Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(4): 1980-1983
Received: 24-05-2018
Accepted: 30-06-2018

Nishchitha M
Student, Plantation, Spices, Medicinal and Aromatic Crops, UHS, Bagalkot, Karnataka, India

Hiremath JS
Assistant professor, Plantation, Spices, Medicinal and Aromatic Crops, UHS, Bagalkot, Karnataka, India

Mahantesh PS
Student, Plantation, Spices, Medicinal and Aromatic Crops, UHS, Bagalkot, Karnataka, India

Pooja MR
Student, Plantation, Spices, Medicinal and Aromatic Crops, UHS, Bagalkot, Karnataka, India

Lokesh CH
Student, Plantation, Spices, Medicinal and Aromatic Crops, UHS, Bagalkot, Karnataka, India

Correspondence
Nishchitha M
Student, Plantation, Spices, Medicinal and Aromatic Crops, UHS, Bagalkot, Karnataka, India

Effect of integrated nutrient management on growth, physiological parameters and yield of Kalmegh (*Andrographis paniculata* Nees.)

Nishchitha M, Hiremath JS, Mahantesh PS, Pooja MR and Lokesh CH

Abstract
Effect of organic, inorganic and bio-fertilizer on growth, yield and quality of kalmegh was studied in a field experiment entitled “Integrated nutrient management in kalmegh (*Andrographis paniculata* Nees.)” during the year 2015-16 at Department of Plantation, Spices, Medicinal and Aromatic Crops at Kittur Rani Channamma College of Horticulture, Arabhavi, University of Horticultural Sciences, Bagalkot. At harvest (120 DAP), maximum number of branches per plant (39.53), leaf area (1003.52 cm^2), leaf area index (2.230), specific leaf area (57.72 cm^2 g^{-1}), higher dry herb yield per plot and hectare (3.57 kg and 6.38 t respectively) were noticed in plants provided with 100:75:50 kg NPK per ha + *Azatobacter* (1 q) enriched in FYM (5 t ha^{-1}) + vermicompost 1 t per ha.

Keywords: growth, yield, days after planting, FYM, NPK

Introduction
Kalmegh (*Andrographis paniculata* Nees.) an acanthaceae member is indigenous to India and has been used in Indian systems of medicine since time immemorial. The fresh and dried leaves of kalmegh and juice extracted from the herb is an official drug in Indian pharmacopeia. The standardization of proper cultivation practices for such a valuable herb is now found essential. The plant is known as `Rice bitters' in West Indies and `King of bitters' or Chiretta' in England. Among the Indian languages, it is known as ‘Kirata’ in Sanskrit, ‘Kirayat’ in Hindi, ‘Kalmegh’ in Bengali, ‘Nelavuepu’ in Malayalam, ‘Nelavemu’ in Telugu and ‘Nelabevinagida’ in Kannada.
The herb is official in Indian Pharmacopoeia (Balachandran and Govindarajan, 2005) [3] as a predominant constituent of at least 26 Ayurvedic formulations used to treat liver ailments. It is one of the herbs, which can be used to treat neoplasm as mentioned in ancient Ayurvedic literature (Patarapanich *et al*., 2007) [9]. The plant is particularly known for its bitter properties and is used traditionally as a remedy against common cold, dysentery, fever, tonsillitis, diarrhea, lever diseases, inflammation, and herpes and so on. Scientists today, however, are focusing on the herb’s application in treating the ‘killer’ diseases that blight modern life, such as heart disease, cancer and even AIDS (Mishra *et al*., 2007) [6]. The plant has been reported to possess antipyretic, antihepatotoxic, antihistamic, analgesic, antibacterial, anti-inflammatory, antifertility and immunosuppressive properties due to its bitter andrographolide content.
Having such a medicinal value and broad geographical distribution throughout the country, indiscriminate collection of *Andrographis paniculata* herb from wild sources without paying any attention towards its conservation and domestication in regular agriculture has caused a sharp decline in the availability of drug to the industries and escalation in its prices. Previously it was found abundantly in forest, but due to continuous and illegal exploitation level in most of its natural habitat in addition to variation in environmental conditions and genetic background of the plant material, the availability of the drug to the industry is inconsistent. Hence, the present experiment was taken up to study the growth and yield of the crop under the influence of integrated nutrients.

Material and Methods
The experiment was carried out in the experimental field of the Department of Plantation, Spices, Medicinal and Aromatic crops, Kittur Rani Channamma College of Horticulture, Arabhavi, Belgaum district, Karnataka. The experiment was laid out as Randomized Block Design (RBD) with three replications.

Treatment details

- Gross plot size : 2.4 x 2.1 m, Net plot size : 1.8 x 1.8 m
- Season : *Kharif* 2015

The details of the factors under study in the experiment are given below.

- T_1 : 75:75:50 kg NPK per ha + FYM at10 t per ha. (Check)
- T_2 : 100: 75: 50 kg NPK per ha + FYM (5 t ha^{-1})
- T_3 : T_1 + *Azatobacter* (2 q) enriched in FYM (10 t ha^{-1})
- T_4 : T_2 + *Azatobacter* (1 q) enriched in FYM (5 t ha^{-1})
- T_5 : T_3 + Vermicompost (1 t ha^{-1})
- T_6 : T_3 + Poultry manure (1 t ha^{-1})
- T_7 : T_4 + Vermicompost (1 t ha^{-1})
- T_8 : T_4 + Poultry manure (1 t ha^{-1})

Forty five days old healthy, uniform sized seedlings were selected and transplanted to the main field at all the stages of planting at a spacing of 30 cm between rows and 15 cm between the plants. Full dose of FYM (farm yard manure), vermicompost, poultry manure and *Azatobacter* enriched in FYM were applied one week before sowing and mixed well with soil. Nitrogen, phosphorus and potash were applied in the form of urea, single super phosphate (P_2O_5) and muriate of potash (K_2O), respectively. Nitrogen was applied in two split doses. Before transplanting, 50 per cent nitrogen and full dose of phosphorus and potassium were applied to plots at 7-10 cm depth in the lines and the remaining 50 per cent of nitrogen was top dressed at 45 days after sowing (DAS). The crop was harvested 4 months after planting (120 DAP) at full flowering stage. While harvesting, the whole plants were cut at 15 cm above the ground level and dried under shade for 3-4 day before storing.

Growth parameters (Number of branches per plant) was recorded at 40, 80 DAP and at harvest (120 DAP) from randomly selected 5 plants. The total number of primary branches per plant was counted and recorded from the tagged plants and the average was worked out.

Physiological parameters

The physiological parameters were recorded at 40, 80 and 120 DAP. The leaf area was calculated on three randomly selected plants by using Biovis instrument. The average was expressed as leaf area in cm^2 per plant.

Leaf area index (LAI)

Leaf area index was computed using the formula suggested by Sestak *et al.* (1971).

$$LAI = \frac{\text{Leaf area of the entire plant (cm}^2)}{\text{Spacing provided (cm}^2)}$$

Leaf area ratio (LAR) (cm^2 g^{-1})

The leaf area ratio was worked out by the formula of Radford (1967) [10] and expressed as cm^2 per g

$$LAR = \frac{\text{Leaf area (cm}^2\text{ plant}^{-1})}{\text{Total dry matter (g plant}^{-1})}$$

Specific leaf weight (SLW) (g. cm^{-2})

The specific leaf weight (g. cm^{-2}) indicates the leaf thickness and was determined by the following formula

$$SLW = \frac{\text{Leaf dry weight (g)}}{\text{Leaf area (cm}^2)}$$

Specific leaf area (SLA) (cm^2 g^{-1})

The inverse of specific leaf weight is the specific leaf area and was calculated as follows:

$$SLA = \frac{\text{Leaf area (cm}^2)}{\text{Leaf dry weight (g)}}$$

Dry herbage yield

The freshly harvested herb of the plot were cleaned and dried in hot air oven at 65ºC till a constant weight is obtained and expressed in kg. Dry yield per hectare was calculated on the basis of dry yield per plot, the final yield was reduced by 10 per cent considering paths, irrigation channels in the field and expressed in quintals per hectare.

Table 1: Effect of integrated nutrient management on number of branches in kalmegh (*Andrographis paniculata* Nees.)

Treatments	Number of branches per plant	
	40 DAP	**At harvest (120 DAP)**
T_1 : 75:75:50 kg NPK ha^{-1} + FYM at10 t ha^{-1} (Check)	8.43	28.93
T_2 : 100: 75: 50 kg NPK ha^{-1}+ FYM (5 t ha^{-1}).	9.60	31.40
T_3 : T_1 + *Azatobacter* (2 q) enriched in FYM (10 t ha^{-1})	10.63	31.90
T_4 : T_2 + *Azatobacter* (1 q) enriched in FYM (5 t ha^{-1})	10.20	32.40
T_5 : T_3 + Vermicompost (1 t ha^{-1})	11.11	35.13
T_6 : T_3 + Poultry manure (1 t ha^{-1})	11.13	35.33
T_7 : T_4 + Vermicompost (1 t ha^{-1})	12.93	39.53
T_8 :T_4 + Poultry manure (1 t ha^{-1})	12.17	37.27
SEm ±	0.30	1.03
CD at 5%	0.92	3.11
CV %	8.47	9.06

DAP = Days after planting

Table 2: Effect of integrated nutrient management on leaf area, leaf area index and leaf area ratio in kalmegh (*Andrographis paniculata* Nees.)

Treatments	Leaf area (cm^2 $plant^{-1}$)			Leaf area index			Leaf area ratio (cm^2 g^{-1})		
	40 DAP	**80 DAP**	**At harvest (120 DAP)**	**40 DAP**	**80 DAP**	**At harvest (120 DAP)**	**40 DAP**	**80 DAP**	**At harvest (120 DAP)**
T_1	221.08	922.18	831.37	0.164	2.049	1.847	16.32	40.72	31.83
T_2	239.67	939.81	850.84	0.178	2.088	1.891	16.44	39.05	30.52
T_3	228.63	928.00	834.20	0.169	2.062	1.854	15.06	37.58	28.66
T_4	272.81	969.53	870.91	0.202	2.155	1.935	17.00	37.26	28.31

T_5	341.49	1006.35	945.83	0.169	2.236	2.102	20.52	36.62	29.44
T_6	357.40	1043.82	931.39	0.177	2.320	2.070	21.46	37.64	28.58
T_7	470.49	1076.30	1003.52	0.232	2.392	2.230	25.26	33.31	26.03
T_8	468.82	1050.33	1001.62	0.232	2.334	2.226	25.84	33.23	25.80
SEm ±	13.37	17.09	16.01	0.009	0.038	0.036	0.92	0.92	0.69
CD at 5%	40.55	51.84	48.57	0.027	0.115	0.108	2.80	NS	NS
CV %	12.34	5.17	5.29	14.170	5.169	5.286	14.04	7.50	7.27

T_1 : 75:75:50 kg NPK ha^{-1} + FYM at10 t ha^{-1} (Check)
T_2 : 100: 75: 50 kg NPK ha^{-1}+ FYM (5 t ha^{-1}).
T_3 : T_1 + *Azatobacter* (2 q) enriched in FYM (10 t ha^{-1})
T_4 : T_2 + *Azatobacter* (1 q) enriched in FYM (5 t ha^{-1}) T_5 : T_3 + Vermicompost (1 t ha^{-1})
T_6 : T_3 + Poultry manure (1 t ha^{-1})
T_7 : T_4 + Vermicompost (1 t ha^{-1})
T_8 :T_4 + Poultry manure (1 t ha^{-1})
NS= Non-significant, DAP= Days after planting

Table 3: Specific leaf area and specific leaf weight as influenced by integrated nutrient management at different stages of crop growth in kalmegh (*Andrographis paniculata* Nees.)

Treatments	SLA (cm^2 g^{-1})			SLW (g cm^{-2})		
	40 DAP	80 DAP	At harvest (120 DAP)	40 DAP	80 DAP	At harvest (120 DAP)
T_1 : 75:75:50 kg NPK ha^{-1} + FYM at10 t ha^{-1} (Check)	43.73	83.09	51.60	23.45	12.04	19.41
T_2 : 100: 75: 50 kg NPK ha^{-1}+ FYM (5 t ha^{-1}).	42.78	84.17	52.96	23.67	11.89	18.97
T_3 : T_1 + *Azatobacter* (2 q) enriched in FYM (10 t ha^{-1})	33.07	85.81	51.74	30.89	11.66	19.33
T_4 : T_2 + *Azatobacter* (1 q) enriched in FYM (5 t ha^{-1})	42.97	85.51	52.82	23.53	11.70	18.94
T_5 : T_3 + Vermicompost (1 t ha^{-1})	57.31	84.93	56.73	17.45	11.78	17.68
T_6 : T_3 + Poultry manure (1 t ha^{-1})	59.95	86.09	55.06	16.90	11.62	18.17
T_7 : T_4 + Vermicompost (1 t ha^{-1})	67.23	89.95	57.72	14.88	10.86	17.34
T_8 :T_4 + Poultry manure (1 t ha^{-1})	64.09	86.39	57.64	15.98	11.62	17.37
SEm ±	2.33	1.38	0.66	1.07	0.17	0.23
CD at 5%	7.08	NS	2.01	3.26	NS	0.70
CV %	13.63	4.83	3.65	15.45	4.43	3.78

DAP = Days after planting, NS = Non-significant

Table 4: Dry herbage yield as influenced by integrated nutrient management in kalmegh (*Andrographis paniculata* Nees.)

Treatments	Dry herb yield	
	Per plot (kg)	Per hectare (t)
T_1 : 75:75:50 kg NPK ha-1 + FYM at10 t ha^{-1} (Check)	2.24	4.00
T_2 : 100: 75: 50 kg NPK ha-1+ FYM (5 t ha^{-1}).	2.39	4.26
T_3 : T_1 + *Azatobacter (*2 q) enriched in FYM (10 t ha^{-1})	2.65	4.73
T_4 : T_2 + *Azatobacter* (1 q) enriched in FYM (5 t ha^{-1})	2.74	4.89
T_5 : T_3 + Vermicompost (1 t ha^{-1})	2.92	5.22
T_6 : T_3 + Poultry manure (1 t ha^{-1})	2.72	4.86
T_7 : T_4 + Vermicompost (1 t ha^{-1})	3.57	6.38
T_8 :T_4 + Poultry manure (1 t ha^{-1})	3.44	6.15
SEm ±	0.15	0.26
CD at 5%	0.45	0.79
CV %	15.54	15.54

Result and Discussion

At harvest (120 DAP), maximum number of branches per plant (39.53) was produced in plants which received 100:75:50 kg NPK per ha + *Azatobacter* (1 q) enriched in FYM (5 t ha^{-1}) + vermicompost 1 t per ha (T_7) which was on par with T_8 (100:75:50 kg NPK ha^{-1} + *Azatobacter* (1 q) enriched in FYM (5 t ha^{-1}) + poultry manure 1 t ha^{-1}) (37.27) compared to other treatments. The present investigation results are in accordance with Mishra and Jain (2014) [5]. They reported that the maximum number of branches per plant was obtained with the application of bio fertilizers (125 g *Azotobacter* + 125 g PSB), chemical fertilizers (50% NPK) and vermicompost (5 t ha^{-1}) in kalmegh. Similar results were also reported by Hemalatha and Suresh (2012) [4] in kalmegh and Nageshwari (1991) [7] in *Coleus parviflorus*. Production of more number of branches in this treatment could be attributed to balanced application of nutrients and higher uptake of nutrients due to the influence of bio-fertilizer and vermicompost resulted in better assimilation of carbohydrates. Maximum production of branches was also related to release of bio-active substaces which are having similar effect to that of growth regulators which help in breaking apical dominance and also division of cells which accelerate the branch production.

At harvest, significantly highest leaf area of 1003.52 cm^2 was recorded when crop was supplied with 100:75:50 kg NPK per ha + *Azatobacter* (1 q) enriched in FYM (5 t ha^{-1}) + vermicompost 1 t per ha and on par with T_8. This increased leaf area might be due to increased number of branches and leaves per plant due to the balanced nutrient supply met through these treatments. Similar results were also reported by Hemalatha and Suresh (2012) [4] in kalmegh, Anasuya (2004) [2] in turmeric.

The leaf area index (LAI) mainly depends on the rate of vegetative growth, number of leaves and leaf area. The LAI was very low at early stages of crop growth and increased significantly with the advancement of crop age up to 80 days after planting (Table 2). After this stage, increase in LAI was negligible in all the treatments. This was due to the senescence and shedding of the lower leaves. These results are in conformity with Somanath (2002) [12] in *C. forskohlii*. The highest LAI of 2.230 was recorded when the crop was supplied with 100:75:50 kg NPK per ha + *Azatobacter* (1 q) enriched in FYM (5 t ha^{-1}) + vermicompost 1 t per ha. This increase in leaf area index might be due to more number of broader leaves as a result of better availability of nutrients to the crop. These results are in line with the studies made by Mishra and Jain (2014) [5] and Parashar *et al.* (2011) [8] in kalmegh. The integrated nutrient management had no significant effect on leaf area ratio at different crop growth stage.

Data on specific leaf area at 120 DAP revealed that maximum specific leaf area (57.72 cm^2 g^{-1}) was observed in T_7-100:75:50 kg NPK per ha + *Azatobacter* (1 q) enriched in FYM (5 t ha^{-1}) + vermicompost 1 t per ha. This might be due to robust growth of the plant at this treatment. The similar results were made by Watson (1958) [14] and Sunil (2010) [13] who reported that application of 100 kg N recorded maximum SLA in *A. paniculata.* Data on specific leaf weight as influenced by different treatments at harvest revealed that maximum specific leaf weight (19.41 g cm^{-2}) was recorded with the application of 75:75: 50 kg NPK per hectare + FYM at 10 t per hectare. This might be due to specific leaf weight increases with increase in leaf thickness and decrease in specific leaf area. The similar results were made by Sunil (2010) and Parashar *et al.* (2011) [8] in kalmegh.

Dry herb yield varied significantly among various treatments. Higher dry herbage yield per plot and per hectare (3.57 kg and 6.38 t, respectively) was produced with the application of 100:75:50 kg NPK per ha + *Azatobacter* (1 q) enriched in FYM (5 t ha^{-1}) + vermicompost 1 t per ha (T_7) which was on par with T_8-100:75:50 kg NPK per ha + *Azatobacter* (1 q) enriched in FYM (5 t ha^{-1}) + poultry manure 1 t per ha.

Increase in dry herbage could be attributed to increase in fresh yield of herbage and also the integrated way has resulted in synergestic effect and encouraged the various growth attributes which ultimately helped in better absorption and utilization of nutrients by the plants, resulted in higher dry matter accumulation and their translocation to different plant parts which in turn reflected in better fresh herbage yield which directly helps in increased dry yield. These findings are line with the findings of Hemalatha and Suresh (2012) [4] in kalmegh and Anuradha (2002) [1] in rosemary.

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