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Influence of potash management on yield and economics of *rabi* maize (*Zea mays* L.)

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Abstract
A field experiment was conducted at College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India during *rabi*-summer seasons of the years 2019-20 and 2020-21 to study the influence of potash management on yield and economics of rabi maize (*Zea mays* L.) with different potash management practices *viz;* Control (Without potash fertilizers) , 30 kg K_2O /ha through MOP or SOP or Schoenite with and without KMB @ 1 lit/ha, 45 kg K_2O /ha through MOP or SOP or Schoenite with and without KMB @ 1 lit/ha and Foliar spray of Schoenite @ 1.5% at 30 and 60 DAS . The soil of the experimental plot was loamy sand in texture, marginal in organic carbon, and medium in available phosphorus and potash. Results revealed that 45 kg K_2O /ha through MOP or SOP or Schoenite along with KMB @ 1 lit/ha recorded significantly higher growth and yield attributes *viz;* plant height at 60 DAS and at harvest, cob length and cob girth. They also produced significantly higher grain and stover yield over rest of the treatments. However, higher net monetary returns of ₹ 101643/ha and BCR of 4.39 was fetched under 45 kg K_2O/ha through MOP + KMB @ 1 lit/ha.

Keywords: potash, maize, MoP, SoP, Schoenite, KMB

1. Introduction

Being C_4 plant, maize has the highest genetic yield potential amongst the cereals owing to its better dry matter accumulation efficiency in a unit area and time, which is why, it often refers to as "Miracle Crop", "King of Grain Crops", "Backbone of America" and "Queen of Cereals", as together with rice and wheat, it provides approximately 30% of the food calories to more than 4.5 billion people in 94 developing countries and the demand for maize in these countries is assumed to double by 2050 (Johnston *et al.*, 2011) [6]. Worldwide it occupies an area of about 184 million ha covering 160 countries providing around 36 per cent towards the global food grain production. In India maize has been emerged as the third most important cereal crop, after rice and wheat, occupying an area of 9.60 million ha with the production of 27.15 million tones, having average productivity of about 2.8 tones/ha, whereas in Gujarat, 0.44 million ha area is covered with a production of 0.68 million tones having productivity of 1659 kg/ha (Anon., 2020) [1], which is quite below the national and world average. One of the major factors responsible for lower yield is imbalance fertilization, particularly potassium. Maize has a high production potential as an exhaustive crop for potassium fertilizer. Kusro *et al.*, (2014) [7] reported that more than 400 kg K_2O/ha of potassium is taken up by maize crop under intensive cropping system.

Among potassium sources, muriate of potash (MOP) is the only fertilizer that totally imported in India. Among common potassic fertilizers, sulphate of potash, is mostly used by the majority of growers only because of its low salt index, non-hygroscopic and chlorine free K-fertilizer compared with muriate of potash, but the cost is expensive. Indigenously, Central Salt and Marine Chemicals Research Institute, Bhavnagar, Gujarat and some private agri-input agencies have developed the extraction process of sulphate of potash (K_2SO_4) and schoenite (K_2SO_4, $MgSO_4$) from sea bittern. Among them, indigenously produced double salts of K, *i.e.*, potassium schoenite (molar mass 415 g/mol) is appropriate for use in sandy and alluvial soils providing a readily available supply of Potassium, Magnesium and Sulfur to growing plants in an ideal ratio (Rathore *et al.*, 2014) [14]. Likewise, inoculation of maize plants with *Bacillus mucilaginosus*, *Azotobacter chroococcum* and *Rhizobium* resulted in significant higher mobilization of potassium from waste mica, which in turn act as a source of potassium for plant growth. *Bacillus mucilaginous* and *Bacillus edaphicus* are the most commonly used Potassium solubilising bacteria (KSB) used as biofertilizer. Potassium rock is solubilised by

KSB through production and secretion of organic acids (Han and Lee, 2005) [3]. However, information pertaining to potassium management in maize through different rates and sources of potassium is unknown. With this background present study was conducted to know the effect of different management practices of K on yield and economics of maize crop.

Materials and Methods

A field experiment was conducted at Agronomy Farm, Anand Agricultural University, Anand during the years 2019-20 and 2020-21 to find out influence of different potash management practices on yield and economics of *rabi* maize (*Zea mays* L.). The experimental site was loamy sand in texture, alkaline in nature (8.23 pH) with low soluble salts (0.18 dS/m), organic carbon (0.36%) and available nitrogen (142 (kg/ha)), medium in available phosphorus (36 kg/ha) and available potassium (227 kg/ha). Fourteen potassium management treatments comprising of Control (Without potash fertilizers), 30 kg K_2O /ha through MOP or SOP or Schoenite with and without KMB @ 1 lit/ha, 45 kg K_2O /ha through MOP or SOP or Schoenite with and without KMB @ 1 lit/ha and Foliar spray of Schoenite @ 1.5% at 30 & 60 DAS were studied under Randomized Block Design (RBD). The maize variety GAYMH 3 (Gujarat Anand Yellow Maize Hybrid) was taken for the experiment. Recommended dose of nutrients i.e., 150: 60:00 NPK kg/ ha were applied through fertilizers uniformly in the furrows, wherein, 50% of recommended dose of nitrogen (RDN) and 100% recommended dose of phosphorus were applied as basal, whereas remaining 50% RDN was applied in two equal splits at 30 and 60 DAS. The nitrogen was applied through urea and phosphorus was applied through DAP. Potash fertilizer was applied as per treatment. Potash mobilizing bacteria (KMB) treatment was applied to the soil after sowing with irrigation as per treatment. Foliar spray of Schoenite @ 1.5% was applied at 30 and 60 DAS. Maize crop was sown at 60 cm x 20 cm spacing in experimental plot. Shelling percentage was calculated using following formula.

$$\text{Shelling percentage} = \frac{\text{Weight of grain}}{\text{Weight of cob with shells}} \times 100$$

The harvest index for each treatment was worked out by using formula given by Donald and Hamblin, 1976.

$$\text{HI (\%)} = \frac{\text{Economic yield (kg/ ha)}}{\text{Economic yield (kg/ ha)} + \text{Biological yield (kg/ ha)}} \times 100$$

The benefit: cost ratio was calculated on the basis of formula given below.

$$\text{BCR} = \frac{\text{Total income (₹/ha)}}{\text{Total expenditure (₹/ha)}} \times 100$$

Results and Discussion

The data pertaining to various growth parameter, yield attributes, yield and economics of maize as influenced by different potash management practices with their statistical inference are presented and discussed as under:

A. Growth parameters

The mean data pertaining to periodical plant height of maize measured periodically at 30, 60 DAS and at harvest as influence by different potash management practices.

Table 1: Periodical plant height (cm) of maize as influenced by different treatments of potash (pooled over two years)

Treatments	At 30 DAS	At 60 DAs	At harvest
T_1: Control	61.25	136.89^{g}	159.77^{e}
T_2: 30 kg/ha K_2O through MOP	64.81	145.64^{efg}	164.17^{de}
T_3: 30 kg/ha K_2O through SOP	63.44	142.44^{fg}	161.33^{e}
T_4: 30 kg/ha K_2O through Schoenite	62.46	144.74^{efg}	162.83^{de}
T_5: 30 kg/ha K_2O through MOP + KMB @ 1 lit/ha	70.63	163.12^{abcd}	186.50^{abc}
T_6: 30 kg/ha K_2O through MOP SOP + KMB @ 1 lit/ha	69.33	160.89^{abcde}	182.33^{abcd}
T_7: 30 kg/ha K_2O through Schoenite + KMB @ 1 lit/ha	71.09	165.07^{abc}	187.17^{abc}
T_8: 45 kg/ha K_2O through MOP	67.67	156.58^{abcdef}	172.00^{bcde}
T_9: 45 kg/ha K_2O through SOP	66.89	149.50^{cdefg}	167.83^{cde}
T_{10}: 45 kg/ha K_2O through Schoenite	69.83	153.88^{bcdef}	169.50^{cde}
T_{11}: 45 kg/ha K_2O through MOP + KMB @ 1 lit/ha	73.69	170.64^{a}	196.33^{a}
T_{12}: 45 kg/ha K_2O through SOP + KMB @ 1 lit/ha	71.57	167.08^{ab}	190.17^{ab}
T_{13}: 45 kg/ha K_2O through Schoenite + KMB @ 1 lit/ha	73.00	170.45^{a}	192.83^{a}
T_{14}: Foliar spray of Schoenite @ 1.5% at 30 & 60 DAS	66.08	147.53^{defg}	166.02^{de}
S.Em. ±	1.92	5.08	6.06
C. D. at 5%	NS	Sig.	Sig.
C.V. %	6.92	8.02	8.43

The plant height (Table 1) at 30 DAS did not exert any significant effect in different potash management treatments. However, at later stages, significantly higher plant height of 170.64 cm and 196.33 cm were recorded under the application of 45 kg K_2O/ ha through MOP + KMB @ 1 lit/ha at 60 DAS and at harvest, respectively. This treatment exhibited at par relations under the treatments T_5, T_6, T_7, T_8, T_9, T_{10}, T_{12}, T_{13} and T_{14} at 60 DAS and with treatments T_{13}, T_{12}, T_5, T_6 and T_7 at harvest. Potassium is most pertinent nutrient that has the potential to enhance cell membranes and the generation of turgor in plants. It is also the major cation for the maintenance of cation-anion balances (Rajarathinam, 2006) [13]. Application of potassium at various rates and sources along with KMB might improve the K efficiency and availability to maize. Han *et al.* (2006) [4] reported that KMB plays an important role in mobilizing potassium to the crop. Potassium activates many enzymes and plays an important role in the maintenance of electrical potential genetics. This might be resulted into longer plants at 45 kg K_2O/ha along with KMB @ 1 lit/ha. Similar results were reported by Shinde *et al.* (2011) [16] and Jadhav *et al.* (2012) [5].

B. Yield attributes

Data pertaining to yield attributes of maize as influenced by different potash management on pooled basis are presented in Table 2.

Results revealed that though number of rows per cob, seed index and shelling percentage of maize did not differ remarkably due to different potash management practices on pooled basis, significant differences on cob length, cob girth and harvest index were observed. During pooled analysis significantly higher cob length (25.92 cm) was recorded under application of 45 kg K_2O/ha through MOP + KMB @ 1 lit/ha, but it was comparable with T_{13} and T_{12} treatments. Same trend was observed for cob girth and being at par for the treatments T_2, T_3, T_4, T_1 and T_{14} significantly higher cob girth (19.51 cm) was reported under the same treatment. Harvest index was also observed significantly higher under application of 45 kg K_2O/ha through MOP + KMB @ 1 lit/ha. The significant increase in cob length and cob girth under the treatment might be the result of adequately higher mineralization of potassium at higher dose (45kg/ha), irrespective of the sources, in presence of KMB which might cause cell elongation, root development, enhance accumulation of photosynthates from source to sink and ultimately increase the cob length and cob girth. The results were in conformity with Pathak *et al.* (2002) [11], Louraduraj (2006) [8] and Zakir *et al.* (2019) [17].

In pooled analysis, significantly higher harvest index of maize (42.81%) was recorded under the same treatment of 45 kg K_2O/ha through MOP + KMB @ 1 lit/ha (T_{11}). However, it was found to be substantially at par with all the treatments except T_1, T_2, T_3 and T_4. As harvest index is a ratio of economic yield to the total biological yield, the results are on calculation basis.

Table 2: Influence of different potash management practices on yield attributes of maize (pooled over two years)

Treatments	Cob length (cm)	Cob girth (cm)	Number of rows per cob	Seed Index (g)	Harvest index (%)	Shelling Percentage
T_1: Control	17.87^{f}	15.10^{d}	15.04	19.28	39.20^{e}	73.44
T_2: 30 kg/ha K_2O through MOP	21.17^{cde}	15.82^{cd}	15.52	20.15	41.53^{bcd}	74.32
T_3: 30 kg/ha K_2O through SOP	19.73^{def}	15.55^{cd}	15.31	19.62	41.26^{cd}	73.60
T_4: 30 kg/ha K_2O through Schoenite	19.23^{ef}	14.94^{d}	15.60	19.59	41.06^{d}	74.19
T_5: 30 kg/ha K_2O through MOP + KMB @ 1 lit/ha	22.67^{bc}	18.10^{ab}	16.65	21.52	42.48^{ab}	76.28
T_6: 30 kg/ha K_2O through MOP SOP + KMB @ 1 lit/ha	22.24^{bcd}	17.70^{abc}	16.28	21.26	42.27^{abc}	76.20
T_7: 30 kg/ha K_2O through Schoenite + KMB @ 1 lit/ha	23.17^{bc}	18.15^{ab}	16.81	21.83	42.52^{ab}	76.56
T_8: 45 kg/ha K_2O through MOP	21.06^{cde}	17.05^{bcd}	15.85	21.06	41.86^{abcd}	75.31
T_9: 45 kg/ha K_2O through SOP	20.50^{cdef}	16.57^{bcd}	15.77	20.90	41.76^{abcd}	74.99
T_{10}: 45 kg/ha K_2O through Schoenite	21.83^{cde}	16.83^{bcd}	15.79	20.62	41.78^{abcd}	75.08
T_{11}: 45 kg/ha K_2O through MOP + KMB @ 1 lit/ha	25.92^{a}	19.51^{a}	17.76	23.24	42.81^{a}	78.15
T_{12}: 45 kg/ha K_2O through SOP + KMB @ 1 lit/ha	23.39^{abc}	18.43^{ab}	17.51	22.19	42.61^{ab}	77.05
T_{13}: 45 kg/ha K_2O through Schoenite + KMB @ 1 lit/ha	24.74^{ab}	18.62^{ab}	17.62	22.72	42.66^{a}	77.13
T_{14}: Foliar spray of Schoenite @ 1.5% at 30 & 60 DAS	19.70^{def}	15.55^{cd}	15.66	20.15	41.75^{abcd}	74.49
S.Em. ±	0.68	0.46	0.85	2.11	0.46	0.46
C. D. at 5%	Sig.	Sig.	NS	NS	Sig.	NS
C.V. %	10.02	9.88	6.97	7.21	1.91	6.85
C.V. %	10.02	9.88	6.97	7.21	1.91	6.85

C. Grain and Stover Yields

Data pertaining to grain and stover yield of maize as influenced by different potash management practices are presented in Table 3. Data showed that different potash treatments significantly influenced the grain yield of maize during both the years (2019-20 and 2020-21) as well as in pooled analysis. Among all the treatments tested, treatment with 45 kg K_2O/ha through MOP + KMB @ 1 lit/ha had produced apparently higher grain yield of 5859 kg /ha and 5796 kg/ha during the year 2019-20 and 2020-21, respectively. However, it remained comparable with treatments T_{10}, T_{12}, T_{13}, T_5, T_6, T_{14}, T_7, T_8 and T_9 and treatments T_{10}, T_{12}, T_{13}, T_5, T_6, T_{14}, T_7, T_8, T_2 and T_9 during the year 2019-20 and 2020-21, respectively.

Results of pooled analysis followed the same trend and revealed that significantly higher grain yield of 5828 kg/ha was recorded under the application of 45 kg K_2O/ha through MOP + KMB @ 1 lit/ha (T_{11}), which was closely related to the treatments T_{12}, T_{13}, T_5, T_6 and T_7. Treatment T_{11} produced 59% higher grain yield compared to control (T_1) during the pooled analysis. The results also indicated that treatment with the same rate (45 kg /ha) with SOP and Schoenite as the sources of potash also responded alike to MOP along with KMB. Similarly, all the sources of potash along with KMB at 30 kg/ha were also found analogous with T_{11}. It was also further pointed out that treatments with KMB had significant influence on yield irrespective of rates (30 or 45 kg/ha) and sources (MoP/SoP/Schoenite) might be due to higher mineralization accrued to synergistic impact of KMB on the efficacy of potash.

Grain yield is a consequential effect of cumulative impact of all the growth and yield attributes. This impact was reflected in higher growth and yield attributes like plant height, cob length, cob girth, number of rows per cob and seed index obtained under the same treatment T_{11}. These results are in conformity with findings of Pathak *et al.* (2002) [11], Han *et al.* (2006) [4], Sharma (2011) [15] and Patil *et al.* (2017) [12] on maize.

The results of pooled analysis showed that significantly higher stover yield (7683 kg/ha) of maize recorded under application of 45 kg K_2O/ha through Schoenite + KMB @ 1 lit/ha (T_{13}). However, it was closely related to treatments T_{11}, T_{12}, T_5, T_6 and T_7. An increase over control was reported to the tune of 38.88, 37.11 and 37.26% under T_{11} during the year 2019-20, 2020-21 and in pooled analysis, respectively. An increase in stover yield under the treatments is mainly attributed to growth attributing parameter like plant height. The results are in close conformity with those of Pandey and Avasthi (2014) [10], Maske *et al*. (2015) [9] and Patil *et al.* (2017) [12].

Table 3: Influence of different potash management on yields of maize

Treatments	Grain yield (kg/ha)			Stover yield (kg/ha)		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
T_1: Control	3665^{d}	3623^{d}	3644^{f}	5644^{e}	5551^{c}	5597^{f}
T_2: 30 kg/ha K_2O through MOP	4828^{bc}	4822^{abc}	4825de	6807^{bcd}	6750^{ab}	6779de
T_3: 30 kg/ha K_2O through SOP	4622^{c}	4641^{bc}	4631^{e}	6549^{cd}	6568^{ab}	6559^{e}
T_4: 30 kg/ha K_2O through Schoenite	4541^{c}	4508^{c}	4525^{e}	6491^{d}	6436^{bc}	6463^{e}
T_5: 30 kg/ha K_2O through MOP + KMB @ 1 lit/ha	5554^{ab}	5507^{ab}	5530^{abc}	7533^{ab}	7435^{ab}	7484^{abc}
T_6: 30 kg/ha K_2O through MOP SOP + KMB @ 1 lit/ha	5406^{abc}	5350^{abc}	5378^{abcd}	7385^{abc}	7278^{ab}	7332^{abcd}
T_7: 30 kg/ha K_2O through Schoenite + KMB @ 1 lit/ha	5629^{ab}	5523^{ab}	5576^{abc}	7608^{ab}	7451^{ab}	7530^{abc}
T_8: 45 kg/ha K_2O through MOP	5058^{abc}	5022^{abc}	5040^{bcde}	7037^{abcd}	6950^{ab}	6994^{bcde}
T_9: 45 kg/ha K_2O through SOP	4977^{abc}	4959^{abc}	4968^{cde}	6956^{abcd}	6887^{ab}	6921^{cde}
T_{10}: 45 kg/ha K_2O through Schoenite	4975^{abc}	4973^{abc}	4974^{cde}	6954^{abcd}	6901^{ab}	6928^{cde}
T_{11}: 45 kg/ha K_2O through MOP + KMB @ 1 lit/ha	5859^{a}	5796^{a}	5828^{a}	7838^{a}	7391^{ab}	7615^{ab}
T_{12}: 45 kg/ha K_2O through SOP + KMB @ 1 lit/ha	5649^{ab}	5624^{ab}	5637^{ab}	7628^{ab}	7552^{a}	7590^{ab}
T_{13}: 45 kg/ha K_2O through Schoenite + KMB @ 1 lit/ha	5714^{ab}	5683^{a}	5698^{a}	7755^{a}	7611^{a}	7683^{a}
T_{14}: Foliar spray of Schoenite @ 1.5% at 30 & 60 DAS	4965^{abc}	4973^{abc}	4969^{cde}	6944^{abcd}	6901^{ab}	6923^{cde}
S.Em. ±	268	297	260	265	307	203
C. D. at 5%	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
C.V. %	9.11	10.14	9.64	6.48	7.40	7.07

Table 4: Economics of maize as influenced by various potash management practices (Av. Of two years)

Treatment	Yields (kg/ ha)		Fixed cost (₹ / ha)	Treatment cost (₹ / ha)	Total cost of cultivation (₹ / ha)	Gross realization (₹ / ha)	Net realization (₹ / ha)	BCR
	Grain	Stover						
T_1: Control	3644	5597	28663	00	28663	83032	54369	2.90
T_2: 30 kg/ha K_2O through MOP	4825	6779	28663	800	29463	109310	79847	3.71
T_3: 30 kg/ha K_2O through SOP	4631	6585	28663	1920	30583	104994	74411	3.43
T_4: 30 kg/ha K_2O through Schoenite	4525	6478	28663	3640	32303	102634	70331	3.18
T_5: 30 kg/ha K_2O through MOP + KMB @ 1 lit/ha	5530	7484	28663	920	29583	124997	95414	4.23
T_6: 30 kg/ha K_2O through MOP SOP + KMB @ 1 lit/ha	5378	7332	28663	2040	30703	121615	90912	3.96
T_7: 30 kg/ha K_2O through Schoenite + KMB @ 1 lit/ha	5576	7530	28663	3760	32423	126020	93597	3.89
T_8: 45 kg/ha K_2O through MOP	5040	6994	28663	1200	29863	114094	84231	3.82
T_9: 45 kg/ha K_2O through SOP	4968	6921	28663	2880	31543	112491	80948	3.57
T_{10}: 45 kg/ha K_2O through Schoenite	4974	6928	28663	5488	34151	112626	78475	3.30
T_{11}: 45 kg/ha K_2O through MOP + KMB @ 1 lit/ha	5828	7781	28663	1320	29983	131626	101643	4.39
T_{12}: 45 kg/ha K_2O through SOP + KMB @ 1 lit/ha	5637	7590	28663	3000	31663	127376	95713	4.02
T_{13}: 45 kg/ha K_2O through Schoenite + KMB @ 1 lit/ha	5698	7652	28663	5608	34271	128735	94464	3.76
T_{14}: Foliar spray of Schoenite @ 1.5% at 30 & 60 DAS	4969	6923	28663	776	29439	112514	83075	3.82

Selling price: Seed: ₹ 21.25/ kg, Stover: ₹ 1.0 / kg

D. On Economics

Economics as influenced by different potassium management practices for maize crop comprised of cost of cultivation, gross income, net realization and B:C ratio obtained on hectare basis during the course of investigation are presented in Table 4.

An appraisal of data presented in Table 4 revealed that maximum net realization of ₹ 101643/ ha was fetched under application of 45 kg K2O /ha through MOP + KMB @ 1 lit/ha (T_{11}) followed by treatment 45 kg K2O /ha through SOP + KMB @ 1 lit/ha (T_{12}) of ₹ 95713 / ha. The lowest net realization of ₹ 54369/ ha was realized under treatment observed in control treatment(T_1).

In case of benefit cost ratio, the highest benefit cost ratio of 4.39 was recorded under application of 45 kg K2O /ha through MOP + KMB @ 1 lit/ha (T_{11}) followed by T_5 i.e. 30 kg K2O /ha through SOP + KMB @ 1 lit/ha (4.23) and T_{12} i.e. 45 kg K2O /ha through SOP + KMB @ 1 lit/ha (4.02).

Conclusion

In light of the two years' field experiment, it can be concluded that higher growth, yield attributes, yield and economics of *rabi* maize could be achieved with an application of 45 kg K_2O /ha either through MOP/SOP/Schoenite along with Potash Mobilizing Bacteria (KMB) 1 lit/ha, however, it was found comparable with 30 kg K_2O /ha either through MOP/SOP/Schoenite along with Potash Mobilizing Bacteria (KMB) 1 lit/ha.

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