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Effect of Potassium and Nickel nutrition on Total Drymatter and Kernal Yield in Maize under Heat Stress

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A B S T R A C T

A field experiment was conducted during *rabi* 2017-18 and 2018-19 at Agricultural College Farm, Bapatla to study the 'Effect of potassium and nickel nutrition on total drymatter and yield in maize under heat stress'. The experiment was laid out in split plot design with three dates of sowing *viz.*, December 20 (M_1), January 10 (M_2) and January 30 (M_3) as main plots and eight subplot treatments as 100% RDK (control) (S_1), 125% RDK (S_2), 1kg Ni ha^{-1} as nickel chloride (S_3), 2 kg Ni ha^{-1} (S_4), 100% RDK+1 kg Ni ha^{-1} (S_5), 100% RDK+2 kg Ni ha^{-1} (S_6), 125% RDK+1 kg Ni ha^{-1} (S_7) and 125% RDK+2 kg Ni ha^{-1} (S_8). The results revealed that total drymatter and yield in maize was influenced significantly by dates of sowing as well as nutrient treatments during both the seasons. Among the dates of sowing during both the seasons, compared to M_1 the total drymatter was reduced by 8.34, 6.59 per cent in M_2 and 18.38, 11.86 per cent in M_3 whereas the kernal yield was reduced by 17.98, 16.56 per cent in M_2 and 50.23, 48.75 per cent in M_3, due to delayed sowings. Application of potassium and nickel, except nickel application without potassium (S_3 and S_4) all other treatments enhanced the total drymatter by 6.49 to 31.51 per cent during 2017-18 and 4.89 to 24.64 per cent during 2018-19 whereas the kernel yield was increased by 6.56 to 29.98 per cent during 2017-18 and 6.18 to 28.36 per cent during 2018-19. The results revealed that application of potassium and nickel enhances the total drymatter and yield over control at all dates of sowing by contributing to a better plant growth and metabolism so that the plant can overcome the stresses undergone due to delayed sowings to some extent.

Keywords

Otal drymatter, Kernal Yield, RDK (Recommended dose of potassium), Nickel *etc.*

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Introduction

Climate is an important factor affecting plant growth, development and productivity. Changing climate pose serious threat on crops by exposing them to various abiotic stresses as light, temperature, drought, water logging and radiation stress. Of these, temperature stress is one in which both high and low temperatures affect plant growth from sub cellular level to whole plant level, as plant metabolism includes various biochemical reactions that are sensitive to temperature. The increase in mean maximum temperature with corresponding increase in minimum temperature creates heat stress on plants. Heat stress causes multifarious and adverse effects on plant metabolism. Morphophysiological characteristics such as phenology, partitioning, shoot growth and extension were greatly hampered by heat stress (Hasanuzzaman *et al*., 2013). Heat stress during the reproductive phase had more deleterious effects on yield, particularly in cereals by reducing number of grains, grain weight and grain yield as the senescence is accelerated reducing the grain filling period.

Maize is the third most important cultivated cereal after rice and wheat. It belongs to the graminae, and designated as 'Queen of cereal' because of its high yield potential among the cereals.

Maize yield components as kernel number and weight are highly influenced by environmental conditions during anthesis and grain filling period. High temperatures reduces the number of kernals per ear by reducing number of ovules fertilized and developed into kernals as well as by increasing kernel abortion.

In coastal regions of Andhra Pradesh as maize is grown after the harvest of *kharif* wetland paddy. This leads to the situation that crop might face heat stress when it reaches reproductive stage.

Potassium plays an important role in plants under environmental stress conditions. It has a great role in turgor regulation, osmotic adjustment and photosynthetic carbon metabolism. Hence it offers abiotic stress resistance to plants by enhancing photosynthetic rate, plant growth and yield (Egilla *et al*., 2001).

Nickel, the recently recognized essential micronutrient is the active center of the enzyme urease required for nitrogen metabolism in higher plants (Yan *et al*. 2008). At low concentrations, it will contribute to plant growth and development by affecting the activation of many other enzymes and water relations of the plant.

Keeping in view of the above mentioned conditions, an experiment to study the effect of potassium and nickel application on total drymatter and kernel yield in maize under heat stress was taken up.

Materials and Methods

The experiment was conducted at Agricultural College Farm, Bapatla located at 15.54^0 N and 80.25^0 E, situated in the Agro Climatic Zone III. The experiment was laid out in split plot design with three replications, three dates of sowing *viz.*, December 20 (M_1), January 10 (M_2) and January 30 (M_3) as main plots and eight subplot treatments as 100% RDK (control) (S_1), 125% RDK (S_2),1 kg Ni ha^{-1} as nickel chloride (S_3), 2 kg Ni ha^{-1} (S_4), 100% RDK+1 kg Ni ha^{-1} (S_5), 100% RDK+2 kg Ni ha^{-1} (S_6), 125% RDK+1 kg Ni ha^{-1} (S_7) and 125% RDK+2 kg Ni ha^{-1} (S_8).

The total drymatter accumulation was estimated from the three plants sampled from each treatment in three replications. The plant parts were separated and dried to a constant weight in hot-air oven at 80^{o}C for two days and the total dry weight was recorded and expressed in g plant^{-1}.Yield was estimated from the sample collected at the time of maturity. The cobs were harvested from the five tagged plants and dried under sun. After thorough drying, shelling of cobs was done and weight of kernels was recorded and then weight was calculated per hectare.

Results and Discussion

Total drymatter (g plant^{-1})

Data on total drymatter at different days after sowing was presented in Table 1, 2 and 3. The total drymatter increased gradually from 20 DAS to harvest and was influenced significantly greatly by dates of sowing and nutrient application, but their interaction was non significant. At 20 DAS, the highest total drymatter was recorded in timely sown crop, M_1 (16.36 g plant^{-1} during 2017-18 and 17.97 g plant^{-1} during 2018-19) and the lowest in the most delayed crop, M_3 (11.20 g plant^{-1} during 2017-18 and 13.46 g plant^{-1} during 2018-19). The reduction due to the heat stress ranged from 2.23 to 5.16 g plant^{-1} during 2017-18 and 1.94 to 4.51 g plant^{-1} during 2018-19.

Among the subplots, all the treatments except S_3 and S_4, significantly increased the total drymatter compared to control and the enhancement ranged from 1.13 to 5.51 g plant^{-1} during 2017-18 and 0.62 to 4.57 g plant^{-1} during 2018-19. Greater total drymatter was recorded in S_8 (17.71 and 19.39 g plant^{-1} during 2017-18 and 2018-19 respectively) and the lower value in S_3 (10.23 and 12.00 g plant^{-1} during 2017-18 and 2018-19 respectively).

Greater total drymatter at 40 DAS was observed in M_1 (40.05 and 40.75 g plant^{-1} during 2017-18 and 2018-19 respectively) followed by M_2 (36.28 and 38.52 g plant^{-1} during 2017-18 and 2018-19 respectively) and M_3 (32.31 and 35.39 g plant^{-1} during 2017-18 and 2018-19 respectively). Due to delayed sowing a reduction of 3.77 to 7.74 g plant^{-1} during 2017-18 and 2.23 to 5.36 g plant^{-1} during 2018-19 was observed.

With the application of potassium and nickel all the treatments except nickel alone applied treatments as S_3 and S_4, all the other treatments significantly enhanced the total drymatter by 1.88 to 8.98 g plant^{-1} during 2017-18 and 1.65 to 2.84 g plant^{-1} during 2018-19. The highest total drymatter was recorded in S_8 (42.47 and 44.90 g plant^{-1} during 2017-18 and 2018-19 respectively) and the lowest in S_3 (29.85 and 31.70 g plant^{-1} during 2017-18 and 2018-19 respectively).

At 60 DAS during both the years, greater total drymatter was recorded in M_1 (94.72 and 100.39 g plant^{-1}) followed by M_2 (86.63 and 92.93 g plant^{-1}) and M_3 (76.28 and 83.36 g plant^{-1}). The reduction due to the heat stress imposed by delayed sowing ranged from 8.09 to 18.44 g plant^{-1} and 7.46 to 17.03 g plant^{-1} respectively.

All the treatments except S_3 and S_4, significantly enhanced the total drymatter from 3.97 to 19.17 g plant^{-1} during 2017-18 and 3.44 to 19.09 g plant^{-1} during 2018-19 compared to S_1. The highest total drymatter was observed in S_8 (99.30 and 105.36 g plant^{-1} during 2017-18 and 2018-19 respectively) and the lowest in S_3 (72.23 and 79.94 g plant^{-1} during 2017-18 and 2018-19 respectively).

The highest total drymatter was recorded in M_1 (190.79 and 196.96 g plant^{-1} during 2017-18 and 2018-19 respectively) and the lowest in M_3 (149.30 and 160.65 g plant^{-1} during 2017-18 and 2018-19 respectively) at 80 DAS. The reduction due to delayed sowing ranged from 17.90 to 41.49 g plant^{-1} duirng 2017-18 and 15.60 to 36.31 g plant^{-1} duirng 2018-19.

Among the potassium and nickel treatments, except S_3 and S_4, all other treatments enhanced the total drymatter by 8.56 to 40.84 g plant^{-1} during 2017-18 and 7.39 to 40.83 g plant^{-1} during 2018-19 compared to S_1. Greater total drymatter was recorded by S_8 (199.52 and 208.29 g plant^{-1} during 2017-18 and 2018-19 respectively) and the least in S_3 (141.77 and 152.06 g plant^{-1} during 2017-18 and 2018-19 respectively).

At harvest, due to delayed sowing a significant reduction of 20.50 to 45.17 g plant^{-1} during 2017-18 and 17.29 to 31.14 g plant^{-1} during 2018-19 was recorded. Greater total drymatter was recorded in M_1 (245.69 and 262.52 g plant^{-1} during 2017-18 and

2018-19 respectively) followed by M_2 (225.19 and 245.23 g plant^{-1} during 2017-18 and 2018-19 respectively) whereas the least in M_3 (200.52 and 231.38 g plant^{-1} during 2017-18 and 2018-19 respectively).

All the treatments except S_3 and S_4 enhanced the total drymatter compared to S_1 during both the years. It ranged from 13.23 to 64.22 g plant^{-1} and 11.20 to 56.35 g plant^{-1} respectively. The highest value was observed in S_8 (268.04 and 285.08 g plant^{-1} respectively) and the lowest in S_3 (178.94 and 209.38 g plant^{-1} respectively).

The reduction due to delayed sowing ranged from 8.34 to 18.38 per cent during 2017-18 and 6.59 to 11.86 per cent during 2018-19. An increment of 6.49 to 31.51 per cent during 2017-18 and 4.89 to 24.64 per cent during 2018-19 was recorded with potassium and nickel application compared to control.

Reduction in total drymatter might be due to delayed sowing resulted in delayed emergence, slow growth rate, lower photosynthetic rate and reduced translocation of assimilates due to enhanced temperatures.

Potassium promotes photosynthesis by increasing the capturing carbon and enzyme rubisco and encouraging synthesis and assimilates transport in developing plant which helps to increase the dry weight of leaves, shoot, root and total dry weight (Swetha *et al*., 2017).

Swetha *et al*. (2017) reported that application of potassium @ 60 kg K_2O ha^{-1} as well as sulphur @ 40 kg S ha^{-1} increased the dry weight of leaves, shoot, root and total plant at 30, 60 DAS and at harvest in maize.

Gheibi *et al*. (2009) observed that shoot and root dry weights were increased in maize seedlings treated with different nickel levels and supplied with urea instead of ammonium nitrate.

Yield (Kg ha^{-1})

Yield as influenced by dates of sowing, potassium and nickel application was presented in Table 4.

A reduction in yield of 1581.16 to 4416.62 kg ha^{-1} during 2017-18 and 1482.28 to 4362.09 kg ha^{-1} during 2018-19 respectively was observed with delay in sowing dates (M_2 and M_3) compared to timely sown crop (M_1).

The highest yield was recorded in December 20 sown crop (M_1) (8792.43 and 8948.36 kg ha^{-1} during 2017-18 and 2018-19 respectively) followed by M_2 (7211.27 and 7466.08 kg ha^{-1} during 2017-18 and 2018-19 respectively) and the lowest in the late sown crop, M_3 (4375.81 and 4586.27 kg ha^{-1} during 2017-18 and 2018-19 respectively).

During both the years, all the sub plot treatments except application of nickel without potassium (S_3 and S_4) recorded a significant enhancement in yield compared to control (S_1). Maximum yield was observed in 125%K+2 kg Ni ha^{-1} (S_8) (8072.35 and 8256.84 kg ha^{-1} respectively) followed by 125%K+1 kg Ni ha^{-1} (S_7) (7715.90 and 7906.25 kg ha^{-1} respectively) and minimum was recorded with 1 kg Ni ha^{-1} (S_3) (5483.81 and 5714.29 kg ha^{-1} respectively).

Compared to S_1, an increase of 407.28 to 1861.80 kg ha^{-1} and 397.84 to 1824.36 kg ha^{-1} respectively was recorded in all the treatments except in S_3 and S_4.

The reduction in yield ranged from 17.98 to 50.23 percent during 2017-18 and 16.56 to 48.75 per cent during 2018-19 respectively was observed with delayed sowings.

Table.1 Effect of potassium and nickel nutrition on total drymatter (g $plant^{-1}$) at 20 and 40 DAS in maize under heat stress

Treatments	20 DAS								40 DAS							
	2017-18				2018-19				2017-18				2018-19			
	M_1 (Dec 20)	M_2 (Jan10)	M_3 (Jan30)	**Mean**	M_1 (Dec 20)	M_2 (Jan10)	M_3 (Jan30)	**Mean**	M_1 (Dec 20)	M_2 (Jan10)	M_3 (Jan30)	**Mean**	M_1 (Dec 20)	M_2 (Jan10)	M_3 (Jan30)	**Mean**
S_1: 100% RDK	15.28	12.32	9.01	12.20	17.05	14.70	12.72	14.82	37.33	33.61	29.54	33.49	38.10	36.04	32.32	35.49
S_2: 125% RDK	16.08	13.53	10.37	13.33	17.78	15.65	12.91	15.44	38.77	35.50	31.85	35.37	39.93	37.27	34.23	37.14
S_3: 1 kg Ni ha^{-1}	12.14	10.32	8.24	10.23	13.97	12.06	9.97	12.00	33.28	30.00	26.27	29.85	33.78	32.16	29.16	31.70
S_4: 2 kg Ni ha^{-1}	12.83	11.30	8.99	11.04	15.53	13.67	10.47	13.22	34.87	31.50	28.23	31.53	35.50	33.91	30.95	33.46
S_5: $S_1 + S_3$	17.14	14.84	11.53	14.50	18.20	16.53	14.17	16.30	41.07	37.46	33.51	37.34	41.49	39.05	36.69	39.08
S_6: $S_1 + S_4$	18.13	15.79	12.78	15.57	19.10	17.45	14.95	17.17	43.57	39.06	34.30	38.97	44.55	41.98	39.23	41.92
S_7: $S_2 + S_3$	19.11	16.89	13.83	16.61	20.37	18.57	15.72	18.22	45.02	40.60	36.39	40.67	44.81	42.61	38.76	42.06
S_8: $S_2 + S_4$	20.19	18.08	14.87	17.71	21.73	19.66	16.79	19.39	46.46	42.53	38.41	42.47	47.85	45.11	41.74	44.90
Mean	16.36	14.13	11.20		17.97	16.03	13.46		40.05	36.28	32.31		40.75	38.52	35.39	

	2017-18			**2018-19**			**2017-18**			**2018-19**		
	Main plots	**Sub plots**	**Interaction**	**Main plots**	**Sub plots**	**Interaction**	**Main plots**	**Sub plots**	**Interaction**	**Main plots**	**Sub plots**	**Interaction**
SEM±	0.30	0.39	0.67	0.32	0.41	0.70	0.66	0.64	1.10	0.56	0.98	1.70
CD @ 0.05	1.16	1.11	NS	1.27	1.16	NS	2.59	1.82	NS	2.21	2.80	NS
CV%	10.44	8.37		10.04	7.70		8.91	5.30		7.22	7.71	

Table.2 Effect of potassium and nickel nutrition on total drymatter (g plant^{-1}) at 60 and 80 DAS in maize under heat stress

Treatments	60 DAS								80 DAS							
	2017-18				2018-19				2017-18				2018-19			
	M_1 (Dec 20)	M_2 (Jan10)	M_3 (Jan30)	**Mean**	M_1 (Dec 20)	M_2 (Jan10)	M_3 (Jan30)	**Mean**	M_1 (Dec 20)	M_2 (Jan10)	M_3 (Jan30)	**Mean**	M_1 (Dec 20)	M_2 (Jan10)	M_3 (Jan30)	**Mean**
S_1: 100% RDK	89.37	80.69	70.32	80.13	95.25	86.96	76.61	86.27	182.54	160.81	132.69	158.68	186.67	167.63	148.08	167.46
S_2: 125% RDK	93.17	85.12	74.01	84.10	98.19	89.96	80.98	89.71	188.79	168.62	144.32	167.24	194.31	177.03	153.21	174.85
S_3: 1 kg Ni ha^{-1}	80.24	73.44	63.01	72.23	89.61	80.46	69.75	79.94	156.13	144.07	125.11	141.77	164.08	153.18	138.91	152.06
S_4: 2 kg Ni ha^{-1}	83.81	77.16	67.25	76.07	91.73	83.18	72.09	82.34	167.57	151.11	131.11	149.93	172.51	159.88	142.31	158.24
S_5: $S_1 + S_3$	97.45	88.47	78.43	88.12	102.67	95.63	84.95	94.42	195.79	177.48	153.89	175.72	202.27	187.66	161.44	183.79
S_6: $S_1 + S_4$	100.86	92.50	81.53	91.63	105.86	99.53	90.25	98.55	204.73	186.11	160.11	183.65	211.86	192.55	171.71	192.04
S_7: $S_2 + S_3$	105.17	96.03	85.07	95.42	108.58	101.77	93.38	101.24	212.49	193.21	168.65	191.45	219.09	202.49	179.98	200.52
S_8: $S_2 + S_4$	107.69	99.61	90.60	99.30	111.22	105.94	98.90	105.36	218.26	201.75	178.54	199.52	224.86	210.43	189.56	208.29
Mean	94.72	86.63	76.28		100.39	92.93	83.36		190.79	172.89	149.30		196.96	181.36	160.65	

	2017-18			2018-19			2017-18			2018-19		
	Main plots	**Sub plots**	**Interaction**	**Main plots**	**Sub plots**	**Interaction**	**Main plots**	**Sub plots**	**Interaction**	**Main plots**	**Sub plots**	**Interaction**
SEM±	2.03	1.90	3.28	1.91	1.46	2.52	3.33	2.88	4.99	3.68	3.06	5.30
CD @ 0.05	7.98	5.41	NS	7.49	4.15	NS	13.06	8.22	NS	14.45	8.75	NS
CV%	11.59	6.62		10.13	4.73		9.53	5.06		10.03	5.12	

Table.3 Effect of potassium and nickel nutrition on total drymatter (g $plant^{-1}$) at harvest in maize under heat stress

Treatments	2017-18				2018-19			
	M_1 (Dec 20)	M_2 (Jan10)	M_3 (Jan30)	**Mean**	M_1 (Dec 20)	M_2 (Jan10)	M_3 (Jan30)	**Mean**
S_1: 100% RDK	232.45	205.41	173.60	203.82	246.64	225.99	213.56	228.73
S_2: 125% RDK	239.35	219.33	192.47	217.05	257.04	238.52	224.22	239.93
S_3: 1 kg Ni ha^{-1}	191.56	179.78	165.48	178.94	224.37	207.89	195.88	209.38
S_4: 2 kg Ni ha^{-1}	205.76	191.96	175.52	191.08	234.15	216.36	201.60	217.37
S_5: $S_1 + S_3$	252.20	232.39	208.75	231.11	271.39	251.70	238.30	253.8
S_6: $S_1 + S_4$	268.61	248.14	219.18	245.31	280.27	262.91	246.90	263.36
S_7: $S_2 + S_3$	280.75	255.69	228.77	255.07	287.95	274.27	257.80	273.34
S_8: $S_2 + S_4$	294.87	268.86	240.40	268.04	298.32	284.18	272.74	285.08
Mean	245.69	225.19	200.52		262.52	245.23	231.38	

	2017-18			2018-19		
	Main plots	**Sub plots**	**Interaction**	**Main plots**	**Sub plots**	**Interaction**
SEM±	3.16	4.60	7.96	4.24	3.74	6.48
CD @ 0.05	12.39	13.12	NS	16.63	10.67	NS
CV%	6.91	6.16		8.42	4.55	

Table.4 Influence of potassium and nickel nutrition on Kernal yield (kg ha^{-1}) in maize under heat stress

Treatments	2017-18				2018-19			
	M_1 (Dec 20)	M_2 (Jan10)	M_3 (Jan30)	**Mean**	M_1 (Dec 20)	M_2 (Jan10)	M_3 (Jan30)	**Mean**
S_1: 100% RDK	8228.79	6537.01	3865.85	6210.55	8370.51	6775.48	4151.45	6432.48
S_2: 125% RDK	8708.49	6948.59	4196.41	6617.83	8895.46	7168.66	4426.84	6830.32
S_3: 1 kg Ni ha^{-1}	7718.86	5724.74	3007.83	5483.81	7889.15	6047.18	3206.54	5714.29
S_4: 2 kg Ni ha^{-1}	7972.68	6145.44	3358.28	5825.47	8183.21	6426.86	3539.66	6049.91
S_5: $S_1 + S_3$	9180.73	7479.52	4461.79	7040.68	9285.61	7734.05	4694.85	7238.17
S_6: $S_1 + S_4$	9278.85	7868.03	4989.38	7378.76	9415.08	8107.02	5198.79	7573.63
S_7: $S_2 + S_3$	9442.56	8253.48	5451.66	7715.90	9654.63	8534.89	5529.23	7906.25
S_8: $S_2 + S_4$	9808.45	8733.36	5675.24	8072.35	9893.20	8934.50	5942.82	8256.84
Mean	8792.43	7211.27	4375.81		8948.36	7466.08	4586.27	

	2017-18			2018-19		
	Main plots	**Sub plots**	**Interaction**	**Main plots**	**Sub plots**	**Interaction**
SEM±	147.24	121.99	211.29	187.08	122.83	212.74
CD @ 0.05	578.13	348.16	NS	734.55	350.55	NS
CV%	10.62	5.39		13.09	5.26	

An enhancement in yield with all the treatments except S_3 and S_4 compared to S_1 from 6.56 to 29.98 per cent during 2017-18 and 6.18 to 28.36 per cent during 2018-19 respectively was recorded.

Reduction in yield due to delayed sowing might be due to the increased temperatures resulted in delayed emergence, decreased crop growth period, increased anthesis and silking interval leading to reduction in yield components.

The enhancement in yield with potassium and nickel application compared to control (100% RDK) might be due to the reduction in anthesis silking interval leading to better cob filling and test weight of kernals. This indicates the role of potassium and nickel in promoting plant growth and development by overcoming the heat stress faced by late sown crops to some extent through the activation of antioxidant system, maintenance of high relative water content and photosynthetic rate.

Cheikh and Jones (1994) from the results of their experiment reported that long term exposure to high temperature severely disrupted the fresh and dry weights of kernals resulting in abortion of 97% of kernals in maize.

Ahmad and Akram, 2017 observed that application of potassium @ 100 and 200 kg ha^{-1} in maize crop sown under early, optimum and late sown conditions, produced maximum crop stand, cobs per plant, grains per cob, 100 grain weight and grain yield, under optimum sown condition.

Singh *et al*., 2011 reported that application of nickel @ 1 and 2 kg ha^{-1} significantly increased the drymatter yield (45 DAS, straw and grain) of wheat compared to control and higher levels of nickel.

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