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Efficiency of sulphate of potash (SOP) as an alternate source of potassium for black pepper (*Piper nigrum* L.)

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Abstract

Field experiments were conducted at two locations, *viz*., Kannur (Kerala) and Chettalli (Kodagu, Karnataka) for evaluating the efficacy of sulphate of potash (SOP) as a source of potassium (K) on black pepper. There were nine treatment combinations *viz*., T_1 -Control, T_2 -Recommended (Rec.) K as muriate of potash (MOP), T_3 -Rec. K as SOP, T_4 -125% of Rec. K as SOP, T_5 -T_3 + SOP 2% foliar spray, T_6 -50% of Rec. K as SOP + SOP 2% foliar spray, T_7 -50% of Rec. K as SOP, T_8 -T_2 + Mg @ 25 kg ha^{-1} as $MgSO_4$ and T_9 - T_3 + Mg @ 25 kg ha^{-1} as $MgSO_4$ laid out in a randomized block design with three replications. The results showed that soil nutrient status in treatment with 25.0% higher recommended K as SOP recorded significantly higher concentrations of soil organic carbon, K, Ca, S, Zn and Cu. The study further revealed that for economic yield of high quality black pepper, 50% of recommended dose of K as SOP for soils of high K status and 100% recommended K as SOP + 2% foliar spray of SOP for soil of low K status can be recommended.

Keywords: economics, nutrition, oleoresin, *Piper nigrum*, piperine, sulphate of potash

Introduction

Area in India under black pepper is 1,83,778 ha with a production of 51,990 tonnes in 2010–11. Although black pepper is native to India, its productivity is low compared to other growing countries and the reasons attributed are poor available soil nutrient status and inadequate nutrient supply and management (Sadanandan *et al*. 2002; Srinivasan *et al*. 2007). Soil survey in major pepper growing regions indicated that soils are low to medium in exchangeable K (Hamza *et al*. 2007). Potassium plays a pivotal role in growth, yield and quality of black pepper and it is essential to supplement it with appropriate K sources (Sadanandan & Hamza 2001). An earlier study indicated that sulphate of potash (SOP) has positively influenced yield and quality of bush pepper (IISR 1996). As SOP is manufactured through physical separation from natural deposits, it can very well fit into organic production package. The aim of the present study is to evaluate SOP under different production systems of black pepper (mono-crop and mixed crop) on yield, quality and economic feasibility.

Materials and methods

The field experiments were conducted in typical black pepper producing areas from 2004 to 2007. Two locations *viz*., one representing plains and

mono-crop situation of black pepper at Kannur District of Kerala and another representing higher elevation as mixed cropping with coffee at Chettalli, Kodagu district of Karnataka were chosen for the study. The soil of Kannur is a *Typic Kandiustult* with clayey, skeletal, kaolinitic, well drained, very deep, surface loamy, gravelly clayey on gentle slopes, moderate-well eroded (Krishnan *et al*. 1996). The Kodagu soil is deep, well drained and clayey with medium available water holding capacity on foot hill slopes with moderately-well drained fine sandy clay, kaolinitic, *Kandic Paleustalf* (Shiva *et al*. 1998). There were nine treatment combinations *viz*., T_1 -Control, T_2 -Recommended (Rec.) K as muriate of potash (MOP), T_3-Rec. K as SOP, T_4 -125% of Rec. K as SOP, T_5 - T_3 + SOP 2% foliar spray, T_6-50% of Rec. K as SOP + SOP 2% foliar spray, T_7-50% of Rec. K as SOP, T_8 - T_2 + Mg @ 25 kg ha^{-1} as $MgSO_4$ and T_9 - T_3 + Mg @ 25 kg ha^{-1} as $MgSO_4$ laid out in a randomized block design with three replications. The Recommended NPK was 140, 55, 270 g per vine in Kannur (soil with low organic matter) and 100, 40, 140 g per vine in Kodagu (soil with high organic matter). Nitrogen and phosphorus were applied as urea and rock phosphate. Estimation of major, secondary and micro nutrients and forms of K was done on soil and leaf samples collected from both the experimental fields, following standard analytical procedures (Sparks 1996). Yield was recorded and quality attributes (oleoresin and piperine) were analyzed as per standard methods (ASTA 1968). The data were analyzed statistically and interpreted. The cost of cultivation of black pepper was worked out for different treatments. The standard package of practices was followed at both the places and the basic cost of cultivation for the standard package was considered as Rs. 32,230. The dry yield was calculated per hectare basis (considering 1000 nos. of vines per ha) and the price of Rs. 235 (average price of five years) was considered as the price of black pepper produce to workout the gross and net return for different treatments. From the returns, the benefit: cost ratio was worked out.

Results and discussion

Effect on soil availability of nutrients

The mean soil nutrient status at Kannur and Kodagu is given in Tables 1 & 2. Results showed that at Kannur, the treatment with 25% higher recommended K as SOP recorded significantly higher concentration of OC, K, Ca, S, Zn and Cu. The control treatment showed the lowest concentration of soil K, Mg, S and Cu. The highest N content was observed in control and P in recommended K as SOP with foliar

Table 1. Effect of sulphate of potash on soil nutrient concentration under black pepper at Kannur (mean of three years)

Treatment	pH	OC (%)	N	P	K	Ca	Mg (mg kg^{-1})	Fe	S	Mn	Zn	Cu
T_1	5.4	1.56	183	41	247	789	157	31	43	18	2.3	13
T_2	5.6	1.40	115	44	351	766	162	33	49	25	2.5	17
T_3	5.5	1.50	90	38	412	767	201	29	119	24	2.4	16
T_4	5.5	2.15	105	38	506	923	169	31	207	23	3.8	24
T_5	5.3	1.65	115	49	359	748	163	39	152	26	2.0	19
T_6	4.9	1.63	105	27	371	786	163	43	72	26	2.5	20
T_7	5.5	1.93	95	34	339	910	167	36	53	22	2.4	16
T_8	4.9	1.75	103	37	269	649	239	38	80	19	1.7	15
T_9	5.6	1.62	90	34	389	723	310	30	154	17	2.9	15
CD (P<0.05)	0.42	0.16	77	13	65	137	35	4.7	21	3.9	0.62	4.9

T_1=Control; T_2=Recommended K as MOP; T_3=Recommended K as SOP; T_4=125% of recommended K as SOP; T_5=T_3 + SOP 2% foliar spray; T_6=50% of recommended K as SOP + SOP 2% foliar spray; T_7=50% of recommended K as SOP; T_8=T_2 + Mg @ 25 kg ha^{-1} as Mg SO_4; T_9=T_3 + Mg @ 25 kg ha^{-1} as Mg SO_4

Table 2. Effect of sulphate of potash on soil nutrient concentration under black pepper at Kodagu (mean of three years)

Treatment	pH	OC (%)	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
			◄				(mg kg^{-1})					►
T_1	4.47	3.4	133	90	236	839	179	60	59	30	4.0	39
T_2	4.11	3.3	161	101	533	823	142	70	65	37	4.3	36
T_3	4.36	3.2	134	89	569	848	178	279	61	30	3.1	38
T_4	4.13	3.1	151	100	905	732	169	304	55	35	3.9	37
T_5	4.00	3.2	155	92	651	813	150	310	59	37	4.1	28
T_6	3.72	3.3	153	87	543	809	148	198	69	36	3.6	34
T_7	3.91	3.4	161	94	479	948	225	176	60	37	4.1	33
T_8	4.11	3.1	141	94	595	729	237	70	69	35	3.8	32
T_9	3.89	3.1	143	92	557	817	308	159	62	35	4.2	33
CD(P<0.05)	0.47	NS	27	NS	78	145	37	41	9.5	NS	NS	6.2

T_1=Control; T_2=Recommended K as MOP; T_3=Recommended K as SOP; T_4=125% of recommended K as SOP; T_5=T_3 + SOP 2% foliar spray; T_6=50% of recommended K as SOP + SOP 2% foliar spray; T_7=50% of recommended K as SOP; T_8=T_2 + Mg @ 25 kg ha^{-1} as Mg SO_4; T_9=T_3 + Mg @ 25 kg ha^{-1} as Mg SO_4

supplementation. $MgSO_4$ applied treatments (T_9 followed by T_8) showed the highest concentration of Mg. When compared over years (data not shown), there was a significant reduction in soil pH, OC, Ca, Mg, Mn, S and Zn contents which might be due to the crop uptake.

At Kodagu, the K concentration was highest in 25% higher recommended K as SOP (T_4), similar to that of Kannur. The pH reduced significantly in SOP treatments as compared to MOP treatments. Roemheld (1983) also reported that application of MOP increased the pH and SOP decreased the pH around the roots of young maize plants. Soil Ca availability was highest in T_7 and the $MgSO_4$ applied treatments recorded higher soil Mg availability. Highest S content was noted in T_5 which was on par with T_4 and T_3 and treatment T_6 showed the highest soil Fe on par with T_7, T_8 and T_9. Over the years, continuous application of fertilizers showed a significant increase in all the major, secondary and micronutrients in the third year as compared to the initial years. The soil K, Ca and Zn contents showed gradual increase over years with the highest buildup in the third year and that of S was maintained over the years (data not shown).

Effect on leaf nutrient concentrations

The mean leaf nutrient status at Kannur and Kodagu is depicted in Tables 3 & 4 respectively. At Kannur, the leaf nutrient concentration varied significantly with respect to all nutrients except Mn, Zn & Cu. Leaf N content was highest in T_8 which was on par with T_1, T_2, T_3, T_7 and T_9. Highest leaf P was noted in the treatments T_2 and T_4. Highest K content was noted in T_5 (2.42%) which was on par with T_4 and T_9 (2.20%). De Waard (1969) reported a critical level of K up to 2% whereas, Sadanandan *et al*. (1996) noted 1.2% to 2.8% as the optimum leaf K level in pepper. The control showed the lowest concentration of leaf P and K. The maximum concentration of leaf Ca, Mg and Fe was noted in the control. When compared over years, there was a significant reduction in leaf P status over years as compared to first year in spite of soil P buildup. The leaf K content increased significantly over years with the highest in the third year. Even though the leaf Ca content was reduced significantly during the second year, it showed an increase in the third year. Fe, Mn, Zn and Cu contents in the leaf showed a reduction in the third year (data not shown).

At Kodagu, the treatment T_3 (recommended K as SOP) registered the maximum content of leaf N, P & K (2.83%, 0.20% and 2.42%, respectively). The N content of T_3 was comparable with that of other treatments except

Table 3. Effect of sulphate of potash on leaf nutrient concentration of black pepper at Kannur (Mean of three years)

Treatment	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	◄		(%)		►	◄	(mg kg^{-1})		►
T_1	2.59	0.29	1.94	1.59	0.35	269	245	16	16
T_2	2.63	0.39	2.03	1.35	0.34	257	190	17	16
T_3	2.55	0.34	2.11	1.55	0.29	251	266	16	16
T_4	2.37	0.39	2.20	1.36	0.28	252	243	16	15
T_5	2.36	0.30	2.42	1.39	0.31	263	239	16	16
T_6	2.44	0.30	2.03	1.43	0.33	243	254	17	16
T_7	2.62	0.31	1.96	1.35	0.30	219	242	16	16
T_8	2.64	0.33	2.08	1.28	0.32	248	226	16	16
T_9	2.56	0.33	2.20	1.25	0.95	240	240	16	17
CD(P<0.05)	0.19	0.07	0.22	0.18	0.05	41	NS	NS	NS

Table 4. Effect of sulphate of potash on leaf nutrient concentration of black pepper at Kodagu (mean of three years)

Treatment	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	◄		(%)		►	◄	(mg kg^{-1})		►
T_1	2.84	0.20	2.16	1.64	0.28	125	371	19	223
T_2	2.81	0.19	2.35	1.58	0.26	115	433	27	281
T_3	2.83	0.20	2.42	1.53	0.28	114	449	22	209
T_4	2.71	0.18	2.31	1.46	0.29	121	444	21	264
T_5	2.82	0.19	2.01	1.52	0.27	118	446	26	270
T_6	2.83	0.19	2.09	1.43	0.23	114	474	20	291
T_7	2.80	0.19	1.88	1.49	0.25	110	365	20	270
T_8	2.78	0.17	1.70	1.49	0.27	108	365	22	290
T_9	2.62	0.19	1.83	1.64	0.27	115	410	21	269
CD(P<0.05)	0.15	NS	0.30	0.19	0.03	NS	78	6.1	52

T_1=Control; T_2=Recommended K as MOP; T_3=Recommended K as SOP; T_4=125% of recommended K as SOP; T_5=T_3 + SOP 2% foliar spray; T_6=50% of recommended K as SOP + SOP 2% foliar spray; T_7=50% of recommended K as SOP; T_8=T_2 + Mg @ 25 kg ha^{-1} as Mg SO_4; T_9=T_3 + Mg @ 25 kg ha^{-1} as Mg SO_4

T_9. Similar to the Kannur, the highest content of leaf Ca, Mg and Fe was observed in the control. Sadanandan *et al*. (2002) also observed a negative correlation of leaf K with Mg. Treatment T6 showed higher Mn content while T_2 recorded the maximum leaf content of Zn and Cu.

Effect on yield of black pepper

At Kannur, the mean yield of three years was found to be on par among the treatments with the maximum of 2.22 kg standard^{-1} in recommended K as SOP with 2% foliar spray (T_5) followed by recommended K as SOP + $MgSO_4$ and recommended K as MOP (Table 5). At Kodagu, highest mean yield of 2.74 kg standard^{-1} was obtained for the treatment recommended K as SOP + 2% foliar spray (T_5) and was on par with 50% of the recommended K as SOP (T_7) and recommended K as SOP + $MgSO_4$ (T_9). The control recorded the lowest yield.

The mean dry yield in Kodagu revealed significantly highest yield in the treatment with recommended dose of K as SOP + 2% foliar spray (920 kg ha^{-1}) which was at par with 50% of the recommended K as SOP (860 kg ha^{-1}) and

Table 5. Effect of sulphate of potash on yield and quality of black pepper (mean of three years)

Treatment	Mean yield (kg standard^{-1})		Oleoresin (%)		Piperine (%)	
	Kannur	Kodagu	Kannur	Kodagu	Kannur	Kodagu
T_1	1.95	1.57	7.75	8.67	5.10	4.73
T_2	2.19	2.30	7.49	8.73	4.99	4.83
T_3	2.04	2.11	7.36	8.77	4.67	4.82
T_4	2.11	2.34	7.55	8.99	4.71	4.75
T_5	2.22	2.74	7.93	10.20	5.11	6.02
T_6	2.17	2.15	7.72	8.89	5.02	5.32
T_7	2.01	2.59	7.47	9.16	5.19	5.87
T_8	1.94	2.11	7.99	8.99	5.09	5.72
T_9	2.20	2.53	7.83	8.05	4.21	4.71
CD(P<0.05)	NS	0.29	0.43	1.20	0.38	0.37

T_1=Control; T_2=Recommended K as MOP; T_3=Recommended K as SOP; T_4=125% of recommended K as SOP; T_5=T_3 + SOP 2% foliar spray; T_6=50% of recommended K as SOP + SOP 2% foliar spray; T_7=50% of recommended K as SOP; T_8=T_2 + Mg @ 25 kg ha^{-1} as Mg SO_4; T_9=T_3 + Mg @ 25 kg ha^{-1} as Mg SO_4

recommended K as SOP + $MgSO_4$ (840 kg ha^{-1}). This was followed by recommended MOP and 125% of K as SOP. But at Kannur, even though higher mean dry yield was recorded in T_2, T_5, T_6 and T_9 treatments, all treatments were on par (Table 7). The overall pooled mean dry yield over locations also revealed significantly higher yield in T_5 followed by T_9 and T_7 treatments. Yadav (2001) also observed that foliar application of potassium sulfate (1.5%) independently or in combination with urea at the pea stage of 8-year-old ber (cv. Umran) trees, improved fruit size, fruit weight, total soluble solids and total sugar. Earlier studies by Amin (1997) also showed higher values for the different growth and yield parameters in spice crops like coriander, fennel and caraway with biofertilizer + half dose of the recommended K as potassium sulphate at par with the full dose (100 kg). Islam (1999) observed that among the sources of potassium, potassium sulphate was superior to other sources in respect of all growth attributes and yield with a 21% increase in yield over the most commonly used MOP in onion.

Table 6. Correlation of soil nutrient levels with yield and quality

	Yield	Oleoresin	Piperine
Oleoresin	0.342*	-	-
Piperine	0.426**	0.844**	-
P	0.332*	-	-
K	0.416**	-	-
Ca	0.322*	-	-
Mg	0.295*	-	-
Fe	-	0.738**	0.537**
Mn	0.294*	0.854**	0.662**
Zn	0.370**	0.301*	0.269*
S	0.361**	0.405**	0.324*

*Significant at p<0.05; **Significant at p<0.01.

Effect on quality of black pepper

The oleoresin, piperine and oil content varied significantly at Kannur. The maximum oleoresin content was noted in T_8 (7.99%), which was on par with T_5 (7.93%), T_9 (7.83%), T_6 (7.72%) and control (7.75%). The highest piperine content was noted in T_7 (5.19%), which was on par with that of T_5 (5.11%), T_1 (5.10%) and T_8 (5.09%). The maximum oil content of 3.3% was noted in T_1, T_2 and T_6 (data not shown).

At Kodagu, T_5 recorded significantly highest oleoresin (10.2%) which was on par with 50% T_7 (9.16%). The piperine content was also high in T_5 (6.02%) and it was on par with T_7 (5.87%) and T_8 (5.72%) (Table 5). The maximum oil content (2.57%) was recorded for T_1 which was on par with all other treatments except T_5, T_6 & T_9.

Table 7. Effect of potassium doses on mean yield, net profit and B: C ratio of black pepper (pooled over locations)

Treatment	Dry yield (kg ha^{-1})		Mean dry yield* (kg ha^{-1})	Net profit (Rs. ha^{-1})	B:C ratio
	Kannur	Kodagu			
T_1	650	520	590	106420	3.30
T_2	730	760	750	141770	4.11
T_3	690	700	700	122270	2.90
T_4	710	780	760	133870	2.99
T_5	740	920	830	150420	3.37
T_6	730	710	720	129570	3.27
T_7	670	860	770	143720	3.86
T_8	650	700	680	124070	3.47
T_9	740	840	790	142170	3.27
CD(P<0.05)	NS	95	60		

T_1=Control; T_2=Recommended K as MOP; T_3=Recommended K as SOP; T_4=125% of recommended K as SOP; T_5=T_3 + SOP 2% foliar spray; T_6=50% of recommended K as SOP + SOP 2% foliar spray; T_7=50% of recommended K as SOP; T_8=T_2 + Mg @ 25 kg ha^{-1} as Mg SO_4; T_9=T_3 + Mg @ 25 kg ha^{-1} as Mg SO_4

The quality parameters when pooled over locations also showed similar pattern (data not shown) with recommended K as SOP + foliar spray (T_5) and 50% of recommended K as SOP (T_7) recording significantly highest piperine followed by T_8. The lowest content of 4.4% was recorded in T_9 and the remaining treatments were also on par with control. In case of oleoresin, T_5 recorded significantly highest content (9.07%) followed by T_8 and T_7, which were on par with other treatments. Horst *et al*. (2002) obtained best results in terms of internal quality in coffee by applying potassium sulphate at a dose of 200 kg K ha^{-1}. Studies by Sadanandan *et al*. (2002) also reported that among different sources of K, potassium sulphate was a better source than potassium chloride or nitrate in optimizing the yield, increasing the berry size and oleoresin content of black pepper.

The correlation studies on soil nutrient availability with yield and quality showed that many of the major, secondary and micro nutrients had significant positive correlation with yield and quality (Table 6). Yield showed highly significant positive correlation (0.416**) with available K followed by soil Zn and S. In addition, soil available P, Ca, Mg and Mn also showed positive correlation with yield. The quality parameters like piperine and oleoresin were mainly influenced by the availability of micronutrients like Fe, Mn, S and Zn. Among these, Mn and Fe showed significantly highest positive influence on oleoresin (0.854** and 0.738**) and piperine (0.662** and 0.537**).

Economics

At Kannur, application of recommended dose of K as MOP (T_2) was found to be the most profitable treatment with a net return of Rs. 1,37,070 followed by T_6 and T_9 with net returns of Rs. 1,31,920 and Rs. 1,30,420, respectively. At Kodagu, application of T_5 was found to be the most profitable treatment with a net return of Rs. 1,71,570 followed by 50% of recommended dose of K as SOP (T_7) and T_9 with net returns of Rs. 1,64,870 and Rs. 1,53,920, respectively (data not shown).

The economics of overall pooled mean dry yield over locations revealed that recommended dose of K as SOP + 2% foliar spray (T_5) recorded highest net return of Rs. 1,50,420 followed by T_7, T_9 and T_2 treatments (Table 7). But the benefit cost ratio was found to be high in MOP treatment (T_2, 4.11) followed by 50% of recommended K as SOP (T_7, 3.86). Even though the SOP treatments have yielded higher with high net profit, the benefit cost ratio was less compared to MOP treatment because of its higher cost (Rs. 20 kg^{-1}) as compared to that of

MOP (Rs. 4.5 kg^{-1}). However, SOP can be used as a supplement for K under certified organic farming systems and a premium price for the black pepper may be expected for the certified organic produce to compensate for the higher price of the input.

The study revealed that for higher yield and quality of black pepper, 50% of recommended dose of K as SOP for soils with high K status and 100% recommended K as SOP + 2% foliar spray for soil with low K status will be optimum as an alternate source of K fertilizer.

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