EFFECT OF NITROGEN LEVEL AND PLANT SPACING ON GROWTH AND YIELD OF TURMERIC (*Curcuma longa* L.)

Thesis

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VCSG Uttarakhand University of Horticulture and Forestry,
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By

Niki Nautiyal

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

HORTICULTURE (PLANTATION CROPS, SPICES, MEDICINAL & AROMATIC PLANTS)

AUGUST, 2015

CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF NITROGEN LEVEL AND PLANT SPACING ON GROWTH AND YIELD OF TURMERIC (*Curcuma longa* L.)"** submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** with major in **PLANTATION CROPS, SPICES AND MEDICINAL & AROMATIC PLANTS** and minor in **SOIL SCIENCE** of the College of Horticulture, VCSG Uttarakhand University of Horticulture and Forestry, Bharsar is a record of *bonafide* research carried out by **Miss. NIKI NAUTIYAL, Id. No. 13165**, under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

(B.P. Nautiyal)
Chairman
Advisory Committee

Bharsar
August, 2015

CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Miss. NIKI NAUTIYAL, Id. No. 13165**, a candidate for the degree of **MASTER OF SCIENCE** with major in **PLANTATION CROPS, SPICES AND MEDICINAL & AROMATIC PLANTS** and minor in **SOIL SCIENCE**, agree that the thesis entitled **"EFFECT OF NITROGEN LEVEL AND PLANT SPACING ON GROWTH AND YIELD OF TURMERIC (*Curcuma longa* L.)"** may be submitted in partial fulfilment of the requirements for the degree.

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Bharsar **(Niki Nautiyal)**
August, 2015 Author

ABBREVIATIONS

DAP	=	Days after planting
FYM	=	Farmyard manure
DMC	=	Demethoxycurcumin
BDMC	=	Bis-demethoxycurcumin
N	=	Nitrogen
P	=	Phosphorus
K	=	Potassium
kg	=	Kilogram
cm	=	Centimetre
g	=	Gram
ha	=	Hectare
m	=	Meter
DMP	=	Dry Matter Production
Df	=	Degree of Freedom
ss	=	Sum of Square
sem	=	Standard Error Mean
ms	=	Mean Square
gm	=	General Mean
cd	=	Critical Difference
treat	=	Treatment
**	=	Significant
RDF	=	Recommended Dose of Fertilizers
RDN	=	Recommended Dose of Nitrogen
Tk	=	Taka (1 Indian Rupee = 1.1922 Bangladesh taka)

CONTENTS

INTRODUCTION

Chapter 1 INTRODUCTION

Curcuma longa L. is a rhizomatous erect herb from the Zingiberaceae family that belongs to the class Monocotyledons. About 40 species of the genus including *C. longa* are indigenous to India indicating the Indian origin. The dried rhizome of the plant *C. longa* L. is called turmeric (Velayudhan *et al*., 1999). Turmeric used as spice and as well as medicinal .Turmeric is commonly known for its medicinal values in the Indian traditional systems of medicine. Turmeric has been used traditionally in "ayurvedic medicine" as an antiseptic, wound healing, and anti-inflammatory. Curcumin, dimethyoxycurcumin and bis- demethoxycurcumin are a dietary phytochemicals obtained from dried rhizomes of the turmeric. Curcumin is a main coloring substance of *Curcuma longa* and two related compounds, demethoxycurcumin (DMC) and bis-demethoxycurcumin (BDMC) are altogether known as curcuminoid. The value of the turmeric products is based on their curcuminoid content (Kulkarni *et al*; 2012). In old Hindu medicine, it is extensively used for the treatment of sprains and swelling caused by injury (Chattopadhyay *et al*., 2004). In recent times, traditional Indian medicine uses turmeric powder for the treatment of biliary disorders, anorexia, coryza, cough, diabetic, hepatic disorders, rheumatism and sinusitis (Aggarwal *et al*., 2005). Certain scientist's admitted that its powder has healing effect on both aseptic and septic wounds of rats and rabbits. Curcumin reduces intestinal gas formation. Ethanolic extract also possesses anti-tumor activity. The crude ether and chloroform extracts of *C. longa* stem are also reported to have antifungal effects. Curcumin increases the activity of pancreatic lipase, amylase, trypsin and chymotrypsin (Chattopadhyay *et al*., 2004). Petroleum ether and aqueous extracts of turmeric have 100% anti-fertility effects in rats. Ethanolic extract possesses anti-tumor activity and inhibits human sperm motility and has the potential for the development of a novel intra-vaginal contraceptive (Rithaporn *et al*., 2003). Sasikumar, (2004) mentioned that turmeric oil is also effective as a mosquito repellant, housefly deterrent while Chattopadhyay *et al*. (2004) demonstrated that powdered rhizome is used to treat bruises, inflamed joints and sprains in Nepal. Curcumin has been a centre of attraction for

potential treatment of an array of diseases, including cancer, Alzheimer disease, diabetes, allergies, arthritis and other chronic illnesses. Turmeric is one of the important export oriented crop of India. It ranks fifth in area among species next to chillies, cumin, coriander and black pepper, whereas it occupies third position in production next to chillies and garlic. In export of species, it ranks second both in quality and value next to chillies. Owing to its medicinal properties, its demand is increasing day by day both in domestic and international market for use in food industry, pharmaceuticals and preservatives in health and body care. The hilly areas of Uttarakhand can be suitable climate for cultivation of turmeric with the use of short duration of variety. Among the agronomic practices, proper plant spacing and appropriate dose of nitrogen is very important for maintaining optimum plant population and proper growth respectively, needed for higher production and productivity of turmeric. Spacing is being one of the most important factors which actively influence the inter plant competition, growth and ultimate yield of turmeric (Manjunathgoud *et al*., 2002). Plant spacing is an important agronomic attribute since it is believed to have effects on light interception during which photosynthesis takes place which is the energy manufacturing medium using green parts of the plant. Good plant spacing gives the right plant density, which is the number of plants, allowed on a given unit of land for optimum yield. Among the essential nutrients, nitrogen plays an import role in the growth and rhizome yield of this crop. With this background, a detailed investigation "Effect of nitrogen level and plant spacing on growth and yield of turmeric (*Curcuma longa* L.)" was planned in the Medicinal and Aromatic Plants Block of V.C.S.G. College of Horticulture (Uttarakhand University of Horticulture and Forestry) Bharsar, Pauri Garhwal (Uttarakhand) at 30.06^0 N Latitude, 78.99^0 E Longitude and at the altitude of 1900 meters above the mean sea level with following objectives:

1. To study the effect of nitrogen level and plant spacing on soil physicol-chemical properties; growth and development; and quality parameter of turmeric.
2. Economic feasibility of nitrogen level and plant spacing on production of turmeric.

REVIEW OF LITERATURE

Chapter 2 REVIEW OF LITERATURE

Plant spacing is an important agronomic attributes since it is believed to have effects on light interception during which photosynthesis takes place which is the energy manufacturing medium using green parts of the plant.Among the essential nutrients, nitrogen plays an import role in the growth and rhizome yield of turmeric. Within the plant, nitrogen serves in the same ways as it does in other organisms as a component of amino acids and nucleic acids. Nitrogen also plays a critical role in the structure of chlorophyll, the primary light harvesting compound of photosynthesis. This, along with its structural role in amino acids, explains why plants require large amounts of nitrogen, and thus why plants require large amounts of nitrogen, and thus why it is often the limiting nutrient for plant growth. Hence, there is need for optimum plant population and appropriate nitrogen level in turmeric to be worked out. An attempt has been made to review the available literature related to plant spacing of turmeric and nitrogen level in India and abroad. The available literature has been classified under following heads:-

1. Effects of plant spacing on crops

1.1 Growth and Development

Plant spacing 30 cm x 50 cm have evidenced significant findings for almost all the parameters in *Curcuma longa* L. as it took significantly least days taken to sprouting (82.00), maximum plant height (67.73 cm), number of leaves per plant (8.0), leaf length (35.22 cm), leaf diameter (9.917 cm) and stem per plant (5.66). Thus it is concluded that a wider plant spacing of 30 cm x 50 cmwould be more beneficial for the commercial production (Kiran*et al*.,2013**)**. Pratop and Singh,(2007) reported that closer spacing at 30 cm x 15 cm and 30 cm x 20 cm gave maximum plant height, whereas maximum number of tillers per main shoot and weight of fresh rhizome per clump was highest at 30 cm x 30 cm and 45 cm x 30 cm spacing. Plant height and relative growth rate/ crop growth rate increased with wider spacing, whereas number of plantlets, leaf length, breadth ratio and leaf area density increased with closer spacing (Gopichand*et al.,* 2006). (Shashidhar*et al.*, 1997) reported that close spacing produced the

tallest plants (23.2 cm) and total dry weight also increased, medium spacing produced plants with the highest number of leaves (10.79) and highest leaf area (28.58 dm^2), and wide spacing produced plants with the highest number of tillers (2.03). A number of scientists including (Abbas *et al.,* 2009; Ahmad *et al.,* 2009 and Jilani*et al.,* 2010) also reported maximum plant height with wider row spacing in different agronomic.

1.2 Yield and yield attributes

Plant spacing 30 cm x 50 cm have evidenced significant findings for almost all the parameters, as it took significantly number of finger per plant (15.67), finger length (5.367 cm), finger weight (76.10 gm), diameter of finger (4.220 mm) and turmeric yield (2184 kg ha^{-1}). Thus it is concluded that a wider plant spacing of 30 cm x 50 cmwould be more beneficial for the commercial production of *Curcuma longa* L. (Kiran*et al*., 2013**)**. Fresh rhizome yield and oil yield increased with wider spacing (Gopichand*et al.,* 2006).

1.3 Economics

The gross return was highest (Tk 107220 ha^{-1}) where 45 cm X 10 cm spacing was used because of highest average yield (17.87 t ha^{-1}) and benefit cost ratio (1.70) of the same treatment was ranked the second position due to higher seed cost was involved. On the other hand, due to the lowest yield (13.42 t ha^{-1}), gross return, gross margin and benefit cost ratio were also the lowest where plants were spaced at 60 X 30 cm^2(Islam *et al*., 2002). Kandiannan and Chandaragiri(2008) noticed that closer spacing (30 cm x 15 cm) produced higher gross return (Rs. 150000 and Rs. 157500) and net return (Rs. 85000 and Rs. 94100), and B: C ratio (2.31 and 2.48) than medium (45 cm x 15 cm) and wider spacings (60 cm x 15 cm).

2. Effects of nitrogen level on crops

2.1 Growth and Development

Sadanandan and Hamza (1998) reported that NPK 60, 50, 120 $kgha^{-1}$ with micronutrients were optimum for varieties Suvarna, Suguna and Alleppey, whereas NPK 50, 40, 100 $kgha^{-1}$ with micronutrients was optimum for Sudarshana.However, plant height, leaves number and finger number increased tremendously with the increased of N levels up to 150 $kgha^{-1}$. The highest plant height (101cm and 102.3cm), maximum leaves number (9.9 and 10.9

/plant) and the highest fingers per plant (42.4 and 43.7) were recorded when 150 kg N was applied followed by 100 kg Nha^{-1} while N_0 failed to exert optimum number of leaves, finger 7.69) recorded under 175 kg Nha^{-1} are the reasons for higher Dry Matter Production than 125 and 150 kg Nha^{-1} (Kandiannan and Chandaragiri,2008). The significant difference in DMP for N levels also reported by other workers **(**Shashidhar*etal*., 1997).

2.2 Yield and yield attributes

Fresh rhizome yield of 22.03 tonnes per hectare as was recorded at medium spacing (45 cm x 22.5 cm) as compared 45 cm x 15 cm by Shashidhar and Sulikeri, (1996).Pawarand Gavande(1992)andPandey(1992) stated that increasing rates of N significantly progressed the yield and other yield contributing characters of turmeric.Haque*et al*., (2007)noticed that finger weight, finger size and turmeric yield increased significantly at 150 N $kgha^{-1}$. Maximum finger weight (380g and $382g^{-1}$ plant), finger size (4.3 x 7.4cm and 7.4 x 7.6 cm) and highest turmeric yield (23.7 tha^{-1} and 24.3 tha^{-1}) were also obtained by said N dose (150 $kgha^{-1}$) during 2005 and 2006.Pawar and Gavande, 1992andPandey, 1992confirmed the present results and reported that highest rhizome yield (33.0 tha^{-1}) was obtained at 160 kg N ha^{-1}.

Application of 175 kg N ha^{-1} yielded 5.7 t ha^{-1} and 6.3 t ha^{-1} rhizomes of curcuma as compared to 125 kg N ha^{-1} and 150 kg N ha^{-1} (Kandiannan and Chandaragiri 2008). Similar findings are also reported by Gopalakrishna *et al.*(1997).

2.3 Economics

The higher N level (175 kg N ha^{-1}) provided better gross (Rs. 142500.00 and Rs. 157500.00) and net returns (Rs. 82300.00 and Rs. 98900.00), and B: C ratio (2.37 and 2.69) than lower and medium levels of N levels (Kandiannan and Chandaragiri, 2008).

MATERIALS AND METHODS

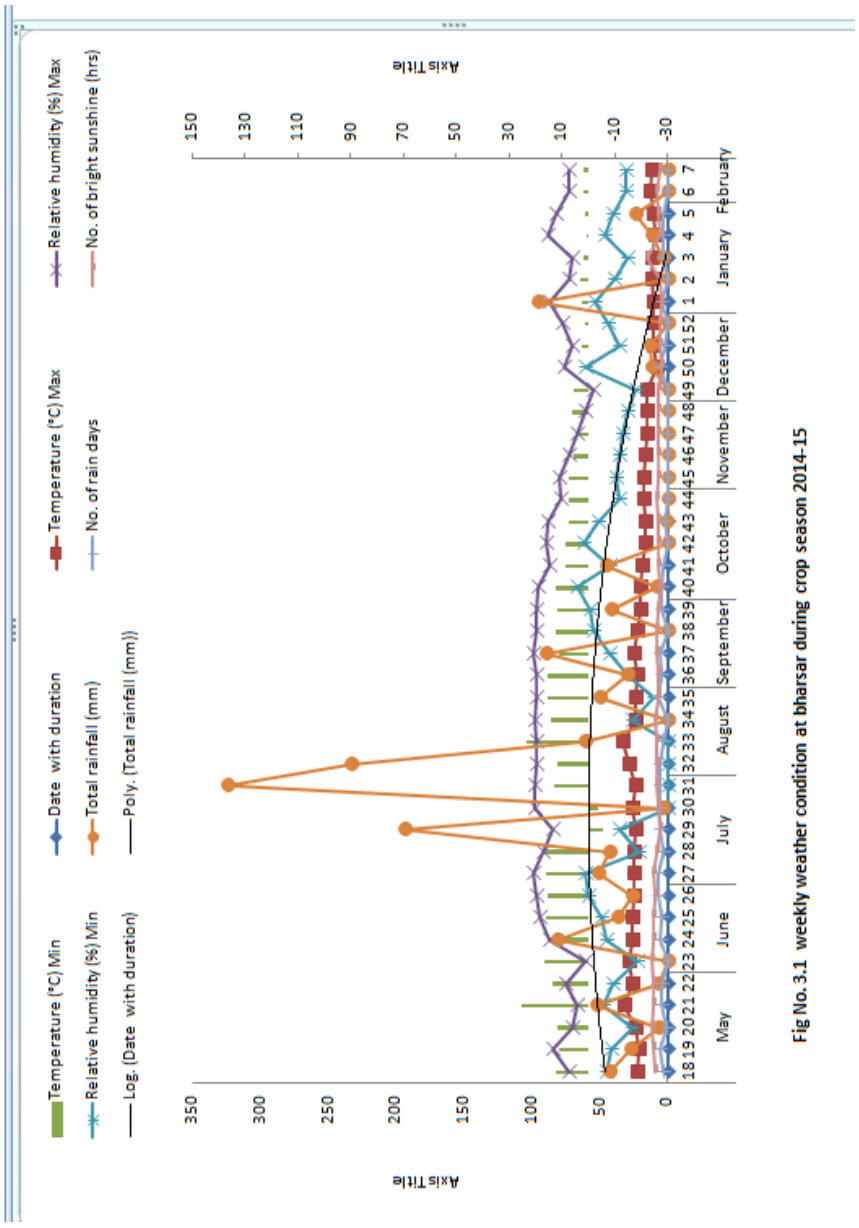

Fig No. 3.1 weekly weather condition at bharsar during crop season 2014-15

Chapter 3 MATERIALS AND METHODS

The details of materials used, experimental procedure's followed and techniques adopted during the course of investigation are described in this chapter. Climatic and edaphic conditions prevailed during crop season, selection of site, cropping history of field and other details are also being presented.

3.1 Experimental site

A field experiment was conducted in Medicinal and Aromatic plants (MAP) Block of College of Horticulture (V.C.S.G. Uttarakhand University of Horticulture and Forestry) Bharsar, Pauri Garhwal (Uttarakhand), during *kharif* season in the month of May, 2014. The centre is situated at 30.06^0 N Latitude, 78.99^0 E Longitude and at the altitude of 1900 meters above the mean sea level.

3.2 Climate and weather

During the experimentation (May to June, 2014) the days in Bharsar are fairly warm followed by cool nights. The area receives adequate sunshine hours whereas the growing period is shorter due to long winter. The area also receives heavy precipitation during monsoon and occasional snow fall during winter season. The mean weekly weather data from planting to harvesting of turmeric for one year between May 2014-March 2015 is presented in Appendix I.

Generally, monsoon arrives in the end of June and continues upto September. Few showers also occur during the winter and occasionally during summer months. Maximum temperature reached 32.7 ^{0}C during the summer and minimum temperature occasionally drops to -3.6 ^{0}C during winter. The data on weather conditions that prevailed during the course of investigation were recorded at the meteorological observatory unit located at College of Horticulture, Bharsar. Mean weekly data are given in Appendix I for 3.1the *kharif* seasons of 2014-15 (Fig No. 3.1).

Maximum temperature during the crop season of 2014-2015 ranged between 7.0-32.7 ^{0}C. Minimum temperature during the crop season 2014-15 ranged between 4.3–24.9 ^{0}C.

Total rainfall received during crop season of 2014-15 was 1604.6 mm, while maximum amount of rainfall (332.5 mm) was received in the month of August (Fig No. 3.1).

3.3 Soil characteristics

The soils are deep clay loam and have profile ranging from water 2 to 3 meter. The soils was found slightly acidic having pH 6, EC 0.21 dSm^{-1}, high in organic carbon 1.67% with N-202 kg ha^{-1}, P_2O_5 23 kg ha^{-1} and K_2O 330 kg ha^{-1} (Table 3.1).

Table 3.1: Chemical properties of soil of experimental field

S. No.	Particulars	Values	Methodology
1.	Organic carbon (%)	1.67 %	Walkley and Black method (Walkley and Black, 1934)
2.	Available nitrogen (kg ha^{-1})	202	Alkaline potassium permanganate (KM_nO_4) method (Subbaiah and Asija, 1956)
3.	Available phosphorus (P kg ha^{-1})	23	Olsen's method (Olsen *et al*., 1954)
4.	Available potassium (K kg ha^{-1})	330	Neutral normal NH_4OAC method (Jackson, 1973)
5.	pH of soil (1:2.5 soil water suspension)	6.0	Blackman glass electrode pH meter (Jackson, 1973)
6.	EC (dSm^{-1})	0.21	Bower and Wilcox, (1965)
7	Bulk density	1.03	Core sampler method (Baver, 1956).

3.4 Cropping history of the experimental plot

Cropping history of the experimental plot during last three years is presented below in the Table 3.2.

Table 3.2: Sequence of crops grown in the experimental plot

Year	Season	Crop
2012-13	*Kharif*	Barren
	Rabi	Barren
2013–14	*Kharif*	Wild marigold
	Rabi	Barren
2014–15	*Kharif*	Turmeric, var. Palam Lalima (Experimental)

3.5 Experimental details

The details of treatments are described as below:

3.5.1 Treatments: 12, all combinations of :

Factor A. Nitrogen level (kg ha^{-1})

(i) 100 (kg ha^{-1})

(ii) 125 (kg ha^{-1})

(iii) 150 (kg ha^{-1})

Factor B. Plant Spacing

(i) 40 cm x 10 cm

(ii) 40 cm x 20 cm

(iii) 40 cm x 30 cm

(iv) 40cm x 40 cm

Table 3.3 Details of treatment combinations are as follows

S.No.	Treatment combination
1	100 (kg ha^{-1}) + 40cm x 10cm
2	150 (kg ha^{-1}) + 40cm x 10cm
3	125 (kg ha^{-1}) + 40cm x 10cm
4	150 (kg ha^{-1}) + 40cm x 20cm
5	100 (kg ha^{-1}) + 40cm x 20cm
6	125 (kg ha^{-1}) + 40cm x 20cm
7	125 (kg ha^{-1}) + 40cm x 30cm
8	100 (kg ha^{-1}) + 40cm x 30cm
9	150 (kg ha^{-1}) + 40cm x 30cm
10	125 (kg ha^{-1}) + 40cm x 40cm
11	100 (kg ha^{-1}) + 40cm x 40cm
12	150 (kg ha^{-1}) + 40cm x 40cm

3.5.2 Design and layout

The experiment was laidout in factorial randomized block design (FRBD) with three replications. The treatments were randomly allotted to different plots as per procedure given by Panse and Sukhatme (1967). The details of the layout plan are given in Table 3.4.

Table 3.4: Details of layout plan

S.No.	Particular	Details
1.	Experimental block	MAP Block
2	Design	Two factor Factorial experiment in RCBD
3.	Total number of treatment combinations	12
4.	Number of replications	3
5.	Total number of plots	36
6.	Gross plot size	2.8 m x 2.4 m
7.	Net plot	2.2 m x 2.0 m
8.	Plant spacing	**(i)** 40 cm x 10 cm **(ii)** 40 cm x 20 cm **(iii)** 40 cm x 30 cm **(iv)** 40 cm x 40 cm
9.	Total number of rows in gross plot	7

3.6 Cultural operations

Details of various cultural operations carried out during the experimentation from field preparation to harvesting.

3.6.1 Field preparation

The field was ploughed once, harrowed thrice and levelled properly with the help of implements and labours. Presowing irrigation was not applied as sufficient stored moisture was available in the soil during start of experiment.

3.6.2 Organic manure and fertilizer application

Recommended dose of phosphorus and potassium for turmeric was 60 Kg ha^{-1} P_2O_5 + 60 Kg ha^{-1} K_2O. One fourth, one fifth and one sixth of the nitrogen as per treatment i.e., 25 Kg N of each treatment and 60 dose of P_2O_5 and 60 dose of K_2O was applied as basal. Remaining of N as per treatments were top dressed in three equal splits, one at 68, second at 87 and another third dose of N at 110 days after planting of turmeric. Urea (46% N), Muriate of Potash (60% K_2O) and NPK (12 % N, 32 % and 16% $P_2O_{5)}$ were used as source for nitrogen, phosphorus and potassium. Farmyard manure (FYM) was also applied on dry weight basis just before sowing.

Table 3.5 Details of cultural operations

S. No.	Operation	Date	Remarks
1.	Land preparation	1 May 2014	Power tiller drawn implements
2.	Layout	2 May 2014	Manually
3.	Organic manure/ Fertilizer application	3 May 2014	Basal application
4.	Planting	3 May 2014	Manually
5.	Weeding I II III	30 June 2014 27 July 2014 08 September 2014	Manually
6.	Top dressing of Urea I II III	 9 July 2014 28 July 2014 20 August 2014	Manually
7.	Treatment with insecticide and fungicide application	3 May 2014	1.5 ml Monocrotophos + 3 ml mancozeb /litre of water, using 1000 L water/ha with hand sprayer
8.	Insecticide and fungicide application	28 July 2014 20 August 2014	Drenched with mancozeb 3 ml litre of water, using 1000 L water/ha with hand sprayer.
9.	Harvesting	18 February 2015	Manually

3.6.3 Rhizome treatment

Rhizomes of turmeric were treated with 1.5 ml Monocrotophos + 3 g Mancozeb/litre of water before planting against insect and fungal diseases.

3.6.4 Seed turmeric and planting

The planting material of turmeric was planted as per treatment during 2014 of experimentation. Turmeric was planted manually in the furrows as per treatment.

3.6.5 Weeding

For controlling weeds, three hand weedings were done manually with the help of Hoe (*Kutala).*

3.6.6 Harvesting

The turmeric crop was harvested manually with the help of *Spade* and Hoe (*Kutala)* when leaves turned completely yellowish giving dry appearance from the net plot area.

3.7 Observations and techniques

Studies regarding growth, development, yield attributes, yield and nutritional aspects during the course of investigation are described as under.

3.7.1 Growth and development studies

Observations on plant height, plant spread, number of green leaves and leaf area per plant were recorded from five tagged plant in second row (northern side) of each plot at 65, 80, 105, 120 and 135 days after planting.

3.7.2 Plant height

Plant height was measured from ground surface to the tip of the top most leaf at 65, 80, 105, 120 and 135 days after planting. Finally, average plant height was reported.

3.7.3 Plant spread

Plant spread was measured by placing the scale on the canopy laterally on the tagged plants and average plant spread was reported.

3.7.4 Number of green leaves

Total numbers of fully developed green leaves from earlier plants were counted and average number of green leaves per plant was reported.

3.7.5 Leaf areas

Length and width of each fully developed green leaves from tagged plants were measured than add after multiplied and average leaf areas per plant was reported.

3.8 Post harvest studies

3.8.1 Number of mother, primary, secondary rhizome per plant

Total Number of mother, primary and secondary rhizome in the five tagged plants were counted and divided by five to work out number of rhizome per plant.

3.8.2 Rhizome yield per plant

The entire rhizome from the five tagged plants were washed and weighed and rhizome weight was recorded. Later on rhizome yield per plant was calculated by dividing the rhizome weight with five.

3.8.3 Rhizome yield per hectare

The rhizome were harvested net plot wise and then processed. The net plot for rhizome was three central rows of turmeric plant of four meter row length in plots. The dry turmeric yield of net plot was then converted to kilogram per hectare at 15 per cent moisture.

3.9 Sampling and processing of soil

The randomly soil collected in the turmeric field for soil sampling. Composite soil sample of each plot was collected by screw auger from 0-15 cm. The samples were air dried in shade on

polythene sheets. After drying, samples were crushed on hard wooden slab with the help of wooden roller and passed through 2 mm sieve and stored in labeled polythene bags for further chemical analysis.

3.9.1 Analysis of soil samples

3.9.1.1 Soil pH

The pH of the soil was determined by using a digital pH meter having glass electrode, in 1:2.5 soil-water suspensions (Jackson, 1973).

3.9.1.2 Electrical conductivity

The electrical conductivity (EC) was determined in 1:2 soil-water suspensions by a conductivity meter (Bower and Wilcox, 1965).

3.9.1.3 Organic carbon

The organic carbon content in soil was determined by following modified Walkley and Black, (1934) method as described by Jackson (1973).

3.9.1.4 Available nitrogen

Available N was determined by alkaline $KMnO_4$ method (Subbiah and Asija, 1956), which is based on the extraction of inorganic and readily oxidizable N from organic compounds. The equipment used automatic N distilled apparatus; N was extracted with 0.32% $KMnO_4$ and distilled by 2.5% NaOH. The distillation process was carried out by Nitrogen Analyzer (Gerhardt) and titration by digital burette (Brand). The liberated ammonia was absorbed in 2% boric acid, containing bromocresol green and methyl red mixed indicator. The amount of ammonia absorbed was determined titrimetrically using standard H_2SO_4 (0.02 N).

3.9.1.5 Bulk density (g cm^{-3})

Bulk density was determined by core sampler method (Baver, 1956).

3.10 Chemical constituent

3.10.1 Essential oil and total oil yield

The volatile oil from air dried rhizome/plot of turmeric plant was distilled by hydro distillation for 3 hr in order to extract the essential oils according to Guenther (1961) and the oil yield hectare^{-1} was calculated.

3.11 Economic Studies

3.11.1 Cost of cultivation

Cost of cultivation of turmeric was calculated on the basis of prevailing local charges for different inputs like labourer , implements, planting, fertilizers and other chemicals, used in cultivation of crops under different treatments.

3.11.2 Gross returns

The yield of turmeric was converted into gross return (Rs ha^{-1}) on the basis of current local market prices of produce.

3.11.3 Net returns

The net return of each treatment was calculated by deducting the cost of cultivation from the gross return of individual treatment.

3.11.4 Benefit: Cost ratio

Benefit–cost ratio was calculated as follows:

$$\text{Benefit: cost ratio} = \frac{\text{Net return}}{\text{Cost of cultivation}}$$

3.12 Statistical analysis

Data collected for various studies in turmeric crops were subjected to the 'analysis of variance' appropriate to the design as given by Cochran and Cox (1959). Test of significance of the treatment differences was done on the basis of F-test. Comparison of treatment means was done using critical differences (CD) at 5 per cent level of significance.

EXPERIMENTAL RESULTS

Chapter 4 EXPERIMENTAL RESULTS

Results obtained from the experiment to effect of nitrogen level and plant spacing on growth and yield of turmeric have been reported in this chapter as follows:

4.1 Growth and development studies

4.1.1 Plant height

Plant height increased with advancement of crop age **(Table 4.1).** Plant height differed significantly due to nitrogen levels at 65, 120 and 135 days after planting (DAP) of growth stages of the crop and due to plant spacing at all the growth stages of crop, except 65 DAP.

Nitrogen level

Significantly higher plant height was observed when N applied 150 kg ha^{-1} in turmeric than rest other level of N at 65, 120 and 135 DAP of growth stages, however it was statistically at par with N applied 125 kg ha^{-1} at 135 DAP. There was no significant effect found within N applied 100 kg ha^{-1} and 125 kg ha^{-1}at 120 DAP and 135 DAP. The lowest height was recorded in 100 kg N applied which remained significantly lower than rest other two levels of nitrogen **(Table 4.1).**

Plant spacing

Significantly higher plant height was observed with plant spacing of 40 cm x 10 cm than rest other spacings at all the growth stages except 65 DAP. The significantly lowest height was recorded with spacing of 40 cm x 40 cm at all the growth stages of crop and it was statistically at par with 40 cm x 30 cm spacing at 80 DAP and 105 DAP **(Table 4.1).**

4.1.2 Number of leaves per plant

Number of leaves increased with advancement of plant age up to 135 DAP **(Table 4.2).** Number of leaves differed non-significantly due to Nitrogen level but differed significantly due to plant spacing at all the growth stages of the crop.

Nitrogen levels

The number of leaves of turmeric was not affected significantly due to application of N though there was a increasing trend observed due to application of N at all the stages of growth **Appendix III (a) – (e).**

Plant spacing

Significantly higher number of leaves was observed in plant spacing of 40 cm x 40 cm at all the growth stages of crop, however it was statistically at par with spacing of 40 cm x 30 cm at all the stages of crop growth except 120 DAP. The lowest number of leaves was recorded in 40 cm x 10 cm plant spacing at all the growth stages of crop **(Table 4.2).**

4.1.3 Leaf area per plant

Leaf areas per plant increased with advancement of plant age and reached to its maximum up to 135 DAP except application of N 150 kg ha^{-1} and spacing of 40 cm x 40 cm at 135 DAP as it was found in decreasing trend **(Table 4.3).**

Nitrogen levels

Application of Nitrogen 150kg ha^{-1} was founded significantly higher leaf area per plant at 65 DAP only, where as no significant effect were found due to remaining dose of N applied at all the growth stages of crop **(Table 4.3).** The lowest leaf area per plants was recorded in 100 kg ha^{-1} Nitrogen level at all the growth stages of crop **(Table 4.3).**

Plant spacing

Likewise higher leaf area per plants was observed with plant spacing of 40 cm x 40 cm at all the growth stages of turmeric except 120 DAP. The lowest leaf area per plants was recorded in spacing of 40 cm x 10 cm at all the growth stages of turmeric and non-significant effect of leaf area per plants was observed with plant spacing of 40 cm x 10 cm at 120 DAP **(Table 4.3).**

Interaction effect

Interaction effect between N level and plant spacing on leaf area/ plant of turmeric was found at 65 days after planting only. Significantly higher leaf area per plant was found due to N applied 150 kg ha^{-1} in plant spacing 40 cm x 40 cm. Lowest leaf area per plant was found with N applied 100 kg ha^{-1} in plant spacing of 40 cm x 10 cm. There was no-significant effect recorded as N applied 125 kg ha^{-1} and 150 kg ha^{-1} in 40 cm x 10 cm; 100 kg ha^{-1} N and 125 kg ha^{-1} N applied in plant spacing of 40 cm x 20 cm; and 100 kg ha^{-1} N and 125 kg ha^{-1} N applied in plant spacing of 40 cm x 30 cm **(Table 4.3).**

Table No. 4.1 Effect of different treatments on plant height (cm) of turmeric at different stages of crop growth

Treatments	Plant height (cm)				
	65 DAP	**80 DAP**	**105 DAP**	**120 DAP**	**135 DAP**
Nitrogen Level (kg/ha)					
100	19.31	33.52	38.63	48.36	50.75
125	22.68	34.75	40.80	51.13	54.38
150	27.08	35.60	41.83	54.55	56.76
S.Em.±	0.54	0.86	1.28	1.01	1.31
C.D. at 5%	1.62	NS	NS	2.99	3.88
Plant Spacing					
40cm x 10 cm	23.97	40.55	47.11	63.11	63.82
40 cm x 20cm	23.37	35.55	42.04	51.80	55.38
40 cm x 30 cm	22.71	32.20	38.26	47.64	51.98
40 cm x 40 cm	22.04	30.17	34.26	42.84	44.69
S.Em.±	0.63	1.00	1.48	1.17	1.51
C.D. at 5%	NS	2.95	4.38	3.45	4.48

Table No. 4.2 Effect of different treatments on number of leaves per plant of turmeric at different stages of crop growth

Treatments	No. of leaves per plant				
	65 DAP	**80 DAP**	**105 DAP**	**120 DAP**	**135 DAP**
Nitrogen Level (kg/ha)					
100	1.83	3.45	4.00	5.12	6.02
125	1.91	3.50	4.13	5.30	6.07
150	1.98	3.57	4.22	5.52	6.22
S.Em.±	0.13	0.10	0.12	0.16	0.16
C.D. at 5%	NS	NS	NS	NS	NS
Plant Spacing					
40cm x 10 cm	1.60	3.24	3.67	4.82	5.51
40 cm x 20cm	1.73	3.42	4.04	5.11	5.87
40 cm x 30 cm	2.00	3.57	4.22	5.31	6.36
40 cm x 40 cm	2.31	3.78	4.53	6.00	6.67
S.Em.±	0.15	0.12	0.13	0.18	0.18
C.D. at 5%	0.46	0.38	0.39	0.55	0.53

Table No. 4.3 Effect of nitrogen level and plant spacing on leaf area per plant (cm^2) at different stages

Treatments	Leaf area per plant (cm^2) at different days after planting (DAP)				
	65 DAP	**80 DAP**	**105 DAP**	**120 DAP**	**135 DAP**
Nitrogen Level (kg/ha)					
100	151.35	540.84	773.57	2406.97	3358.22
125	165.67	590.20	800.31	2468.71	3529.60
150	188.10	625.08	828.87	3867.28	3606.45
S.Em.±	2.39	32.60	20.42	898.97	117.36
C.D. at 5%	6.96	NS	NS	NS	NS
Plant Spacing					
40cm x 10 cm	118.11	469.36	670.27	2074.33	3011.30
40 cm x 20cm	138.60	519.06	719.98	2273.41	3383.86
40 cm x 30 cm	171.42	576.56	815.00	2567.48	3652.15
40 cm x 40 cm	245.36	776.53	998.42	4742.06	3,945.04
S.Em.±	2.72	37.65	23.57	1038.04	135.52
C.D. at 5%	8.04	111.13	69.60	NS	400.04

Table No4.3 Interaction effect between N level and plant spacing on leaf area / plant of turmeric at 65 DAP

Treatments	100 kg N	125 kg N	150 kg N
40 cm x 10 cm	103.86	124.13	126.33
40 cm x 20 cm	130.86	132.80	152.13
40 cm x 30 cm	161.33	163.93	189.00
40 cm x 40 cm	209.33	241.80	284.93
S.Em.±	4.71		
C.D. at 5%	13.95		

4.1.4 Plant spread

Plant spreads increased with advancement of plant age and reached to its maximum up to 135 DAP **(Table 4.4).** Plant spread differed significantly due to nitrogen applied at 65 DAP and plant spacing at all the growth stages of crop.

Nitrogen levels

Nitrogen when applied 150 kg ha^{-1} recorded significantly higher plant spread at 65 DAP where as it was at par with N applied 125 kg ha^{-1}. The plant spread of turmeric was not affected significantly due to N application at all the other growth stages though there was a increasing trend observed due to N application at all the stages of growth **Table 4.4 and Appendix V (a) – (e).** Application of N 100 kg ha^{-1} attained the lowest plant spread at all the growth stages of crop **(Table 4.4).**

Plant spacing

Significantly higher plant spread was observed with plant spacing of 40 cm x 40 cm at all the stages of crop where as it was at par with plant spacing of 40 cm x 30 cm at 105 DAP, 120 DAP and 135 DAP. The lowest plant spread was recorded in 40 cm x 10 cm plant spacing at all the growth stages of turmeric **(Table 4.4).**

4.1.5 Fresh yield, dry yield and dry yield recovery

Fresh yield, dry yield and dry recovery differed significantly due to nitrogen level and plant spacing **(Table 4.5).**

Nitrogen levels

When nitrogen applied 150kg ha^{-1} significantly higher fresh yield, dry yield and dry recovery were found where as it was at par with nitrogen applied 125 kg ha^{-1} on fresh yield and dry yield **(Table 4.5).** The lowest fresh yield, dry yield and dry recovery were recorded with nitrogen application100 kg ha^{-1} **(Table 4.5).**

Plant spacing

Significantly higher fresh yield, dry yield and dry recovery were observed in plant spacing of 40 cm x 10 cm. The lowest fresh yield, dry yield and dry recovery were recorded in 40 cm x 40 cm plant spacing **(Table 4.5)**.

Interaction effect

Interaction effect between N level and plant spacing on dry recovery of turmeric was found only. Significantly higher dry recovery was found due to N applied 150 kg ha^{-1} in plant spacing 40 cm x 10 cm. lowest dry recovery was found with N applied 100 kg ha^{-1} in plant spacing of 40 cm x 40 cm. There was no-significant effect recorded as N applied 100 kg ha^{-1} and 125 kg ha^{-1} in 40 cm x 10 cm; 100 kg ha^{-1} N, 125 kg ha^{-1} N and 125 kg ha^{-1} N applied in plant spacing of 40 cm x 20 cm; and 100 kg ha^{-1} N, 125 kg ha^{-1} N and 150 kg ha^{-1} N applied in plant spacing of 40 cm x 30 cm; and 125 kg ha^{-1} N and 150 kg ha^{-1} N applied in plant spacing of 40 cm x 40 cm **(Table 4.5).**

4.1.6 Essential oil and oil yield

Essential oil and oil yield not differed significantly due to nitrogen level and oil yield differed significantly due to plant spacing **(Table 4.6).**

Nitrogen levels

When N was applied 125 kg ha^{-1} found higher essential oil and oil yield. The lowest essential oil and oil yield was recorded in 100 kg ha^{-1} nitrogen application **(Table 4.6).** The essential oil and oil yield were observed remained non-significantly.

Plant spacing

Higher essential oil was observed in plant spacing of 40 cm x 10 cm where as it was observed significant effect on oil yield. The lowest essential oil was recorded with 40 cm x 40 cm plant spacing where as it was observed non-significantly difference. Higher oil yield was observed in plant spacing 40 cm x 10 cm and they are significantly higher than remaining spacing. The lowest oil yield was recorded in 40 cm x 40 cm plant spacing. There was no significant effect was found between plant spacing of 40 cm x 40 cm and 40 cm x 30 cm; and 40 cm x 30 cm and 40 cm x 20 cm **(Table 4.6).**

Table No. 4.4 Effect of different treatments on plant spread (cm) of turmeric at different stages of crop growth

Treatments	**Plant spread (cm)**				
	65 DAP	**80 DAP**	**105 DAP**	**120 DAP**	**135 DAP**
Nitrogen Level (kg/ha)					
100	12.95	31.06	33.13	36.48	38.95
125	14.15	31.96	34.88	38.71	40.53
150	14.91	32.89	35.36	39.58	41.65
S.Em.±	0.49	0.94	1.18	1.10	0.848
C.D. at 5%	1.46	NS	NS	NS	NS
Plant Spacing					
40cm x 10 cm	10.26	28.62	30.26	33.80	34.51
40 cm x 20cm	12.60	30.18	33.64	37.90	41.35
40 cm x 30 cm	13.68	32.86	35.82	39.54	41.84
40 cm x 40 cm	19.46	36.22	38.11	41.80	43.80
S.Em.±	0.57	1.09	1.36	1.27	0.97
C.D. at 5%	1.69	3.23	4.02	3.77	2.89

Table No 4.5 Effect of different treatments on fresh yield, dry yield and dry recovery

Treatments	**Fresh yield, dry yield and dry recovery (%)**		
	Fresh yield (t/ha^{-1})	**Dry yield (t/ha^{-1})**	**Dry recovery (%)**
Nitrogen Level (kg/ha)			
100	14.85	2.44	19.90
125	17.01	2.87	20.81
150	17.96	3.16	24.45
S.Em.±	0.47	0.18	0.57
C.D. at 5%	1.41	0.53	1.68
Plant Spacing			
40 cm x 10 cm	25.10	7.16	27.13
40 cm x 20cm	19.20	2.34	22.09
40 cm x 30 cm	14.02	1.21	19.79
40 cm x 40 cm	8.12	0.59	17.89
S.Em.±	0.55	0.20	0.66
C.D. at 5%	1.63	0.61	1.94

Table No 4.5: Interactioneffect ofnitrogen level and plant spacing on dry yield recovery (%) of turmeric

Treatments	**100kg/ha^{-1}**	**125kg/ha^{-1}**	**150kg/ha^{-1}**
40 cm x 10 cm	22.45	23.10	35.75
40 cm x 20 cm	22.00	22.13	22.16
40 cm x 30 cm	19.27	19.23	20.91
40 cm x 40 cm	15.94	18.73	18.99
S.Em.±	1.14		
C.D. at 5%	3.37		

Table No.4.6: Effect of different treatments on essential oil (%) and oil yield (l/ha^{-1})

Treatments	**Essential oil and Oil yield**	
	Essential oil (%)	**Oil yield (l/ha^{-1})**
Nitrogen Level (kg/ha^{-1})		
100	0.20	7.65
125	0.25	11.01
150	0.22	8.19
S.Em.±	0.02	2.31
C.D. at 5%	NS	NS
Plant Spacing		
40cm x 10 cm	0.26	27.01
40 cm x 20cm	0.20	4.75
40 cm x 30 cm	0.23	2.86
40 cm x 40 cm	0.20	1.18
S.Em.±	0.03	2.67
C.D. at 5%	NS	7.89

4.1.7 Residual soil fertility status, bulk density and particle density

Organic carbon, available nitrogen and bulk density were non-significant due to nitrogen level but organic carbon and available nitrogen significantly affected by plant spacing **(Table 4.7).**

Nitrogen levels

Nitrogen at 100 kg ha^{-1} was found showed organic carbon and available nitrogen as compared to other level but it was non-significant difference than other level of nitrogen application **(Table 4.7).** Bulk density was non significantly affected by different level of nitrogen application.

Plant spacing

Significantly higher organic carbon and available nitrogen were observed in plant spacing of 40 cm x 40 cm. The lowest organic carbon and available nitrogen were recorded in 40 cm x 10 cm of plant spacing **(Table 4.7)** where as non significant effect of plant spacing was found on bulk density after harvesting of crop **(Table 4.7).**

4.1.8 Economical studies of N level and plant spacing

Nitrogen levels

Application of nitrogen 150 kg ha^{-1} was reported higher cost of cultivation .The lowest cost of cultivation was recorded in 100 kg ha^{-1} nitrogen level **(Table 4.8).** The gross return higher was recorded in nitrogen application 150 kg ha^{-1} and the gross return lower was recorded in 100 kg ha^{-1} nitrogen level. Application of 150 kg ha^{-1} nitrogen was found higher net return and the lowest net return was recorded in 100 kg ha^{-1} nitrogen level **(Table 4.8).**The maximum benefit cost ratio was recorded in nitrogen application 150 kg ha^{-1} and the benefit cost ratio minimum was recorded in 100 kg ha^{-1} nitrogen level.

Plant spacing

Higher cost of cultivation was observed in plant of spacing 40 cm x 10 cm. The lowest cost of cultivation was recorded in 40 cm x 10 cm plant spacing was observed. Higher gross return was noted in plant spacing 40 cm x 40 cm. The lowest gross return was found in plant spacing 40 cm x 30 cm. The net return higher was observed in plant spacing

40 cm x 10 cm and lowest net return was observed in plant spacing 40 cm x 40 cm. The benefit cost ratio higher was observed in 40 cm x 20 cm plant spacing and lowest benefit cost ration was recorded in plant spacing of 40 cm x 40 cm.

Table No. 4.7: Effect of different treatmentson organic carbon (%), available N (kg/ha) and BD (mg/cm^3)

Treatments	**Organic carbon (%)**	**Available N (kg/ha^{-1})**	**BD (gcm^{-3})**
Nitrogen Level (kg/ha^{-1})			
100	1.91	209.34	1.09
125	1.86	207.93	1.15
150	1.80	207.41	1.11
S.Em.±	0.03	1.35	0.02
C.D. at 5%	NS	NS	NS
Plant Spacing			
40cm x 10 cm	1.74	204.43	1.13
40 cm x 20cm	1.77	206.07	1.10
40 cm x 30 cm	1.85	208.61	1.13
40 cm x 40 cm	2.08	213.81	1.11
S.Em.±	0.04	1.55	0.02
C.D. at 5%	0.12	4.60	NS

Table No. 4.8: Economics of turmeric as influenced by different treatment

Treatments	**Cost of Cultivation (Rs/ ha)**	**Gross Return (Rs/ha)**	**Net Return (Rs/ha)**	**Benefit: Cost ratio**
Nitrogen Level (kg/ha)				
100	20968	148600	127632	6.07
125	21263	170200	148937	7.00
150	21557	179600	158043	7.33
Plant Spacing				
40cm x 10 cm	94790	251000	156210	1.64
40 cm x 20cm	57290	192000	134710	2.35
40 cm x 30 cm	44990	140200	95210	2.11
40 cm x 40 cm	38990	81200	42210	1.08

DISCUSSION

Chapter 5 DISCUSSION

The experimental findings presented in the previous chapter, in order to quantify the relative contribution of nitrogen level and plant spacing, provide a detailed account of performance of turmeric in terms of growth and development, yield and its attributes, nutrients content, quality (essential oil) and residual soil fertility.

The growth and yield parameters of a crop are the function of various metabolic processes which in turn depends upon above ground and below ground environmental factors to which the plant is exposed. In the present chapter an attempt has been made to evaluate the interacting factors, which are meaningful and relevant in context of present study.

5.1 Effect of weather

The establishment and growth of plant depend on environmental factors to which it is exposed. Full potential of a crop in terms of growth and yield is achieved only when it get favourable climatic condition. Performance of turmeric in the light of weather has been discussed as below:

In the present study, most of the growth parameters of turmeric viz. plant height **(Table 4.1)**, number of leaves **(Table 4.2)**, plant spread **(Table 4.4)** and leaf area **(Table 4.3)** at all the stages were higher during the experimentation of crop (2014). This may be attributed to well distributed rainfall resulting favourable conditions for proper growth of turmeric which led to better development of photosynthetic organ (source) responsible for manifestation of yield. Ishimine *et al*. (2003) reported that improvement of crop cultivation technology for local climatic and edaphic factors is important for successful production.

5.2 Effect of nitrogen

Nitrogen is a component of chlorophyll and therefore essential for photosynthesis. It is also the basic element of plant proteins, including the genetic material DNA and RNA, and is important in periods of rapid plant growth. Plants use nitrogen by absorbing nitrate or

ammonium ions through the roots. Nitrogen is such an important key nutrient element for plants that it warrants careful management, and ,if mismanaged can lead to severe environmental problems.

5.2.1 Growth and development

It was postulated that the crop of turmeric and including crop's of Zingiberaceae family respond well to the application of nitrogen. As nitrogen combined with high concentrations of chlorophyll utilizes the sunlight as an energy source to carryout essential plant functions including nutrient uptake. Chlorophyll is associated with the production of simple sugars from carbon, hydrogen, and oxygen. Healthy plants often contain 3 to 4 per cent nitrogen in their above-ground tissues. This is a much higher concentration compared to other nutrients. Nitrogen is a major component of amino acids, the building blocks of proteins. Without proteins, plants wither and die. Some proteins act as structural units in plant cells while others act as enzymes, making possible many of the biochemical reactions on which life is based. Nitrogen is a component of energy –transfer compounds, such as ATP (adenosine triphosphate). ATP allows cells to conserve and use the energy released in metabolism. Finally, nitrogen is a significant component of nucleic acids such as DNA, the genetic material that allows cells (and eventually whole plants) to grow and reproduce. Without nitrogen, there would be no life. In view of these fact's, in the present study application of nitrogen @ 150 kg ha^{-1} improved the plant growth of turmeric in terms of plant height **(Table 4.1),** number of leaves **(Table 4.2),** plant spread **(Table 4.4)** and leaf area **(Table 4.3).** Here it may be pointed out as discussed earlier, about the direct and indirect contribution of nitrogen towards the plant nutrition. Beneficial effects of nitrogen on growth parameters of turmeric have also been reported by Modupeola and Olaniyl (1993).

5.2.2 Yield attributes and yield

Final yield of crop is the cumulative effect of yield attributes and the factors, which directly and indirectly influence them. A crop can perform the best, only when spread of the foliage on the ground surface is in such a manner that the utilization of natural resources would be maximum. In present study, fresh and dry yield per hectare of turmeric **(Table 4.5)**

increased significantly by the use of nitrogen @ 150 kg ha^{-1}. As discussed earlier, this might be mainly due to improvement in growth which resulted marked improvement in yield attributes of turmeric **(Table 4.5).**

In the present study **(Table 4.5),** use of 150 kg N ha^{-1} recorded the maximum fresh yield as well as dry yield **(Table 4.5)** of the turmeric crop. As already has been stated earlier, yield of a crop is resultant of a per plant yield and plant population in a unit area, while per plant yield is dependent on yield attributes like number of mother rhizome's per plant, number of primary fingers per rhizome, secondary rhizome's per rhizome and rhizome weight etc. It was interesting to note that, while plant population remained unchanged due to nitrogen application, the per plant yield significantly improved with the application of 150 kg N ha^{-1} over its lower doses and this was mainly because of the improvement brought about in number of mother rhizomes per plant, number of primary fingers per rhizome, number of secondary fingers per rhizome and weight of rhizome **(Table 4.5).** Singh *et al*. (1992) observed significant improvements in rhizome yield of turmeric with increased N levels up to 120 kg N ha^{-1} in India. Similarly Meerabai *et al*. (2000) recommended an application of 120 kg N and 120 kg K_2O ha^{-1} for turmeric planted in coconut gardens.

The best rhizome yield of **17.96 t ha^{-1}** was recorded with 150 kg N ha^{-1} and this was followed by yield **(17.01 t ha^{-1})** obtained under 125 kg N ha^{-1} while the lowest of **14.85 t ha^{-1}** was obtained from the 100 kg N ha^{-1}. The increase in yield of turmeric with increase in N application may be explained on the fact that nitrogen being active constituent of protoplasm enzyme and chlorophyll plays a role of catalytic agent in various physiological processes, accelerate cell division and speed up the photo assimilation which in turn boost the plant growth and improve the plant structures (Pandey 1992).

The higher yields at the higher nitrogen level may be due to better stem size and higher number of rhizomes per plant which may result from increase in number of leaf per plant with increase in nitrogen level. This may result into the higher photosynthesis. This trend was in line with Medhi and Bora (1993).

The results stated reveal that yield attributes viz. number of mother rhizomes per plant, number of primary fingers per rhizome, number of secondary fingers per rhizome and weight of rhizome increased significantly due to direct application of 150 kg ha^{-1} nitrogen over lower dose. The increase in yield attributes might be due to better translocation of photosynthates towards sink, which ultimately increased the fresh yield.

5.2.3 Qualitative studies

When nitrogen was applied 125 kg ha^{-1} found higher essential oil and lowest essential oil was recorded in 100 kg ha^{-1} nitrogen application.

5.2.4 Soil fertility studies

On reviewing the results **(Table 4.7),** it is quite clear that increase in the availability of N in the soil with nitrogen level may be attributed to addition of nutrients. Besides, nitrogen reacts with native nutrients present in the soil and thereby improved the soluble and available forms of nutrients.

5.2.5 Economics

The economic significance worked out on the basis of the tried doses of nitrogen **(Table 4.8)** revealed that the maximum gross return (Rs. 179500 ha^{-1}) and net returns (Rs. 158043 ha^{-1}) were obtained with the use of nitrogen at 150 kg ha^{-1}. The further study of (**Table 4.8)** indicated that, on the basis of nitrogen at 150 kg ha^{-1} had a net return of over its lower doses of 100 kg ha^{-1}. Again, the benefit: cost ratio at 150 kg N ha^{-1} was also much higher (7.33). Undoubtly, such a result quite clearly indicated the superiority of the application of N @ 150 kg ha^{-1} for profitable cultivation of the turmeric.

5.3 Effect of plant spacing

Crop yield is the conversion of solar energy into useful form of chemical energy which is mainly governed by its genetic makeup. However, efficiency for utilization of solar energy in terms of yield can be enhanced either by the alteration in genetic makeup of crop plant or by agronomic manipulation. Plant spacing is one of the ways of agronomic manipulations which maintain the optimum plant population. Variations due to different plant spacing on growth, yield attributes and yields of turmeric are discussed below.

5.3.1 Growth and development

The growth of turmeric measured in terms of plant height **(Table 4.1)**, number of leaves/plant **(Table 4.2)**, plant spread **(Table 4.4)** and leaf area/plant **(Table 4.3)** were in superior order under plant spacing of 40 cm x 40 cm as compared to other plant spacing. Here it may be pointed out that, the competition between plants for space, sunlight, nutrients, water etc. was very less as compared to other which resulted better growth and development of plant spacing of 40 cm x 40 cm. Further, turmeric crop with spacing 40 cm x 40 cm also improved the fertility status and physical condition of soil **(Table 4.7)** which augmented growth and development of turmeric under plant spacing of 40 cm x 40 cm.

Plant spacing was significant on plant height, No. of leaves, leaf spread and leaf area. In most of the cases, the spacing 40 cm x 40 cm of turmeric gave the best performance for all growth stages. This could be explained in terms of sufficient food reserves which probably encouraged vigorous plant growth and eventually translate into yield. This is in agreement with the findings of Alam *et al*. (2003).

5.3.2 Yield attributes and yield

The fresh yield and dry yield being chief economic characteristic, need special consideration, while evaluating the treatment effects.

The fresh and dry weights of rhizome per plant were increased with increasing the distance between plants **(Table 4.5).**

In the present study, the highest fresh yield of turmeric **(25.10 t ha^{-1}) (Table 4.5)** was recorded in plant spacing of 40 cm x 10 cm which was significantly superior to rest other plant spacing. Here it may be elucidated that yield attributing characters like mother rhizome, primary finger, secondary finger and yield per plant were also maximum per unit area of plant spacing of 40 cm x 15 cm as compared to rest other spacings **(Table 4.5)**. In othe words primary fingers, secondary fingers and yield/plant were reported maximum with spacing of 40 cm x 40 cm but could not achieved the maximum production per unit area. Similar findings have also been reported to increase yield and to decrease interference with weeds by Baki *et al*. (1995) and Murphy *et al*. (1996**).**

5.3.3 Qualitative studies

Quality was judged in terms of essential oil content in rhizomes of the turmeric. The highest essential oil was observed in plant spacing of 40 cm x 10 cm and lowest essential oil was recorded with 40 cm x 40 cm plant spacing **(Table 4.6).**

It is evident from data in (**Table 4.6)** that the volatile oil percentage of turmeric was increased as a result of 40 cm x 10 cm spacing, on the other hand distance of 40 cm x 40 cm resulted the lowest percentage in this respect. The best result of essential oil yield lit./ha was obtained by distance of 40 cm x 10 cm but growing plants at 40 cm x 40cm give the lowest yield **(Table 4.6).**

5.3.4 Soil fertility

It may, be seen that when turmeric was grown with 100 kg ha^{-1} nitrogen, significant reduction took place in the fertility status of above nutrients. Here, it may be pointed out that, turmeric is a heavy feeder crop which removed higher amounts of N and resulted poor fertility status of soil, even lower than origin status of available N and organic carbon (%) **(Table 4.7)** and gradually decreased with increasing plant spacing **(Table 4.7).**

5.2.5 Economics

Reference to Table 4.8 indicated that plant spacing of 40 cm x 10 cm proved superior as this fetched higher gross return (Rs. 251000) and net return (Rs.156210 ha^{-1}) but plant spacing of 40 cm x 20 cm proved best as this fetched highest benefit: cost (B: C) (2.35) ratio than 40 cm x 10 cm (1.64), 40 cm x 30 cm (2.11) and 40 cm x 40 cm (1.08) plant spacing. This might be due to a sizable increase in yield and decrease in cost of planting material.

On the other hand, plant spacing under 40 cm x 30 cm and 40 cm x 40 cm adversely reduced the yield of turmeric **(Table 4.8)** however the yield per plant of the same spacing were more than 40 cm x 10 cm and 40 cm x 20 cm because of good yield per plant of turmeric but it could not compensate the losses occurred due to reduced over all yield and lower gross return (Rs.140200 ha^{-1} and Rs. 51000 ha^{-1} of 40 cm x 30 cm and 40 cm x 40 cm, respectively) and resulted the lowest net profit (Rs.95210 ha^{-1} and Rs. 42210 ha^{-1} of 40 cm x 30 cm and 40 cm x 40 cm, respectively) and B: C ratio (1.08 and 1.64 of 40 cm x 10 cm and 40 cm x 40 cm, respectively).

SUMMARY AND CONCLUSION

Chapter 6 SUMMARY AND CONCLUSION

A field experiment entitled "Effect of plant spacing and nitrogen level on growth and yield of turmeric (*Curcuma longa* L.)" was conducted at Medicinal and Aromatic Plants (MAPs) Block VCSG Uttarakhand University of Horticulture and Forestry, Bharsar during *Kharif* 2014. The treatments consisted of three nitrogen level (100 kg ha^{-1}, 125 kg/ha and 150 kg ha^{-1}) and four plant spacing (40 cm x 10 cm, 40 cm x 20 cm, 40 cm x 30 cm and 40 cm x 40 cm). The experiment was laid in factorial randomized block design (two factors RCBD) with 3 replications. The recommended package of practices was followed for raising the crops. Key findings of the investigation are summarized as follows:

1. Tallest plants along with higher number of leaves per plant were obtained when turmeric fertilized with 150 kg ha^{-1} at all the growth stages of crop. Plant spacing of 40 cm x 40 cm, influenced the plant height and number of leaves significantly except plant height at 65 DAP which did not influence significantly.
2. Application of nitrogen 150 kg ha^{-1} and spacing with 40 cm x 40 cm reported the maximum leaf area per plant of turmeric at all the growth stages. Leaf area of turmeric could not be affected significantly due to nitrogen at all the growth stages of crop except 65 DAP. Plant spacing of 40 cm x 40 cm affected the leaf area significantly at all the growth stages of crop except 120 DAP.
3. Application of nitrogen 150 kg ha^{-1} and spacing with 40 cm x 40 cm reported the maximum horizontal plant spread per plant of turmeric at all the growth stages. Plant spread of turmeric could not be affected significantly due to nitrogen at all the growth stages of crop except 65 DAP. Plant spacing of 40 cm x 40 cm affected the leaf area significantly at all the growth stages of crop.
4. Nitrogen application 150 kg ha^{-1} and plant spacing of 40 cm x 10 cm increased the fresh yield and dry yield significantly.
5. Nitrogen application 150 kg ha^{-1} and plant spacing of 40 cm x 10 cm increased the dry recovery of rhizome yield significantly..

6. Nitrogen level and plant spacing could not bring improvement in essential oil content of turmeric. Significantly higher oil yield was obtained in plant spacing of 40 cm x 10 cm where as nitrogen level could not affect significantly to oil yield.
7. Organic carbon and available nitrogen in soil were higher with application of 150 kg ha^{-1} nitrogen and higher with plant spacing of 40 cm x 40 cm. Bulk density of soil at the time of harvesting could not significantly affected by nitrogen level and plant spacing.
8. The highest gross return (Rs.179500 ha^{-1}), net return (Rs.158043 ha^{-1}) and B:C ratio (7.33) were obtained under nitrogen application 150 kg ha^{-1}. Plant spacing of 40 cm x 20 cm recorded maximum benefit: cost ratio.

In the light of results summarized above, it remains no more obscure that nitrogen level 150 kg ha^{-1} along with recommended dose of P_2O_5 and K_2O fertilizer is the most appropriate and profitable (Rs.158043/ha-net return). Not only the net profit but also the oil content and total productions of oil yield are improved. Plant spacing with 40 cm x 20 cm is economical to use because of higher benefit: cost ratio **(2.35)** is obtained with the same plant spacing.

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APPENDICES

Appendix-I

Standard meteorological weather data of 2014 at VCSG Uttarakhand University of Horticulture and Forestry, Bharsar-246123

Week no. & month	Date with duration	Temperature (°C)		Relative humidity (%)		Total rainfall (mm)	No. of rain days	No. of bright sunshine (hrs)
		Max.	Min.	Max.	Min.			
18 May	30-6M	22.7	12.0	72	45	42.0	3	9.1
19 ,,	07-13	20.56	11.01	84	41	26.5	5	9.9
20 ”	14-20	23.1	11.9	70	26	07.0	1	11.2
21 ”	21-27	32.0	24.9	66	47	52.0	4	10.1
22 ,,	28-3J	25.6	13.7	75	40	07.0	4	10.5
23 June	04-10	28.5	16.5	60	22	00.0	0	11.2
24 ”	11-17	25.4	15.3	87	45	80.5	5	10.2
25 ”	18-24	26.0	15.8	94	48	36.5	4	09.8
26 ”	25-1Jul	24.4	15.0	97	58	26.0	7	08.9
27 July	2-8	24.2	15.8	99	61	51.0	7	09.7
28 ,,	09-15	24.2	17.1	92	21	42.0	3	07.8
29 ”	16-22	23.5	-5.7	85	36	194.0	6	05.6
30 ”	23-29	25.5	-3.6	98	00	02.5	5	06.5
31 ”	30-5A	23.3	12.7	98	00	323.5	6	08.0
32 Aug.	06-12	28.8	11.9	97	00	232.5	5	07.9
33 ”	13-19	32.7	23.2	97	00	61.0	3	07.5
34 ”	20-26	23.7	13.9	98	26	00.0	0	09.4
35 ”	27-3S	23.0	15.3	97	10	49.5	7	07.2
36 Sep.	04-10	21.7	15.1	97	29	29.5	4	07.1
37 ”	11-17	25.0	11.1	99	42	89.3	6	07.7
38 ”	18-24	22.6	12.0	96	54	00.0	0	08.1
39 ”	25-1Oct.	20.0	11.6	97	57	41.5	4	06.8
40 Oct.	02-8	20.2	12.1	95	67	08.1	4	05.6
41 ,,	09-15	18.9	08.8	87	43	44.5	3	06.7
42 ”	16-22	16.3	08.7	89	62	00.0	0	06.2
43 ”	23-29	16.7	07.5	88	51	01.0	2	07.0
44 ”	30-5N	17.3	07.1	78	35	00.0	0	07.4
45 Nov	06-12	17.6	07.3	80	38	00.0	0	07.2
46 ”	13-19	16.4	05.4	73	35	00.0	0	06.9
47 ”	20-26	15.0	04.7	67	33	00.0	0	06.4
48 ”	27-3D	14.6	05.9	61	29	00.0	0	06.3
49 Dec.	04-10	15.3	05.2	54	24	00.0	0	06.2
50 ,,	11-17	07.9	01.1	76	60	11.20	5	04.6
51 ,,	18-24	10.2	02.2	70	36	12.5	2	05.8
52 ,,	25-31	10.2	01.0	77	44	00.0	0	05.7
1 Jan	01-7 Jan	09.8	02.2	87	53	95.0	4	04.3
2 ,,	08-14	11.9	02.7	73	39	00.0	0	05.6
3 ,,	15-21	10.9	01.5	70	30	03.5	3	14.6
4 ,,	22-28	09.2	00.8	88	46	12.0	3	05.2
5 ,,	29-4Feb	10.1	01.4	82	40	23.0	3	06.7
6 Feb	05-11	12.4	01.9	72	31	00.0	0	07.4
7 ,,	12-18	11.4	01.5	72	31	00.0	0	05.9

Appendix-II (a)

Analysis of variance for plant height (cm) of turmeric at 65 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	6.22			
Factor A	3	280.84	93.61	25.89	0.00000*
Factor B	2	11.37	5.68	1.57	0.22974
Interaction A X B	6	95.47	15.91	4.40	0.00455*
Error	22	79.53	3.61		
Total	35	473.45			

* Significant at 5% level of probability

Appendix-II (b)

Analysis of variance for plant height (cm) of turmeric at 80 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	51.20			
Factor A	3	452.34	150.78	16.63	0.00001***
Factor B	2	20.29	10.14	1.30	0.34427
Interaction A X B	6	113.62	18.95	2.06	0.09500
Error	22	198.75	9.03		
Total	35	836.19			

* Significant at 5% level of probability

Appendix-II (c)

Analysis of variance for plant height (cm) of turmeric at 105 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	106.75			
Factor A	3	557.45	185.81	9.36	0.00035**
Factor B	2	28.23	14.11	0.71	0.50186
Interaction A X B	6	302.56	50.42	2.54	0.05052
Error	22	436.50	19.84		
Total	35	1,431.50			

* Significant at 5% level of probability

Appendix-II (d)

Analysis of variance for plant height (cm) of turmeric at 120 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	59.62			
Factor A	3	1389.05	463.01	32.90	0.00000***
Factor B	2	76.82	38.41	2.73	0.08682
Interaction A X B	6	476.60	79.45	5.66	0.00111**
Error	22	308.77	14.03		
Total	35	2310.88			

* Significant at 5% level of probability

Appendix-II (e)

Analysis of variance for plant height (cm) of turmeric at 135 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	37.96			
Factor A	3	1168.24	389.41	18.79	0.00000***
Factor B	2	109.16	54.58	2.63	0.09422
Interaction A X B	6	700.65	116.77	5.63	0.00114**
Error	22	455.71	20.71		
Total	35	2471.72			

* Significant at 5% level of probability

Appendix-III (a)

Analysis of variance for Number of leaves/ plant of turmeric at 65DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.36			
Factor A	3	2.26	0.75	3.39	0.0357*
Factor B	2	0.13	0.06	0.30	0.7403
Interaction A X B	6	0.46	0.07	0.34	0.9052
Error	22	4.89	0.22		
Total	35	10.11			

* Significant at 5% level of probability

Appendix-III (b)

Analysis of variance for Number of leaves/ plant of turmeric at 80 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.93			
Factor A	3	0.70	0.23	1.77	0.18170
Factor B	2	0.30	0.15	1.16	0.33068
Interaction A X B	6	0.49	0.08	0.61	0.71434
Error	22	2.91	0.13		
Total	35	6.35			

* Significant at 5% level of probability

Appendix-III (c)

Analysis of variance for Number of leaves/ plant of turmeric at 105 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.94			
Factor A	3	1.73	0.57	3.53	0.03158*
Factor B	2	1.14	0.57	3.49	0.04799*
Interaction A X B	6	1.04	0.17	1.05	0.41694
Error	22	3.60	0.16		
Total	35	9.47			

* Significant at 5% level of probability

Appendix-III (d)

Analysis of variance for Number of leaves/ plant of turmeric at 120 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.18			
Factor A	3	5.71	1.90	5.96	0.00391**
Factor B	2	0.02	0.01	0.04	0.95590
Interaction A X B	6	2.63	0.44	1.37	0.26801
Error	22	7.03	0.32		
Total	35	16.59			

* Significant at 5% level of probability

Appendix-III (e)

Analysis of variance for Number of leaves/ plant of turmeric at 135 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.88			
Factor A	3	3.86	1.28	4.30	0.01562*
Factor B	2	0.32	0.16	0.54	0.58695
Interaction A X B	6	3.18	0.53	1.77	0.15104
Error	22	6.58	0.29		
Total	35	14.84			

* Significant at 5% level of probability

Appendix-IV (a)

Analysis of variance for Number of leaf area / plant of turmeric at 65 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	234.55			
Factor A	3	73376.03	24458.67	366.35	0.00000***
Factor B	2	1090.62	545.31	8.16	0.00222**
Interaction A X B	6	21448.52	3574.75	53.54	0.00000***
Error	22	1468.78	66.76		
Total	35	97618.53			

* Significant at 5% level of probability

Appendix-IV (b)

Analysis of variance for Number of leaf area / plant of turmeric at 80 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	16741.83			
Factor A	3	459977.18	153,325.72	12.08	0.00007***
Factor B	2	23529.98	11,764.99	0.92	0.41248
Interaction A X B	6	73972.99	12,328.83	0.96	0.47038
Error	22	280670.58	12,757.75		
Total	35	854892.57			

* Significant at 5% level of probability

Appendix-IV (c)

Analysis of variance for Number of leaf area /plant of turmeric at 105 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	69864.05			
Factor A	3	513295.40	171098.46	34.19	0.00000***
Factor B	2	8178.10	4089.05	0.817	0.45461
Interaction A X B	6	71153.64	11858.94	2.37	0.06430
Error	22	110075.22	5003.41		
Total	35	772566.43			

* Significant at 5% level of probability

Appendix-IV (d)

Analysis of variance for Number of leaf area /plant of turmeric at 120 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	20039007.46			
Factor A	3	29340621.29	9780207.10	1. 08	0.40773
Factor B	2	16701238.00	8355619.00	0.861	0.43647
Interaction A X B	6	52823697.06	8803949.51	0.9	0.50736
Error	22	21335250.52	9697856.84		
Total	35	332257414.35			

* Significant at 5% level of probability

Appendix-IV (e)

Analysis of variance for Number of leaf area /plant of turmeric at 135 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	58288.27			
Factor A	3	1223300.36	407,766.78	2.46	0.08897
Factor B	2	1336686.62	668,343.30	4.04	0.03196*
Interaction A X B	6	2308140.38	384,690.06	2.32	0.06835
Error	22	3636888.84	165,313.12		
Total	35	8563304.46			

* Significant at 5% level of probability

Appendix-V (a)

Analysis of variance for Number of plant spread (cm) turmeric at 65 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	22.46			
Factor A	3	388.90	129.63	43.66	0.00000***
Factor B	2	6.73	3.36	1.13	0.34002
Interaction A X B	6	74.30	12.38	4.17	0.00600**
Error	22	65.32	2.96		
Total	35	557.72			

Significant at 5% level of probability

Appendix-V (b)

Analysis of variance for Number of plant spread (cm) turmeric at 80 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	49.95			
Factor A	3	230.13	76.71	7.12	0.0016**
Factor B	2	21.47	10.73	0.99	0.3851
Interaction A X B	6	78.70	13.11	1.21	0.3346
Error	22	236.99	10.77		
Total	35	617.26			

Significant at 5% level of probability

Appendix-V (c)

Analysis of variance for Number of plant spread (cm) turmeric at 105 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	49.57			
Factor A	3	170.18	56.72	3.39	0.03584*
Factor B	2	29.24	14.62	0.87	0.43067
Interaction A X B	6	158.25	26.37	1.57	0.20016
Error	22	367.39	16.70		
Total	35	774.63			

Significant at 5% level of probability

Appendix-V (d)

Analysis of variance for Number of plant spread (cm) turmeric at 120 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	175.35			
Factor A	3	66.26	22.08	1.50	0.24174
Factor B	2	65.89	32.94	2.24	0.13016
Interaction A X B	6	259.15	43.19	2.93	0.02930*
Error	22	323.53	14.76		
Total	35	890.20			

Significant at 5% level of probability

Appendix-V (e)

Analysis of variance for Number of plant spread (cm) turmeric at 135 DAP

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	193.34			
Factor A	3	87.81	29.27	3.39	0.03594*
Factor B	2	25.69	12.84	1.49	0.24734
Interaction A X B	6	409.77	68.29	7.91	0.00013**
Error	22	189.75	8.62		
Total	35	906.38			

Significant at 5% level of probability

Appendix-VI

Analysis of variance for Number of fresh yield turmeric

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	23.03			
Factor A	3	7102.13	2,367.37	259.53	0.00000***
Factor B	2	204.61	102.36	11.21	0.00044**
Interaction A X B	6	110.91	18.48	2.02	0.10500
Error	22	200.67	9.12		
Total	35	7641.37			

Significant at 5% level of probability

Appendix-VII

Analysis of variance for Number of dry yield turmeric

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.14			
Factor A	3	239.51	79.83	205.29	0.00000***
Factor B	2	3.12	1.56	4.02	0.03252*
Interaction A X B	6	1.34	0.22	0.57	0.74361
Error	22	8.55	0.38		
Total	35	253.69			

Significant at 5% level of probability

Appendix-VIII

Analysis of variance for Number of dry yield recovery turmeric

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	13.07			
Factor A	3	430.14	143.38	36.57	0.00000***
Factor B	2	138.90	69.45	17.71	0.00003***
Interaction A X B	6	218.97	36.49	9.31	0.00004***
Error	22	86.24	3.92		
Total	35	887.33			

Significant at 5% level of probability

Appendix-IX

Analysis of variance for Number of essential oil turmeric

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0. 05			
Factor A	3	0. 28	0. 09	0.93	0.43912
Factor B	2	0. 15	0. 08	0.76	0.47621
Interaction A X B	6	0. 25	0. 04	0.42	0.85343
Error	22	0. 15	0. 10		
Total	35	0. 88			

Significant at 5% level of probability

Appendix-X

Analysis of variance for Number of oil yield turmeric

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	362.13			
Factor A	3	32969.97	1323.32	20.57	0.00000***
Factor B	2	78.21	39. 06	0.60	0.55337
Interaction A X B	6	174.46	29. 68	0.45	0.83585
Error	22	1415.17	64. 26		
Total	35	5999.84			

Significant at 5% level of probability

Appendix-XI

Analysis of variance for Number of bulk density turmeric

Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0. 17			
Factor A	3	0. 06	0. 02	0.27	0.84069
Factor B	2	0. 17	0. 09	1.22	0.31216
Interaction A X B	6	0. 21	0.04	0.56	0.79734
Error	22	0.15	0. 07		
Total	35	0. 13			

Significant at 5% level of probability

Appendix-XII (a)

Common cost of cultivation

	Item details	Cost (Rs.) 2007
A.	Land preparation	
	3 harrowing + leveling (4 hrs for harrowing + 1 hr for leveling @ Rs. 300/hrs	3900
B.	Planting techniques	
	i. Furrow opening 2 hrs/ha @ Rs. 300/hrs	600
	ii. Labour charges (10 labours for planting and seed covering)	2000
C.	Manure	
	FYM @ 5 t/ha (Rs. 600/t)	3000
D.	Fertilizers	
	Phosphorus @ 60 kg/ha through SSP	2790
	Potash @ 60 kg/ha through MOP	1600
E.	Irrigation @ Rs. 50/hr for 20 hrs (for four irrigation)	1000
F.	Pesticide application	500
G.	Harvesting	
	10 man days @ Rs. 200/man day	2000
H.	Cleaning, washing and drying of rhizomes	
	10 man days @ Rs. 200/man day	2000
I.	Transportation (Tractor @ 300/hr)	300
J.	Land revenue @ Rs. 100/ha	100
	TOTAL	19790

Appendix- XII (b)

Common cost of cultivation

	Treatment	Quantity	Rate (Rs.)	Cost (Rs.)
A.	Planting spacing			
	i. 40 cm x 10 cm	25.0 q/ha	3000/q	75000.00
	ii. 40 cm x 20 cm	12.5 q/ha	3000/q	37500.00
	iii. 40 cm x 30 cm	8.4 q/ha	3000/q	25200.00
	iv. 40 cm x 40 cm	6.4 q/ha	3000/q	19200.00
B.	Nitrogen level			
	i. 100 kg	100 kg/ha	1178/q	1178.00
	ii. 125 kg	125 kg/ha	1178/q	1473.00
	iii. 150 kg	150 kg/ha	1178/q	1767.00

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ABSTRACT

ABSTRACT

Name	:	Niki Nautiyal	**Id. No.**	:	13165
Semester and year of admission	:	1st Sem., 2013-14	**Degree**	:	M.Sc. Horticulture (Plantation, Spices, Medicinal and Aromatic Plants)
			Deptt.	:	Medicinal and Aromatic Plants
Major	:	Plantation, Spices, Medicinal and Aromatic Plants	**Minor**	:	Soil Science

Thesis title : "Effect of nitrogen level and plant spacing on growth and yield of turmeric (*Curcumalonga* L.)"

Advisor : Dr. B.P. Nautiyal

A field experiment was conducted during *kharif* season of 2014 at Medicinal and Aromatic Plants Block of VCSG Uttarakhand University of Horticulture and Forestry, Bharsar to study the "Effect of nitrogen level and plant spacing on growth and yield of turmeric (*Curcumalonga* L.)". The treatments were consisted of three nitrogen level (100 kg nitrogen ha^{-1}, 125 kg nitrogen $ha^{-1}$and 150 kg nitrogen ha^{-1}) and four plant spacing (40 cm x 10 cm, 40 cm x 20 cm, 40 cm x 30 cm and 40 cm x 40 cm). The experiment was laid down in two factor RBD with 3 replications.Most of the growth parameters viz. plant height, number of leaves, plant spread and leaf area of turmeric were significantly higher under 150 kg ha^{-1} nitrogen application. Similar, results were also obtained with plant spacing of 40 cm x 40 cm for turmeric.Yield attributes improved due to higher dose of nitrogen level (150 kg ha^{-1}) and plant spacing with 40 cm x 40 cm but in turns of per unit area, maximum yield being improved with 40 cm x 10 cm ha^{-1}.

The highest gross return (Rs.179600 ha^{-1}), net return (Rs.158043 ha^{-1}) and B: C ratio (7.33) was obtained under 150 kg nitrogen ha^{-1}. Plant spacing with 40 cm x 10 cm recorded maximum gross return (251000) and net return (156210) but maximum benefit: cost ratio (2.35) observed in plant spacing of 40 cm x 20 cm.

(B.P. Nautiyal)
Advisor

(Niki Nautiyal)
Author

सारांश

नामः निकी नौटियाल

अभिज्ञान संख्याः13165

प्रवेश का छमाही एवं वर्षः पहला छमाही,2013–2014

उपाधिः एम0एस–सी0 औद्यानिकी
(वृक्षारोपण, मसाले, औषधीय एवं सगंध पौधे)

विभागः औषधीय एवं सगंध पौधे

मुख्यः वृक्षारोपण, मसाले, औषधीय एवं सगंध पौधे

सुक्ष्मः मृदा विज्ञान

शोध विषयः "नाइट्रोटजन की विभिन्न मात्राओं एवं पौधों के अन्तराल का हल्दी (*कुरकुमा लौंगा* एल0) की वृद्वि एवं उपज पर प्रभाव"

सलाहकारः प्रो0 बी0 पी0 नौटियाल

"नाइट्रोटजन की विभिन्न मात्राओं एवं पौधों के अन्तराल का हल्दी (*कुरकुमा लौंगा* एल0) की वृद्वि एवं उपज पर प्रभाव" का अध्ययन हेतु वर्ष 2014 के खरीफ ऋतु में वीर चन्द्र सिंह गढ़वाली उत्तराखण्ड औद्यानिकी एवं वानिकी विश्वविद्यालय के औषधीय एवं सगंध पौधा प्रखण्ड में प्ररीक्षण किया गया था। जिसमें तीन नाइट्रोजन की मात्राओं (100 किलोग्राम नाइट्रोजन प्रति हैक्टेयर, 125 किलोग्राम नाइट्रोजन प्रति हैक्टेयर,एवं 150 किलोग्राम नाइट्रोजन प्रति है हैक्टेयर,) एवं चार पौध अन्तरालों (40 से0मी0 x 10 सेमी0, 40 से0मी0 x 20 सेमी0, 40 से0मी0 x 30 सेमी0 एवं 40 से0मी0 x 40 सेमी0) को उपचार के लिए प्रयोग किया गया था। प्रस्तावित शोध को यादृच्छिक ब्लॉक डिजाइन रूपरेखा में दो घटक के साथ तीन प्रतिकृति में दोहराया गया था। अधिकतम वृद्वि मापदण्डों जैसे पौधों की लम्बाई, पत्तियों की संख्या, पौधों का फेलाव एवं पत्तियों का क्षेत्रफल) 150 किलोग्राम नाइट्रोजन प्रति हैक्टेयर में सार्थक रूप में उत्तम पाया गया था। ऐसा ही प्रतिफल 40 से0मी0 x 40 सेमी0 की पौध अंन्तराल में भी पाया गया था। नाइट्रोजन की अधिक मात्रा (150 किलोग्राम प्रति हैक्टियर)एवं पौध अन्तराल 40 से0मी0 x 40 सेमी0 में उपज को प्रभावित करने वाले कारक का सुधार हुआ परन्तु उपज प्रति इकाई क्षेत्रफल के अनुसार 40 से0मी0 x 10 सेमी0 के पौध अन्तराल में उत्तम पाया गया था।

सर्वाधिक सकल लाभ (रू0 1,79,600.00 प्रति हैक्टेयर), शुद्व लाभ (रू0 1,58,043.00 प्रति हैक्टेयर) एवं लाभःलागत अनुपात (7.33) नाइट्रोजन की 150 किलोग्राम प्रति हैक्टेयर मात्रा पर पाया गया था। 40 से0मी0 x 10 सेमी0के अन्तराल पर सर्वाधिक सकल लाभ (रू0 2,51,000.00) एवं शुद्व लाभ (रू0 1,56,210.00) पाया गया था परन्तु सर्वाधिक लाभःलागत अनुपात (2.35) 40 से0मी0 x 20 सेमी0,के अन्तराल पर पाया गया था।

(प्रो0 बी0 पी0 नौटियाल)
सलाहकार

(निकी नौटियाल)
लेखक

VITA

VITA

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