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Full Length Research Paper

Evaluation of polyhalite in comparison to muriate of potash for corn grain yield in the Southern Highlands of Tanzania

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Recent exploration of new multi-nutrient potassium fertilizers such as polyhalite and a lack of understanding of their effects on corn grain yield performance motivated establishing six corn (*Zea mays L.*) fertilizer trials in the Southern Highland region of Tanzania, under rain-fed conditions, in 2015. The objective was to determine whether applying 20 kg ha^{-1}of K_2O from two different sources together with the recommended practice of 120 and 30 kg ha^{-1}of N and P_2O_5, respectively, with no K_2O, increases corn grain yields. Fertilizer treatments were: 1) Control in which no fertilizer was applied; 2) Recommended practice of 120 and 30kg ha^{-1}of N and P_2O_5(NP); 3) NP + 20 kg ha^{-1} of K_2O as Muriate of Potash (MOP); 4) NP + 20 kg ha^{-1} of K_2O as Polyhalite (POLY4); and 5) NP + MOP + 28 kg S ha^{-1}as Kieserite (MOP + Kieserite). Kieserite was applied at a rate to balance the S applied in the POLY4 treatment. Measured variables were grain yield, stover weight, number of cobs, vigour and plant populations. Treatments of interest were compared by using single degree freedom linear contrasts. All fertilizer treatments significantly outperformed the Control at all locations. The NP, POLY4 and MOP+Kieserite treatments had significantly higher grain yields than MOP at one, two and two out of six locations, respectively. Similarly, NP, POLY4 and MOP+Kieserite treatments had numerically higher grain yields at four, five and five locations, respectively over MOP. When averaged across the six locations, NP, POLY4 and MOP+Kieserite treatments had grain yields 357, 621 and 662 kg ha^{-1}higher than MOP, respectively. These results indicate the importance of sulphur nutrition for corn and that POLY4 is a source of sulphur and potassium for corn production in the Southern Highland regions of Tanzania.

Keywords: Polyhalite, Potassium, Sulphur, Corn, MOP.

INTRODUCTION

Moisture and soil nutrients are major constraints for narrowing the yield gap in Africa (Fischer *et al.*, 2014). Continuous cropping coupled with under application of fertilizers lead to nutrient mining, soil depletion and lower productivity. The old, highly leached soils in Africa's humid and sub-humid zones have inherently low nutrient levels. Nitrogen and phosphorus are generally considered as the most limiting nutrients for crop production in Africa, (Bationo and Mokwunye, 1991).

Scientists at ICRISAT addressed this issue through micro dosing technology, which advocates the application of small and affordable quantities of fertilizer either at the time of planting or as a part of top dressing (ICRISAT, 2009). Micro-dose technology has been widely promoted due to the low fertilizer application rate and the high probability of yield response (Palé *et al.*, 2009) in addition to a favorable fertilizer/grain price ratio. The application and usefulness of this technology is variable as per soil, climate and crop conditions.

For example, in Burkino Faso, micro-dose involves an application of 19 kg ha^{-1}of N and 19 kg ha^{-1} of P_2O_5. We

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extended micro-dose technology to the application of potassium in corn to evaluate the effects of applying 20 kg ha^{-1}of K_2O from two different K sources.

The majority of soils within Tanzania's humid and sub-humid regions are categorized as severely weathered, acidic, and infertile with limited but variable nutrient releasing capacities needed to sustain low-input agriculture (Szilas *et al.*, 2005, Bisanda *et al.*, 1998). Funakawa *et al.* (2012) analyzed 94 soil samples collected from different parts of Tanzania and reported that soil textures were sandy clay loam to clay loam, the dominant clay mineral was kaolinite, and average soil properties were 22 g C kg^{-1} soil, soil pH of6.1, base saturation % of95, and cation exchange capacity (CEC), exchangeable K, Mg and Caas 14, 1.1, 2.8,and 6.9 cmolc kg^{-1}, respectively. According to Wickama *et al.*(2015), 40% of corn area under subsistence farming has potassium levels below the critical minimum, signifying the potential for response to potassium fertilization.

The Southern Highlands of Tanzania is an agriculturally important area growing a range of crops including corn, beans, wheat, potatoes and vegetables. Elevation ranges between 400 to 3000 m.a.s.l. The mean annual rainfall varies from 750 mm to 3500 mm with a unimodal rainfall pattern from May to November. Corn is the major crop and foodstuff in the region and is grown primarily as a monocrop system (Bisanda *et al.*, 1998). Corn grown in this area is within mega maize environment – IV, dry mid-altitude subtropical conditions as defined by Fischer *et al.* (2014) with a potential yield of 9 t ha^{-1}.Current fertilizer recommendations to offset nutrient deficiencies in most parts of Southern Highlands for corn are 80-120 kg N ha^{-1}applied in two split applications and 23-69 kg P_2O_5ha^{-1} applied as a basal application (Lyimo and Temu, 1992; Mowo *et al*, 1993). However, little or no response to N and P fertilizer could result from soil mining of K due to repeated non-application of K fertilizer (Nyambilila *et al*., 2013). Generally, fertilizer sources of these nutrients are urea, single super phosphate (SSP) or triple super phosphate (TSP), Di-Ammonium Phosphate (DAP) and calcium ammonium nitrate (CAN) when used in combination supply the crop's nutrient requirements of calcium and sulphur in addition to N and P.

The global usage of potassium chloride (MOP) as the main potassium fertilizer and the use of different soil testing methods for plant available potassium were recently questioned and critiqued by Khan *et al.* (2014). From their survey of 2100 yield response trials they concluded that there was no beneficial response to MOP fertilizer application, possibly due to chloride toxicity (Khan *et al.*, 2014). However, in their critique of their paper, Bar-Yosef *et al.* (2015) suggested that lack of a beneficial response to MOP could be due to other growth limiting factors such as moisture and nitrogen application. They further argued that MOP should be evaluated at a specific agro climatic zone to avoid the masking effect of agro ecological factors. Khan *et al.* (2015) responded standing by their conclusion that MOP application is not necessary to improve crop yields, adding that results of 224 of the surveyed trials indicated reduced grain yields resulting from MOP application in North America. Khan *et al*. (2014) recommended potassium sulphate (SOP) as an alternative to MOP while Bar-Yosef *et al.* (2015) cited the cost of SOP as a constraint for its wide spread usage.

A search for alternate potassium sources lead to the exploration of polyhalite in North Yorkshire in the United Kingdom (Kemp *et al*., 2016). Polyhalite can decrease reliance on MOP as a potassium source and has an advantage over SOP with lower processing losses. Compared to MOP and SOP, the agronomic performance of polyhalite as a fertilizer is less known. Thus improved understanding of its performance is essential owing to demand for alternative cost effective K resources.

Polyhalite was evaluated for its potassium content by Fraps and Schmidt (1932). However, its use as a commercial fertilizer is becoming popular with the discovery of large quantities in the Zechstein deposits in the North Sea basin, east of the United Kingdom (Kemp *et al.* 2016). POLY4 is the trademark name of a commercial granulated polyhalite fertilizer from Sirius Minerals who is conducting global agronomic trials. Here we refer to Polyhalite in granular form as POLY4.

POLY4's nutrient value is 14% K_2O, 17% CaO, 6% MgO and 19% S, with solubility in water of 27 g L^{-1}at 25 °C and is pH neutral (Sirius Minerals, 2016). In addition, POLY4 can be added to NPK blends without adversely effecting storage life or quality (Albadarin *et al.,* 2017). Agronomic effectiveness of polyhalite in the form of enhanced yields was reported in peanuts (*Arachishypogaea* L.) by Hoang *et al.* (2016) in sandy soils under humid tropical climate of Vietnam. Tiwari *et al.* (2015) evaluated polyhalite as a fertilizer in mustard and sesame and reported increased yields from its application when compared with MOP under sandy loam soils in North India. They attributed such increased yields to the sulphur content of polyhalite. However, no peer reviewed studies have been published to our knowledge that relate to the agronomic performance of POLY4 on any crop under African conditions.

The specific objective of the current study was to evaluate POLY4 as a multi-nutrient fertilizer for corn in the Southern Highland conditions of Tanzania and assess any difference in yield response by changing the potassium source from MOP to POLY4.

MATERIALS AND METHODS

Six corn research trials were established in 2014-15 in major corn growing agro ecological zones of the

Table 1. Details of experimental trials, regions, coordinates, elevation, description and soil series.

Trial name	Uyole	Mbimba	Ismani	Seatondale	Milundikwa	Suluti
Region	Mbeya	Mbeya	Iringa	Iringa	Rukwa	Ruvuma
Latitude	08°.54900′S	09°.04614′S	07°.33410′S	07°.47569′S	07°.40355′S	10°.32491′S
Longitude	033°.30840′E	032°.56380′E	035°.45623′E	035°.41792′E	031°.23507′E	036°.04540′E
Altitude (m)	1783	1501	1343	1537	1838	872
Soil series	MollicAndosol	HumicNitosol	Chromic Cambisol	FerralicCambiso l	FerralicCambiso l	OrthicFerraso l
pH (H_2O)	5.6	5.2	5.6	5.5	5.5	5.3
Organic Carbon (gkg^{-1})	20	18	8	6	25	6
N ($g\ kg^{-1}$)	1.7	2.5	2.3	2.5	2	1.9
P ($mgkg^{-1}$)	2	5	4	13	5	10
CEC (cmol(+)/kg)	18	16	15	5	16.	12
K ($mg\ kg^{-1}$)	917	246	234	117	445	230
Ca ($mg\ kg^{-1}$)	1240	394	774	356	944	270
Mg ($mg\ kg^{-1}$)	149	149	403	192	257	210
Na ($mg\ kg^{-1}$)	262	214	204	209	233	218
S ($mg\ kg^{-1}$)	13	16	36	20	9	12
Fe ($mg\ kg^{-1}$)	105	77	78	26	61	114
Zn ($mg\ kg^{-1}$)	3	1	1	1	1	2
Texture	Sandy clay loam	Clay	Sandy clay	Sandy loam	Sandy clay	Sandy clay
Sand (%)	53	42	60	82	45	64
Silt (%)	22	13	4	2	13	1
Clay (%)	25	45	36	16	42	35

Southern Highlands of Tanzania (Table 1). Locations were selected to represent the major corn growing belt of the Southern Highland region's conditions. Composite soil samples from a depth of 0-25 cm were taken from the experimental sites and sent for analysis at the Agricultural Research Institute-Uyole and Sokoine University of Agriculture soil laboratory to provide information on the general fertility status of the trial sites. Parameters analyzed included soil pH, CEC, exchangeable bases (Ca, Mg, K and Na), particle size analysis, total available phosphorus, total nitrogen, organic carbon, sulphur (S) and micro nutrients (Fe, Zn, Cu and Mn). Soil pH was determined as described by McLean (1982) and the EC was determined using an electrical conductivity meter (Okalebo *et al.*, 1993). The CEC of the soil was determined using the ammonium acetate saturation method as described by Chapman (1965). Exchangeable Ca^{2+} and Mg^{2+} were determined by atomic adsorption spectrophotometry from the ammonium acetate leachate while K and Na were determined by the flame photometer method (Chapman, 1965). Total N was determined by the Micro Kjeldahl digestion-distillation method according to the procedure described by Bremner and Mulvaney (1982). Available phosphorus was determined by the Bray and Kutz method and for soils with pH less than 5.5 the Olsen method (Olsen and Sommers, 1982) was used. Organic carbon content was determined by the Walkley and Black method as described by Nelson and Sommers (1982). The particle size analysis was determined by the hydrometer method after dispersing the soil samples with sodium hexametaphosphate solution (Day, 1965). The textural classes were determined using the USDA textural class triangle (Soil Survey Staff, 1992; Okalebo *et al.*, 1993).

Experiments were sown in the month of November with the onset of rains. Land preparation was done by cultivation followed by one discing. Details of dates and site management were listed in the Table 2.

Treatments were the same in five sites: 1) Control, where no fertilizer was applied; 2) NP, where N and P_2O_5 were applied at 120 and 30 kg ha^{-1}, respectively; 3) MOP, where 20 kg K_2Oha^{-1} was applied as MOP in addition to N and P_2O_5 applied in treatment NP;4) POLY4, where POLY4 supplied 20 kg K_2O ha^{-1} in addition to N and P_2O_5 applied in treatment NP; 5) MOP + Kieserite, where 28 kg S ha^{-1} was applied as Kieserite ($MgSO_4$) to the MOP treatment to supply the same amount of sulphur as in the POLY4 treatment. At the dry area in Ismani location, N and P_2O_5 were applied at a lower rate of 80 and 20 kg ha^1, respectively, with the same K_2O and S fertilizer additions in all treatments.

Nitrogen was split applied, once at pre-planting and another one at V6 growth stage. All phosphorus and potassium fertilizers were applied at seven days before planting and incorporated by discing.

Experimental design at each site was a randomized block design with four replications. Each experimental plot was

Table 2. Dates of various agronomic activities in six corn trials.

	Activity / Location	Uyole	Mbimba	Ismani	Seatondale	Milundikwa	Suluti
1	Planting	20/12/2014	24/12/2014	29/12/2014	31/12/2014	09/01/2015	07/01/2015
2	1st Weeding	05/01/2015	22/01/2015	26/01/2015	23/01/2015	07/02/2015	29/01/2015
3	1st Top dressing	16/01/2015	27/01/2015	03/02/2015	16/02/2015	16/02/2015	30/01/2015
4	2nd Weeding	06/02/2015	05/03/2015	03/03/2015	21/02/2015	10/03/2015	14/02/2015
5	2nd Top dressing	20/02/2015	06/03/2015	04/03/2015	04/03/2015	11/03/2015	16/02/2015
6	Harvesting	10/08/2015	26/07/2015	18/07/2015	19/07/2015	16/07/2015	21/07/2015

6m long by 5m wide with spacing between rows of 75 cm and between plants of 30 cm. Variety UH 615 was seeded at a rate of 25 kg ha^{-1}.

Agronomic data collection started with plant vigour. The vigour were scored from each treatment plot when plants were about to tassel by using visual judgement guided by a scale of 0-5 score. Whereby 0 score means no plants in the plot to be assessed and 5 means best phenotypic expression (gene by environment interaction) expected.

When all plants have tasseled in the field, 10 plants were selected at random from the inner area of (4.5 by 4.5 meters) rows and their heights were measured from the soil surface to the base of the first silk by using a stiff metallic tape measure/ruler. Average heights of the 10 plants measured were used as an indicator plant height of a treatment.

When all crops have dried in the field, July to August in southern highlands of Tanzania, in a net harvest area (4.5 by 4.5 meters), plant stand and cobs harvested from each treatment plot were counted. Total weights of cob and stover per harvest area were measured by using a field measuring scale balance. The stover yields per hectare were directly computed from net area harvested and weights measured. Two samples were taken from the dried cobs in each treatment plots, grain moisture was recorded by using grain moisture tester (Draminski Moisture meter). Finally the grain yields for each plot were computed from the cob weight, adjusted grain moisture (13%) and net harvested area.

Statistical analysis was carried out using Genstat software edition 17 (VSN international, 2011) using ANOVA. Due to interest in the comparison of specific treatments, data was analyzed at each location using single degree freedom orthogonal contrasts when the p value for treatments was less than 0.1. Similarly, data was also analyzed over all trials by using location as a random variable. Here, replication/block was nested within location. Multiple linear regressions were used to identify the important yield attributes influencing the yield.

RESULTS AND DISCUSSION

Yield

When the analysis was performed over all locations, each treatment provided with fertilizer significantly outperformed Control (Table 3). Treatments POLY4 and MOP+Kieserite had significantly higher grain yield than MOP while the recommended NP practice was on par with MOP, POLY4 and MOP+Kieserite. Lower yields in MOP treatment compared to POLY4 and MOP+Kieserite could be attributed to the competition between chloride and sulphate anions for root absorption. This competition could be more severe in MOP treatments due to the addition of chloride anions coupled with the lack of sulphur application (Table 3)

Data was also analyzed by site to look for the detailed performance of each treatment (Table 3). Significant differences among treatments for corn yield were observed at all locations except at Ismani (Fig. 1A). The lack of response to fertilizer at Ismani could be attributed to high temperature and low rainfall resulting in low yields. Mean yields across the treatments at Ismani was 2549 kg ha^{-1} when compared with a mean yield of 5601 kg ha^{-1} for the remaining locations. Treatments containing K_2O application, MOP, POLY4 and MOP + Kieserite, had 481, 496 and 1571 kg ha^{-1}higher grain yield than the recommended practice of NP treatment, although variation was high. Efficient turgor maintenance from potassium application could be a reason for this trend. Multiple linear regressions indicated that the major yield attribute influencing yield at this site were number of cobs followed by plant vigour. These two variables explained 70% of the variation in yield.

Contrary to the trend observed at Ismani, significant differences among treatments were observed at the remaining five sites (Fig.1B to Fig.1F). All fertilizer applied treatments significantly outperformed Control treatment and these results illustrate the importance of N and P in southern high land conditions for corn in Tanzania.

Treatments NP, POLY4 and MOP+Kieserite had significantly higher grain yields than MOP at Uyole (Fig. 1B). High exchangeable soil K content, 917 mg kg^{-1} of soil (Table 1) was observed at this trial site. More understanding is required for this yield reduction from the MOP treatment when compared with the NP treatment. Chloride anions competing with available sulphate ions resulting in reduced tissue sulphur concentrations could have hindered yields in MOP treatment, explaining this result. However, tissue nutrient concentration was not measured in these trials. The yield attribute influencing yield at Uyole was plant vigour which accounted for 43% of the total variation of yield.

Table 3. Table of p values for ANOVA and treatments of interest through contrast analysis for corn grain yield and yield attributes. Analysis was done over all locations. Replication was nested within each location.

Treatments	Grain yield	Stover weight	Crop vigour	Plant height	No. of plants	No. of cobs
ANOVA	<.001	0.085	<.001	<.001	NS	0.002
Control vs POLY4	<.001	NS	<.001	<.001	NS	<.001
NP vs POLY4	NS	NS	0.115	NS	NS	NS
MOP vs POLY4	0.037	NS	0.083	NS	NS	NS
MOP+Kieseritevs POLY4	NS	NS	0.525	NS	NS	NS
NP vs MOP	NS	NS	0.874	NS	NS	NS
MOP+Kieseritevs MOP	0.026	NS	0.019	NS	NS	NS
NP vsMOP+Kieserite	NS	NS	0.028	NS	NS	NS
Control vs NP	<.001	NS	<.001	<.001	NS	0.017
Control vs MOP	<.001	NS	<.001	<.001	NS	0.005
Control vsMOP+Kieserite	<.001	NS	<.001	<.001	NS	<.001

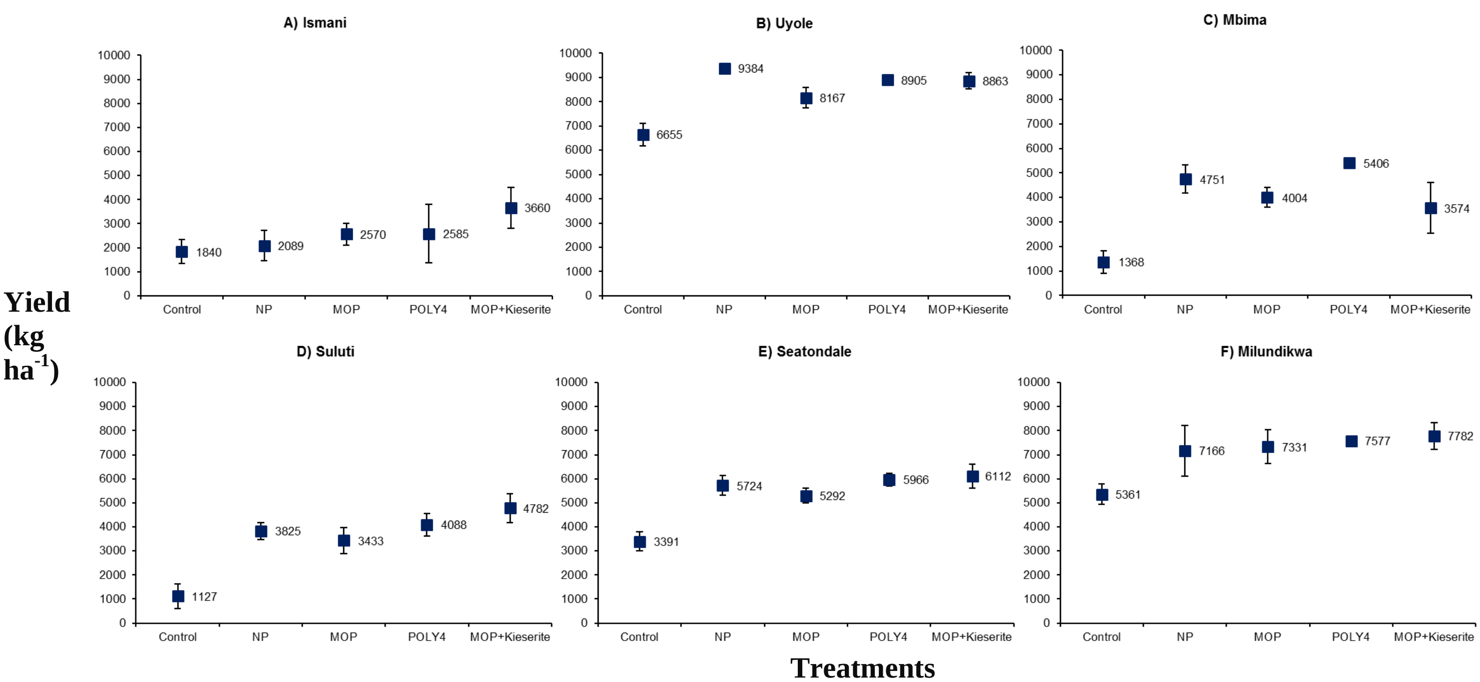

Fig. 1. Effect of treatments on corn grain yield, kg ha^{-1} at six different locations in Southern Highlands of Tanzania. Error bars indicate the standard error of mean. Data labels are mean corn grain yields.

Another instance of reduced yield for MOP treatment was observed at Mbimba. Here, MOP and MOP+Kieserite recorded significantly lower grain yields than POLY4 (Fig. 1C). Although not statistically significant, NP had747 and 1177 kg ha^{-1}higher grain yield than MOP and MOP+Kieserite treatments. Similar to the observation made at Uyole, the only significant variable explaining variation, in yield was plant vigour which was 46% less in the MOP treatments.

At Suluti, MOP+Kieserite significantly outperformed the MOP treatment but not NP or POLY4 treatments. The MOP treatment recorded 392, 655 and 1349 kg ha^{-1} numerically lower grain yields than the NP, POLY4 and MOP+Kieserite treatments (Fig.1D). Again, similar to the trend observed at Ismani, Uyole and Mbimba locations, the major yield attribute influencing yield was crop vigour. Crop vigour along with cob number explained 94% of variation in yield.

At the remaining two locations; Seatondale and Milundikwa, no significant differences among the NP, MOP, POLY4 and MOP+Kieserite treatments were observed (Fig.1E and Fig. 1F). At Seatondale, and Milundikwa, variables plant height and number of cobs explained 84% of variation in grain yield.

In summary, data analysis averaged over all locations indicated that POLY4 and MOP+Kieserite recorded significantly higher yields than MOP (Table 3). Data analysis by location indicated significantly reduced yields for MOP when compared with NP at one out of five responding locations. Similarly, MOP recorded significantly lower yields than both POLY4 and MOP+Kieserite at two locations. MOP

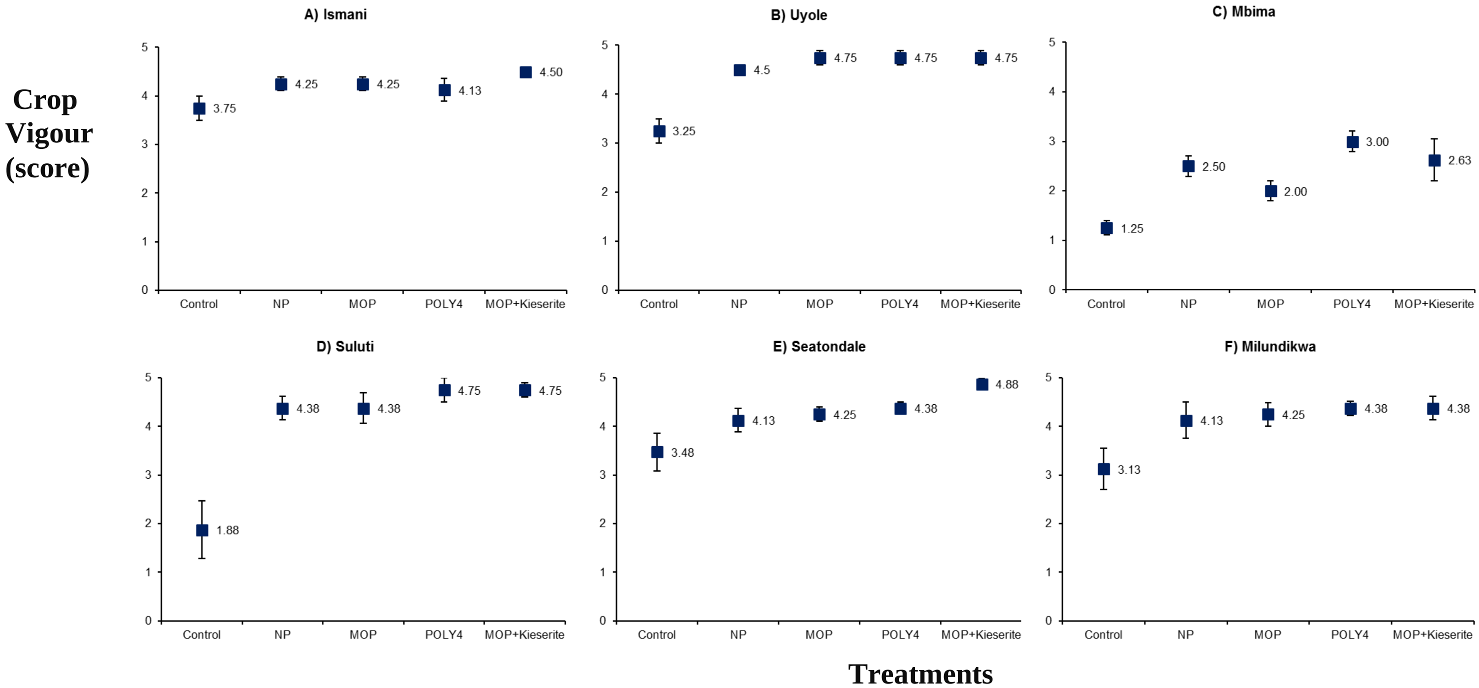

Fig. 2. Effect of treatments on corn vigour at six different locations in Southern Highlands of Tanzania. Error bars indicate the standard error of mean. Data labels are mean corn vigour.

recorded numerically lower yields than NP at four out of five locations. Similarly, POLY4 at five and MOP+Kieserite at four locations recorded numerically higher yields than MOP (Fig. 1). These results could be attributed to the sulphur nutrition from either POLY4 or Kieserite and competition between chloride and sulphate anions. Another reason could be attributed to the higher adsorption or fixation of potassium from MOP to the clay particles. Such adsorption or fixation could be lower for POLY4 or MOP+Kieserite due to the competition between monovalent (K^+) and divalent (Ca^{2+}, Mg^{2+}) cations. There could be other factors such as synchrony between availability of nutrients and peak crop nutrient demand, and differences in rates of application of S, Mg and Ca. There is a need for further and more detailed research including tissue and grain nutrient concentrations to understand the performance of these products.

This six-location data confirms that POLY4 could be used as source of K under the Southern Highland conditions of Tanzania and was on par with MOP+Kieserite on corn grain yield performance.

No statistically significant differences between NP and POLY4, or NP and MOP+Kieserite were observed at all locations. However, POLY4 recorded numerically higher yield than NP practice at four out of five responding locations and the difference across the locations was 218 kg per hectare (Fig.1). In comparison, MOP+Kieserite had numerically higher yield than NP treatment at three out of five responding locations and the difference across all these locations was 53 kg ha^{-1}(Fig.1). The difference between POLY4 and MOP+Kieserite across all locations was 166 kg ha^{-1}. Data showed that the probability of yield response could be increased by switching from MOP to POLY4 as a source of potassium under these micro K dosing conditions.

Similar to the observed results at Suluti, Seatondale and Milundikwa, Ndunguru (2015) reported increased corn grain yield of 1.4 and 1.3 t ha^{-1} by application of 80 kg K_2O through MOP+Sulphur application at two locations, Lusewa and Namabengo, respectively, in the Southern Highlands of Tanzania. Source of sulphur in their study was ammonium sulphate. Significant response to K from MOP at above mentioned sites could be due to low soil K conditions, 62 and 31mg K kg^{-1}, respectively, in comparison to the soil K in the current study which ranged from 112 to 917 mg K kg^{-1}.

Extensive literature is available on the performance of MOP on corn and other crops. However, very few peer reviewed studies were available from the literature in the last two decades pertaining to polyhalite's performance as a fertilizer. Sutradhar *et al*., (2016) evaluated MOP, polyhalite and MOP+Polyhalite blends in Minnesota for corn grain yield. Increased grain yield from polyhalite compared to MOP was attributed to sulphur from polyhalite. These results support the findings of the current study.

Similar to current results regarding the reduced yields for MOP treatment, Wortmann *et al.,* 2009 analyzed 34 corn trials in Nebraska under irrigated conditions and concluded that MOP application at 40 kg ha^{-1} reduced grain and biomass yields. At most of these locations, soil residual potassium was more than 125 ppm.

Vigour

POLY4 and MOP+Kieserite treatments were found to be more vigorous than MOP across all locations (Table 3). Similar to the observations made for grain yield, significant differences among treatments were observed at all locations (Fig.2). As expected, Control was less vigorous than other treatments across all sites. Multiple linear regressions indicate that crop vigour was influencing and explaining the variation in yield. In general, no significant differences among NP, MOP, POLY4 and MOP+Kieserite were observed. Significant correlations between vigour and grain yield were observed at all measured locations. Observed correlation coefficients were 0.74, 0.7, 0.61, 0.79, 0.92, 0.68at Ismani, Mbimba, Milundikwa, Seatondale, Suluti, Uyole, respectively.

Stover weight, plant population, and number of cobs

When the analysis was done for all locations, no significant differences were observed among NP, MOP, POLY4 and MOP+Kieserite for stover weight, plant height, plant population and number of cobs (Table 3).
Significant correlations between plant height and grain yield were observed at all locations including Ismani. Observed correlation coefficients were 0.74, 0.5, 0.62, 0.85, 0.88, and 0.4 at Ismani, Mbimba, Milundikwa, Seatondale, Suluti and Uyole respectively.
As observed for plant height and vigour, significant correlations between the number of cobs and grain yield were observed at all measured locations except Uyole. Observed correlation coefficients were 0.8, 0.54, 0.58, 0.85, and 0.95 at Ismani, Mbimba, Milundikwa, Seatondale, and Suluti respectively.

SUMMARY

In the Southern Highlands region of Tanzania, six corn trials were conducted in 2015 to evaluate polyhalite, trademarked by Sirius Minerals as POLY4, versus recommended NP practice, MOP and MOP+Kieserite. Application of MOP alone did not increase corn grain yield compared to recommended NP practice at any of the six locations but significantly depressed yield at one out of 6 locations. This could be attributed to non sulphur application in MOP treatment besides competition between chloride and sulphate anions for root absorption. Also, the MOP treatment had numerically lower grain yields than NP treatment at four out of six locations. Such reduced yields were not observed for POLY4 and MOP+Kieserite treatment. On the other hand, POLY4 treatment significantly increased grain yield compared to NP at one of five responding sites and numerically enhanced yield at five out of six sites. MOP+Kieserite in general performed similarly to POLY4 which illustrate the value of sulphur to corn yields at these locations. There was no response to magnesium in the fertilizers since soil magnesium levels were high. Comprehensive research including tissue and post-harvest soil nutrient analysis is essential for confirming the results and understanding the reasons and mechanisms of the observed results in the current study.

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