

Influence of Planting Ratio and Micronutrient Application on the Seed Yield of Single-Cross Maize Hybrids (*Zea mays* L.)

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Abstract

The field experiment was conducted at NSP, UAS, GKVK, Bengaluru, to study the effect of planting ratio and micronutrient application on seed yield in single cross maize hybrid. The experiment consists of four planting ratio, two hybrids and three micronutrient application. Significant differences were noticed between the treatments for seed yield parameters. Between the hybrids, Hema (51.02 and 52.00q/ha) recorded the higher seed yield compared to Nithyashree (27.14 and 25.10q/ha) at GKVK and Mandya, respectively. However, between the locations, GKVK was found to be more suitable place for seed production than Mandya. Planting ratio P₁ (4:1) maximizes overall seed yield per hectare at GKVK (41.09 q/ha), performing on par with P₄ (6:2) at 39.90 q/ha and P₂ (4:2) at 39.51 q/ha. On the contrary, P₃ (5:1) consistently produces lower yields (35.82 q/ha) because the higher proportion of female rows leads to pollen shortages.

Key words: *Zea mays* L., Planting ratio, Micronutrient, Parental lines, Seed yield

Maize is an important cereal crop used as a raw material for food and feed processing and recently worldwide as bio-fuel. In many countries, it is the basic staple food and an important ingredient in the diet of people. Worldwide, it has been estimated that approximately 17 per cent of the total grain produced is consumed as food. India ranked as the 5th largest producer of maize in the world in 2024, with a production of 43.41million tonnes from an area of 12.09 million hectares and productivity of 3.59 tonnes per ha [1]. It is the third most important cereal in India after wheat and rice. The major maize growing states are Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Punjab, Andhra Pradesh, Himachal Pradesh, West Bengal, Karnataka, Jammu and Kashmir, jointly accounting for over 95 per cent of the national maize production. The maize production in 2024-25 was 6.19 million tonnes from an area of 1.91 million hectares with an average productivity of 3.23 tonnes per hectare [1]. Though, the area under maize has shown an increasing trend, with maize emerging as a competitive crop, the level of production has substantially risen to meet the growing demand for supply of quality seed. Seed yield is the most important and complex trait. Efforts have also been made to undertake breeding of high yielding corn hybrids which are stable across locations for both wet (*kharif*) and dry (*rabi*) seasons [2-3]. In the hybrid seed production, seed yield and quality attributes can be increased through optimum female to male parental rows [4]. The planting proportion of rows decides the amount of hybrid seed produced and is influenced by vigour of the parents (male and female) and especially the pollen production ability of male parent [5]. To get more hybrid seed, one may be enticed to put more number of female rows without taking care to supply adequate pollens to seed parent rows. The

optimum planting ratio developed for one hybrid may not be suitable the same for another hybrid of the same crop. Since standardization of planting ratios in maize hybrid seed production to enhance the availability of viable pollens to receptive stigma for good pollination and further increasing the seed yield by managing the female to male parental ratios. Maize responds greatly to nutrient application. Apart from major nutrients, despite being needed in small quantities, micronutrients are also essential for the overall performance and health of the maize crop. They include iron, manganese, zinc, copper, molybdenum and boron. Among the micronutrients, Fe and Zn are more important to maize [2]. An attempt was made to determine the optimum planting ratio with micronutrients application in single cross maize hybrids (NAH-2049 and NAHH-1137) seed production to enhance seed set and seed yield quality.

MATERIALS AND METHODS

The experiment was conducted at the experimental blocks of National Seed Project, Gandhi Krishi Vigyan Kendra, University of Agricultural Sciences, Bengaluru and G block of Zonal Agricultural Research Station, V.C. Farm, Mandya during rabi/summer season. The experiment consisted of twenty four treatment combinations with three factors viz. Hybrid (H): H₁: NAH-2049 and H₂: NAH-1137, Planting ratio (P): P₁: 4:1 (Female: Male), P₂: 4:2 (Female: Male), P₃: 5:1 (Female: Male), P₄: 6:2 (Female: Male), Micronutrient (M): M₁: RDF (150:75:40 NPK kg/ha) + ZnSO₄ 10 kg/ha, M₂: RDF (150:75:40 NPK kg/ha) + FeSO₄ 10 kg/ha, M₃: RDF (150:75:40 NPK kg/ha) + 10 kg ZnSO₄ + FeSO₄10 kg/ha. The

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recommended fertilizer dose (RDF) of 150:75:40 kg NPK per ha were applied to the crop. Out of this, 75 kg N and entire P and K along with micronutrients as per the treatments were applied as basal dose at the time of sowing and the remaining quantity of N was applied at grand growth stage. The observations were recorded on seed yield parameters such as number of seed rows per row, number of seed rows per cob, seed weight, seed yield per plant, seed yield per plot and seed yield per hectare. The data collected from experiments were analyzed statistically by the procedure prescribed by Sundarrajan *et al.* [6]. Critical difference was calculated at 5 per cent level wherever 'F' test was significant. The data on percentage of germination was transferred into Arc Sine values and transferred data was used for statistical analysis.

RESULTS AND DISCUSSION

The higher number of seeds per row (26.20) was observed in P₂ (4:2) followed by P₁ (4:1) (24.38) which was significantly differed with P₃ (5:1) (22.22) at Mandya. Amongst the planting ratios, P₂ (4:2) recorded more number of seeds per cob (329.85 and 320.03), seed weight (99.47 and 93.80 g) and seed yield per plant (106.69 and 100.49 g) which was significantly differed with P₃ (5:1) (269.31 and 270.43), (74.60 and 78.26 g), (77.38 and 82.04 g) at GKVK and Mandya, respectively. Amongst the planting ratios, P₄ (6:2) recorded more seed yield per plot (3.06 and 2.91 kg) followed by P₃ (5:1) (1.86 and 1.97 kg) and P₂ (4:2) (1.71 and 1.61 kg) which was significantly differed with P₁ (4:1) (1.48 and 1.48 kg) at GKVK

and Mandya, respectively. The higher seed yields in planting ratio of 6:2 have been realized due to availability of requisite quantity of pollen to cover the required number of male rows and planting ratio 4:1 did not yield more because of less number female rows per plot and increase in female rows reported in pollen shortage and hence performance was inferior with increased female rows. Yield parameters were more superior with planting ratio of 6:2 as reported by Mahadeshwaran *et al.* [7] in sorghum and Raja Rao and Kulkarni [8] in bajra due to bold sized seeds and optimum development of seeds from better and early pollen source during high stigma receptivity. At GKVK, amongst the planting ratios, P₁ (4:1) recorded more seed yield per hectare (41.09 q) which was on par with P₄ (6:2) (39.90 q) and P₂ (4:2) (39.51 q) which was significantly differed with P₃ (5:1) (35.82 q). The higher seed yield have been realised due to availability of requisite quantity of pollen to cover the required number of female rows as reported by Raja Rao and Kulkarni [8] in pearl millet. Similar results also reported by Jabeen *et al.* [9]; Kumar *et al.* [10] in pearl millet^[5]; Reddy *et al.* [11]; Patil and Bharud [12]; Birendra Prasad [13] in sorghum and Vinutha [14] in maize. With respect to hybrids higher number of seeds per row (28.60 and 29.45), number of seeds per cob (397.59 and 391.83), seed weight (116.71 and 116.08 g), seed yield per plant (121.63 and 123.66 g), seed yield per plot (2.65 and 2.69 kg), and seed yield per hectare (51.02 and 52.00 q) were recorded in H₂ (NAH-1137) followed by H₁ (NAH-2049) (17.87 and 18.68), (199.38 and 198.26), (59.12 and 57.04 g), (64.51 and 59.48 g), (1.41 and 1.30 kg) and (27.14 and 25.10 q) at GKVK and Mandya, respectively.

Table 1 Influence of planting ratios and micronutrients on number of seeds per row and number of seeds per cob in single cross maize hybrids

Cross maize hybrids																	
Treatment	Number of seeds per row								Number of seeds per cob								
	GKVK				Mandya				GKVK				Mandya				
	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	
P ₁	H ₁	17.40	18.13	18.87	18.13	18.87	19.13	19.27	19.09	194.85	203.36	218.53	205.58	196.12	198.92	200.32	198.45
	H ₂	25.73	25.53	28.13	26.47	28.97	29.73	30.33	29.68	343.15	352.59	394.80	363.51	392.18	400.43	412.36	401.66
P ₂	H ₁	19.40	16.40	20.00	18.60	19.67	19.40	19.47	19.51	220.69	181.65	224.00	208.78	208.85	203.00	216.65	209.50
	H ₂	31.07	31.67	33.67	32.13	32.47	32.47	33.73	32.89	438.32	451.84	462.61	450.92	422.49	426.20	443.00	430.56
P ₃	H ₁	16.13	16.60	15.80	16.18	17.93	17.27	18.40	17.87	179.20	173.89	177.88	176.99	187.77	181.95	200.96	190.23
	H ₂	25.73	25.47	27.60	26.27	26.93	26.27	26.53	26.58	360.67	349.07	375.15	361.63	360.65	341.81	349.45	350.64
P ₄	H ₁	19.60	18.53	17.53	18.56	18.60	17.20	18.93	18.24	222.19	197.15	199.12	206.15	198.37	176.65	209.60	194.88
	H ₂	29.67	29.53	29.40	29.53	28.47	28.07	29.40	28.64	414.08	421.47	407.33	414.29	383.00	372.72	397.67	384.46
		P × M				P × M				P × M				P × M			
P ₁		21.57	21.83	23.50	22.30	23.92	24.43	24.80	24.38	269.00	277.97	306.67	284.55	294.15	299.67	306.34	300.05
P ₂		25.23	24.03	26.83	25.37	26.07	25.93	26.60	26.20	329.51	316.75	343.31	329.85	315.67	314.60	329.83	320.03
P ₃		20.93	21.03	21.70	21.22	22.43	21.77	22.47	22.22	269.93	261.48	276.51	269.31	274.21	261.88	275.21	270.43
P ₄		24.63	24.03	23.47	24.04	23.53	22.63	24.17	23.44	318.13	309.31	303.23	310.22	290.69	274.69	303.63	289.67
		H × M				H × M				H × M				H × M			
H ₁		18.13	17.42	18.05	17.87	18.77	18.25	19.02	18.68	204.23	189.01	204.88	199.38	197.78	190.13	206.88	198.26
H ₂		28.05	28.05	29.70	28.60	29.21	29.13	30.00	29.45	389.05	393.74	409.97	397.59	389.58	385.29	400.62	391.83
Mean		23.09	22.73	23.88	23.23	23.99	23.69	24.51	24.06	296.64	291.38	307.43	298.48	293.68	287.71	303.75	295.05
		S.Em±	CD (P=0.05)		CV (%)	S.Em±	CD (P=0.05)		CV (%)	S.Em±	CD (P=0.05)		CV (%)	S.Em±	CD (P=0.05)		CV (%)
P		0.90	NS			0.41	1.83			9.66	43.49			4.29	19.30		
H		0.37	6.72			0.20	3.54			4.25	76.36			4.27	76.79		
M		0.44	NS			0.26	1.61			6.92	NS			5.12	31.16		
P×H		0.75	3.36		9.18	0.39	1.77		5.38	8.50	38.25		11.35	8.55	38.47		8.50
P×M		0.87	NS			0.53	NS			13.83	NS			10.24	35.44		
H×M		0.62	NS			0.37	NS			9.78	NS			7.24	NS		
P×H×M		1.23	NS			0.75	NS			19.56	NS			14.48	NS		

Planting ratios (P)	Hybrids (H)	Micronutrients (M)	NS: Non-Significant
P ₁ : 4:1	H ₁ : NAH-2049	M ₁ : RDF + ZnSO ₄ 10 kg/ha	
P ₂ : 4:2	H ₂ : NAH-1137	M ₂ : RDF + FeSO ₄ 10 kg/ha	
P ₃ : 5:1		M ₃ : RDF + ZnSO ₄ 10 kg/ha + FeSO ₄ 10 kg/ha	
P ₄ : 6:2			

Table 2 Influence of planting ratios and micronutrients on seed weight and seed yield per plant in single cross maize hybrids

Treatment		Seed weight (g/cob)								Seed yield (g/plant)							
		GKVK				Mandya				GKVK				Mandya			
		M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean
P ₁	H ₁	58.72	57.86	59.37	58.65	55.23	56.03	58.92	56.73	61.39	60.86	68.37	63.54	58.36	57.43	64.05	59.95
	H ₂	101.52	101.97	123.88	109.13	115.26	118.46	127.09	120.27	115.19	118.30	130.55	121.35	115.26	125.79	135.09	125.38
P ₂	H ₁	64.84	62.87	66.98	64.90	59.62	57.88	62.86	60.12	71.51	68.87	77.65	72.68	61.22	61.08	66.46	62.92
	H ₂	130.50	132.18	139.42	134.03	124.93	124.10	133.43	127.49	130.50	139.51	152.08	140.70	135.00	134.10	145.10	138.06
P ₃	H ₁	51.75	51.63	53.26	52.21	54.08	52.30	58.71	55.03	58.42	51.63	60.93	56.99	55.82	53.70	60.11	56.54
	H ₂	97.17	96.72	97.07	96.99	105.64	97.68	103.59	102.31	97.17	99.06	97.07	97.76	105.64	104.68	112.26	107.53
P ₄	H ₁	61.15	58.69	62.32	60.72	57.36	51.00	60.46	56.27	61.15	62.35	70.99	64.83	60.49	52.60	62.39	58.49
	H ₂	134.36	123.29	122.46	126.71	114.33	109.16	119.28	114.26	134.36	123.29	122.46	126.71	123.06	118.56	129.35	123.66
		P × M				P × M				P × M				P × M			
P ₁		80.12	79.91	91.63	83.89	85.24	87.24	93.00	88.50	88.29	89.58	99.46	92.44	86.81	91.61	99.57	92.66
P ₂		97.67	97.52	103.20	99.47	92.27	90.99	98.15	93.80	101.00	104.19	114.87	106.69	98.11	97.59	105.78	100.49
P ₃		74.46	74.18	75.16	74.60	79.86	74.99	81.15	78.67	77.79	75.34	79.00	77.38	80.73	79.19	86.19	82.04
P ₄		97.76	90.99	92.39	93.71	85.84	80.08	89.87	85.26	97.76	92.82	96.73	95.77	91.78	85.58	95.87	91.07
		H × M				H × M				H × M				H × M			
H ₁		59.12	57.76	60.48	59.12	56.57	54.30	60.24	57.04	63.12	60.93	69.48	64.51	58.97	56.20	63.25	59.48
H ₂		115.89	113.54	120.71	116.71	115.04	112.35	120.85	116.08	119.30	120.04	125.54	121.63	119.74	120.78	130.45	123.66
Mean		87.50	85.65	90.60	87.92	85.81	83.33	90.54	86.56	91.21	90.48	97.51	93.07	89.36	88.49	96.85	91.57
		S.Em±	CD (P=0.05)		CV (%)	S.Em±	CD (P=0.05)		CV (%)	S.Em±	CD (P=0.05)		CV (%)	S.Em±	CD (P=0.05)		CV (%)
P		1.50	6.77			1.00	4.49			2.20	9.88			2.16	9.71		
H		1.19	21.34			1.54	27.60			1.31	23.56			1.88	33.78		
M		1.86	NS			1.54	9.36			2.04	12.44			2.81	17.08		
P×H		2.38	10.69		10.38	3.07	NS		8.71	2.62	11.80		10.76	3.76	NS		15.01
P×M		3.73	12.89			3.08	NS			4.09	14.15			5.61	NS		
H×M		2.63	NS			2.18	NS			2.89	NS			3.97	24.15		
P×H×M		5.27	NS			4.35	NS			5.78	NS			7.94	NS		

Table 3 Influence of planting ratios and micronutrients on and seed yield per plot and seed yield per hectare in single cross maize hybrids

Treatment		Seed yield (kg/plot)								Seed yield (q/ha)							
		GKVK				Mandya				GKVK				Mandya			
		M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean
P ₁	H ₁	0.98	0.97	1.09	1.02	0.93	0.92	1.02	0.96	27.28	27.05	30.39	28.24	25.94	25.53	28.19	26.55
	H ₂	1.84	1.89	2.09	1.94	1.84	2.01	2.16	2.01	51.20	52.58	58.02	53.93	51.23	55.91	59.56	55.56
P ₂	H ₁	1.14	1.10	1.24	1.16	0.98	0.98	1.06	1.01	26.49	25.51	28.76	26.92	22.67	22.62	24.62	23.30
	H ₂	2.09	2.23	2.43	2.25	2.16	2.15	2.32	2.21	48.33	51.67	56.33	52.11	50.00	49.67	53.74	51.13
P ₃	H ₁	1.40	1.24	1.46	1.37	1.34	1.29	1.44	1.36	27.05	23.90	28.21	26.39	25.84	24.86	27.83	26.18
	H ₂	2.33	2.38	2.33	2.35	2.54	2.51	2.69	2.58	44.98	45.86	44.94	45.26	48.91	48.46	51.97	49.78
P ₄	H ₁	1.96	2.00	2.27	2.07	1.94	1.68	2.00	1.87	25.48	25.98	29.58	27.01	25.20	21.92	26.00	24.37
	H ₂	4.30	3.95	3.92	4.05	3.94	3.79	4.14	3.96	55.98	51.37	51.03	52.79	51.28	49.40	53.89	51.52
		P × M				P × M				P × M				P × M			
P ₁		1.41	1.43	1.59	1.48	1.39	1.47	1.59	1.48	39.24	39.81	44.20	41.09	38.58	40.72	43.87	41.06
P ₂		1.62	1.67	1.84	1.71	1.57	1.56	1.69	1.61	37.41	38.59	42.54	39.51	36.34	36.14	39.18	37.22
P ₃		1.87	1.81	1.90	1.86	1.94	1.90	2.07	1.97	36.02	34.88	36.57	35.82	37.37	36.66	39.90	37.98
P ₄		3.13	2.97	3.10	3.06	2.94	2.74	3.07	2.91	40.73	38.68	40.30	39.90	38.24	35.66	39.95	37.95
		H × M				H × M				H × M				H × M			
H ₁		1.37	1.33	1.52	1.41	1.30	1.22	1.38	1.30	26.57	25.61	29.23	27.14	24.91	23.73	26.66	25.10
H ₂		2.64	2.61	2.69	2.65	2.62	2.62	2.83	2.69	50.12	50.37	52.58	51.02	50.35	50.86	54.79	52.00
Mean		2.01	1.97	2.11	2.03	1.96	1.92	2.11	1.99	38.35	37.99	40.91	39.08	37.63	37.30	40.72	38.55
		S.Em±	CD (P=0.05)		CV (%)	S.Em±	CD (P=0.05)		CV (%)	S.Em±	CD (P=0.05)		CV (%)	S.Em±	CD (P=0.05)		CV (%)
P		0.04	0.17			0.06	0.27			0.97	4.38			0.97	NS		
H		0.03	0.48			0.04	0.70			0.57	10.27			0.80	14.44		
M		0.04	0.25			0.06	0.39			0.84	5.11			1.20	7.30		
P×H		0.05	0.24		10.04	0.08	0.35		15.57	1.14	5.14		10.52	1.61	NS		15.24
P×M		0.08	NS			0.13	NS			1.68	5.81			2.40	NS		
H×M		0.06	NS			0.09	0.55			1.19	NS			1.70	10.32		
P×H×M		0.12	NS			0.18	NS			2.37	NS			3.39	NS		

Significant differences were observed with respect to micronutrient application with more number of seeds per row (24.51), number of seeds per cob (303.75), seed weight (90.54 g) were recorded in M₃ (10 kg ZnSO₄ + 10 kg FeSO₄) which were significantly differed with M₂ (10 kg FeSO₄) (23.69), (287.71) and (83.33 g) at Mandya but non-significant at GKVK. Among the micronutrient application, combined application of 10 kg ZnSO₄ + 10 kg FeSO₄ (M₃) was yielded significantly highest seed yield per plant (97.51 and 96.85 g), seed yield per plot (2.11 and 2.11 kg) and seed yield per hectare (40.91 and 40.72 q) which were significantly differed with M₂ (10 kg FeSO₄) (90.48 and 88.49 g), (1.97 and 1.92 kg) and (37.99 and 37.30 q) at GKVK and Mandya, respectively [15]. Amongst the interaction of planting ratios in hybrids (P x H), significantly more number of seeds per row was recorded in P₂ x H₂ (32.13 and 32.89) which was significantly differed with P₃ x H₁ (16.18 and 17.87) at GKVK and Mandya, respectively. At GKVK significantly more (450.92) number of seeds per cob was recorded in P₂ x H₂ followed by P₄ x H₂ (414.29) which was significantly differed with P₃ x H₁ (176.99). At Mandya significantly more (430.56) number of seeds per cob was recorded in P₂ x H₂ which was on par with P₁ x H₂ (401.66) followed by P₄ x H₂ (384.46) which was significantly differed with P₃ x H₁ (190.23). At GKVK, significantly more seed weight (134.03 g) was recorded in P₂ x H₂ which was on par with P₄ x H₂ (126.71 g) which was significantly differed with P₃ x H₁ (52.21 g). Significantly more seed yield per plant (140.70 g) was recorded in P₂ x H₂ which was on par with P₄ x H₂ (126.71 g) which was significantly differed with P₃ x H₁ (56.99 g) at GKVK, whereas, at Mandya it was found non-significant differences [16-17]. The higher seed yield per plot was recorded in P₄ x H₂ (4.05 and 3.69 kg) followed by P₃ x H₂ (2.35 and 2.58 kg) which was significantly differed with P₁ x H₁ (1.02 and 0.96 kg) at GKVK and Mandya, respectively. At GKVK significantly more seed yield per hectare was recorded in P₁ x H₂ (53.93 q) which was on par with P₄ x H₂ (52.79 q) and P₂ x H₂ (52.11 q) which was significantly differed with P₃ x H₁ (26.39 q). Amongst the interaction of planting ratios and micronutrients, significantly higher number of seeds per cob (329.83) was observed in P₂ x M₃ which was on par with P₂ x M₁ (315.67) which was significantly differed with P₃ x M₂ (261.88) at Mandya. Amongst the interaction of hybrids and micronutrients, higher seed yield per plant (130.45 g), seed

yield per plot (2.83 kg) and seed yield per hectare (54.79 q) was observed in H₂ x M₃ which was significantly differed with H₁ x M₂ (56.20 g), (1.22 kg) and (23.73 q) respectively at Mandya location. This study showed that the Hybrid NAH-1137 significantly outperforms NAH-2049 across all measured yield components and seed yield per hectare at both GKVK and Mandya. Among planting ratios, P₁ (4:1) maximizes overall seed yield per hectare at GKVK (41.09 q/ha), performing on par with P₄ (6:2) at 39.90 q/ha and P₂ (4:2) at 39.51 q/ha. Conversely, P₃ (5:1) consistently produces inferior yields (35.82 q/ha) because the higher proportion of female rows leads to pollen shortages. The combined application of 10 kg ZnSO₄ + 10 kg FeSO₄ significantly improves seed yield compared to applying FeSO₄ alone [18].

CONCLUSION

The study demonstrated that hybrid, planting ratio and micronutrient application significantly influenced seed production and yield attributes at Gandhi Krishi Vignana Kendra (GKVK) and Mandya, Karnataka. Among the hybrids, NAH-1137 (H₂) consistently recorded superior values for seeds per row, seeds per cob, seed weight, seed yield per plant, seed yield per plot and seed yield per hectare compared with NAH-2049 (H₁), indicating its better seed production potential. Among planting ratios, P₁ (4:1) recorded the highest seed yield per hectare at GKVK (41.09 q/ha), while P₄ (6:2) produced the highest seed yield per plot at both locations. The relatively lower performance of P₃ (5:1) was associated with inadequate pollen availability with the increased proportion of female rows. Combined application of 10 kg ZnSO₄ + 10 kg FeSO₄ (M₃) significantly improved seed yield per plant, plot and hectare over FeSO₄ (Ferrous sulfate) alone, demonstrating the benefit of balanced micronutrient nutrition. The interaction effects further indicated that P₂ x H₂ was superior for several yield attributes, while P₄ x H₂ resulted in higher seed yield per plot. Similarly, the H₂ x M₃ combination produced substantially higher seed yield under Mandya conditions. Overall, the results indicate that NAH-1137 combined with an appropriate male : female planting ratio and integrated Zn and Fe nutrition can enhance hybrid seed production, with the optimum planting ratio varying according to the yield component and location.

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