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Effect of crop establishment/irrigation techniques and nitrogen levels on growth, yield, nutrient uptake and quality of hybrid maize (*Zea mays* L.)

P.K. Singh*, Sachin Kumar, Arvind Kumar, Raj Kumar

Department of Agronomy, R.K. (P.G.) College, Shamli, C.C.S.U., Meerut, U.P247776, India

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Abstract

A field experiment was conducted during 2010 and 2011, under three replications. One row in Furrow Irrigated Raised Bed/ every furrow irrigation increased plant height by 7.94 %, stem girth by 46.47 per cent, and dry matter at maturity by 23.69 % over conventional sowing/ conventional irrigation. Similarly, number of leaves increased by 19.26 and 24.65 % leaf area by 25.83 and 26.65 %, over conventional practice at 60 and 90 days after sowing, respectively. Besides, it resulted 1.91 and 1.82 % higher total chlorophyll over conventional practice at 30 and 60 days after sowing, respectively and increased grain by 60.72 %, biological 42.44 % and stover yield by 30.2 % over conventional practice and also resulted 3.43 higher starch and 12.05 % protein content over conventional practice. One row in FIRB/ every furrow irrigation, had 62.1, 51.5 and 42.9 % higher uptake for nitrogen, phosphorus and potassium over conventional practice of crop establishment, respectively. Though, growth, yield attributes and yields were recorded highest with 200 kg N level, but the differences remained non significant with 150 Kg N. Application of 150 kg N/ha out yielded 10.78, 21.71 and 2.58 % higher biological, grain and stover yield over 100 kg N/ha. To harness existing agri-resources and attaining higher quality and quantity of maize production, the crop should be raised on FIRB and irrigated in each furrow and should be fertilized with 150 kg N/ha.

* **Corresponding Author:** P.K. Singh ✉ singh.pk1971@gmail.com

Introduction

Maize (*Zea mays* L.) is created as queen of cereals by virtue of its higher productivity. In India, traditional practice of sowing and irrigation of crop without any spatial arrangement is being practiced in most of maize growing tracts. The excessive exploitation of ground water resources for irrigation from shallow and deep aquifers has caused the water table to fall and has created many other environmental problems (Xia *et al.* 2005). The groundwater table is falling steadily at the rate of about 1m/year and the main factors leading to this decline are the expansion of the area under the water exploiting crops and in appropriate techniques of irrigation, resulting in low water-use efficiency (Zhang *et al.* 2006). Therefore, it is the matter of imperative importance to control the fall in rate of the ground water table by increasing the water-use efficiency of the crops by virtue of adopting appropriate planting/ irrigation technology. Bed planting has long been recognized as a yield boosting and water saving measure in field crops. Furrow Irrigated Raised Bed technique (FIRB) has recently emerged as the most potential water saving technique in the Indo-Gangetic plains of northern western India. FIRB planting besides saving 31.2 per cent irrigation water, also boosts yield up to 24 percent in the cereals. FIRB planting by virtue of facilitating better seeds germination, root establishment, enhanced root aeration, tends the plants to exploit its soil as well as aerial environment to the most possible extent (Jat, *et al.* 2005). Besides, it also prevents from excess moisture problem in heavy soils. As maize, is highly sensitive to both excess as well as shortage of moisture and paucity of information is available on the performance of maize to the FIRB planting with irrigation schedules. Therefore, the present investigation was conducted to evaluate the performance of different planting /irrigation techniques and nitrogen levels to elucidate their effects on growth, yield attributes, yields, nutrient uptake and quality of maize (*Zea mays* L.).

Materials and methods

A field experiment was conducted for two consecutive years (2010 and 2011) at Agronomic Research Block of R.K. (P.G.) College, Shamli, (U.P.) India. The soil of experimental field was sandy loam in texture, nearly neutral in reaction (p^H 7.4), low in available nitrogen (170.4 kg N/ha), medium in available phosphorus (14.2 Kg P/ha) and available potassium (163.35 kg K/ha). Bulk density of the experimental field was 1.51 g/cm^3. The experiment was conducted in Split Plot Design with planting techniques/ irrigation schedules as main plot and nitrogen levels as sub plot under three replications. The maize variety Ganga 11 was sown as per treatments. The FIRBS were made with the help of spade and planting was done by hand with the help of khurpi. The FIRB spacing in one row FIRB was kept 67.66 cm and plant to plant 20 cm apart where as, in case of two row in FIRB, FIRB spacing was kept 78 cm with plant to plant 20cm space. In the main plot treatment No. 5 and 6 the crop was sown conventionally followed by FIRB preparation in month of July at knee height stage. Recommended dose of P and K were applied at the time of sowing @60 kg P_2O_5 and 40 kg K_2O/ha, however, nitrogen was applied as per treatments. Weeds were controlled manually by khurpi. Precise quantity of water as per treatments was applied when plants started to show initial wilting symptoms. The crop was harvested plot wise at the commencement of appropriate maturity. Required plant protection measures were adopted as and when found necessary. The occurrence of different phenological stages was judged visually. The data pertaining to crop growth, development, yields, protein and starch content and their yield were subjected to appropriate statistical analysis. Cost of cultivation and net monitory returns were calculated based on prevailing market price of the inputs and produce (Labour ₹ 180/labour, seed cost ₹ 120/kg, Stover ₹ 95/quintal, grain ₹ 950/ quintal).

The total chlorophyll content in leaves was determined by Dimethyl Sulfoxide Method (DMSO) and calculated with the help of following formula:

$$\text{Total chlorophyll (mg/g leaf fresh weight)} = \frac{20.2 \times A\,645 + 8.02 + A\,663 \times V}{1000 \times W}$$

Where, A, V and W were absorbance, final volume and weight of sample, respectively.

Results and discussion

Growth and growth parameters

Plant height of maize at maturity was significantly influenced by planting/irrigation techniques and nitrogen levels. Highest plant height (166.70 cm) noticed under two rows in FIRB every furrow irrigation, which stood significantly higher than other crop establishment techniques except one row in FIRB every furrow irrigation (166.45 cm). On an average, two rows in FIRB every furrow irrigation recorded 8.25 per cent taller plants than conventional sowing conventional irrigation (154.20 cm). However, highest value of number of physiologically active leaves (14.55), leaf area (4612.22 cm^2), stem girth (5.20 cm) and dry matter accumulation (184.45 g/plant) at 60 DAS were recorded under one row in FIRB/ every furrow irrigation. The number of physiologically active leaves and per plant leaf area noticed with one rows in FIRB/ every furrow irrigation at 60 DAS were 19.26 and 25.84 per cent higher over conventional practice, respectively. Where as, at 90 DAS same recorded 24.65 and 26.65 per cent higher number of leaves and leaf area over conventional practice. Stem girth and dry matter accumulation also was significantly influenced and recorded highest with one row in FIRB/ every furrow irrigation. Plants enjoying same had 46.48 per cent thick stems and accumulated 23.79 per cent higher biomass than those grown conventionally. The higher value of different growth parameters might be due to increased root proliferation, enhanced root aeration, higher content of chlorophyll and adequate and appropriate moisture under one row in FIRB/ every furrow irrigation. Sangakkara *et al.* (2010) also reported lower bulk density and reduced penetration resistance under raised bed planting.

Table 1. Effect of planting techniques/irrigation schedules and nitrogen levels on plant height, stem girth, dry matter yield, number of leaves, leaf area, and total chlorophyll content of maize *Cv*. Ganga 11 (Mean of two years).

Treatments	*Plant height (cm)*	*Stem girth (cm)*	*Dry matter (g/plant)*	*Leaves/plant*		*Leaf area (cm^2/plant)*		Chlorophyll content (mg/g leaf fresh weight)	
				60DAS	90DAS	60DAS	90DAS	30DAS	60DAS
Planting techniques/ irrigation schedules									
Conventional sowing / Conventional irrigation	154.2	3.6	149.1	12.2	10.9	3665.3	3612.5	1.537	1.513
One row in FIRB / Every furrow irrigation	166.5	5.2	184.5	14.6	13.7	4612.2	4575.4	1.566	1.541
Two row in FIRB/ Every furrow irrigation	166.7	4.8	157.3	13.5	12.9	3694.8	3663.3	1.543	1.518
One row in FIRB/Alternate furrow irrigation	156.1	4.2	173.9	13.5	12.7	4298.8	4241.5	1.541	1.515
Conventional sowing-FIRB / EF irrigation	164.1	4.7	171.4	12.9	11.9	3832.5	3833.5	1.543	1.515
Conventional sowing-FIRB / AF irrigation	156.3	4.0	165.4	12.1	11.1	3773.2	3749.8	1.540	1.514
S.E.M.	2.67	0.18	3.39	0.19	0.18	121.62	119.93	0.0006	0.0011
C. D. (P=0.05)	8.41	0.57	10.68	0.62	0.55	383.09	377.77	0.0019	0.0033
Nitrogen level (Kg N/ha)									
100	153.8	4.1	139.1	11.2	10.3	3235.0	3771.1	1.540	1.514
150	168.1	4.4	178.3	14.0	12.9	4570.3	4445.6	1.552	1.526
200	175.8	5.2	195.4	15.8	14.8	4896.5	4686.2	1.574	1.548
S.E.M.	2.83	0.10	3.54	0.11	0.11	116.91	114.23	0.0002	0.0012
C.D. (P=0.05)	8.24	0.28	10.30	0.33	0.33	340.66	333.01	0.0055	0.0025

*FIRB=Furrow Irrigated Raised Bed, EFI= Every Furrow Irrigation, AFI= Alternate Furrow Irrigation.

Application of 200 kg N/ha, significantly influenced plant height (175.80 cm), number of leaves (15.80 at 60 DAS and 14.75 leaves at 90 DAS), leaf area (4896.45 cm^2 at 60 DAS and 4886.20 cm^2 at 90 DAS), stem girth (5.16 cm) as well as dry matter accumulation (195.35 g/plant). Nitrogen @200 kg N/ha resulted 14.34 per cent taller plants, maintained 41.07 and 43.20 per cent higher number of leaves at 60 and 90 DAS, respectively, 51.36 and 39.01 per cent higher leaf area at 60 and 90 DAS, respectively, 27.41 % thick stems and accumulated 40.48 per cent additional dry matter at maturity than 100 kg N/ha. Enhanced growth due to nitrogen application might was due to vital importance of nitrogen in the synthesis of chlorophyll, protoplasm, proteins, RNA and DNA and also in the synthesis of plant hormones. Thus, enabled the plants to photosynthesize higher quantity of photo assimilates. The finding confirms the result of Jat, *et al.* 2006.

Table 2. Effect of planting techniques/irrigation schedules and nitrogen levels on yield attributes, yields and harvest index of maize *cv*. Ganga 11.

Treatment	Cob length (cm)	Grains/cob	Grain yield/cob (g)	1000-grain wt. (g)	Yields (q/ha)			Harvest index
					Biological	Grain	Stover	
Planting techniques/ irrigation schedules								
Conventional sowing / Conventional irrigation	11.9	246.3	57.2	232.9	82.7	33.2	49.5	0.401
One row in FIRB / Every furrow irrigation	14.3	408.4	105.8	259.2	117.8	53.4	64.5	0.452
Two row in FIRB/ Every furrow irrigation	13.5	400.4	102.9	257.8	111.1	50.0	61.1	0.450
One row in FIRB/Alternate furrow irrigation	11.6	337.2	82.6	245.6	97.6	44.6	53.1	0.456
Conventional sowing-FIRB / EF irrigation	12.3	394.4	99.8	253.3	101.8	44.7	57.2	0.438
Conventional sowing-FIRB / AF irrigation	12.0	310.7	74.6	240.5	93.7	39.7	53.9	0.423
S.E.M.	0.29	3.72	1.63	1.73	2.98	1.03	1.97	0.0035
C. D. (P=0.05)	0.91	11.73	5.14	5.47	9.40	3.12	5.97	0.0111
Nitrogen levels (kg/ha)								
100	12.3	346.1	85.1	246.1	97.4	41.9	55.6	0.429
150	12.5	351.2	87.1	248.1	107.9	50.9	57.0	0.462
200	13.1	351.4	87.9	250.4	115.9	52.7	63.2	0.454
S.E.M.	0.19	2.65	1.59	1.45	2.12	0.88	1.24	0.0145
C.D. (P=0.05)	0.58	7.73	4.63	4.23	6.16	2.55	3.61	0.0425

*FIRBS=Furrow Irrigated Raised Bed System, EFI= Every Furrow Irrigation, AFI= Alternate Furrow Irrigation.

Yield attributes, yields and harvest index

The yield attributes of maize *viz*., cob length, grains/ cob, grain yield/cob and 1000-grain weight were significantly influenced due to crop establishment techniques. Maximum cob length (14.3 cm), grains/ cob (404.4 grains /cob), grain yield/ cob (105.8 g/cob) and 1000-grain weight (259.2 g) was observed under one row in FIRB / every furrow irrigation which registered its significant superiority over other crop establishment techniques but could not cross the level of significance to two row in FIRB/every furrow irrigation. Plants under one row in FIRB/ every furrow irrigation wore, 20.17, 65.81, 84.96 and 11.29 percent higher cob length, grains/cob, grain yield/ cob and 1000-grain weight, respectively, over conventional practice of crop establishment. Higher value of yield attributing characters with FIRB planting accomplished with every furrow irrigation might was due to accelerated root aeration and root activity and maintaining higher chlorophyll content in their leaves thus plants had higher pace of photoassimilate production thus higher value of different yield parameters.

Nitrogen levels also mad marked impact on different yield attributing characters. Highest cob length (13.1

cm), grains /cob (351.44 grains/cob), grain yield /cob (87.9g) and 1000-grain weight (250.4 g) was observed with 200 kg N/ha, which remained on par to 150 kg N/ ha and stood significantly superior to 100 kg N/ha. Application of 150 kg N/ha resulted 2.35 percent higher grain yield/cob over 100 kg N/ha. Higher value of growth parameters with 200 kg N/ha was attributed to higher content of chlorophyll thus maintaining higher rate of growth. The result endorses the finding of Saini and Mathauda 2013.

Table 3. Effect of planting techniques/irrigation schedules and nitrogen levels on produce quality and nutrient uptake maize cv.

Treatment	Total nutrient uptake (kg/ha)			Protein content (%)	Starch content (%)	Protein yield (kg/ha)	Starch yield (kg/ha)
	Nitrogen	Phosphorus	Potassium				
Planting techniques/ irrigation schedules							
Conventional sowing / Conventional irrigation	94.0	19.8	57.8	9.37	67.03	300.4	2112.3
One row in FIRB / Every furrow irrigation	145.9	30.1	82.6	10.51	69.28	561.9	3506.0
Two row in FIRB/ Every furrow irrigation	136.6	28.5	78.6	10.42	69.07	528.1	3501.7
One row in FIRB/Alternate furrow irrigation	115.8	24.8	67.9	9.69	68.46	435.1	3055.9
Conventional sowing-FIRB / EF irrigation	122.3	25.2	71.0	10.15	68.33	453.2	3046.9
Conventional sowing-FIRB / AF irrigation	108.7	22.4	61.6	9.76	67.54	379.9	2635.4
S.E.M.	2.28	0.40	1.24	0.0638	0.433	12.65	119.5
C. D. (P=0.05)	7.19	1.29	3.95	0.201	0.1.367	39.89	376.9
Nitrogen levels (kg/ha)							
100	114.3	23.8	65.9	9.86	68.02	406.8	2796.4
150	130.3	25.3	70.2	9.44	68.34	446.1	2956.4
200	131.2	26.3	74.3	10.15	68.45	479.5	3176.3
S.E.M.	2.40	0.55	1.12	0.049	0.457	10.51	91.05
C.D. (P=0.05)	6.98	1.61	3.27	0.145	1.329	30.62	265.21

*FIRBS=Furrow Irrigated Raised Bed System, EFI= Every Furrow Irrigation, AFI= Alternate Furrow Irrigation.

Data (Table-3) reveal that grain as well as stover yields were significantly influenced due to planting / irrigation techniques. One row in FIRB/ every furrow irrigation resulted 117.9 q/ha biomass, 53.4 q/ha grain and 64.5 q/ha stover yield. One row in FIRB / every furrow irrigation resulted 42.44, 60.72 and 30.18 % higher biological, grain and stover yield, respectively over conventional sowing/ conventional irrigation. Higher grain yield obtained with one row in FIRB /every furrow irrigation was attributed to higher chlorophyll content, increased root proliferation/ penetration and maintaining prolonged grain filling period. The result endorses finding of Jiyang Zhang *et al.*, 2007. Harvest index also was significantly influenced due to crop establishment /irrigation techniques and recorded maximum with one row in FIRB /alternate furrow irrigation (0.456) followed by one row in FIRB / every furrow irrigation (0.452) which were statistically at par to each other.

Application of 200 kg N /ha resulted significantly higher biomass (115.9 q/ha) and grain yield (52.7 q/ha) than 100 kg N/ha (97.4 q/ha biomass and 41.9 q/ha grain) which was statistically at par to 150 kg N/ha (107.9 q /ha biomass and 50.9 q/ha grain). The stover yield obtained with 200 kg N was 13.67 per cent higher than 100 kg N/ha. The higher biomass, grain and stover yield obtained with 200 kg N/ha was attributed to higher value of different yield attributing parameters. Highest harvest index (0.462) was noticed under 150 N/ha. The higher harvest index with 150 kg N /ha was attributed to relatively higher grain yield. The result confirms the finding of Mallikarjunswamy *et al.* 1997.

Nutrient uptake

Planting/ irrigation techniques as well as nitrogen levels had significant effect on total NPK uptake (Table3.). Amongst planting/irrigation techniques maximum N uptake (145.9 kgN/ha), P utake (30.1 kg P/ha) and K uptake (82.62 kg K/ha) was analyzed with one row FIRB/ every furrow irrigation followed by two row in FIRB/ every furrow irrigation (136.6 kg N/ha, 28.5 kg P/ha and 78.6 kg K/ha), which stood statistically at par to the one row FIRB/every furrow irrigation and was significantly higher than other crop establishment techniques. The plants under one row in FIRB/ every furrow irrigation, had 62.1, 51.5 and 42.9 % higher uptake for nitrogen, phosphorus and potassium over conventional practice of crop establishment, respectively. Higher uptake of nutrients with FIRB planting/ every furrow irrigation was attributed to increased aeration, which enhanced the root proliferation and also might facilitated the transformation of nutrients in readily available form. The higher uptake of nutrients was also attributed to relatively higher level of biomass yield. The results corroborate the finding of Hussaini *et al.* 2001.

Table 4. Economics of different treatments for maize *Cv.* Ganga 11.

Treatment	Cost of cultivation (₹)	Gross return (₹)	Net return (₹)	B:C ratio (₹ : ₹)
Planting techniques/ irrigation schedules				
Conventional sowing / Conventional irrigation	14600	31688	17088	1.170
One row in FIRB / Every furrow irrigation	16108	50023	33915	2.106
Two row in FIRB/ Every furrow irrigation	16720	46931	30211	1.807
One row in FIRB/Alternate furrow irrigation	16160	41799	25639	1.587
Conventional sowing-FIRB / EF irrigation	17160	42061	24901	1.451
Conventional sowing-FIRB / AF irrigation	16601	37604	21003	1.265
Nitrogen level (Kg N/ha)				
100	16222	39543	23321	1.438
150	16883	47491	30608	1.813
200	17542	49376	31834	1.815

*FIRB=Furrow Irrigated Raised Bed, EFI= Every Furrow Irrigation, AFI= Alternate Furrow Irrigation.

The nitrogen fertilization also had marked impact on the total uptake of nitrogen, phosphorus and potassium. Highest for the same was recorded with 200 kg N/ha (131.2 kg N/ha, 26.3 kg P/ha and 74.3 kg K/ha) followed by 150 kg N level (130.3 kg N/ha, 25.3 kg P/ha and 70.2 kg K/ha). The differences in total NPK uptake between 200 kg N/ha to 150 kg N/ha remained non significant. Application of 200 kg N/ha resulted 14.8 % higher nitrogen, 10.5 % higher phosphorus and 12.7 % higher potassium uptake over 100kg N/ha. Higher nitrogen uptake with 200 kg level was due to higher N availability made through extraneous application by fertilizer. Where as, higher uptake of phosphorus and potassium was attributed to higher biomass production. The result endorses the finding of Patel *et al.* 2006.

Quality

The quality parameters were influenced significantly with various planting techniques and nitrogen levels (Table-3). The highest protein content (10.5 %) was recorded with one row in FIRB / every furrow irrigation, which stood statistically at par to two row in FIRB/ every furrow irrigation (10.42 %) and was significantly superior to rest of the crop establishment techniques. Least content of protein in corn grains were analyzed with conventional sowing/ conventional irrigation (9.37 %). The produce from one row in FIRB/ every furrow irrigation, had 12.2 % higher protein assimilation in their grains over conventional practice. Protein yield also was significantly higher under one row in FIRB/ every furrow irrigation (561.9 kg protein /ha) which was statistically on par to two row FIRB /every furrow irrigation (528.1 kg protein/ha) and was significantly higher than other crop establishment techniques. Enhanced content of protein was due to higher chlorophyll content and late senescence of leaves which enabled the plants to maintain higher nitrate

reductase activity for prolonged period. Where as, higher protein yield was attributed to higher protein content and their respective higher yields. Result is in accordance to finding of Sangakkara *et al.* 2010. Nitrogen levels also had significant effect on protein content and protein yield as well. Maximum protein content (10.15 %) and protein yield (479.5 kg protein /ha) obtained under 200 kg N level followed by 150 kg N level (9.44% protein and 446.1 kg protein yield/ha). The plants nurtured with 200 kg N/ha had 17.87 % higher protein yield over 100 kg N/ha. Higher protein content with 200 kg N/ha might was due to direct involvement of nitrogen as a major constituent in the biochemical configuration of protein.

Planting/ irrigation techniques varied for starch content and their yield during both the years of experimentation. One row in FIRB /every furrow irrigation resulted highest starch content (69.33 and 69.23 %) which stood significantly higher than conventional sowing/ conventional irrigation (66.98 and 67.09 %) and conventional sowing- FIRB/ alternate furrow irrigation (67.41 and 67.48 %) during 2010 and 2011, respectively and remained statistically on par to rest of the planting / irrigation techniques. The plants under one row in FIRB /every furrow irrigation accumulated 3.50 and 3.19 per cent higher starch in their grain over conventional sowing/ conventional irrigation during 2010 and 2011, respectively. Higher content of starch with one row in FIRB/ every furrow irrigation might was attributed to enhanced root proliferation, chlorophyll content, higher period for grain filling which resulted bold seeds with higher starch content their in. Result corroborates the finding of Hussein *et al.*, 2001.

Nitrogen levels could not cross the level of significance in respect of starch content in their seeds.

Economics

Highest cost of production (₹ 17160/ ha) was involved with conventional sowing- FIRB/ every furrow irrigation. Because the FIRB were prepared in July at knee height stage hence some additional labour was needed. Maximum gross (₹ 50023/ha), net return (₹ 33915) and B:C ratio (2.106 ₹ / ₹) incurred with one row in FIRB /every furrow irrigation, followed by two row in FIRB/ every furrow irrigation ₹ 46931, ₹ 30211 and 1.807 ₹ / ₹, respectively. One row in FIRB/ every furrow irrigation resulted 57.86, 98.47 and 80.0 per cent higher gross, net return and B:C ratio over conventional practice of crop sowing and irrigation. Higher gross and net return with one row in FIRB/ every furrow irrigation were attributed to increased grain and stover yields. However, higher B:C ratio was attributed to relatively higher net return incurred. Nitrogen levels also differed markedly for cost of production, gross and net returns as well as B:C ratio. Highest cost of cultivation (₹ 17542 /ha) was involved with 200 kg N/ha. Like wise gross return (₹ 49376), net return (₹ 31843) and B:C ratio (1.815 ₹ / ₹) also were recorded highest with 200 kg N/ha. The net return obtained with 200 kg N /ha stood 36.50 % higher over 100 kg N (₹ 23321). The difference in net return between 200 to 150 kg N / was meager, only ₹ 1225/ha.

Therefore, to harness existing agri-resources and for attaining higher quantity, quality and profitability in maize production, the crop should be raised on FIRB and irrigated in every furrow and should be fertilized with 150 kg N /ha.

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