 cm with 80% CPE and fertigation by conventional fertilizer N & K and water soluble P.	7477
T_5 :	PR at 30/90 cm with 100% CPE and conventional fertilizer N & K fertigation.	7615
T_6 :	PR at 30/90 cm with 100% CPE and fertigation by conventional fertilizer N & K and water soluble P.	7720
T_7 :	PR at 30/90 cm with 80% CPE and conventional fertilizer N & K fertigation.	7505
T_8 :	PR at 30/90 cm with 80% CPE and fertigation by conventional fertilizer N & K and water soluble P.	7732
T_9 :	Planting at 45 cm row with recommended practices.	5654
T_{10} :	Planting at 60 cm row with recommended practices.	5942
S.Em ±		242
CD at 5%		718

Note: DAS= Days after Sowing; PR= Paired row planting; CPE=Cumulative pan evaporation; N=Nitrogen; P= Phosphorus; K= Potassium; Recommended practices = Ridges and furrow irrigation with soil application of NPK.

Total nutrient uptake at 60 DAS

Paired row planting of maize at 30/90 cm with irrigation at 80% CPE and conventional fertilizer nitrogen, potassium and water soluble phosphorus fertigation recorded significantly higher nitrogen, phosphorus and potassium uptake (75.83, 23.97 and 54.18 kg ha^{-1}, respectively) as compared to planting of maize at 45 or 60 cm row spacing with recommended practices (37.50 to 45.26, 10.18 to 11.29 and 32.41 to 35.16 kg ha^{-1}, respectively) and rest of the drip fertigation treatments (14.06 to 20.56 kg ha^{-1}) for phosphorus uptake (Table 2). However, rest of the drip fertigation treatments (74.15 to 70.31, 22.39 and 49.07 to 54.08 kg ha^{-1}, respectively) were on par with former treatment except paired row planting of maize at 30/60 cm with irrigation at 80 or 100% CPE and nitrogen and potassium fetigation with soil applied or water soluble phosphorus treatments (55.38 to 64.56 kg ha^{-1}) for nitrogen uptake and paired row planting of maize at 30/60 cm with irrigation at 80 or 100% CPE and nitrogen and potassium fetigation with soil application of phosphorus treatments (44.13 to 46.02 kg ha^{-1}) for potassium uptake.

Table 2: Total nitrogen, phosphorus and potassium uptake by maize plant (kg ha-1) at 60 DAS as influenced by drip fertigation under different planting geometry

Treatments		Nitrogen	Phosphorus	Potassium
T_1 :	PR at 30 /60 cm with 100% CPE and conventional fertilizer N & K fertigation.	58.07	15.60	46.02
T_2 :	PR at 30 /60 cm with 100% CPE and fertigation by conventional fertilizer N & K and water soluble P.	64.56	18.08	50.25
T_3 :	PR at 30 /60 cm with 80% CPE and conventional fertilizer N & K fertigation.	55.38	14.06	44.13
T_4 :	PR at 30 /60 cm with 80% CPE and fertigation by conventional fertilizer N & K and water soluble P.	61.78	16.45	49.07
T_5 :	PR at 30/90 cm with 100% CPE and conventional fertilizer N & K fertigation.	72.24	20.56	53.20
T_6 :	PR at 30/90 cm with 100% CPE and fertigation by conventional fertilizer N & K and water soluble P.	74.15	22.39	54.08
T_7 :	PR at 30/90 cm with 80% CPE and conventional fertilizer N & K fertigation.	70.31	20.26	52.29
T_8 :	PR at 30/90 cm with 80% CPE and fertigation by conventional fertilizer N & K and water soluble P.	75.83	23.97	54.18
T_9 :	Planting at 45 cm row with recommended practices.	37.50	10.18	32.41
T_{10} :	Planting at 60 cm row with recommended practices.	45.26	11.29	35.16
S.Em ±		2.23	0.51	1.83
CD at 5%		6.64	1.52	5.42

Note: DAS=Days after sowing; PR= Paired row planting; CPE=Cumulative pan evaporation; N=Nitrogen; P= Phosphorus; K= Potassium; Recommended practices = Ridges and furrow irrigation with soil application of NPK.

Total nutrient uptake by maize at harvest

Paired row planting of maize at 30/90 cm with irrigation at 80% CPE and conventional fertilizer nitrogen, potassium and water soluble phosphorus fertigation recorded significantly higher nitrogen, phosphorus and potassium uptake (246.80, 76.31 and 229.88 kg ha^{-1}, respectively) as compared to planting of maize at 45 or 60 cm row spacing with recommended practices (183.61 to 195.15, 51.53 to 53.53 and 177.89 to 187.68 kg ha^{-1}, respectively) and rest of the drip fertigation treatments (212.33 to 235.52, 58.38 to 73.90 and 207.29 to 221.23 kg ha^{-1}, respectively) except paired row planting of maize at 30/90 cm with irrigation at 100% CPE and conventional fertilizer nitrogen, potassium and water soluble phosphorus fertigation (239.46 kg ha^{-1}) for nitrogen uptake and paired row planting of maize at 30/90 cm with irrigation at 100% CPE and nitrogen and potassium fetigation with soil applied or water soluble phosphorus treatments (226.32 to 228.32 kg ha^{-1}) for potassium uptake (Table 3). Higher uptake of nitrogen, phosphorus and potassium in maize could be due to application of nutrients in readily available form through drip irrigation for once in four days in 10 splits upto 50 DAS in accordance with maize plant growth and further adoption of drip irrigation keeps the maize root zone active and healthy for more uptake of nutrients due to availability of moisture maintained always at field capacity.

Table 3: Total nitrogen, phosphorus and potassium uptake by maize plant (kg ha^{-1}) at harvest as influenced by drip fertigation under different planting geometry

Treatments		Nitrogen	Phosphorus	Potassium
T_1 :	PR at 30 /60 cm with 100% CPE and conventional fertilizer N & K fertigation.	218.54	59.85	211.88
T_2 :	PR at 30 /60 cm with 100% CPE and fertigation by conventional fertilizer N & K and water soluble P.	225.63	64.01	218.35
T_3 :	PR at 30 /60 cm with 80% CPE and conventional fertilizer N & K fertigation.	212.33	58.38	207.29
T_4 :	PR at 30 /60 cm with 80% CPE and fertigation by conventional fertilizer N & K and water soluble P.	223.32	62.49	216.92
T_5 :	PR at 30/90 cm with 100% CPE and conventional fertilizer N & K fertigation.	235.52	69.58	226.61
T_6 :	PR at 30/90 cm with 100% CPE and fertigation by conventional fertilizer N & K and water soluble P.	239.46	73.90	228.82
T_7 :	PR at 30/90 cm with 80% CPE and conventional fertilizer N & K fertigation.	233.08	67.59	221.23
T_8 :	PR at 30/90 cm with 80% CPE and fertigation by conventional fertilizer N & K and water soluble P.	246.80	76.31	229.88
T_9 :	Planting at 45 cm row with recommended practices.	183.61	51.53	177.89
T_{10} :	Planting at 60 cm row with recommended practices.	195.15	53.53	187.68
S.Em ±		2.74	0.63	2.53
CD at 5%		8.13	1.88	7.53

Note: DAS= Days after Sowing; PR= Paired row planting; CPE=Cumulative pan evaporation; N=Nitrogen; P= Phosphorus; K= Potassium; Recommended practices = Ridges and furrow irrigation with soil application of NPK.

Nutrient use efficiency of maize (kg kernel /kg fertilizer)

The paired row planting of maize at 30/90 cm with irrigation at 80% CPE and conventional fertilizer nitrogen, potassium and water soluble phosphorus fertigation was recorded significantly higher nitrogen, phosphorus and potassium use efficiencies (52, 103 and 193 kg kernel kg^{-1} fertilizer, respectively) as compared to planting of maize at 45 or 60 cm row spacing with recommended practices (38 to 40, 75 to 79 and 141 to 149 kg kernel kg^{-1} fertilizer, respectively) (Table 4). However, rest of the drip fertigation treatments (51 to 47, 94 to 103 and 176 to 193 kg kernel kg^{-1} fertilizer, respectively) on par with former treatment. The higher nutrient use efficiency was mainly due to higher dry matter production and yield for applied nutrients as evidenced by higher uptake of nutrients in the experiment. Further, could be due to better availability of nutrients and water in root zone as a result of frequent fertigation scheduling once in four days in turn better root activity besides reduction in loss of nutrients primarily due to reduced leaching of nutrients in drip fertigation as compared to soil application of fertilizer with surface irrigation. These results are in conformity with Latif *et al*. (2001) [5]; Hassan *et al*. (2010) [4] and Richa Khanna (2013) [7] in maize. They also indicated above facts in their experiments.

Table 4: Nutrient use efficiency (kg kernel kg^{-1} fertilizer) of maize at harvest as influenced by drip fertigation under different planting geometry

Treatments		Nitrogen	Phosphorus	Potassium
T_1 :	PR at 30 /60 cm with 100% CPE and conventional fertilizer N & K fertigation.	47	95	177
T_2 :	PR at 30 /60 cm with 100% CPE and fertigation by conventional fertilizer N & K and water soluble P.	50	100	188
T_3 :	PR at 30 /60 cm with 80% CPE and conventional fertilizer N & K fertigation.	47	94	176
T_4 :	PR at 30 /60 cm with 80% CPE and fertigation by conventional fertilizer N & K and water soluble P.	50	100	187
T_5 :	PR at 30/90 cm with 100% CPE and conventional fertilizer N & K fertigation.	51	102	190
T_6 :	PR at 30/90 cm with 100% CPE and fertigation by conventional fertilizer N & K and water soluble P.	51	103	193
T_7 :	PR at 30/90 cm with 80% CPE and conventional fertilizer N & K fertigation.	50	100	188
T_8 :	PR at 30/90 cm with 80% CPE and fertigation by conventional fertilizer N & K and water soluble P.	52	103	193
T_9 :	Planting at 45 cm row with recommended practices.	38	75	141
T_{10}:	Planting at 60 cm row with recommended practices.	40	79	149
S.Em ±		2	3	6
CD at 5%		5	10	18

Note: DAS= Days after Sowing; PR= Paired row planting; CPE=Cumulative pan evaporation; N=Nitrogen; P= Phosphorus; K= Potassium; Recommended practices = Ridges and furrow irrigation with soil application of NPK.

Chemical properties and available nutrient status of soil after harvest of maize crop

Soil chemical properties did not differ significantly by paired row spacing, irrigation levels and drip fertigation practices. However, the soil pH, electrical conductivity and organic carbon varied from 7.41 to 7.73, 0.06 to 0.13 dSm^{-1} and 0.545 to 0.645 %, respectively between the treatments. Significantly higher available nitrogen in soil was due to paired row planting of maize at 30/60 cm with irrigation at 80% CPE and conventional fertilizer nitrogen, potassium fertigation and soil application of phosphorus (208.31 kg ha^{-1}) as compared to planting of maize at 45 or 60 cm row spacing with recommended practices (167.59 to 159.60 kg ha^{-1}) and rest of the paired row drip ferigation treatments (168.70 to 195.43 kg ha^{-1}) (Table 5). The available phosphorus content after harvest of maize was due to planting of maize at 45 or 60 cm with recommended practices (51.28 or 50.59 kg ha^{-1}) was statistically higher as compared to paired row spacing, irrigation levels and drip fertigation treatments (17.65 to 46.58 kg ha^{-1}). The available potassium content in the soil after harvest of maize was significantly more in paired row planting of maize at 30/60 cm with irrigation at 80% CPE and conventional fertilizer nitrogen, potassium fertigation and soil application of phosphorus (182.24 kg ha^{-1}) as compared to planting of maize at 45 or 60 cm row spacing with recommended practices (157.93 to 140.72 kg ha^{-1}) and rest of the paired row drip ferigation treatments (148.61 to 168.79 kg ha^{-1}), except paired row planting of maize at 30/60 cm with irrigation at 100% CPE and conventional fertilizer nitrogen, potassium fertigation and soil application of phosphorus (176.52 kg ha^{-1}). Higher available nutrients after harvest of the maize crop was due to all applied nutrient may not be taken by maize crop under surface irrigation with wetting and drying of soil led to lesser mineralization of nutrients for plants uptake and higher economic yield and due to drip irrigation effects non available nutrient may transformed into available form. These results are conformity with the findings of chein *et al.* (2000) [1]; Hassan *et al.* (2010) [4] and Yamuna (2014) [8].

Based on the results of the study, it is concluded that The paired row planting of maize at 30/60 or 30/90 cm with irrigation at 80 or 100% CPE with conventional fertilizer nitrogen, potassium fertigation and soil applied or water soluble phosphorus recorded significantly more total nitrogen and potassium uptake at 60 DAS (70.31 to 75.83 and 49.07 to 54.18, respectively), at harvest (239.46 to 246.80 and 226.61 to 229.88 kg ha^{-1}, respectively). The significantly higher phosphorus uptake recorded in paired row planting of maize at 30/90 cm with irrigation at 80% CPE and conventional fertilizer nitrogen, potassium and water soluble phosphorus at 60 DAS and at harvest (33.97 and 76.31 kg ha^{-1}, respectively) as compared to planting of maize at 45 or 60 cm row spacing with recommended practices. Similarly, the nitrogen, phosphorus and potassium use efficiencies were significantly more due to paired row planting of maize at 30/60 or 30/90 cm with irrigation at 80 or 100% CPE and conventional fertilizer nitrogen, potassium fertigation and soil applied or water soluble phosphorus (47 to 52, 94 to 103 and 187 to 193 kg kg^{-1}, respectively) over planting of maize at 45 or 60 cm row spacing with recommended practices (38 to 40, 75 to 79 and 141 to 149 kg kg^{-1}, respectively). Significantly higher available nitrogen and potassium in soil after harvest of the maize crop in paired row planting of maize at 30/60 cm with irrigation at 80% CPE and conventional fertilizer nitrogen, potassium fertigation and soil application of phosphorus (208.31 and 182.24 kg ha^{-1}) as compared to planting of maize at 45 or 60 cm row spacing with recommended practices (167.59 to 159.60 and 157.93 to 140.72 kg ha^{-1}). Whereas, significantly higher available phosphorus content in planting of maize at 45 or 60 cm with recommended practices (51.28 or 50.59 kg ha^{-1}) as compared to paired row spacing, irrigation levels and drip fertigation treatments (17.65 to 46.58 kg ha^{-1}).

Table 5: Soil chemical properties and available nutrient status after harvest of maize crop as influenced by drip fertigation under different planting geometry

Treatments		pH	EC (dS m^{-1})	OC (%)	Avail. N (kg ha^{-1})	Avail. P_2O_5 (kg ha^{-1})	Avail. K_2O (kg ha^{-1})
T_1	PR at 30 /60 cm with 100% CPE and conventional fertilizer N & K fertigation.	7.41	0.13	0.620	195.43	40.78	176.52
T_2	PR at 30 /60 cm with 100% CPE and fertigation by conventional fertilizer N & K and water soluble P.	7.59	0.09	0.615	186.08	34.54	168.79
T_3	PR at 30 /60 cm with 80% CPE and conventional fertilizer N & K fertigation.	7.42	0.08	0.625	208.31	46.58	182.24
T_4	PR at 30 /60 cm with 80% CPE and fertigation by conventional fertilizer N & K and water soluble P.	7.63	0.09	0.615	195.27	36.72	167.79
T_5	PR at 30/90 cm with 100% CPE and conventional fertilizer N & K fertigation.	7.41	0.10	0.605	174.97	24.30	155.24
T_6	PR at 30/90 cm with 100% CPE and fertigation by conventional fertilizer N & K and water soluble P.	7.73	0.11	0.550	176.59	19.05	151.45
T_7	PR at 30/90 cm with 80% CPE and conventional fertilizer N & K fertigation.	7.41	0.06	0.605	178.66	28.08	160.00
T_8	PR at 30/90 cm with 80% CPE and fertigation by conventional fertilizer N & K and water soluble P.	7.52	0.09	0.545	168.70	17.65	148.61
T_9	Planting at 45 cm row with recommended practices.	7.67	0.09	0.645	167.59	51.28	157.93
T_{10}	Planting at 60 cm row with recommended practices.	7.63	0.10	0.640	159.60	50.59	140.72
S.Em ±		0.10	0.10	0.023	2.74	1.91	5.39
CD at 5%		NS	NS	NS	8.13	5.66	16.03

Note: DAS=Days after Sowing; PR=Paired row planting; CPE=Cumulative pan evaporation; N=Nitrogen; P=Phosphorus; K=Potassium; Recommended practices = Ridges and furrow irrigation with soil application of NPK; NS=Non Significant;

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