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Full Length Research Paper

Assessing N-use efficiency, planting time and economics of fertilizer N in rose-scented geranium (*Pelargonium graveolens* L' Herit) in Western Himalayan Region of India

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A field experiment was conducted to study the effect of N levels and planting times on growth, biomass and oil yield attributes, agronomic efficiency (AE) and partial factor productivity (PFP), and economics of N application through marginal analysis. Results indicated that reducing the duration (from planting to harvesting) from December (144 days) to April (74 days) significant result in reduction in percent dry matter production, biomass, oil yield, PFP, AE and net income. Nitrogen application significantly increased dry matter production, leaf/stem ratio, biomass and oil yield in February planted crop. The AE of applied N, were also higher in February planted crop. The AE of applied nitrogen at 50, 100 and 150 kg N ha^{-1} were 188, 224 and 200 kg^{-1} kg N respectively. At 100 kg N ha^{-1} the crop earned a maximum profit Rs. 30.02. The quality of essential oil was not significantly influenced by application of different nitrogen levels.

Key words: Nitrogen, fertilizer, agronomic efficiency, scented geranium.

INTRODUCTION

Pelargonium graveolens (L'Herit), family, belonging to the Geraniaceae also known as rose-scented geranium, a native of dry rocky slopes of Cape Province in South Africa, is an important essential oil bearing crop. The crop was introduced in the Shevroy hills of Tamil Nadu by some enterprising French people during 1900 to 1910, from where its systematic cultivation spread to other regions, including plains (Rajeswara and Bhattacharya, 1992; Rajeswara, 2002). The essential oil of rose-scented geranium, extracted by steam distillation of freshly harvested shoot biomass, is widely used in the fragrance and flavor industries, and also has widespread use in aromatherapy.

In India, the geranium that yields a rose-scented geranium essential oil is traditionally grown in the Southern and Western hilly areas characterized by temperate climatic and gravelly acidic soils (Ram et al., 1995; Singh et al., 1996). The total annual world production of geranium oil is about 800 ton. The domestic demand for this oil is increasing although its production has declined over the year necessitating efforts to increase the production. Efforts made at Central Institute of Medicinal and Aromatic Plants, Lucknow have resulted in development of a variety 'CIM-Pawan' with higher oil yields well accepted by perfumery industry.

Since geranium crop is an exhaustive feeder of plant nutrients, higher productivity results in removal of nutrient in substantial amounts, which generally exceeds replenishments through fertilizers and manures leading

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ultimately to deterioration in soil fertility (Prakasa et al., 1986). Farmers have therefore resorted to use higher amounts of chemical fertilizers than recommended doses, particularly in case of N fertilizers to maintain the yield levels previously attained. Recent surveys of western hills of Uttrakhand revealed that more than 25% of farmers apply as high as 100 kg N ha^{-1} well above the recommended doses (100N:60P:60K) to each crop. This needs to be seriously looked into particularly in the coarse textured permeable soils of hills where N losses are very high.

Geranium is a perennial crop usually planted in the winter season (October to February) and harvested 5 to 6 months after planting. Continuous cultivation of the crop has resulted in loss of soil fertility, deficiencies of nutrients and decline in productivity and crop yields have been observed in same areas; a system probably suffering due to production fatigue (Bhaskar et al., 2001). This might have resulted in applying greater levels of N fertilizers alone. The rational approach would be to improve, the use efficiency of applied fertilizers, and not the fertilization rate, in order to sustain the productivity of crops as well as to minimize the environmental hazards. The objectives of this study therefore, were to:

1. Estimate the oil yield per unit of fertilizer N use at different dates of planting.
2. Compare yield advantages of balanced application of N at different dates of planting.
3. Elucidate the economics of fertilizer N application in geranium cultivation at different dates of planting.

MATERIALS AND METHODS

Site, soil and climate

A field experiment was conducted during the cropping season, 2004 to 2005 at the resource centre of Central Institute of Medicinal and Aromatic Plants, Purara, Bageshwar which is located between the coordinates 28º 60′ to 31º 29′ N, 77º 49′ to 80º 60′ E and at a height of 1250m msl. Climatologically, Purara is categorized as sub temperate (1200 to 1700 msl) zone. The valleys are usually hot during summers and cool during winter. The monsoon usually breaks in June and continues up to September.

The soil samples were drawn from the 0 to 15 cm soil layer by a core sampler, 80 mm diameter at four places in the experimental fields before commencement of experiment. These four samples were thoroughly mixed, bulked and a representative sample drawn for determination of organic C (Walkley and Black method), available N (Modified Macro-Kjeldhal method), 1 N NH_4F extractable P and 1 N NH_4OAC extractable K, following Jackson (1973). The pH content was 6.5, organic carbon 0.35%, available N 175 kg ha^{-1} available P 7 kg ha^{-1} and 135 kg ha^{-1} available K.

Treatments and crop culture

The treatment combination comprised of four levels of nitrogen application 0, 50, 100 and 150 kg N ha^{-1} and five dates of planting, that is, 15th of each month viz, December, January, February, March and April. The experiment was laid out in a factorial randomized block design (plot size, 3 × 2 m) with three replications.

Phosphorus (Single Super Phosphate, 16% P) and potassium (Muriate of Potash 56% K) were applied as per recommended dose which are, 80 and 60 kg ha^{-1} at the time of planting (Mishra et al., 2000). Sixty day-old rooted cutting of geranium cv CIM-Pawan were planted at 50 × 50 cm plant spacing. Nitrogen was applied as per treatment in two splits, 50% at the time of planting and remaining 50% after 55 days of planting. The crop were grown under irrigated conditions and irrigated as and when required.

Ten plants per treatment were randomly selected for recording observations at the time of harvesting. The crop was harvested during the last week of June. Essential oil was extracted by hydrodistillation (Clevenger, 1928) at harvest and oil yield was calculated by multiplying the herb yield with corresponding oil content.

The oil samples were subjected to GC analysis on Nucon gas chromatograph model 5765, equipped with FID using BP-20 (coated with carbowax 30 m) fused silica column, 0.32 mm × 0.25 µm film thickness under the following conditions: Carrier gas hydrogen with 8 PSI inlet pressure, injector and detector temperatures 200 and 230ºC, respectively. The oven temperature was programmed at 4ºC/min.

The compounds were identified by comparing the retention times of the peaks on BP-20 column with those of standard compounds run under the same conditions. Coinjection with authentic samples was also done wherever possible to corroborate identities.

Nitrogen-use efficiency

Nitrogen-use efficiency was measured in terms of partial factor productivity (PFP) and agronomic efficiency (AE) of fertilizer N. The PFP, a ratio of the herb yield to the applied nitrogen, a useful measure of nitrogen-use efficiency providing an integrative index that quantifies total economic output relative to the utilization of nitrogen in the system, including native soil nitrogen and nitrogen from applied fertilizers can be to increased by increasing the amount, uptake and utilization of nitrogen and by increasing the efficiency with which applied nitrogen is taken up by the crop and utilized to produce herb. Therefore applied fertilizer N and PFP was calculated as suggested by Yadav (1998).

$$PFP_n = Y_n / F_n$$

where PFP_n is the partial factor productivity of nitrogen (PFP_n). Y_n the herb yield of N-fertilized plots; F_n is the amount of fertilizers/plots. All these are expressed as kg ha^{-1}.

The agronomic efficiency (AE), an incremental efficiency from applied fertilizer N over control, was calculated as

$$AEN= \quad Y_n–Y_o/F_n$$

where AEN were the AE of applied fertilizer N, Y_n the herb yield of fertilized N plots, Y_o the herb yield of unfertilized plots (control), F_n are the amounts of fertilizer N. All these are expressed as Kg ha^{-1}.

Economic analysis

Economic evaluation of fertilizer N was made through marginal analysis. For this, the cost of cultivation (CC) of rose-scented geranium was calculated on the basis of different operations performed and materials used for growing the crops. For geranium, the operations and materials used were: Geranium cutting preparation rooted cutting maintenance; transplanting of geranium rooted cutting in the field, irrigation, and harvesting and oil distillation. The prices of different materials used and operation performed were: planting material at Rs. 0.25 $cutting^{-1}$, field pre-

Table 1. Effect of nitrogen levels on percent dry matter production and leaf/stem ratio of rose-scented geranium as influenced by planting time.

Nitrogen levels (kg ha^{-1})	Date of planting (Months)					
	December	January	February	March	April	Mean
	% Dry matter production					
Control	21.03	19.52	25.02	16.40	16.53	19.70
N_{50}	26.31	25.58	25.84	26.10	21.36	25.04
N_{100}	35.40	32.15	31.84	31.45	24.52	31.07
N_{150}	30.55	36.15	35.50	32.31	27.23	32.35
Mean	28.32	28.35	29.55	26.56	22.41	27.04
LSD (0.05)						
Nitrogen level (N)			1.43			
Date of planting (D)			3.14			
N × D			NS			
	Leaf/stem ratio					
Control	1.17	1.21	1.65	1.56	1.07	1.33
N_{50}	1.34	1.30	1.80	1.72	1.57	1.55
N_{100}	1.45	1.58	1.98	1.81	1.77	1.72
N_{150}	1.85	1.76	2.44	2.16	1.69	1.98
Mean	1.45	1.46	1.97	1.81	1.52	1.64
LSD (0.05)						
Nitrogen level (N)			0.11			
Date of planting (D)			0.12			
N × D			NS			

paration and planting Rs. 1350 operation^{-1}, N Rs. 6.24 kg^{-1}, P Rs. 9.75 kg^{-1}, K Rs. 15.33 kg^{-1}, irrigation Rs. 110 unit^{-1}, labour Rs. 93.05 unit^{-1}, oil distillation Rs 2.0 kg^{-1} (fresh herb). Gross returns (GR) were calculated by multiplying oil yield by oil price, that is, Rs 3250 kg^{-1} of geranium. Net Returns (NR) were calculated as NR=GR-GC. Marginal returns (MR) for the given fertilizer application treatment over the control were calculated as

$$MR = (NR_f – NR_c / CC_f – CC_c) \times 100$$

where, NR_f is the net returns from a given fertilizer application treatments, f, NR_c the net returns from the control plots (no fertilizer application), CC_f the CC for a given fertilizer application treatment and CC_c is the CC in the control plots.

Statistical analysis

The data were subjected to statistical analysis following analysis of variance (ANOVA) technique as applicable to randomized block design (Cochran and Cox, 1959).

RESULTS AND DISCUSSION

Effect on dry matter production

Delay in planting from December to April decreased percent dry matter production (Table 1). Reduction of dry matter production was marked when the planting was carried out in April. Percent dry matter production increased with increasing rate of nitrogen application. The differences between different doses of N application, that is, 50, 100 and 150 kg N ha^{-1} were significant in respect of percent dry matter production. A similar observation has been made in other aromatic crops (Bhaskar et al., 2001).

Effect on leaf/stem ratio

The crop planted on February had maximum leaf/stem ratio (Table 1). Leaf/stem ratio increased with increasing rate of nitrogen up to 150 kg N ha^{-1}. Application of nitrogenous fertilizers has been shown to produce significantly higher leaf/stem ratio (Bhaskar et al., 2001; Mohan and Sampath, 1983). Leaf/stem ratio is the desirable component of oil yields as leaves are the main source of oil. The differences in leaf/stem ratio with different nitrogen levels under different planting times, however, were not significant.

Effect on biomass yield

Delay in planting from December to April significantly decreased biomass yield of geranium (Table 2). The reduction was to an extent of 13, 24, 42.88 and 69.94% in January, February, March and April plantings, respec-

Table 2. Effect of nitrogen levels on biomass yield and oil yield of rose-scented geranium as influenced by planting time.

Nitrogen levels (kg ha^{-1})	**Date of planting (Months)**					
	December	**January**	**February**	**March**	**April**	**Mean**
	Biomass yield (t ha^{-1})					
Control	26.32	24.07	14.62	10.51	6.28	16.35
N_{50}	36.54	31.61	25.89	23.86	10.85	25.75
N_{100}	58.13	42.36	43.76	31.74	17.41	38.72
N_{150}	58.18	56.58	51.31	36.35	20.20	44.52
Mean	44.84	38.64	33.89	25.61	13.68	31.33
LSD (0.05)						
Nitrogen level (N)			3.06			
Date of planting (D)			3.42			
N × D			6.84			
Oil yield (kg ha^{-1})						
Control	25.49	22.26	21.83	16.53	10.42	19.30
N_{50}	31.73	31.61	45.75	43.20	18.08	34.07
N_{100}	52.90	36.18	76.07	56.15	36.02	51.46
N_{150}	44.61	48.88	85.64	62.31	36.38	55.56
Mean	38.68	34.73	57.32	44.55	25.22	40.10
LSD (0.05)						
Nitrogen level (N)			5.62			
Date of planting (D)			6.28			
N × D			12.57			

tively. The biomass yield increased significantly with the increase in nitrogen application up to 150 kg N ha^{-1}. The first 50 kg N ha^{-1} increased the biomass yield over control by 57%, whereas the second and third increases of 50 kg N ha^{-1} improved the biomass yield further by 50 and 15%. Higher biomass yield with increased levels of N application probably resulted from better expression of growth and yield attributing characters (Bhaskar et al., 1998; Prakasa et al., 1985, 1986, 1988; Narayana et al., 1987).

The interaction effect between planting times and nitrogen levels was significant in biomass yield. A delay in planting time from December to April resulted in a significant decreased in biomass yield. However biomass yield increased with increasing levels of N application. Similar results were also observed in the yield of ocimum and mints (Ram et al., 2002; Singh et al., 1986; Rajeswara, 1999).

Effect on oil yield

The trends in oil yield at different planting times and nitrogen levels were significant for all the combinations (Table 2). Oil yields for all planting time in plots receiving N_{50}, N_{100} and N_{150} treatments were significantly greater than that in control plots. Increase in levels of N significantly increased the oil yields. Planting during February significantly produced higher yields at all levels of N. This was probably due to higher herb yields with higher L/S ration with significantly higher oil content recovered in February planted crops. The plots receiving 150 kg N ha^{-1} exhibited 292% higher oil yield in February planted geranium over control. Cumulative oil yields from five planting time were significantly influenced by all the factors studied in the experiment. Another interesting trend observed in this study was linear increase in oil yield up to February, which declined in March and April planting. The differences in essential oil yields in different planting time and nitrogen levels have shown significant interaction of planting time and nitrogen response. Rose - scented geranium, palmarosa and basil exhibited similar response to nitrogen (Narayana et al., 1986b; Bhaskar et al., 2001; Rajeswara et al., 1992; Singh et al., 1988; Prakasa et al., 1985, 1988).

Partial factor productivity

The PFP of applied N (PFP_n), in rose-scented geranium ranged from 134 kg herb kg^{-1} N in (50 kg N ha^{-1}) in April to 731 kg herb kg^{-1} N in December (Table 3). Delay in planting time and increased in N levels decreased the PFP_n in kg herb/kg fertilizer N. The mean of PFP_n however was the highest (567.6 kg herb kg^{-1} N) in December and the lowest (175.22 kg herb kg^{-1} N) in April planted geranium. Over planting time and N levels PFP_n was 399.68 kg herb kg^{-1} N. PFP_n averaged over N levels

Table 3. Effect of nitrogen levels on partial factor productivity (PFP) and agronomic efficiency (AE) of rose-scented geranium as influenced by planting time.

Nitrogen levels (kg ha^{-1})	Date of planting (Months)					
	December	January	February	March	April	Mean
	PFP (kg fresh herb kg^{-1} applied fertilizer)					
N_{50}	731.00	632.33	517.66	477.00	217.00	515.00
N_{100}	583.33	423.66	437.66	317.33	174.00	387.20
N_{150}	388.00	377.33	342.00	242.33	134.66	296.86
Mean	567.44	477.77	432.44	345.55	175.22	399.68
LSD (0.05)						
Nitrogen level (N)			38.59			
Date of planting (D)			47.24			
N × D			81.82			
Agronomic efficiency fresh herb (kg kg^{-1} N)						
N_{50}	204.33	152.00	225.66	267.00	91.33	188.06
N_{100}	320.00	183.33	291.33	212.33	111.33	223.66
N_{150}	212.33	216.66	280.00	196.66	92.66	199.66
Mean	245.55	184.00	265.66	225.33	98.44	203.88
LSD (0.05)						
Nitrogen level (N)			NS			
Date of planting (D)			47.92			
N x D			NS			

was greatest in 50 kg N ha^{-1}. Increased levels of applied N decreased the PFP_n. The differences in all N levels were significant at all planting times.

Agronomic efficiency

Agronomic efficiency (AE) of the rose-scented geranium planted in February was significantly higher than that of the crop planted in other month (Table 3). Agronomic efficiency (AE) of fertilizer N was in the order 100 > 150 > 50kg N applied at all the planting times.

However, in 100 kg N ha^{-1}, it was significantly greater than in 150 kg N ha^{-1} in December planted crops. AE in 100 kg N ha^{-1} was greater than 150 kg N ha^{-1} by 51 % in December followed by 20% in April planted crops. The AE in different dates of planting which have similar doses of fertilizer was also compared. Agronomic efficiency had negative response in respect of nitrogen doses at different date of planting; low agronomic efficiency at higher rates of N. Similar trend was also observed by Prakasa et al. (1986, 1988) and Rajeswara et al. (1992).

Net returns (NR)

The mean data for different planting times at different levels of N indicated that application of N fertilizer resulted in significant greater net incomes compared to the control (Table 4). The NR increased significantly with the increase in nitrogen application up to 150 kg N ha^{-1}. The first 50 kg N ha^{-1} increased the NR over control by 208%, second 50 kg N ha^{-1}, 83% whereas the third 50 kg N ha^{-1} increased by 10%. February planting was found to be most economical.

The interaction effect between planting time and nitrogen levels was significant in NR of geranium crop and it indicated that delay in planting time from December to April resulted in a significant reduction in NR.

Marginal analysis

Marginal analysis of different fertilizer N levels for each date of planting (Table 5) indicated that the greatest marginal profits were obtained from 100 kg N ha^{-1} or 150 kg N ha^{-1} application, when planted in February and from the 100 kg N ha^{-1} treatment in December, March and April plantings.

On an average, profit of Rs. 15.49 Re^{-1} invested can be obtained from December planted crop; Rs 14.42 Re $^{-1}$ invested from January planted crop, Rs 43.26 Re^{-1} invested from February, Rs 34.65 Re $^{-1}$ invested from March and Rs 17.34 Re^{-1} invested from April planted crops. The profit increased significantly with the increase in nitrogen levels up to 100 kg N ha^{-1}. The first 50 kg N ha^{-1} increased the profit by over 87%, whereas the second 50 kg N ha^{-1} decreased profit by about 3%.

Table 4. Total cost of cultivation (Rs.ha^{-1}) and net returns (Rs.ha^{-1}) from the rose- scented geranium under different nitrogen levels in different planting times.

Date of planting (Months)	Nitrogen levels (kg ha^{-1})				
	Control	N_{50}	N_{100}	N_{150}	Mean
	Cast of cultivation Rs. (×100)				
December	436.10	464.25	469.79	475.34	460.37
January	435.15	463.29	468.84	474.39	460.41
February	432.10	460.24	465.79	471.34	457.36
March	421.10	449.14	454.69	460.24	446.26
April	324.95	353.09	358.64	364.19	350.21
Mean	409.86	438.00	443.55	449.10	435.12
	Net income Rs (× 100)				
December	392.54	567.08	1249.67	974.70	795.99
January	288.30	564.25	707.11	1114.21	668.46
February	277.37	1026.85	2006.60	2312.06	1405.72
March	116.22	955.06	1370.29	1565.05	1001.65
April	13.69	234.51	812.11	818.15	469.62
Mean	217.62	669.55	1229.15	1356.83	868.29

Table 5. Marginal analysis (%) of fertilizer N application versus control (no fertilizer) at different date of planting.

Nitrogen levels (kg ha^{-1})	Date of planting					
	December	January	February	March	April	Mean
	Marginal analysis %					
N_{50}	620	980	2663	2981	784	1605
N_{100}	2544	1242	5132	3722	2369	3002
N_{150}	1483	2104	5185	3692	2048	2902
Mean	1549	1442	4326	3465	1734	2503

Conclusion

All the plant growth parameters and yield attributes at various planting times and fertilizer N was compared to the unfertilized plots. The response of rose-scented geranium crop to applied N fertilizer and planting time was greater in high fertilizer N dose and optimum crop length was 135 days when crop was planted in February. Though higher yields were obtained with 150 kg N ha^{-1}, use efficiency was maximum at 100 kg N ha^{-1}. Considering the low chemical input, farming is prevalent in western hilly regions, practices towards improving fertilizer use efficiency and identifying N efficient genotypes would be an area of future research.

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