Short communication

Effect of potassium and secondary nutrients on the essential oil and oleoresin contents in kacholam (*Kaempferia galanga* L.)

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Abstract

Kacholam (*Kaempferia galanga* L.) is an important medicinal and aromatic oil yielding crop of Kerala. A study was conducted in the College of Horticulture, Vellanikkara, Kerala to identify the role of potassium and secondary elements, *viz*., sulphur, calcium and magnesium, on the essential oil and oleoresin content of the rhizomes of kacholam. Twelve treatments including the package of practices recommendations of Kerala Agricultural University for kacholam, and combinations of the same with extra dose of potassium, sulphur, calcium and magnesium were applied in the crop in a randomized block design with three replications. Top dressing of sulphur and magnesium resulted in higher rhizome yields (8.56 and 8.24 Mg ha^{-1}). Sulphur application also resulted in higher oleoresin and essential oil contents. Higher sulphur and calcium contents in rhizomes were related to application of these elements. Path co-efficient analysis revealed that the secondary nutrients play a decisive role in the development of oleoresin and essential oil in kacholam.

Key words : Kacholam, *Kaempferia galanga* L., Secondary nutrients, Oleoresin, Essential oil.

Low soil fertility is a major factor responsible for poor crop performance in rainfed agriculture. Widespread nutrient deficiencies and deteriorating soil health are the causes of low nutrient use efficiency, productivity and profitability. Studies conducted all over the country have revealed that Indian soils have low organic carbon, low to moderate available phosphorus, and generally adequate extractable potassium. However, equally important are the reported widespread deficiencies of sulphur, boron, and zinc. In Kerala, of the samples collected from alluvial soil and brown hydromorphic soil, 56 per cent and 83 per cent respectively were sulphur deficient (Nair, 1995). This indicates that deficiency of sulphur and the other secondary nutrients may be involved in low expressed yields and quality. However, there are very few recommendations for these nutrients in crops. The association of sulphur, calcium and magnesium with higher yield and quality in kacholam (*Kaempferia galanga* L.) was reported by Gangadharan and Menon (2003; 2006). The role of potassium in production of curcumin in turmeric has been reported by Akamine et al. (2007). Kacholam is a high value medicinal and aromatic oil yielding crop of Kerala, the rhizomes of which have increasing demand in ayurveda and in the perfumery industry. Hence a study was conducted to identify the influence of potassium and secondary elements, *viz.*, calcium, magnesium and sulphur on the essential oil and oleoresin contents of the rhizomes.

The experiment was conducted at College of Horticulture, Vellanikkara, Thrissur, Kerala during the year 2010-2011. Kacholam was intercropped in a coconut garden according to the recommendations

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of the Kerala Agricultural University (KAU, 2011). Twelve treatments were imposed in a randomized block design with three replications. Treatments were as follows:

T_1 : POP (Package of practices recommendations of Kerala Agricultural University) i.e., 20 Mg FYM and 50:50:50 kg N, P and K ha^{-1}; ½ N, entire P and ½ K applied 1 month after planting (MAP) and ½ N and ½ K applied 3 MAP
T_2 : 10 Mg FYM and NPK as in POP
T_3 : POP plus 20 kg S ha^{-1} applied 1 MAP
T_4 : POP plus 20 kg S ha^{-1} applied 3 MAP
T_5 : POP plus additional 25 kg K ha^{-1} applied 3 MAP
T_6 : T_5 plus 20 kg S ha^{-1} applied 1 MAP
T_7 : T_5 plus 20 kg S ha^{-1} applied 3 MAP
T_8 : POP plus 20 kg S and 20 kg Ca ha^{-1} applied 1 MAP
T_9 : POP plus 20 kg S and 20 kg Mg ha^{-1} applied 1 MAP
T_{10} : 50:50:50 kg N, P and K ha^{-1}
T_{11} : 20 Mg FYM ha^{-1}
T_{12} : Absolute control (no manures or fertilizers)

The yield, nutrient, oleoresin and essential oil contents of rhizomes were recorded and the data were subjected to analysis of variance using the statistical package MSTAT-C (Freed, 1986). Rhizomes were harvested from the net plot area separately for each treatment and the yields were expressed on per hectare basis. Rhizomes were chopped into small pieces and then dried to constant weight at 70^0C to 80^0C in a hot air oven, the dry rhizome yield per plot calculated and expressed on per hectare basis. The contents of major and secondary nutrients in the rhizomes were estimated by standard procedures. N, P and K were estimated by the procedures detailed by Jackson (1973). Ca and Mg contents were estimated by the atomic absorption spectrophotometer (Page, 1982), while S was estimated turbidimetrically using a spectrophotometer (Williams and Steinberg, 1959). Essential oil content of rhizomes was estimated by steam distillation adopting Clevenger trap apparatus, and oleoresin content by soxhlet extraction as per AOAC (1980). Duncan's Multiple Range Test (DMRT) was used to compare means (Duncan, 1955; Gomez and Gomez, 1984). To find out the level of contribution of major and secondary nutrients on the development of oleoresin and essential oil path co-efficient analysis was done as per Singh and Chaudhary (1979).

Data on fresh and dry yields, as well as on oleoresin and essential oil contents of kacholam at harvest are presented in Table 1. Harvest was done seven months after planting. Fresh and dry rhizome yields showed significant difference between the treatments. T_3, in which S was applied as first top dressing one MAP along with package of practices recommendations, and T_9, where Mg was also top dressed along with S, one MAP recorded higher rhizome yields (8.56 and 8.24 Mg ha^{-1}) and the yields obtained from these plots were about 93% and 85% more than absolute control. These treatments were on par with T_4 and T_8, where S alone was given as second top dressing at three MAP and S was applied along with Ca as first top dressing one MAP. But when an extra dose of K was top dressed along with S one MAP and three MAP (T_6 and T_7 respectively), the yields were reduced (5.80 and 5.99 Mg ha^{-1}) as compared to these treatments, but were on par with package of practices recommendations (T_1), while absolute control recorded the lowest yield (4.43 Mg ha^{-1}) . Oleoresin content of rhizomes ranged from 2.07 to 3.07 per cent. There was significant difference among treatments. Oleoresin contents were higher in T_3 and T_4, which received S as first and second top dressing, and these treatments were on par with T1 (POP) and T_{10}, where NPK fertilizers alone were applied. In essential oil content also, T_4 showed the highest value (1.49%), followed by T_9, T_8, T_{10} and T_3 all of which were on par. The lowest content of both oleoresin and essential oil were in T_{12} (absolute control).

Nutrient contents in rhizomes at harvest are given in Table 2.All treatments were on par with regard

Table 1. Rhizome yield and oleoresin and essential oil contents as influenced by nutrient management in kacholam

Treatment No.	Treatment	Fresh yield ($Mg\ ha^{-1}$)	Dry yield ($Mg\ ha^{-1}$)	Oleoresin (%)	Essential oil (%)
T_1	POP	5.94^{bc*}	2.08^{bc}	3.00^{a*}	0.80^{b}
T_2	POP less 10 t FYM	6.28^{b}	2.21^{b}	2.53^{bc}	0.80^{b}
T_3	POP+ S-1 MAP	8.56^{a}	2.84^{a}	3.07^{a}	1.08^{ab}
T_4	POP+ S-3 MAP	8.19^{a}	2.87^{a}	3.07^{a}	1.49^{a}
T_5	POP+ K-3 MAP	5.84^{bc}	2.04^{bc}	2.40^{cd}	0.96^{b}
T_6	POP+ K+S-1 MAP	5.80^{bc}	2.04^{bc}	2.50^{c}	0.96^{b}
T_7	POP+ K+S-3 MAP	5.99^{b}	2.09^{bc}	2.43^{cd}	0.93^{b}
T_8	POP+ S + Ca - 1 MAP	7.64^{a}	2.68^{a}	2.37^{cd}	1.13^{ab}
T_9	POP+ S + Mg - 1 MAP	8.24^{a}	2.89^{a}	2.33^{cd}	1.26^{ab}
T_{10}	50:50:50 kg N,P,K	5.57^{bcd}	2.04^{bc}	2.87^{ab}	1.10^{ab}
T_{11}	FYM alone	4.74^{cd}	1.66^{cd}	2.40^{cd}	0.80^{b}
T_{12}	Absolute control	4.43^{d}	1.55^{d}	2.07^{d}	0.80^{b}

*In a column, means with the same superscript do not differ significantly at 5% level

to N content except for T_{12} (absolute control) and T_{11}, where only FYM was applied. P content was more in T_4 (0.24%), in which S was applied as second top dressing along with package of practices recommendations of Kerala Agricultural University, and was on par with all treatments except T_6 and T_7. In these two treatments, S was top dressed along with additional dose of K at one and three months after planting. K content was more in T_7 (which was top dressed with a higher dose of K along with S at three MAP) and was on par with all treatments from T_1 to T_6. T_3, where S was top dressed at one MAP showed the highest S content (0.31%). T_4, in which S was applied as second top dressing registered the second highest value for S content in rhizomes. T_3 was significantly superior to all other treatments, with respect to S content. Ca contents were highest in T_5 where additional K was top dressed three months after planting and in T_8, the treatment receiving Ca and S as first top dressing, one MAP. Mg showed highest value of 0.23 per cent in T_5, where extra dose of K was top dressed and in T_3, where S was top dressed at one MAP. S, Ca and Mg contents were lowest in absolute control.

To find out the level of contribution of major and

Table 2. Content of nutrients in rhizomes at harvest as influenced by nutrient management in kacholam

Treatment No.	Treatment	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)
T_1	POP	1.92^{ab*}	0.23^{a}	1.74^{ab}	0.22^{d}	0.39^{de}	0.20^{c}
T_2	P0P less 10 t FYM	1.92^{ab}	0.21^{ab}	1.65^{ab}	0.22^{d}	0.33^{e}	0.21^{bc}
T_3	POP+ S-1 MAP	1.76^{abc}	0.21^{ab}	1.67^{ab}	0.31^{a}	0.38^{de}	0.23^{a}
T_4	POP+ S-3 MAP	1.92^{ab}	0.24^{a}	1.81^{ab}	0.28^{b}	0.43^{cd}	0.20^{bc}
T_5	POP+ K-3 MAP	1.69^{abc}	0.21^{ab}	1.86^{ab}	0.24^{d}	0.59^{a}	0.23^{a}
T_6	POP+K+S-1 MAP	1.71^{abc}	0.15^{b}	1.76^{ab}	0.27^{c}	0.50^{bc}	0.19^{cd}
T_7	POP+K+S-3 MAP	1.81^{ab}	0.15^{b}	2.11^{a}	0.26^{c}	0.42^{cd}	0.19^{cd}
T_8	POP+ S + Ca - 1 MAP	1.62^{abc}	0.20^{ab}	1.34^{b}	0.22^{d}	0.53^{ab}	0.21^{bc}
T_9	POP+ S + Mg - 1 MAP	1.92^{ab}	0.18^{ab}	1.44^{b}	0.19^{e}	0.38^{de}	0.22^{ab}
T_{10}	50:50:50 kg N,P,K	1.98^{a}	0.18^{ab}	1.42^{b}	0.17^{f}	0.42^{cd}	0.21^{bc}
T_{11}	FYM alone	1.56^{bc}	0.18^{ab}	1.39^{b}	0.16^{fg}	0.41^{cde}	0.18^{de}
T_{12}	Absolute control	1.38^{c}	0.16^{ab}	1.42^{b}	0.15^{g}	0.33^{e}	0.16^{e}

*In a column, means with the same superscript do not differ significantly at 5% level secondary nutrients at various growth stages on the contents of oleoresin and essential oil, path co-efficient analysis was done. The two dependent characters in the study were oleoresin content and essential oil content. From the data on direct and indirect effect of nutrient contents of rhizomes on oleoresin content (Table 3), it is evident that N, P, Mg and S were significantly and positively correlated with oleoresin content. Rhizome yields, both fresh and dry, also had a strong positive correlation. With regard to the direct effects of nutrients, N, P and S had strong positive effect while K and Ca were negatively related.

From Table 4, it is seen that N, Ca, Mg and S had strong significant positive correlation with essential oil content. N, P and Ca had strong positive direct effect on essential oil content but K was again negatively related. Fresh rhizome yield and oleoresin and essential oil contents were positively related while dry yields exerted negative effects.

The effect of S on increasing rhizome yields was strongly indicated (Table 1). Sulphur is reported to play a major role in increasing nitrogen use efficiency (Fismes et al., 2000; Kopriva and Rennenberg, 2004). Sulphur is also observed to play

Table 3. Direct and indirect effect of nutrient contents and yield of rhizomes on oleoresin content in kacholam

	N	P	K	Ca	Mg	S	FY	DY	Correlation with oleoresin content
N	**0.2827**	0.0176	-0.0841	-0.0137	0.0243	0.1269	0.0985	-0.0828	0.3694**
P	0.0240	**0.2073**	-0.0431	0.0086	0.0134	0.0024	0.0838	-0.0740	0.2225*
K	0.1166	0.0438	**-0.2039**	-0.0215	0.0063	0.1738	0.0150	-0.0049	0.1254
Ca	0.0196	-0.0091	-0.0223	**-0.1971**	0.0293	0.1033	-0.0013	0.0048	-0.0729
Mg	0.0898	0.0364	-0.0168	-0.0754	**0.0765**	0.1140	0.3529	-0.2663	0.3111**
S	0.1048	0.0015	-0.1036	-0.0595	0.0255	**0.3421**	0.2941	-0.2144	0.3905**
FY	0.0428	0.0267	-0.0047	0.0004	0.0414	0.1545	**0.6512**	-0.4933	0.4190**
DY	0.0467	0.0306	-0.0020	0.0019	0.0407	0.1465	0.6414	**-0.5009**	0.4049**
Residual effect (P) : 0.6332									

* Significant at 5% level;** Significant at 1% level; FY – fresh rhizome yield; DY – dry rhizome yield

Table 4. Direct and indirect effect of nutrients contents and yield of rhizomes on essential oil content in kacholam

	N	P	K	Ca	Mg	S	FY	DY	Correlation with essential oil content
N	**0.2913**	0.0126	-0.0074	0.0161	-0.0111	-0.0150	0.3221	-0.2612	0.3475**
P	0.0247	**0.1487**	-0.0038	-0.0102	-0.0062	-0.0003	0.2741	-0.2334	0.1937
K	0.1202	0.0314	**-0.0180**	0.0254	-0.0029	-0.0205	0.0491	-0.0154	0.1694
Ca	0.0202	-0.0065	-0.0020	**0.2330**	-0.0134	-0.0122	-0.0043	0.0152	0.2300*
Mg	0.0926	0.0261	-0.0015	0.0892	**-0.0351**	-0.0134	1.1538	-0.8403	0.4714**
S	0.1080	0.0010	-0.0091	0.0703	-0.0117	**-0.0403**	0.9616	-0.6766	0.4033**
FY	0.0441	0.0191	-0.0004	-0.0005	-0.0190	-0.0182	**2.1288**	-1.5568	0.5971**
DY	0.0481	0.0220	-0.0002	-0.0022	-0.0186	-0.0173	2.0969	**-1.5805**	0.5482**
Residual effect (P) :0.4476									

* Significant at 0.05 level; ** Significant at 0.01 level; FY – fresh rhizome yield; DY – dry rhizome yield

a role in the proper utilization of phosphorus and potassium in plants (Kumar and Singh, 1994). Rhizome yields were also seen to be significantly higher when sulphur was applied in combination with calcium or magnesium (Table 1). Gangadharan (2003) had speculated on the improvement in the development of quantitative yield in kacholam by the application of $MgSO_4$ one month after planting. Similarly, Singh and Dwivedi (1993) reported maximum tuber yields in potato when sulphur was applied through gypsum. Application of additional dose of K three MAP was found to increase Ca and Mg contents of rhizomes at harvest (Table 2), but the effect on S content was inhibitory. Increased potassium doses, when combined with sulphur, produced less yields as compared to application of sulphur, or sulphur with calcium or magnesium along with recommended nutrient doses.

A perusal of the data in Table 1 revealed that accumulation of essential oil strongly followed the trend of rhizome yield. Treatments including sulphur application, either alone (T_3 or T_4) or with calcium or magnesium (T_8 and T_9) along with recommended package of practices resulted in higher essential oil yields. Oleoresin contents followed a slightly different pattern. Though treatments T_3 and T_4 exerted superiority here also, the treatment receiving recommended POP was on par. Ca and Mg application did not improve oleoresin contents. Overall, considering the direct effects, K was seen to be negatively related with both oleoresin and essential oil contents. Ca exerted a negative direct effect on oleoresin content but the effect on essential oil content was positive. Similarly, while S and Mg positively affected oleoresin content, the effect on essential oil content was negative. Different pathways and involvement of different nutrients in development of oleoresin and essential oil are indicated.

Similar results have been obtained in ginger (Haque et al., 2007) and cassava (Suja et al., 2006). Interactions of K and S leading to improved yields and quality have been reported in potato (Lalitha et al., 1997) and onion (Nandi et al., 2002). Trials with varying doses of these elements for arriving at the optimum combination are called for.

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