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Research Paper

Effect of single-cross hybrids, plant population and fertility levels on productivity and economics of maize (*Zea mays*)

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2013 and 2014 at Mudhol, Karnataka, to find out suitable maize (*Zea mays* L.) hybrids and to optimize plant population and fertility levels for higher productivity and profitability of maize. Treatments comprised 3 maize hybrids ('NK 6240', 'Super 900 M' and 'Arjun'), 2 plant populations (111,111 and 83,333 plants/ha) and 5 fertility levels [($N_{(150)}$ $P_2O_{5(65)}$ $K_2O_{(65)}$, (150, 65 and 65 kg/ha of N, P_2O_5 K_2O respectively), $N_{(187)}$ $P_2O_{5(81)}$ $K_2O_{(81)}$, $N_{(225)}$ $P_2O_{5(97)}$ $K_2O_{(97)}$, $N_{(262)}$ $P_2O_{5(114)}$ $K_2O_{(114)}$ and $N_{(300)}$ $P_2O_{5(130)}$ $K_2O_{(130)}$)]. Among the hybrids, significantly higher grain yield (10.14 t/ha), stover yield (14.38 t/ha), gross returns (₹ 139,487/ha), net returns (₹87,560/ha) and benefit: cost ratio (2.68) were recorded in 'NK 6240'. Plant population of 111,111 plants/ha gave significantly higher grain (9.80 t/ha) and stover yields (14.68 t/ha), gross returns (₹135,233/ha), net returns (₹84,563/ha) and benefit: cost ratio (2.65) over 83,333 plants/ha. Application of $N_{(300)}$ $P_2O_{5(130)}$ $K_2O_{(130)}$ kg/ha showed significant improvement in growth and yield attributes and it was reflected in significantly higher grain yield (10.42 t/ha) and stover yield (14.08 t/ha). The similar trend was also noticed in gross returns (₹142,969/ha), net returns (₹87,859/ha) and benefit: cost ratio (2.65). Interactive effects of hybrids, plant population and fertility levels reveled that, combination of hybrid 'NK 6240' under plant population of 111,111 plants/ha supplied with $N_{(300)}$ $P_2O_{5(130)}$ $K_2O_{(130)}$ kg/ha recorded significantly higher grain yield (12.14 t/ha), stover yields (16.65 t/ha) and uptake of nutrients (366.0 kg N/ha, 71.9 kg P/ha and 172.1 kg K/ha). Gross returns (₹166,759/ha), net returns (₹109,148/ha) were significantly higher in this treatment than rest of the treatments. However, benefit: cost ratio was higher (2.89) with 'NK 6240' at 111,111 plants/ha along with application of $N_{(262)}$ $P_2O_{5(114)}$ $K_2O_{(114)}$ kg/ha.

Key words : Economics, Fertility levels, Maize hybrids, Plant population, Productivity

Maize occupies a pride place among the cereals in our country. India grows about 8.71 m ha of maize with total annual production of 22.3 mt of grain, giving an average yield of 2.55 t/ha (ICAR, New Delhi, 2014) which is tremendously lower than other maize-growing countries. There are many reasons for low productivity of maize in India, among them cultivation of impotent genotypes (Jogdand *et al*., 2008), under planting density (Bisht *et al.*, 2012) and mismanagement of plant nutrition (Singh, 2010; Paramasivan *et al*., 2011) are considered to be the major ones. However, today, single-cross hybrids are clearly the preferred cultivars of maize for achieving high yield (Singh, 2010). Because of their hybrid vigour over double cross, 3 ways cross hybrids and composites are familiar among the farmers year after year. In-spite of this, presently hybrids constitute just 30% of total plantings in a given year. It is estimated that hybrids would constitute 90% of the total area by 2050, and this would provide a major boost to the maize production (Indiastat.com, 2013). Further, single-cross hybrids are known for their erectophyll leaf orientation and higher leaf area at silking and grain-filling stage, made them to be flexible for higher planting density. Panting density is one of the practices that made significant change in productivity of maize. Further, yield gap in maize is due to inadequate and imbalanced fertilization and lack of distinct fertilizer recommendations for high-yielding single cross hybrids. Karnataka being one of the major producers of maize, assessment of most suitable planting density and fertility

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levels to high yielding single-cross hybrids for irrigated ecosystem of Karnataka is the untouched part of maize research. Hence a field experiment was conducted to exploit the potential of maize under irrigated ecosystem.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) seasons of 2013 and 2014 at Mudhol, Karnataka, to study the effects of single-cross hybrids, plant population and level of fertilization on growth and yield attributes, yield, nutrient uptake and economics of maize production. The soil of the experimental site was deep black, alkaline, low in organic carbon and available nitrogen (237 kg/ha), medium in available phosphorus (23 kg/ha) and high in available potassium (427 kg/ha). The experiment was laid out in split-split plot design and was replicated thrice. Three hybrids (H_1,'NK 6240', 'H_2,'Super 900 M' and H_3, 'Arjun'), 2 populations (P_1, 111,111 and P_2, 83,333 plants/ha) and 5 fertility levels [F_1, $N_{(150)}$ $P_2O_{5(65)}$ $K_2O_{(65)}$ (50, 65 and 65 kg N, P_2O_5 and K_2O/ha respectively) (RDF), $N_{(187)}$ $P_2O_{5(81)}$ $K_2O_{(81)}$ (125% of RDF), $N_{(225)}$ $P_2O_{5(97)}$ $K_2O_{(97)}$ (150% of RDF), $N_{(262)}$ $P_2O_{5(114)}$ $K_2O_{(114)}$ (175% of RDF), $N_{(300)}$ $P_2O_{5(130)}$ $K_2O_{(130)}$ (200% of RDF)] were assigned to main plot, subplot and sub-subplots, respectively.

Well decomposed farmyard manure @ 10 tonnes and 25 kg $ZnSO_4$ and $FeSO_4$/ha were applied uniformly and seeds were treated with phosphorus-solibilizing bacteria and *Azospirillum* each @ 750 g/ha. As per the treatments, seed rows were maintained at 45 cm and 60 cm to accommodate 111,111 and 83,333 plants/ha in subplots. Inter-row spacing of 20 cm was maintained for both the populations. Basal dose of nitrogen (15% of RDN), phosphorus (100% RD P_2O_5), potassium (RD K_2O) and micronutrients were applied at the time of sowing and remaining nitrogen was applied in 4 splits (Table 1). Observations on growth, yield attributes, grain and stover yields were recorded as per the standard procedure. Growth indices such as crop-growth rate and net assimilation rate were calculated as per Watson (1952) and Gregory (1926) respectively. The cost of cultivation, gross, net returns and benefit: cost ratios were calculated on the basis of prevailing market price of different input and output. Data were statistically analyzed as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth attributes

Among the maize hybrids, 'NK-6,240' showed significantly higher plant height and total dry matter production at harvesting followed by 'Super 900 M' and 'Arjun' (Table 2). Higher dry-matter production with 'NK 6240' could be owing to significantly higher crop-growth rate and net assimilation rate. The hybrids 'NK 6240' and 'Super 900 M', however, were at par in terms leaf-area index (LAI), leaf-area duration (LAD) and soil plant analysis decision (SPAD) values at 90 days after sowing (DAS) and were significantly higher than hybrid 'Arjun'. The superiority of former hybrids could be attributed to higher combining ability, wider adaptability and stability in hybrid vigour and favourable genotypic basis. Similar findings were reported by Azam *et al.* (2007). Plant population of 111,111 plants/ha recorded significantly higher growth attributes such as plant height at harvest, leaf-area index at 90 DAS and LAD was superior to lower plant population. However, total dry-matter production was higher with lower plant population of 83,333 plant/ha and was statistically excelled over higher plant population (111,111 plants/ha). Significantly higher plant height, leaf-area index, SPAD-chlorophyll meter reading and total dry-matter accumulation were associated with higher fertility [$N_{(300)}$ $P_2O_{5(130)}$ $K_2O_{(130)}$ kg/ha], however, it was at par with $N_{(262)}$ $P_2O_{5(114)}$ $K_2O_{(114)}$ kg/ha. The higher growth-attributing parameters with these fertility levels could be owing to increased availability of nutrients under assured irrigated condition. Maize being a C_4 plant responds to applied fertilizer under adequate moisture condition (Thavaprakaash *et al.,* 2005).

Table 1. Fertilization schedule for maize

Fertility levels	kg/ha					
	Basal (N P_2O_5 K_2O)	N 1st split (20 DAS)	N 2nd split (35 DAS)	N 3rd split (50 DAS)	N 4th (65 DAS) split	Total fertilizer (N P_2O_5 K_2O)
F_1	15:65:65	30	45	45	15	150:65:65
F_2	19:82:82	38	56	56	19	188:82:82
F_3	23:98:98	45	68	68	23	225:98:98
F_4	26:115:115	53	79	79	26	263:115:115
F_5	30:130:130	60	90	90	30	300:130:130

DAS, Days after sowing

Grain and stover yield

Hybrid 'NK 6240' and 'Super 900 M' gave significantly higher grain and stover yields (Table 3) than hybrid 'Arjun'. Higher yield experienced with former hybrids were traced back to higher growth and yield attributes as the yield attributes (cob length, cob girth, grain weight/plant and 1,000-grain weight) of 'NK 6240' and 'Super 900 M' were significantly higher than 'Arjun'.

Increase in plant population per unit area from 83,333 to 111,111 plants/ha increased the grain yield from 8.61 to 9.80 t/ha. Despite of lower yield attributes in higher plant population (grain weight/plant and 1,000-grain weight), higher grain yield under higher plant population may be attributed to more number of harvestable cobs/unit area. Better development of yield attributes at lower plant density could not compensate the loss in grain yield due to less number of harvestable cobs/unit area (Bisht *et al.,* 2013) and was obvious because in non-tillering cereal like maize, the reduced plant population/unit area could not compensate to the final yield through the yield/plant harvested was little lower in higher plant population.

Among the fertility levels, application of $N_{(300)}$ $P_2O_{5(130)}$ $K_2O_{(130)}$ kg/ha recorded significantly higher grain and stover yields and was at par with $N_{(262)}$ $P_2O_{5(114)}$ $K_2O_{(114)}$ kg/ha (Table 3). The increase in yield at higher fertility level was owing to increased sink capacity. The grain yield of maize is mainly depends on the growth and yield attributes. The positive and significant improvement in crop-growth rate and net assimilation rate attributed to higher leaf-area index, total dry-matter production during crop-growth and development which increased yield attributes resulted in enhanced grain yield (Shrikanth *et al.,* 2009).

The interactions of hybrids, plant population and fertility levels were significant. The significantly higher grain and stover yields were recorded in $H_1P_1F_5$ on account of higher number of harvestable cobs, cob length and weight. The treatment combination $H_1P_2F_5$ also recorded at par grain yield with that of $H_1P_1F_5$ due to higher grain weight/plant and comparable cob length and 1,000-grain weight.

Nutrient uptake

Variation in nutrient uptake were recorded among the hybrids (Table 4); 'NK 6240' removed significantly higher amount of nitrogen, phosphorus and potassium and was closely followed by 'Super 900 M'. Single-cross maize hybrids produce more biomass/plant leading to higher biomass production may be the most relevant cause for higher nutrient uptake (Jat *et al*., 2012). Between the plant population 111,111 plants/ha recorded higher nitrogen, phosphorus and potassium uptake and was obvious because of

Table 2. Effect of hybrids, plant population and fertility levels on growth and yield parameters of maize (pooled data of 2 years)

Treatment	Plant height at harvest (cm)	LAI at 90 DAS	LAD at 90 DAS (days)	SPAD at 90 DAS	TDMP at harvest (g/plant)	CGR at 60–90 DAS	NAR at 60–90 DAS	Cob length (cm)	Cob girth (cm)	Grain weight/ plant (g)	Harvest index (%)
Maize hybrids (H)											
H_1, 'NK 6240'	193.3	5.17	146.5	41.9	290.8	53.32	5.3	17.7	15.9	174.6	41.3
H_2, 'Super 900 M'	184.0	5.20	144.0	44.5	275.3	50.63	5.2	18.7	17.2	163.9	40.9
H_3, 'Arjun'	164.0	4.08	118.2	41.9	201.8	35.44	3.6	16.2	13.4	90.9	39.0
SEm±	2.3	0.10	3.8	0.6	2.3	1.60	0.23	0.4	0.39	3.5	0.61
CD (P=0.05)	9.2	0.37	15.0	2.6	9.1	4.80	0.70	1.5	1.52	13.8	2.38
Plant population/ha (P)											
P_1, 111,111	186.4	5.26	147.6	40.9	240.0	52.44	4.7	17.1	15.4	136.6	39.9
P_2, 83,333	174.4	4.38	124.9	44.5	271.9	40.48	4.7	17.9	15.6	149.6	40.9
SEm±	2.1	0.06	1.5	0.7	3.1	0.67	0.12	0.2	0.28	2.7	0.46
CD (P=0.05)	7.4	0.21	5.3	2.6	10.9	2.10	0.40	0.9	0.96	9.3	1.58
Fertility levels kg/ha (F)											
F_1, $N_{(150)}$ $P_2O_{5(65)}$ $K_2O_{(65)}$	158.5	4.02	115.9	36.0	218.9	41.51	4.1	15.5	14.0	101.8	37.2
F_2, $N_{(187)}$ $P_2O_{5(81)}$ $K_2O_{(81)}$	166.6	4.41	124.7	39.9	245.1	44.88	4.6	16.4	14.7	121.2	39.2
F_3, $N_{(225)}$ $P_2O_{5(97)}$ $K_2O_{(97)}$	179.6	4.81	135.6	42.4	258.8	46.73	4.7	17.6	15.5	150.2	40.8
F_4, $N_{(262)}$ $P_2O_{5(114)}$ $K_2O_{(114)}$	193.8	5.30	148.5	46.6	272.1	49.30	4.9	18.7	16.4	168.0	42.2
F_5, $N_{(300)}$ $P_2O_{5(130)}$ $K_2O_{(130)}$	203.6	5.54	156.5	48.9	284.9	49.89	5.2	19.3	16.9	174.4	42.6
SEm±	2.8	0.07	2.0	0.7	5.4	1.03	0.15	0.2	0.25	2.2	0.86
CD (P=0.05)	8.18	0.21	5.7	2.2	15.5	3.13	0.50	0.6	0.70	6.3	2.46

LAI, Leaf-area index; LAD, leaf-area duration; SPAD, soil plant analysis decision; TDMP, total dry-matter production CGR, crop-growth rate; NAR, net assimilation rate; DAS, days after sowing higher crop stand which produced higher biomass/ha. Our results confirm the finding of Nagaraju (2005). Among the fertility levels, increased fertility levels enhanced the nutrient uptake of maize. Nutrient application even up to $N_{(300)}\ P_2O_{5(130)}\ K_2O_{(130)}$ kg/ha enhanced the nitrogen, phosphorus and potassium uptake, but it was on a par with $N_{(262)}\ P_2O_{5(114)}\ K_2O_{(114)}$ kg/ha. Increased nutrient levels increased the availability of nutrients in the soil, resulting in

Table 3. Grain yield and stover yield of maize as influenced by hybrids, plant population and fertility levels (pooled data of 2 years)

Treatment		Grain yield (t/ha)							Stover yield (t/ha)						
		Fertility levels (kg/ha)							Fertility levels (kg/ha)						
Hybrids	Plant population	F_1	F_2	F_3	F_4	F_5	Mean	Mean	F_1	F_2	F_3	F_4	F_5	Mean	Mean
H_1	P_1	8.73	9.70	11.57	11.92	12.14	10.81	10.14	14.93	15.00	16.03	15.61	16.65	15.64	14.38
	P_2	7.90	8.64	9.98	10.01	10.80	9.47		12.83	12.01	13.92	13.38	13.48	13.12	
	Mean	8.31	9.17	10.77	10.97	11.47			13.88	13.50	14.98	14.49	15.06		
H_2	P_1	8.90	10.22	11.53	11.67	11.83	10.83	9.89	15.93	15.56	16.37	15.98	16.42	16.05	14.33
	P_2	7.03	8.21	9.46	10.07	9.98	8.95		10.12	12.72	13.93	13.28	12.96	12.60	
	Mean	7.97	9.22	10.50	10.87	10.91			13.02	14.14	15.15	14.63	14.69		
H_3	P_1	6.75	7.00	7.47	8.56	9.04	7.76	7.59	12.57	12.48	11.62	12.36	12.69	12.34	11.84
	P_2	4.97	6.83	8.11	8.51	8.70	7.43		9.02	10.94	12.23	12.27	12.25	11.34	
	Mean	5.86	6.91	7.79	8.54	8.87			10.79	11.71	11.93	12.31	12.47		
Mean of P_1	8.13	8.97	10.19	10.72	11.00	9.80		14.48	14.35	14.67	14.65	15.25	14.68		
Mean of P_2	6.63	7.89	9.18	9.53	9.83	8.61		10.65	11.89	13.36	12.98	12.90	12.36		
Mean	7.38	8.43	9.69	10.12	10.42			12.57	13.12	14.02	13.81	14.08			

Sources	Grain yield SEm±	Grain yield CD (P=0.05)	Stover yield SEm±	Stover yield CD (P=0.05)
Hybrids (H)	0.16	0.65	0.30	1.17
Plant population (P)	0.15	0.53	0.15	0.52
Fertility levels (F)	0.22	0.63	0.33	0.93
H × S	0.27	0.93	0.26	0.91
H × F	0.39	1.10	0.57	1.62
S × F	0.32	0.90	0.46	1.32

H_1, NK 6240; H_2, Super 900 M; H_3, Arjun; P_1, 111,111 plants/ha; P_2, 83,333 plants/ha;
F_1, $N_{(150)}\ P_2O_{5(65)}\ K_2O_{(65)}$; F_2, $N_{(187)}\ P_2O_{5(81)}\ K_2O_{(81)}$; F_3, $N_{(225)}\ P_2O_{5(97)}\ K_2O_{(97)}$; F_4, $N_{(262)}\ P_2O_{5(114)}\ K_2O_{(114)}$; F_5, $N_{(300)}\ P_2O_{5(130)}\ K_2O_{(130)}$

Table 4. Nutrient uptake of maize and economics of maize as influenced by hybrids, plant population and fertility levels (pooled data of 2 years)

Treatment	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)	Gross returns (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio
Maize hybrids (H)						
H_1, 'NK 6240'	290.4	49.0	112.7	139.49	87.56	2.68
H_2, 'Super 900 M'	281.1	46.9	110.8	136.24	81.86	2.49
H_3, 'Arjun'	220.1	34.9	90.7	105.00	61.09	2.38
SEm±	3.3	0.8	3.4	2.23	2.23	0.05
CD (P=0.05)	12.9	3.3	13.2	8.76	8.76	0.21
Plant population/ha (P)						
P_1, 111,111	282.5	51.2	131.5	135.23	84.56	2.65
P_2, 83,333	245.2	36.0	81.9	118.58	69.11	2.38
SEm±	4.0	0.9	2.6	2.01	2.01	0.04
CD (P=0.05)	13.8	3.1	9.0	6.96	6.96	0.14
Fertility levels kg/ha (F)						
F_1, $N_{(150)}\ P_2O_{5(65)}\ K_2O_{(65)}$	205.1	30.8	73.5	102.55	57.51	2.27
F_2, $N_{(187)}\ P_2O_{5(81)}\ K_2O_{(81)}$	248.9	37.9	84.7	116.57	69.01	2.44
F_3, $N_{(225)}\ P_2O_{5(97)}\ K_2O_{(97)}$	265.9	43.7	108.0	133.42	83.35	2.65
F_4, $N_{(262)}\ P_2O_{5(114)}\ K_2O_{(114)}$	290.1	50.7	127.8	139.03	86.44	2.64
F_5, $N_{(300)}\ P_2O_{5(130)}\ K_2O_{(130)}$	309.3	54.9	139.6	142.97	87.86	2.59
SEm±	5.7	0.8	2.4	2.94	2.94	0.06
CD (P=0.05)	16.3	2.4	6.8	8.36	8.36	0.17

higher uptake of the nutrients. This enhanced the vegetative growth which ultimately increased nutrients concentration in total biomass of plants (Jat *et al*., 2012).

Economics

Among the hybrids, 'NK 6240' fetched significantly higher gross returns net returns and benefit: cost ratio than the other hybrids. 'Super 900 M' was the next best. Higher plant population recorded more gross returns, net returns and benefit: cost ratio than lower population. Similar opinions of increase in profitability with increased plant density was expressed by Gollar and Patil (2000). Application of higher fertility level $N_{(300)}$ $P_2O_{5(130)}$ $K_2O_{(130)}$ kg/ha recorded higher gross and net returns over lower fertility levels on account of higher grain and stover yields of maize at higher nutrient levels. The results confirm the findings of Pagad (2014).

Thus, maize hybrid 'NK 6240' or 'Super 900 M' at 111,111 plants/ha along with application of $N_{(262)}$ $P_2O_{5(114)}$ $K_2O_{(114)}$ kg/ha was more productive and profitable cropping practice for maize under irrigated ecosystem.

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