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Nitrogen and potassium nutrition of French basil (*Ocimum basilicum* Linn.)

E V S Prakasa Rao, K Puttanna, R S Ganesha Rao & S Ramesh

Central Institute of Medicinal and Aromatic Plants, Resource Centre
Allalasandra, Bangalore-560065, India.
E-mail: cimapfsbangalore@vsnl.net

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Abstract

Studies were undertaken on red sandy loam soil (*Kandiustalf*) in a semi-arid tropical climate at Bangalore (Karnataka) to find out the effect of fertilizer application in influencing oil production, quality and soil fertility in French basil (*Ocimum basilicum*). The study showed that application of nitrogen (up to 100 kg ha^{-1}) increased herb and essential oil yields in the main crop, first ratoon and second crop while potassium application (up to 80 kg ha^{-1}) increased the yields in the second ratoon and second crop suggesting that soil potassium depletion occurred with time. Nitrogen application increased methyl chavicol (by 4.1%) and decreased linalool (by 14.2%) contents in basil oil. Yield increases were accompanied by higher removal of nitrogen, phosphorus and potassium from soil (by 247%, 23% and 94%, respectively) by the crop and lower amounts of exchangeable potassium (by 37.8 %) in soil. Due to the depletion of soil potassium, interactions between nitrogen and potassium were significant in the second crop of basil. Application of 100 kg nitrogen ha^{-1} and 80 kg potassium ha^{-1} gave optimum yield and quality of oil.

Keywords: essential oil, French basil, nitrogen, *Ocimum basilicum*, potassium.

Introduction

Ocimum basilicum Linn., commonly known as French basil or sweet basil is an important aromatic plant cultivated in many parts of the world for its essential oil. In India, sweet basil is mainly cultivated in Assam, Bihar, Jammu, Madhya Pradesh, Maharastra, Uttar Pradesh and West Bengal. A fertilizer dose of 100:40:40 N: P_2O_5: K_2O has been recommended for basil (Dhar 2002). Packages for production of basil oil are being developed in a semi-arid tropical climate in South India, where a variety of commercially important essential oils are produced (Rao *et al*. 2000a). It is a common practice by farmers who own distillation units and specialize in production of aromatic crops to grow the same crop repeatedly. The present study deals with improved methods for the production of good quality basil oil by application of nitrogen and potassium.

Materials and methods

The field experiment was conducted during 2000–01 at Central Institute of Medicinal and Aromatic Plants, Resource Centre, Bangalore. Bangalore is located at an altitude of 930 m MSL and the climate is semi-arid tropical. The soil is red sandy loam (*Kandiustalf*) with pH 5.87, electrical conductivity 0.05dS m^{-1}, organic carbon 3.7g kg^{-1}, Olsen's P_2O_5 17.7 kg ha^{-1} and exchangeable K_2O 143.8 kg ha^{-1}. Basil seeds were sown in the nursery on 4 October 2000 and the seedlings were planted in 3.6 m x 3.6 m beds at a spacing of 30 cm x 30 cm on 15 November 2000. The treatments consisting of all combinations of N levels (0, 100, 200 kg ha^{-1}) and K levels (0, 40, 80 kg K_2O ha^{-1}) were arranged in a factorial randomized block design with three replications. The entire quantity of K and a common dose of 40 kg P_2O_5 ha^{-1} were applied as basal dose, whereas, N was applied in 2-monthly equal splits. N was applied in the form of urea, P_2O_5 as super phosphate and K_2O as muriate of potash. One main crop and two ratoons were taken at full bloom on 5 February 2001, 20 March 2001 and 25 April 2001, respectively. Nitrogen alone was applied at half the rates to the ratoon crops. After the second ratoon, the crop was removed and again 50-day old seedlings were planted on 1 May 2001 on the same plot with the same treatments as in the case of the first crop. The second crop was harvested on 16 August 2001.

At each harvest, herb samples of basil were distilled in a Clevenger type apparatus for essential oil determination. Moisture in the herb was determined gravimetrically in duplicate samples by drying to constant weight in a hot air oven at 80°C. The dried material was preserved for nutrient analysis. The oil samples were collected, dried over anhydrous sodium sulphate and were analysed in a Perkin Elmer (PE 8000) gas chromatograph for the major constituents, methyl chavicol and linalool. The gas chromatograph was equipped with a BP-1 column (methyl polysiloxane stationary phase), and flame ionization detector. Nitrogen was used as carrier gas at 10 psi inlet pressure and temperature was programmed from 60 to 220°C at 5°C min^{-1}. Peak identification was done by co-injection with authentic compounds and also by calculating Kovat's index. Essential oil yields were calculated based on herb yields and mean oil contents.

The dried plant samples were powdered in a Wiley Mill and analysed for N, P and K. Soil samples were collected soon after taking second ratoon of first crop on 25 April 2001 and after harvest of second crop on 17 August 2001 and analysed for Olsen's P and exchangeable K. The data were statistically analysed by analysis of variance method (Cochran & Cox 1957).

Results and discussion

The main crop of basil yielded higher quantity of herb; on an average, the herb yield decreased by 30.8%, 72.6% and 50.0% in the first and second ratoon and the second crop, respectively, from the main crop yields (Table 1). Herb yields obtained were higher than earlier findings but they were in agreement with the yield levels reported by Gulati *et al.* (1978). Basil responded to N application in the main and first ratoon crop up to 100 and 50 kg N ha^{-1}, respectively (Table1). There was no response to N application in the second ratoon. Application of K_2O did not affect the herb yield of basil in the main and first ratoon crops; however, in the second ratoon, the plots that had received a basal dose of 80 kg K_2O ha^{-1} yielded significantly higher quantities of herb. This may be due to depletion of soil K with time. Although the interaction effect of N and K on the yield of basil was not significant in any of the three harvests, in order to test whether it becomes significant in another crop of basil, a second crop of basil was taken in the same plots with the same treatments. In the second crop, both main effects of N and K and their interaction effect were significant (Tables. 1 and 2). Basil responded to application of 100 kg N ha^{-1} only when 80 kg K_2O ha^{-1} was applied in the second crop. Lack of response to K in the initial stages and definite response in the later stages indicates depletion of K in the soil with the progress of time and availability of K finally becomes a limiting factor for growth and yield of basil.

As in the case of herb yields, oil yields also reduced with progress of time (Table 1). The mean yields of oil were 55.7, 44.6, 21.8 and 33.6 l ha^{-1} in the main crop, first ratoon, second ratoon and the second crop,

Table 1. Effect of N and K application on herb and oil yield of first crop of basil

Treatment (kg N ha^{-1} $year^{-1}$)	Herb yield (t ha^{-1})				Oil yield (l ha^{-1})				
	Main crop	First ratoon	Second ratoon	Total	Main crop	First ratoon	Second ratoon	Total	Second crop
N level*									
0	4.28	4.29	3.10	11.67	19.9	22.0	20.7	62.6	17.8
100	16.08	9.83	3.15	29.03	75.8	50.3	20.7	146.8	38.6
200	16.62	11.46	3.85	31.91	77.5	58.7	25.4	161.6	41.8
SE±m	1.02	0.96	1.40	1.66	23.2	4.9	2.9	9.4	4.0
CD (P=0.05)	2.10	1.97	NS	3.40	47.7	8.6	NS	19.3	8.1
K level*									
0	11.60	7.63	2.91	22.14	54.0	39.1	19.2	112.3	29.2
40	12.12	8.89	3.17	24.17	56.4	45.6	20.8	122.8	29.9
80	13.20	9.04	4.06	26.30	61.5	46.3	26.7	134.5	39.2
SE±m	1.02	0.96	0.40	1.66	23.2	8.6	2.9	9.4	4.0
CD (P=0.05)	NS	NS	1.09	NS	NS	NS	5.9	16.5	8.1

* Only N at half the above rates was applied to ratoons; NS=Not significant; Interaction of N and K was not significant

Table 2. Interaction effect of N and K application on herb and oil yield of second crop of basil

N level (kg N ha^{-1} $year^{-1}$)	Herb yield (t ha^{-1}) K level (kg K_2O ha^{-1} $year^{-1}$)			Oil yield (l ha^{-1}) K level (kg K_2O ha^{-1} $year^{-1}$)		
	0	40	80	0	40	80
0	4.37	2.81	2.81	23.2	15.0	15.0
100	5.74	6.36	9.63	30.6	34.0	51.3
200	6.29	7.62	9.58	33.6	40.7	51.1
SE±m		1.28			6.6	
CD (P=0.05)		2.63			14.0	

respectively. There was response to N up to 100 kg ha^{-1} in the first harvest and second crop and up to 50 kg ha^{-1} in the first ratoon (Table 1). The effect of K and the interaction of N and K on basil oil yields were not significant. There was no significant response to N in the second ratoon. However, there was response to K in the second ratoon and in the second crop. Application of 80 kg K_2O ha^{-1} increased basil oil yields over control but application of 40 kg K_2O ha^{-1} and control were on par. In the second crop, interaction effect of N and K on basil oil yields was also significant (Table 2). High yields of basil oil were produced when both N at 100 or 200 kg ha^{-1} and K_2O at 80 kg ha^{-1} were applied.

The oil content in basil is generally not affected by application of N and K, except occasionally (Gulati *et al.* 1978). The mean oil content on dry basis was 2.78%. The oil content in aromatic crops is mainly genetically controlled. In the main and second crops combination of high levels of N and K slightly decreased oil content in basil.

Composition of oil

Methyl chavicol: Higher application of N (100 or 200 kg ha^{-1}) significantly increased the concentration of methyl chavicol in basil oil (Table 3).

Linalool: Application of N (100 or 200 kg ha^{-1}) significantly decreased the concentration

Table 3. Effect of N and K on quality of basil oil

Treatment (kg ha^{-1} $year^{-1}$)	First crop (Main)		First ratoon		Second ratoon		Second crop	
	% L	% M	% L	% M	% L	% M	% L	% M
N level*								
0	27.4	66.6	31.9	61.6	28.7	66.0	26.8	65.3
100	24.2	60.9	26.8	66.6	27.7	68.0	24.9	67.0
200	23.2	71.5	25.6	60.8	25.5	69.5	24.2	68.2
SE±m	0.73	0.75	0.52	0.51	0.90	0.59	0.63	0.66
CD (P=0.05)	1.5	1.5	1.5	1.5	1.8	1.2	1.3	1.4
K level*								
0	25.1	69.9	27.8	65.6	27.7	67.7	25.7	66.4
40	24.8	68.7	28.3	65.4	27.6	67.7	25.4	67.1
80	24.9	68.8	28.1	65.1	26.6	68.2	24.8	67.2
SE±m	0.73	0.75	0.52	0.50	0.90	0.59	0.63	0.66
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

*Only N at half the above rates were applied to ratoons; M=Methyl chavicol; L=Linalool; NS=Not significant

of linalool in basil oil (Table 3). Methyl chavicol and linalool were negatively correlated ($r^*=-0.84$). The essential oil composition of several aromatic crops were reported to be unaffected by application of fertilizers (Rao 1992; Puttanna *et al*. 2001). However, in some short duration aromatic crops like *Tagetes minuta* L. (Rao *et al*. 2000b) and *Foeniculum vulgare* Mill. (Kahn *et al*. 1999), changes in essential oil composition due to fertilizer application have been reported. Gulati *et al.* (1978) also reported about 4% increase in methyl cinnamate content in a chemotype of basil oil on application of 120 kg ha^{-1} N.

Nitrogen content

The N content in basil was not affected by treatments (data not presented). The mean N content in the main crop, first ratoon, second ratoon and the second crop of basil were 1.81%, 1.41%, 1.36% and 1.49%, respectively. Nitrogen content in basil was negatively correlated with linalool content ($r^*=-0.53$) and it was positively correlated with methyl chavicol content ($r^*=0.61$) in basil oil.

Potassium content

The K content in basil was not affected by the treatments in the first crop (Table 4). When no K was applied, the concentration of this element in basil decreased in successive harvests. This might be due to decreasing supply of K to basil. Potassium supply from the soil might have been sufficient for the main crop; therefore there was no increase in K content on its application. In subsequent harvests, application of N decreased K content in basil. This might have been caused by the dilution effect of increased herb yields due to N application over control.

Phosphorus content

Application of N up to 200 kg ha^{-1} decreased the P content in basil significantly. In the first ratoon, application of N up to 100 kg ha^{-1} decreased the P content. In the second ratoon, application of N at 50 or 100 kg ha^{-1} decreased the P content but 50 and 100 kg N treatments were on par. Application of K at 80 kg ha^{-1} increased the P content significantly (Table 4), which was pronounced in 100 and 200 kg ha^{-1} N levels. In the second crop, application of 200 or 100 kg ha^{-1} N were on par.

The decrease in P content in basil on N application may be caused by dilution effect of increased herb yields. Puttanna (2000) observed similar dilution effect in citronella. The increase in P content on application of K

Table 4. Effect of N and K application on P and K contents of basil

Treatment (kg ha^{-1} year^{-1})	Main crop		First ratoon		Second ratoon		Second crop	
	P (%)	K (%)	P (%)	K (%)	P (%)	K (%)	P (%)	K (%)
N level*								
0	0.37	2.06	0.43	1.89	0.37	1.42	3.94	1.73
100	0.26	1.82	0.33	1.35	0.29	1.08	3.12	1.35
200	0.27	1.89	0.28	1.33	0.30	1.16	3.13	1.46
SE±m	0.03	0.20	0.03	0.12	0.03	0.09	0.04	0.10
CD (P=0.05)	0.07	NS	0.07	0.25	0.07	0.19	0.07	0.21
K_2O level*								
0	0.30	1.82	0.35	1.38	0.31	1.08	0.40	1.10
40	0.28	1.90	0.34	1.46	0.28	1.05	0.38	1.64
80	0.31	2.04	0.35	1.73	0.37	1.53	0.35	1.79
SE±m	0.03	0.20	0.03	0.12	0.03	0.09	0.04	0.10
CD (P=0.05)	NS	NS	NS	0.25	0.07	0.19	NS	0.21

*Only N at half the above rates was applied to ratoons; NS=Not significant; Interaction effects were not significant.

might be because uptake of K as a cation facilitated the uptake of P in anionic forms.

Nitrogen uptake

In each harvest, application of N up to the highest level significantly increased N uptake (Table 5). The main effect of K on N uptake was not significant in any harvest. However, the interaction effect of N and K application was significant in the main crop, first ratoon, as well as the second crop. In general, application of K increased the uptake of N. Nitrification of applied N is known to be rapid in these soils (Puttanna 2000). Uptake of K in cationic form might have facilitated the uptake of nitrate.

Potassium uptake

In general, application of a high dose of nitrogen increased the uptake of K (Table 5). There was no significant increase in the uptake of K due to application of K in the main crop but in all subsequent harvests K uptake was increased by K application. In the second crop, the interaction effect of N and K was also significant. When no N was applied, application of K to the soil was not effective in increasing the uptake of K by basil.

Phosphorus uptake

Application of N up to 200 kg ha^{-1} increased P uptake by the main crop (Table 5). In the first ratoon, application of N up to 100 kg ha^{-1} increased P uptake by basil. In the second ratoon, application of N had no significant effect on uptake of P by basil. On the other hand, application of K_2O at 80 kg ha^{-1} increased the uptake of P significantly over control as well as over application of K_2O at 40 kg ha^{-1}. Application of N up to 200, 100, 100 kg ha^{-1} for the main crop, first ratoon and second ratoon, respectively, increased the total uptake of P by basil. None of the treatments had any effect on the uptake of P by the second crop.

Exchangeable potassium in soil

Exchangeable K in the soil decreased due to cultivation of basil. Application of N up to 200, 100, 100 kg ha^{-1} for the main crop, first ratoon and second ratoon, respectively, resulted in decrease in soil exchangeable K_2O after the first crop from 143.8 to 77.6 kg ha^{-1}. Application of K_2O to basil at 80 kg ha^{-1} resulted in a higher level of soil exchangeable K_2O (100.1 kg ha^{-1}), than when no K was applied (76.5 kg ha^{-1}). After the second crop,

Table 5. Effect of N and K application (kg ha^{-1} year^{-1}) on uptake of N and K (kg ha^{-1}) by basil

N level*	K_2O level*	Main crop			First ratoon			Second ratoon			Second crop		
		N uptake	P uptake	K uptake	N uptake	P uptake	K uptake	N uptake	P uptake	K uptake	N uptake	P uptake	K uptake
0	0	10.89	2.83	15.69	3.06	3.30	13.19	6.77	2.46	8.19	13.66	4.59	14.01
	40	10.85	2.93	15.30	10.81	4.26	19.32	9.60	2.29	9.38	8.40	3.46	12.85
	80	12.41	3.08	18.51	8.70	3.23	16.76	7.40	2.55	10.82	7.74	3.12	14.57
100	0	43.70	7.10	37.40	11.40	4.58	14.39	7.54	1.57	5.10	20.27	4.65	10.23
	40	46.44	8.24	49.59	28.75	6.24	26.93	9.11	1.81	6.40	16.47	3.38	15.20
	80	48.95	9.15	67.09	26.51	6.05	31.31	10.62	2.85	11.82	26.80	5.60	30.00
200	0	54.21	6.52	48.39	32.73	5.68	25.21	9.95	1.80	6.65	19.77	4.49	12.32
	40	71.39	7.98	57.64	29.21	5.33	23.82	11.17	1.92	6.97	26.67	5.00	24.93
	80	54.62	7.25	46.93	33.98	6.06	31.43	15.73	4.01	16.79	23.54	5.00	26.42
$SE\pm m_N$		4.91	0.73	5.72	2.72	0.64	3.22	1.48	0.33	1.51	1.98	0.5	2.40
$SE\pm m_K$		4.91	0.73	5.72	2.72	0.64	3.22	1.48	0.33	1.51	1.98	0.65	2.40
$SE\pm m_{N \times K}$		8.51	1.26	9.91	4.71	1.10	5.57	2.57	0.57	2.62	3.43	1.13	4.15
$CD\ (P=0.05)_N$		10.08	1.49	11.74	5.58	1.30	6.60	3.04	NS	NS	4.07	NS	4.92
$CD\ (P=0.05)_K$		NS	NS	NS	NS	NS	6.60	NS	0.68	3.10	NS	NS	4.92
$CD\ (P=0.05)_{N \times K}$		17.48	NS	NS	9.66	NS	NS	NS	NS	NS	7.04	NS	8.51

*Only N at half the above rates was applied to ratoons; NS=Not significant the K_2O content in the soil showed significant differences due to N and K interaction. Application of K_2O to basil at 80 kg ha^{-1} resulted in higher level (100.1 kg ha^{-1}) of K_2O in soil. When no N was applied, application of 40 kg K_2O ha^{-1} was not sufficient and soil exchangeable K_2O was brought down to 69.3 kg ha^{-1}.

Available phosphorus in soil

Available P in soil increased after cultivation of basil (data not presented). None of the treatments had any significant effect on the P content in soil either after the first or second crop of basil. This might indicate that the application of 40 kg P_2O_5 ha^{-1} as a common dose was adequate.

The study indicated that optimum application of N and K fertilizers augmented essential oil yield of basil. N application also tended to improve methyl chavicol content in oil. Since K depletion took place with continuous cropping of French basil as indicated by soil and plant data, proper combination of N and K is important for sustained production of the crop in this region.

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