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Effect of Drip Fertigation and Planting Geometry on Growth, Yield, Water Use Efficiency and Economics of Maize (*Zea mays* L.) in Southern Dry Zone of Karnataka

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Abstract

A field experiment was conducted during *Kharif* 2014 at 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 cm from 45 cm and 30/90 cm row spacing with two irrigation levels *viz.*, 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). These combinations were compared with 45 or 60 cm traditional row spacing with recommended practices. The hybrid used was NAH - 1137. The results revealed that paired row planting of maize 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, kernel (7505 to 7732 kg ha^{-1}) yield of maize as compared to planting of maize at 45 or 60 cm row spacing with furrow irrigation and conventional fertilizer application. Similarly, the former treatments recorded higher water use efficiency (102 to 116 kg ha-cm^{-1} and 2.34 to 2.77, respectively). However, paired row planting of maize at 30/60 cm with similar drip fertigation recorded on par with above treatments. Whereas, adoption of drip fertigation gave 24.33 to 33.19 per cent higher kernel yield of maize and saves 4.16 to 16.69 per cent water as compared to surface irrigation. While, application of phosphatic fertilizer through soil application (SSP) saves Rs.7,317 ha^{-1} over water soluble phosphours fertigation (MAP) under drip.

Maize (*Zea mays* L.) is one of the most important cereal crop next to rice, wheat and sorghum in India. It is one of the most versatile emerging crops with highest genetic yield potential among the cereals. 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 due to 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. So, paired row planting system provides facility to introduce suitable intercrop along with saving cost on drip lateral lines. Further, the fertigation is a modern agro-technique, provides an excellent opportunity to maximize yield and minimize environmental pollution (Hagin and Lowengart, 2002) by increasing fertilizer use efficiency.

Material and Methods

A field experiment was conducted during Kharif 2014 at College of Agriculture, VC Farm, Mandya comes under Southern Dry Zone of 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}). The 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 per cent CPE along with two fertilizer combination *viz.*, conventional fertilizer nitrogen (Urea), potassium (MOP) fertigation with water soluble phosphorus (MAP) or soil application of phosphorus (SSP). These combination were compared with 45 or 65 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 at 10 schedules in four days interval from 10 days 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 20 and 35 days after sowing for the conventional practices. Irrigation were

scheduled as per the treatments by talking decennial average evaporation data obtained from Agro met observatory of College of Agriculture, VC Farm, Mandya (Karnataka). Irrigation was scheduled at two days interval in drip and six to eight days interval in ridge and furrow method of irrigation. The quantity of water discharged for the individual treatment was measured with water meter fixed to the system. The recommended agronomic practices and plant protection measures were adopted as and when required. Data on yield, growth parameters, yield attributes, water use efficiency and economics were documented and analysed statistically.

Results and Discussion

Planting of maize at 30 cm between rows and 90 cm between paired row with irrigation at 80 per cent 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 was 24.33 to 33.19 per cent compared to regular planting of maize at 45 or 60 cm row with recommended practices (Table I and III). The similar trend was also observed for stover yield (Table I). 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 irrigation in combination with water soluble fertilizers favoured higher uptake of nutrients which resulted in better growth and yield parameters (Table I) and final yield of maize plant. The results obtained are in confirmity with the findings of Ramulu *et al.* (2010) and Chris o' Neil *et al.* (2006).

Yield parameters *viz.*, Kernels per cob (527.67 cob^{-1}) and shelling percentage (86.63 %) were statistically higher due to planting of maize at 30 cm between rows and 90 cm between paired rows with irrigation at 80 per cent CPE and fertigation with conventional fertilizer nitrogen, potassium and water soluble phosphorus over planting of maize at 45 or 60 cm row spacing with recommended practices (Table I). Further, rest of the paired row spacing, irrigation levels and drip fertigation treatments were on par with former treatment except planting of maize at 30 cm between rows and 60 cm between paired rows with irrigation at 80 or 100 per cent CPE and conventional fertilizer nitrogen, potassium fertigation and soil applied or water soluble phosphours treatments. Superiority of yield attributes might be due to optimum plant population of 55,555 plants per hectare in 30 / 90 cm paired row as against 74,074 plants per hectare in 30 / 60 cm paired row and increased availability of water and nutrients in the soil due to drip fertigation and their uptake by crop, thus resulting in better growth of plants as observed in the experiment (Table I) and by better yield attributes. Logically, the increase in cob length, cob girth and number of rows per cob facilitated the accommodation of more number of kernels per row, number of kernels per cob, kernels weight and shelling percentage. Similar results were also obtained by Patil *et al.* (2011) and Sharana Basava *et al.* (2012) in maize.

Planting of maize at 30 cm between rows and 90 cm between paired rows with irrigation at 80 per cent CPE and conventional fertilizer nitrogen, potassium and water soluble phosphorus fertigation recorded significantly higher growth parameters at harvest for plant height (192.77 cm), leaf area index per plant (3.12) and total dry matter accumulation of maize (344.27 g $plant^{-1}$) over planting of maize at 45 or 60 cm regular row spacing with recommended practices and was on par with rest of the drip fertigation treatments. Similar results have been obtained by Rajanna (2003) and Richa Khanna (2013) in maize. They were also opinioned that increased growth parameters of crop grown under drip fertigation due to maintaining moist condition around root zone helps to create favourable environoment for roots to grow and absorb water and nutrients more effectively. They also attributed the differences due to continuous availability of the required quantity of water along with balanced nutrition under drip.

Water use efficiency : Growing of maize in regular 45 or 60 cm row spacing with surface irrigation and recommended practices consumed higher total water (776 mm per ha^{-1}) as compared to paired row

TABLE I

Growth, yield parameters and yield of maize at harvest as influenced by drip fertigation under different planting geometry

Treatments	Plant height	Leaf area	Total dry matter production	Kernels	Kernels weight	Shelling per cent	Yield (kg ha^{-1})	
							Kernels	Stover
T_1: PR at 30/60 cm with 100 % CPE and conventional fertilizer N & K fertigation.	195.23	3.71	303.27	391.95	94.67	62.80	7091	7706
T_2: PR at 30/60 cm with 100% CPE and fertigation by conventional fertilizer N & K and water soluble P.	204.60	3.79	317.38	400.56	102.00	67.22	7531	7809
T_3: PR at 30/60 cm with 80 % CPE and conventional fertilizer N & K fertigation	191.84	3.65	299.22	397.36	93.33	65.10	7030	7767
T_4: PR at 30/60 cm with 80 % CPE and fertigation by conventional fertilizer N & K and water soluble P.	201.29	3.78	310.87	414.35	100.33	68.47	7477	7888
T_5: PR at 30/90 cm with 100 % CPE and conventional fertilizer N & K fertigation	189.09	2.95	332.33	504.45	137.33	85.04	7615	7787
T_6: PR at 30/90 cm with 100 % CPE and fertigation by conventional fertilizer N & K and water soluble P	192.65	2.99	336.30	509.69	138.33	85.94	7720	7860
T_7: PR at 30/90 cm with 80 % CPE and conventional fertilizer N & K fertigation	187.04	2.89	327.46	488.07	135.67	84.45	7505	7705
T_8: PR at 30/90 cm with 80 % CPE and fertigation by conventional fertilizer N & K and water soluble P.	192.77	3.12	344.27	527.67	139.67	86.63	7732	7884
T_9: Planting at 45 cm row with recommended practices	181.30	3.06	229.22	347.59	76.67	60.58	5654	6351
T_{10}: Planting at 60 cm row with recommended practices	172.43	2.40	241.42	407.05	106.33	67.70	5942	6582
S.Em±	5.66	0.17	11.20	25.88	2.60	2.04	242	221.57
CD at 5%	16.82	0.50	33.28	105.36	7.73	6.05	718	658.32

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

planting of maize at 30 / 60 or 30 / 90 cm with drip irrigation at 80 per cent CPE (665 mm ha^{-1}) or 100 per cent CPE (745 mm ha^{-1}) with conventional fertilizer nitrogen, potassium fertigation and soil applied or water soluble phosphorus treatments. The higher water consumed in surface irrigation was mainly due to lower application efficeency with surface method of application as compared to drip irrigation. Whereas, total effective rainfall received during the cropping period was 344.5 mm in 27 rainy days. Further, irrigating the maize crop at 80 per cent CPE gave 16.69 per cent water saving as compared to 4.16 per cent water saving in 100 per cent CPE over surface irrigation (Table II).

Paired row planting of maize at 30/90 cm with irrigation at 80 per cent CPE and conventional fertilizer nitrogen, potassium and water soluble phosphorus fertigation recorded significantly higher water use efficiency (116 kg ha cm^{-1}) as compared to planting of maize at 45 or 60 cm row spacing with recommended practices (73 to 77 kg ha cm^{-1}) and was on par with rest of the drip fertigation treatments (113 to 106 kg ha cm^{-1}) except paired row planting of maize at 30/60 cm with irrigation at 100 per cent CPE and conventional fertilizer nitrogen, potassium fertigation and soil application of phosphorus (95 kg ha cm^{-1}). The increased water use efficiency is sattributed to increased kernel yield due to favourable effects of

TABLE II

Water use efficiency of maize (kg ha - cm^{-1}) as influenced by drip fertigation under different planting geometry

Treatments	Water applied (mm)		Effective rainfall (mm)	Total water used (mm)	Water use efficiency (Kg ha cm^{-1})	% water saved over surface irrigation
	Land preparation and establishment	During crop growth stages				
T_1: PR at 30/60 cm with 100 % CPE and conventional fertilizer N & K fertigation.	76.13	324.37	344.5	745	95	4.16
T_2: PR at 30/60 cm with 100% CPE and fertigation by conventional fertilizer N & K and water soluble P.	76.13	324.37	344.5	745	101	4.16
T_3: PR at 30/60 cm with 80 % CPE and conventional fertilizer N & K fertigation	76.13	2244.37	344.5	665	106	16.69
T_4: PR at 30/60 cm with 80 % CPE and fertigation by conventional fertilizer N & K and water soluble P.	76.13	244.37	344.5	665	112	16.69
T5: PR at 30/90 cm with 100 % CPE and conventional fertilizer N & K fertigation	76.13	324.37	344.5	745	102	4.16
T6: PR at 30/90 cm with 100 % CPE and fertigation by conventional fertilizer N & K and water soluble P	76.13	324.37	344.5	745	104	4.16
T7: PR at 30/90 cm with 80 % CPE and conventional fertilizer N & K fertigation	76.13	244.37	344.5	665	113	16.69
T8: PR at 30/90 cm with 80 % CPE and fertigation by conventional fertilizer N & K and water soluble P.	76.13	244.37	344.5	665	116	16.69
T9: Planting at 45 cm row with recommended practices	88.47	343.03	344.5	776	73	-
T10: Planting at 60 cm row with recommended practices	88.47	343.03	344.5	776	77	-
S.Em ±		NA	NA	NA	NA	3NA
CD at 5%	-	-	-	-	10	-

TABLE III

Economics of maize crop as influenced by drip fertigation under different planting geometry

Treatments	Per cent yield increased over corresponding regular planting		Additional cost on drip by considering depreciation cost for five years and two crops in a year (Rs. ha^{-1})		Additional cost on fertilizer over recommended soil application (Rs. ha^{-1})		Additional net returns over conventional planting with recommended practices (Rs. ha^{-1})		Benefit cost ratio	
	45 cm	60 cm	45 cm	60 cm	45 cm	60 cm	45 cm	60 cm	45 cm	60 cm
Paired row with 100 % CPE and conventional fertilizer N, K fertigation and soil application of P	25.41	28.15	8,211	6896	0.00	0.00	16,539	20,852	2.47	2.77
Paired row with 100 % CPE and fertigation by conventional fertilizer N & K and water soluble P	33.19	29.92	8,211	6,896	7,317	7,317	15,002	14,937	2.20	2.34
Paired row with 80 % CPE and conventional fertilizer N, K fertigation and soil application of P	24.33	26.30	8,211	6,896	0.00	0.00	15,785	19,385	2.45	2.73
Paired row with 80 % CPE and fertigation by conventional fertilizer N & K and water soluble. P	32.24	30.12	8,211	6,896	7,317	7,317	14,335	15,108	2.18	2.34
Conventional planting with surface irrigation and recommended practices	-	-	-		7,183	7,183	40,503	44,712	2.12	2.28

Note : CPE = Cumulative pan evaporation; N = Nitrogen; P = Phosphorus; K = Potassium; Recommended practices = Ridges and furrow with soil application of NPK

paired row irrigation levels and drip fertigation as explained in above paragraphs. This was in accordance with Ponnuswamy and Santhy (2008) and Richa Khanna (2013) in maize. These studies revealed that supplying water nearer to the plant roots without much loss of water through drip resulting in higher water use efficiency.

Economics : The higher additional net returns (Rs.19,385 to 20,852 ha^{-1}) over conventional 60 cm row spacing with recommended practices and B:C ratio (Rs. 2.73 to 2.77) recorded with adoption of paired row 30/90 cm with irrigation at 80 or 100 per cent CPE and conventional fertilizer nitrogen, potassium fertigation and soil application of phosphorus as compared to application of water soluble phosphorus fertilizer (Rs.14,937 to 15,108 ha^{-1} and Rs. 2.34, respectively) are presented in Table III. The higher additional net returns and B:C ratio recorded with these treatments was due to 26 to 30.12 per cent increased yield over regular planting with recommended practices. Further, soil applied phophatic fertilizer recorded higher additional net returns than water soluble phosphorus fertigation was due to more cost on water soluble phosphorus fertilizer (MAP) of Rs. 92.00 per kg as compared to Rs. 8.20 per kg in case of conventional soil applied phosphatic fertilizer (SSP). Similar results are also reported by Vishwanath *et al*. (2000); Ramulu *et al.* (2010) and Richa Khanna (2013).

From the foregoing discussion, it could be inferred that adoption of paired row planting of maize at 30 cm between rows and 90 cm between paired rows with irrigation at 80 or 100 per cent CPE and conventinal fertilizer nitrogen, potassium fertigation and water soluble phosphorus or soil application of phosphorus gave 26.30 to 30.12 per cent higher kernel yield of maize and saves 4.12 to 16.69 per cent water used. The soil application of phosphatic fertilizer under drip irrigation saves Rs. 7,317 ha^{-1} and gave additional net returns of Rs.19,385 to 20,852ha^{-1}.

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