EFFECT OF NPKS ON THE GROWTH AND YIELD OF NAGA CHILLI (*Capsicum chinense*)

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CERTIFICATE

This is to certify that the thesis entitled **EFFECT OF NPKS ON THE GROWTH AND YIELD OF NAGA CHILLI (*Capsicum chinense*)** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE IN SOIL SCIENCE** embodies the result of a piece of bona fide research work carried out by **Jhutan Ch. Sarker,** Registration No. **06-01937** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any other institutes.

I further certify that any help or sources of information, as have been availed during the course of this investigation have duly been acknowledged.

Dated:
Dhaka, Bangladesh

Prof. Dr. Alok Kumar Paul
Department of Soil Science
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Supervisor

DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

The present experiment was conducted at Citrus Research Station, Bangladesh Agricultural Research Institute, Jaintapur, Sylhet during the period from January, 2014 to June 2014 to evaluate the effect of different levels of NPKS on the growth and yield of naga chilli. There were 14 treatment combinations comprising four levels of each of N (0, 80, 100 and 120 kg/ha), P (0, 50, 75 and 100 kg/ha), K (0, 100, 120 and 140 kg/ha) and S (0, 10, 20 and 30 kg/ha). The experiment was laid out in Randomized Complete Block Design with three replications. There were significant variations among the treatments with plant height (cm), spreading (cm), number of branches, stem diameter (cm), plant volume (cm^3), days to 50 per cent flowering, days to first harvest, days to complete harvest, number of fruits per plant, fruit weight (g), fruit length and diameter (cm), pericarp weight (g), number of seeds per fruit, 1000 seed weight (g), dry fruit weight (g), and fruit yield (t/ha) of naga chilli. Highest plant height, spreading, number of branches, stem diameter, plant volume, number of fruits/plant, fruit size, single fruit weight, pericarp weight of naga chilli were achieved from the treatment combination of N_{100} P_{50} K_{120} S_{20} (T_6) while the control (native nutrient) exhibited the lowest. Maximum fruit yield (25.77 t/ha) was obtained from N_{100} P_{50} K_{120} S_{20} followed by N_{100} P_{75} K_{120} S_{20} (24.83 t/ha) and N_{80} P_{75} K_{120} S_{20} (24.40 t/ha) of NPKS application whereas the control plots yielded the minimum (8.75 t/ha). The highest gross margin (Tk. 907.99/m^2) and marginal rate of return (33833.33%) was also obtained from the same treatment. Application of N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) appear to be the best for maximizing the growth and yield of naga chilli for Sylhet region.

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LIST OF ABBREVIATIONS

%	=	Percent
@	=	At the rate
^{o}C	=	Degree centigrade
BARI	=	Bangladesh Agricultural Research Institute
BAU	=	Bangladesh Agricultural University
BBS	=	Bangladesh Bureau of Statistics
cv.	=	Cultivar (s)
DAT	=	Days After Transplanting
DMRT	=	Duncan's Multiple Range Test
e.g	=	For example
et al.	=	And others
etc.	=	Etcetera
g	=	Gram
i.e.	=	That is
Kg	=	Kilogram
LSD	=	Least Significant Difference
SAU	=	Sher-e-Bangla Agricultural University
T	=	Treatment
MRR	=	Marginal Rate of Return
FAO	=	Food and Agricultural Organization

CHAPTER 1
INTRODUCTION

Naga Chilli (*Capsicum chinense* Jacq.) as a member of the Solanaceae family (tribe Solaneae, subtribe Capsicinae), also known as the world's hottest chilli entered in the Guinness book of world record (2006) with a pungent level of 879,953 to 1,001,304 SHU (Adriana *et al.*, 2008). Naga chilli is traditionally cultivated in hilly orchard along with citrus. Due to its extra-ordinary pungency level, oleoresin powder extracted from Naga chilli is predicted to dominate the world market in coming years as the mainstay for riot control (Ritesh *et al.*, 2000).

The Naga Chilli plant is a wonderful gift of nature as it possesses a pleasant and palatable aroma. The crop is native to the North eastern part of Bangladesh, growing in Brahmaputra flood plain (Bhagowati *et. al.*, 2009) also known as Naga Morish or Dorset naga (that derivative from Bangladesh). Naga Chilli is an interspecies hybrid, mostly *Capsicum chinensis* with some *Capsicum frutescens* genes. The plant grows to a height of 57-129 cm at 6 months. It may even grow taller in semi-perennial situation. The leaves have a characteristic crinkle look. Flowers are greenish white with a touch of light brown. The anthers are blue while the filaments are purple. Fruits are light green, creasy white and dark green which turn bright red at maturity. The fruit posses 4-5 locules and bears about 25-35 slightly rinkled seeds. There are at least three distinct colours found like light red, dark red and orange (Bhagowati *et al.*, 2009).

They have been incorporated into a number of medicinal preparations in the ancient literature around the World (Meghvansi *et al.*, 2010), contain biologically active components with physiological and biochemical functions which play a key role in human health (lhami *et al.*, 2007). This extreme character of this chilli is due to the volatile phenolic amine 'capsaicin and dihydrocapsaicin', which is responsible for the pungency found mainly in the placenta as well as fleshy tissue of the fruit (Rahman, 2012; Heiser, 1969) has been found to be very high (Sanatombi and Sharma, 2008), may prevent various diseases associated with Cardiovascular system, Cancer and neurological diseases (Menichini *et al.*, 2009 and Mueller *et al.*, 2010) also used as traditional medicine for the treatment of ulcers, diabetes, Rheumatism (Tolan *et al.*, 2004), headache, night blindness (Deorani and Sharma, 2007), rheumatism, arthritis, gastritis, ankylosing spondylitis, digestive diseases (Sarwa *et al.*, 2012) and to reduce chronic congestion (Bhagowati and Changkija (2009).

The Naga chillies are cultivated as vegetable as consumed fresh with feast and also they are used as condiment. The people of the north eastern India used the fruits in different food formulations like flavouring curries due to its high-quality fragrance and pungency. Countries like Canada, Europe, Japan, Korea and the USA, where it is used to enhance spiciness of food (González-Estrada, 2006).

The indigenous peoples inhabiting near forest area use the chilli powder or its smoke to keep elephants away from their agriculture fields (Sarwa *et al.*, 2012). Scientists are now using this chilli for modern innovative like ‘anti-mugger aerosols’ which cause attackers to gasp and twitch helplessly for 20 minutes (Bosland and Votava, 2000) also used in personal self-defence and for treating pain from neuropathies (Islas-Flores *et al.*, 2005).

Naga chilli is grown successfully in North-eastern region of Bangladesh during the Rabi season (Rashid, 1999). But the acreage is not satisfactory due to the unawareness of the growers on production technology. The average yield of Naga chilli in Bangladesh was 4.5-5.5 ton/hectare (personal experience). This yield is relatively low compared to that of other Naga chilli producing countries like, UK (51.88 t/ha), Sweden (54.35 t/ha), Austria (56.70 t/ha) and Israel (64.20 t/ha) (FAO, 2010). Production of Naga chilli could be increased in many ways; of which the most important one is the judicious nutrient management; for healthy growth of plants and optimum yield (Grewal and Trehan, 1979).

In naga chilli cultivation, fertilizer is the single most important factor that plays a crucial role in increasing growth and yield. Excessive or under dose of N, P, K and S can affect the growth and yield of good quality naga chilli. By optimizing fertilizer use efficiency rapid growth of Naga chilli can be achieved (Mellor, 2001).

The effect of the individual nutrient on the plant development has another major impact on the fertilizer requirements. Nitrogen, phosphorus and potassium are critical for chilli growth and development (Jones, 2008). Nitrogen is associated with vegetative and biomass accumulation (Rai, 1981), phosphorus to seed and root development (Mitra *el al.*, 1990) and potassium is associated with fruit development, quality and manufacture of sugar and starch; important in a multi-nutrient fertilizer application (Brady, 1995) while sulphur is associated with synthesis of amino acids, co-enzyme, thiamine and chlorophyll (Tisdale *et al.*, 1984). Thus, the synchronization of nutrients availability through right dose of fertilizer application is recommended to optimize yield, fruit quality, and mineral nutrient efficient use without threatening sustainability. Therefore increasing the yield of this crop by judicious application of optimum rate of nutrients especially N, P, K and S is an urgent need and has sufficient scope.

In the recent years some crops of North-eastern region of Bangladesh are gaining importance because of export potentiality worldwide, stimulating family farming and increased employment and income generation from agriculture. Naga chilli is one of them with very much popularity for its aroma, pungency, nutritive value and possible diversified use. There has an also immense scope in international market due to its remarkably high capsaicin content. As the production of naga chilli in Bangladesh is still in the hand of marginal farmers and its production technology has not yet been standardized; information regarding the use of different doses of N, P, K and S fertilizers in naga chilli production is inadequate. Thus, a detailed and systematic study is needed to find out the best combination of fertilizer dose for growth and yield which will ultimately help in increasing productivity and economic return. Consequently the communities of naga chilli growers will be benefited by exploiting their environment and other resources being improving their economic status will contribute in the national economy further. Agricultural research and extension services providers may find the new way for innovative research and extension on this unique chilli. Government policy makers, GOs, NGOs and private sector may be benefited by using the findings to set policies and to invest more under less economical risks aimed at Naga chilli production thus contributing to overall food security.

Therefore, the present study was aimed to evaluate the effect of nitrogen, phosphorus, potassium and sulphur doses of fertilization in Naga chilli on their growth, yield and profitability.

Under the above circumstances, the present study was undertaken with the following objectives-

- To find out the optimum dose of NPKS fertilizers for better growth and yield of Naga chilli.
- To determine the most effective dose of NPKS fertilizers for the highest economic return.

CHAPTER 2

REVIEW OF LITERATURE

Naga chilli is one of the most popular vegetable crops throughout the world as well as in Bangladesh. Especially from the nutritional point of view, Naga chilli drew much attention to the researchers throughout the world to develop its production technology. Like many other vegetable crops. Different levels of N, P, K and S influence the growth and yield of Naga chilli. Researches on various aspects of its production technology have been carried out worldwide. Among these, limited number of works has been done in Bangladesh on the effect of NPKS on growth and yield of Naga chilli. The purpose of this chapter is to examine literature reports which are pertinent to the experiments undertaken by the author.

Adam *et al*., (2002) reported that application of high mineral fertilizer rate (100:32:72 kg/bed) combined with bio fertilizers at 3 kg produced highest total fruit yield and the most favourable fruit quality.

Ahmed *et al.,* (2007) reported that an increase in nitrogen application resulted in maximum fruit length, fruit weight, vine length and yield.

Alabi, (2006) found that P levels significantly increased pepper plant height, number of leaves and branches per plant and leaf area up to 125 kg P/ha level and concluded that poultry droppings increased the yield components of pepper more significantly than the phosphorous.

Alam *et al*., (2007) carried out an experiment on the effect of vermicompost and N, P, K and S fertilizers showed that chemical fertilizers were more efficient in the first four weeks of application suggesting that the vermicompost may have taken at least four weeks to have a more favourable effect on plant growth.

Aliyo, (2000) reported that the application of FYM + poultry manure at 5t per ha each supplemented with 50 kg N per ha resulted in significantly higher fruit compared with other treatment in pepper.

Almeselmani *et al.,* (2010) found that Potassium increases production of beneficial compounds such as protein, ascorbic acid, lycopene, total soluble solids, titratable acidity, and reduces sugar levels.

Aminifard *et al.,* (2010) carried out an experiment to evaluate the effect of nitrogen fertilizer on growth and yield of solanecious crops under field conditions. Nitrogen was applied in four rates (0, 50, 100 and 150 Kg ha^{-1}). They observed that increasing the N levels of the fertilizers to 50 kg N ha^{-1} significantly increased the yield while yield decreased at the highest rate of nitrogen. This decrease in yield might be due to excess levels of nitrogen in the plant. The marked effect of nitrogen on yield might be due to the cumulative stimulating effect of nitrogen on the vegetative growth characters which form the base for flowering and fruiting.

Aujla *et al.,* (2007) revealed that fruit yield increased significantly with increasing nitrogen level up to 150kg per hectare.

Baghour *et al.,* (2001) in their study reported that total P had a quadratic response to N fertilization with maximum concentrations at low N dosages of 6 and 12 g/m at the onset of flowering. High N concentrations caused a negative effect on P absorption and transport. Total P, inorganic, and organic concentrations responded linearly to K, with the highest values at the lowest K treatment. Potassium fertilization reduced P concentrations while the highest K treatment significantly increased yields.

Bajaj *et al.,* (1979) found that the application of 0 P in combination of the highest dose of N resulted in increased pepper plant dry matter content as well as 0 N and highest P rate. The combination of N and P fertilizers applied at any selected rates reduced plant dry matter content when compared to the 0 P high N, and 0 N high P treatments.

BARC, (1997) found that Fertilizers effect on the production system of modern agriculture and play a vital role to increase the yield provided other factors are not limiting. Chemical fertilizers today hold the key to the success of the crop production system of Bangladesh agriculture, being responsible for about 50 percent of the total production.

Bavec *et al*., (2003) obtained highest fruit number (2.59) and fruit yield per ha (230.56 q/ha) with split applications of 200 kg N per ha in chilli.

Berke *et al.,* (2005) found that pepper is a heavy feeder of NPK and therefore required a liberal application of 450 kg/ha N, 220 kg/ha P and 400 kg/ha K. Forty percent of the N should be applied as basal fertilizer before transplanting. The remaining 60% should be side dressed in three equal amounts at 2, 4, and 6 weeks after transplanting (WAT). Half of the P and K should be applied as basal fertilizer, and the remainder should be side-dressed at 4 WAT.

Berova and Karanatsidis, (2009) observed increased photosynthetic pigments and leaf gas exchange in red chilli (*Capsicum annum* L.) due to application of vermicompost.

Bosland and Votava, (2000) reported that pepper required adequate amounts of major and minor nutrients to produce well. The nutrients normally used on peppers are nitrogen and phosphorus. Some early nitrogen fertilizer is needed for young seedlings but too much nitrogen on the other hand can over stimulate growth, resulting in large plants with few early fruits, or delaying maturity and increasing risk of serious plant or pod rots. They suggested 10 t/ha organic manure, 140 kg/ha N, 100 kg/ha P_2O_5, and 200 kg/ha K_2O for light soils.

Bosland *et al*., (1994) stated during growth, nitrogen may be applied to achieve more yields. A side dressing of 22-34 kg/ha of nitrogen is applied when the first flower buds appear and when the first fruits are set.

Buzetti *et al.*, (2007) carried out an experiment to evaluate the effects of applications of nitrogen (urea) and potassium doses (potassium chloride) on the yield and quality of chilli under drip irrigation. Nitrogen doses (0, 50, 100 and 150kg N ha^{-1}) were combined in a factorial arrangement with potassium doses (0, 50, 100 and 150kg K_2O ha^{-1}). Nitrogen increased the number and total mass of fruits, number of marketable fruits, and fruit length/width shape ratio.

Chaudhari *et al*., (1995) also studying the performance in relation to fertilizer application found that yields increased with the application of fertilizers.

Chaudhary *et al.,* (2007) carried out a two year trial on the effect of fertilizer rate, application timing and plant spacing on yield and nutrient content of bell pepper. Response of *Capsicum* to plant spacing (45 x 50, 60 x 50 and 75 x 50cm) and graded doses of nitrogen (100, 150, 200 and 250 kg N ha-1) and phosphorus (100, 150 and 200 kg P_2O_5 per ha) was studied on a sandy loam soil. Generally, increased levels of nitrogen application up to 200 kg N per ha, significantly improved plant growth, yield and yield attributes but further increase in nitrogen level did not bring significant improvement in these characters. Application of phosphorus significantly influenced only yield and yield attributes up to 150 kg P_2O_5 per ha.

Chavan *et al*., (1997) recorded higher fruit yield (1975.30 kg/ha) with application of 75 kg N per ha + FYM 7.5 t per ha, which was significantly higher than control (1076.50 kg/ha) in chilli.

Chougule and Mahajan, (1979) reported significantly higher number of branches per plant with the application of 200:120:120 kg NPK per ha, while less number of branches were noticed with 100:60:60 kg NPK per ha.

Coltman and Riede, (1992) tested different levels of K (25, 50, 100, 200 and 300 mg·L-1) in a greenhouse experiment of potted tomato plants and monitored the petiole sap K concentration. Plant height, and stem diameter were significant ly different due to K concentrations while yield was quadratically related to increasing external K concentrations.

Cotter, (1986) stated Peppers require adequate amount of major and minor nutrients. However, they appear to be less responsive to fertilizer, compared with onion, lettuce and Cole crops.

Damke *et al*., (1988) observed greater plant height (60.3 cm) and yield in chilli (1.52 t/ha) with application of FYM at 9 t per ha along with 50:50:50 kg of N, P_2O_5 and K_2O per ha.

Duraisamy *et al*., (1999) reported significantly higher fruit yield of 12.44 t per ha with the application of 96:77:70 kg NPK with 12.5 t FYM per ha in tomato cv. Paiyur-1 as compared to other fertilizer levels.

EARO, (2004) reported fertilizer requirements vary with soil type and previous crop history. And thus a balanced nutrient level is required for maximum production. In Ethiopia, the recommended fertilizer rate for the hot pepper is, 200 kg/ha DAP and 100 kg/ha for UREA.

Eifediyi and Remison, (2009) observed that the effect of different NPK levels of 0, 100, 200, 300 and 400 kg per ha on the number of fruits, fruit length, fruit girth and fruit weight of cucumber was significant. The number of fruits per plant, fruit length, fruit girth, fruit weight per plant and total yield per hectare increased significantly with increase in inorganic fertilizer application up to a point and yield decreased at the highest level.

Everet and Subramanya, (1983) in a study of plant spacing and N and K rates of field grown pepper plants, reported that increased N-K2O rates from 150-210 to 294-415 lb/acre, respectively, had no effect on pepper yield, fruit number, and average fruit weight of pepper in any of the three seasons that the study was performed.

Firoz, (2009) conducted an experiment at the Hill Agricultural Research Station, Khagrachari, Bangladesh to find out the effect of nitrogen (60, 80, 100 and 120 kg ha-1) and phosphorus (80, 100 and 120 kg ha^{-1}) on the growth and yield of okra in hill slope condition during the rainy season. The highest yield (16.73 t/ha) was obtained from 100 kg N/ha, which was statistically identical to 120 kg per hectare. In case of phosphorus, the highest yield of 15.77 t/ha was obtained from 120 kg P_2O_5/ha and was closely followed by the dose of 100 kg P/ha (4.73 t/ha). Considering the treatment combinations, the highest yield (19.22 t/ha) was produced by $N_{100}P_{120}$.

Frempong *et al.,* (2006) reported a significant difference between manured treated plots than the control. There were significant differences between compost and other manure plots (poultry and cow dung) at 60 days after planting. Also, it was observed in the study that inorganic fertilizers produced more leaf chlorophyll content than cow dung and the control at 90 days after planting.

Gill *et al.*, (1974) in a study of the effect of nitrogen and phosphorus application rates on seed yield of sweet pepper, phosphorus rates decreased the days to flower. Phosphorus rates alone increased the number of branches per plant from 4.1 to 5.8. Increased P rates resulted in significant yield increases; higher P rates increased considerably the number of fruits per plant as well as seed yield.

Golcz *et al.,* (2012) reported that the total yield, marketable yield, commercial fruit yield and total average yield per plant were increased by increasing application rates of nitrogen (N) and potassium (K) fertilizers on pepper plant. They also stated that chilli pepper has the greatest requirement for potassium (40%) and nitrogen (31%) in relation to the total amount of absorbed nutrients.

Gopinath *et al.*, (2009) observed that integrated crop management (FYM 10 q ha^{-1}) and recommended NPK 100:22:41.5 kg ha^{-1} has recorded maximum number of bell pepper fruits (23.7) and fruit yield (37 kg per ha) as compared to an amended control.

He *et al.*, (1999) found the effect high NO_3 supply on hydroponically grown plants tended to increase K concentration and to decrease Ca and Mg. No effect, however, was reported on the concentration of P in the petiole sap of different leaf positions.

Hedge, (1997) showed that nutrient uptake and dry matter production (fruit yield) of hot pepper are closely related.

Heuvelink, (2005) found that Phosphorus is essential to crops, in much smaller quantities than N. It is associated with early root development and architecture especially when P levels are low.

Hidetoshi, (2007) found K fertilization has been associated with increased fruit quality, plant growth and yield. A positive correlation was shown between increased rates of potassium and fruit weight and number of flowers and fruits. About, two-thirds of the K uptake is allocated to fruits.

Hiremath *et al.,* (2003) observed that, application of higher fertilizer levels improved yield and yield attributes significantly.

Hochmuth *et al.*, (1988) found potassium application rates ranging from 22 to 255 kg/ha in combination with N have positive effect on bell pepper yield.

Huang and Snapp, (2009) showed the high amount of quality which was influenced by high amount of K or the greatest amount of K fertilizer application which was associated with increased cracbioassaytibility as indicated by a fruit bioassay.

Ibrahim, (1998) carried out an experiment to determine the optimum N and K fertilizer rate for yield and quality parameters. Results revealed that the pepper plants have responded significantly ($P< 0.001$) to the nitrogen fertilizer (100 and 200 kg N ha^{-1}) by increasing plant length, yield and nutrient content. However, potassium fertilizers have less effect on both plant parameters. Increasing N addition increased plant yield, however increasing K addition did not make a significant ($P< 0.277$, 827 respectively) difference on the yield. Under high nitrogen and potassium fertilizer application, flowering time was earlier than that of the control plants. Nitrogen treatments increased the plant N, P and K concentration. The study showed that K fertilizer has no significant influence on nutrient concentration. Results have shown that pepper plants have a higher K content.

Ikeda and Osawa, (1981) found naga chilli depends on chemical fertilizers for optimal growth and high yields. NPKS are the major macro nutrients that are necessary for physic-morphological and biological development of plants. Better growth of the plants when nitrogen is apply in the form of NH_4, but root development is better with NO_3 & NH_4.

Ingle *et al.,* (1993) observed that plant height in chilli was observed with four split application of 100 kg N per ha and basal dose of 50 kg each P_2O_5 and K_2O per ha.

Islam *et al.* (1987) found Sulphur is very much beneficial for increasing the production of vegetable and rice. Sulphur deficiency delays growth and development of plant.

Islam, (2006) conducted a field experiment at the Horticultural Farm, BAU, Mymensingh during the period from November 2005 to February 2006, to study the effect of plant nutrients on growth and yield. It was found that the highest gross yield (54.11 t/ha) was produced by the treatment combination $N_{113}P_{33}K_{75}S_{20}$ + Zn_7Mo_o kg/ha, while the highest marketable yield of carrot (49.394 t/ha) was obtained from the treatment combination of $N_{113}P_{33}K_{75}S_{20}$ + Zn_7Mo_o kg/ha.

Jilani *et al.,* (2008) reported that nitrogen application at 100 kg/ha produced significantly maximum survival percentage, fruit length, fruit diameter, fruit volume, fruit weight and yield per hectare.

Jones, (1999) in his study found that toxicity due to excess fertilization results in dark green leafage. Flower clusters are more numerous but bud abortion increases. It also inhibits flower development, fruit setting and formation, increase susceptibility to lodging, disease and insect invasion.

Kaminwar and Rajagopal, (1993) observed the highest chilli fruit yield, quality and nutrient efficiency with application of 100:50:100 kg NPK per ha.

Kinet *et al.,* (1985) found nitrogen influences flower development of several vegetable crops including pepper, tomato and cucumber. However, the effect of fertilizer upon flowering and fruit set of green pepper has produced contradictory results. Nitrogen is known to be the most important nutrient affecting fruit yield in pepper.

Konopinski, (1995) in an experiment found S in Naga chilli plants roles in the synthesis of glucosinolates, typical compounds determining the flavour of fruits. S deficiency affects photosynthesis, the synthesis of protein, vitamins and can reduce yields and quality of crops.

Kulvinder and Srivastova, (1988) working on *capsicum* realized that parameters such as plant height, number of branches, number of fruits per plant, fruit length and diameter and yield increased with increasing rates of fertilizer application. They also reported that the combination of N and P fertilizers at higher levels resulted in maximum yield being the most economic treatment for capsicum.

Lal, (1992) observed maximum fruit length (5.99 cm) in chilli cv. Pant C-1 with the application of 150:50:50 kg NPK per ha and the minimum fruit length (4.54 cm) was recorded in control.

Lau and Stephenson, (1994) found the positive role of Phosphorus in flower and seed production.

Laxman *et al.,* (2000), indicated that yield and yield attributes of chilli cv.RCH-1 were highly influenced by the foliar spray of urea. The maximum fruit yield (193.06 q/ha) as obtained with the treatment of 1.5 per cent urea spray.

Locascio *et al.,* (1985) showed early availability of N appears necessary for plant growth, fruit size and yield of pepper. The yield was greater with a single N application than split applications when plants were grown under mulch.

Lombin *et al.*, (1991) found that the importance of integrated nutrient use in crop production in recent years cannot be overemphasized in view of the high cost of chemical fertilizer to meet crop nutrient requirement. Complimentary use of organic manure and mineral fertilizers has proved to be a sound strategy to maintain soil fertility in many parts of the world.

Maheswari and Haripriya, (2007) noted that application of FYM 25 t/ha along with neem cake at 2 t/ha recorded the maximum ascorbic acid (179.30 and 180.34 mg/100 g) and capsicin (0.83 and 0.85 per cent) content in chilli.

Mallanagouda *et al*., (1995) reported maximum plant height (65.5 cm) and number of branches per plant (10.1) in chilli when FYM was applied at 25 t per ha along with 75:35:35 kg NPK per ha compared to inorganic fertilizers alone (56.7 cm and 8.93). Integrated application of recommended dose of NPK+FYM improved the growth parameters as well as yield and yield components in chilli.

Man Chanda and Bhopal, (1987) working on pepper observed that the highest plant density and highest N levels gave the highest yield and quality of fruits.

Matta and Cotter, (1994) found that phosphorus results in a better yield and more red colored fruit.

May *et al.,* (1982) recorded the highest yield of 12.3t/ha from N and P application rates of 150 and 100 kg/ha respectively.

Mello *et al.,* (2000) recorded higher fruit weight and yield of pepper with 100g poultry manure/hole + 100% NPK (130: 458: 262: kg N: P_20_5:K_20/ha) compared with treatments of 150 g peat compost/hole + 70 or 100% NPK; 100g wood chip compost (pine) per hole + 70 or 100 % NPK. Similarly, plant height and pepper fruit yield/ha increased with increasing levels of N with maximum yield recorded at 160 kg N/ha.

Mengel and Kirkby, (1980) said that, solanaceas vegetable crops of pepper generally take up large amounts of nutrients from the soil.

Mitra *et al.*, (1990) observed that application of N fertilizer increase the yield and vitamin-C content while P and K have no appreciable effect on the accumulation of vitamin-C, carotene, thiamine and riboflavin. They also found excessive N application, however, reduce the yield, but all nutrients at high rates raised the carotene content. The reducing, non-reducing and total sugar contents in the xylem and non-reducing and total sugar contents in the phloem are increase with high P application.

Naidu *et al*., (1999) observed higher number of fruits per plant (24.3) and fruit yield (149 q/ha) with the application of 80:60:50 kg NPK per ha in addition to 20t FYM per ha. It was significantly superior over control (17.3 and 100 q respectively).

Nanthakumar and Veeraragavathatham, (2001) recorded significantly higher fruit yield (26.8 t/ha) with application of 100:100:100 kg NPK and 12.5 t FYM per ha as compared to 75:75:100 kg NPK per ha alone (20.1 t/ha) in brinjal.

Narasappa *et al*., (1985) reported that the application of 150 kg N + 10 t FYM per ha increased the green chilli yield by 60.42 per cent over the control. The higher level of fertilizer application of N, P_2O_5 and K_2O at 60 kg per ha each with FYM produced higher yield of capsicum (12.20 q/ha) as compared to without FYM (9.81 q/ha).

Natarajan, (1990) noticed higher plant height and number of branches per plant in chilli when FYM was applied @ 25 t per ha as a basal dose along with 75:33:35 kg NPK per ha. While higher fruit yield of chilli (1.83 t/ha) when FYM 25 tonnes per ha was applied as basal dose along with 75:35:35 kg NPK per ha.

Nirmala and Vadivel, (1999) noticed significantly less number of days to appearance of first female flower (30) and narrower sex ratio (6) with the application of FYM (30 t/ha) along with 35 kg nitrogen per ha as compared to FYM and nitrogen applied individually in cucumber. This also significantly increase in number of fruits (9/branch), length of the fruit (11 cm), girth of the fruit (9 cm) and fruit yield (1435 g/plant)

Nirmala *et al*., (1999) recorded significantly higher fruit length (15.53 cm), fruit girth (11.79 cm), fruit number (9.71/vine) and fruit yield (1435.1 g/vine) with application of FYM (30 t/ha) + N (35 kg/ha) over all other manorial treatments. Application of 100:100:100 kg NPK per ha and 12.5 t FYM per ha recorded significantly higher fruit yield (26.8 t/ha) compared to 75:75:100 kg NPK per ha alone (20.1 t/ha).

Omafra, (2001) found that at the reproductive growth and fruits set, N levels may be raised to promote fruit production. This is especially true in sub-optimal conditions such as periods of high rainfall and humidity.

Omotoso and Shittu, (2007) conducted an experiment to determine the effect of NPK fertilizer application rates and method of application on growth and yield of okra (*Abelmoschus esculentus* (L.) Moench). Okra seed variety LD88 were treated to three levels of NPK fertilizer rates (0, 150 and 300 kg NPK ha^{-1}) and two methods of fertilizer application (ring and band method). The result indicated that the fertilizer NPK significantly increased yield and yield components with 150NPKkgha^{-1} giving optimum yield of okra.

Osman and George, (1984) reported the effect of mineral nutrition on seed yield and seed quality of sweet pepper plants. Combinations of N, P, and K at two different rates resulted in significant differences between the two phosphorus rates on fruit and seed yield of sweet pepper. There were no differences on plant height, foliage dry weight, and number of fruits per plant.

Pal *et al*., (2002) reported that fruit yield increased with increase in N up to 187.5kg N/ha and beyond this yield decreased.

Pareya, (1992) reported that chilli (Anaheim cv.) fruit production was maximized at 240 kg N per ha applied.

Patil and Biradar, (2001) recorded the highest dry chilli (19.12 q/ha) when applied with 200 per cent RDF + FYM + vermicompost compared to 100 per cent of RDF + FYM (13.86 q/ha) alone. Nair and Peter (1990) revealed that, the application of high rates of both organic (15 t/ha FYM) and inorganic fertilizers (175:40:75 kg NPK/ha) increased the fruit yield during all the three seasons.

Rahman *et al*., (2010) found that application of *Trichoderma* compost with NPK fertilizers significantly increased the germination percentages and vigour index of chili.

Rekha and Gopalkrishnan, (2001) noticed that application of organic manures alone (FYM) recorded minimum vine length (5.80 cm) and number of branches per plant (12). While, the treatment which received an additional dose of inorganic fertilizers (70:25:50 kg NPK/ha) recorded maximum vine length (7.10 m) and number of branches (18) in bitter gourd` while longest (26.7 cm) and thickest (17.5 cm) fruits were recorded by FYM (25 t/ha) with inorganic fertilizers (70:25:25 kg NPK/ha) in bitter gourd.

Renuka and Ravisankar, (2001) reported that integrated application of FYM (15 t/ha) with NPK (120:70:70 kg/ha) resulted significantly higher number of branches (3.66) as compared to their individual application in tomato.

Revanappa, (1993) observed significantly higher number of primary, (6.31), secondary (16.36) and tertiary (53.0) branches per plant with the application of 250:75:75 kg NPK per ha. The increase in number of branches with enhancement of N was attributed to rapid meristematic activity in plants.

Revanappa *et al*., (1998) noticed that number of days required for flowering were increased (78.00 to 30.56 days) with increase in N (130 to 250 kg/ha) and with basal dose of 75 kg per ha each P_2O_5 and K_2O.

Rini and Sulochana, (2006) studied that growth promotion and yield was more pronounced when *T. harzianum* (TR20) + and *Pseudomonas fluorescens* (P28) were applied in conjunction with one another in chilli.

Roe *et al*., (1997) found that fruit yields from the plants grown in plots amended with compost was 30.3, 35.7 and 31.1 t per ha in control plots, 50 per cent and 100 per cent recommended dose of fertilizer (RDF) as compared to the yields of 19.8, 31.1 and 32.0 t per ha respectively with control, 50 per cent and 100 per cent RDF without compost in chilli.

Rosati *et al.,* (2002) observed that plant yield increased with increasing N fertilization. They suggested that application of 120kg N per hectare for better yield of chilli.

Roy *et al,* (2010) found that, length and breadth of fruit and number of fruits per plant increased significantly with increasing nitrogen doses up to 100 kg N per ha. However, average weight of fruit content increased significantly up to 150 kg N per ha. On the other hand, average weight of fruit and yield increased significantly with increasing levels of P up to the treatment 30 kg P per ha, whereas length of fruit and number fruits per plant was increased significantly up to the 60 kg P per ha. Considering the combined effect of nitrogen and phosphorus, the maximum significant length of Capsicum, breadth of Capsicum, number of fruits per plant and, average weight of fruit as well as yield were found in the treatment combination of 150 kg N and 30 kg P per ha.

Roy *et al*., (2011) conducted a field experiment to study the effects of nitrogen and phosphorus on the fruit size and yield of *Capsicum*. The treatments comprised 4 levels of N (0, 50, 100 & 150 kg per ha) and 3 levels of P (0, 30 and 60 kg per ha). Length and breadth of fruit and number of fruits per plant increased significantly with increasing nitrogen doses up to 100 kg N per ha. However, average weight of fruit content increased significantly up to 150 kg N per ha. On the other hand, average weight of fruit and yield increased significantly with increasing levels of P up to the treatment 30 kg P per ha, whereas length of fruit and number fruits per plant increased significantly up to the 60 kg P per ha. Considering the combined effect of nitrogen and phosphorus, the maximum significant length of fruit, breadth of fruit, number of fruits per plant and, average weight of fruit as well as yield were found in the treatment combination of 150 kg N and 30 kg P per ha.

Sahoo and Panda, (2000) recorded higher seed yield (3269 kg/ha) with the application of N, P_2O_5, K_2O at 80, 40, 40 kg along with FYM at 5 t per ha compared to control (1323 kg/ha) and inorganic fertilizer (3036 kg/ha) alone in maize.

Sarker, (2007) carried out an experiment at the Horticulture Farm. BAU. Mymensingh, during the period from December, 2006 to March, 2007 to study the effect of NPKS and crop duration on the growth and yield of carrot. It was observed that the highest gross yield (46.51 t/ha) and marketable yield (41.52 t/ha) were obtained from the treatment of $N_{135}P_{39}K_{90}S_{84}$ kg/ha.

Semiha *et al.,* (2006) obtained higher fruit number (59.4 fruits / m2) and yield (71.2 t/ha) with the application of 200mgN per litre.

Sendurkumaran *et al*., (1998) found the application of FYM (15 t/ha) + 150:100:50 kg NPK per ha recorded significantly higher plant height (73.21 cm) and number of branches (62.01/plant) as compared to different fertilizer levels in tomato cv. Co.3.

Shamima and Islam, (1990) reported that the application of 120:90:90 kg NPK per ha increased the seed yield (26 q/ha) as compared to control (8.5 q/ha) in chilli.

Sharma, (1995) noticed that application of increased levels of N (30 to 120 kg/ha) significantly increased the days to 50 per cent flowering (34.2 to 39.0 days) in tomato with basal dose of 30 and 60 kg P_2O_5 and K_2O per ha respectively.

Sharma *et al.,* (1996) stated yield of fruits significantly increased with increasing rates of nitrogen. They found out that the highest yield and highest income invested was recorded at the highest nitrogen rate on chilli. They concluded that the best treatment to promote yield and profitability was 120kg N and 30kg P_2O_5 /ha. Yields ranged from 36.19kg/ha in the unfertilized control to 88.49kg/ha with the application of NPK.

Shashidhara, (2000) reported higher seed weight (5.84 g) by applying FYM (5 t/ha) + 50 per cent RDF compared to 50 per cent RDF alone (5.02 g) in chilli.

Shashidhara, (2006) stated that chilli responded well to fertilization with 11 to 22 applications in terms of increased growth and yield properties.

Shinde *et al*., (2003) recorded highest internodes length (14.57 cm), highest number of branches per vine (4.09), highest number of leaves per vine (36.55) in case of ridge gourd cv. DPL-RG-17 due to application of 100:50:50 kg $N:P_2O_5:K_2O$ per ha, also produced highest fruit yield per vine (1.76 kg/vine) and highest fruit yield per ha (117.33 q/ha)

Shrivastava, (1996) reported that initiation of flowering and days to 50 per cent flowering were delayed by four to six days in sweet pepper plants receiving 100:250:250 kg NPK per ha. The delay in 50 per cent flowering was related to enhance vegetative growth of plants.

Simonne *et al.,* (1998) also found that higher N rates tended to increase K foliar concentration of bell pepper grown in the field. In contrast, Ca concentration increased with higher N rates.

Singandhupe *et al.,* (2003) reported that application of nitrogen at 120 kg N per ha through the drip irrigation in ten similar splits at 8-days intervals achieved a supreme tomato fruit yield as compared to the furrow irrigation when nitrogen was applied in two equal splits.

Singh, (1995) working on capsicum realized that parameters such as plant height, number of branches, number of fruits/plant, fruit length and diameter and yield increased with increasing rates of fertilizer application.

Singh and Srivastava, (1995) carried out a field trial in 1989-96, Uttar prodesh, India, to find out the role and requirement of sulphur on the growth and yield of potato using three doses of sulphur (0, 25 and 50 kg/ha) with NPK fertilizers. The highest tuber yield was obtained when 50 kg S/ha and NPK were applied.

Singh *et al*., (2000) found yield of chilli fruits increased with increasing nitrogen levels and the highest fruit yield was recorded with 120 kg N ha-1+ 60 kg P/ha.

Sinha, (1975) observed the tallest plants (65.8 cm) with the highest level of N (105 kg/ha) and P_2O_5 and K_2O (each 50 kg/ha) compared to control (54.7 cm) in chilli.

Solaiman and Rabbani, (2006) reported that the highest plant, fruits per plant as well as greatest fruit size, fruit yield/plant, fruit yield/ha were obtained from the application of the recommended dose of nutrients viz. (200 kg N + 35 kg P + 80 kg K + 15 kg S/ha).But similar results were obtained from the treatment receiving 5 kg cow dung/ha along with half of the recommended dose of nutrients viz.(100 kg N + 17.5 kg P + 40 kg K + 7.5 kg S/ha).

Sundstrom *et al.* (1987) observed tabasco pepper red fruit yield increased as a result of seed treatment methods were reported by. The researchers found that plug planted pre-germinated seed increased red fruit yields. Plots established by transplanting or by use of pre-germinated seed produced higher total fruit yields. The study concluded that of all the seed treatment, and planting methods that were tested, crop performance of pre-germinated seeds was superior.

Surlekov and Rankov, (1989) reported greater plant height, number of branches and number of leaves per plant in chilli with the application of farmyard manure @ 20 t per ha along with 100:80:100 kg N, P_2O_5 and K_2O per ha.

Sutagundi, (2000) reported that early flowering (43.66 days) and significantly higher 100 seed weight (0.6 g) with application of FYM (10 t/ha) as compared to 100:50:50 kg NPK per ha (43.75 days) in chilli.

Tei *et al.*, (2002) in their study observed nitrogen fertilization affects vegetative growth and biomass accumulation, as it is associated to increasing photosynthate source capacity.

Tropea *et al.*, (1982) found that chilli yield was higher with fertilization of 313:214:538 kg N: P: K per ha.

Uddin and Khalequzzaman, (2003) stated that fertilizer is one of the major factors of crop production. Among the factors, nitrogen is very much essential for good plant establishment and expected growth.

Umamaheswarappa and Krishnappa, (2004) reported that application of nitrogen fertilizers increased the growth and yield of cucumber (cv. Poinsette).

Vijayakumar *et al.,* (2010) found that maximum shoot length and number of branches per plant as well as higher yields in eggplant (42.33 t per ha in 1^{st} crop and 37.90 t per ha in 2^{nd} crop) were recorded in treatment drip irrigation at 75% of pan evaporation with fertigation of 75% of recommended N and K, when were applied through fertigation with 12 equal splits from 3rd week to 14th week after planting.

Vijaykumar *et al*., (1995) concluded that the highest chilli seed yield was obtained with the application of 200:100:60 kg NPK per ha.

Wanknade and Morey, (1982) studied the effect of phosphate and plant spacing on growth and yield of field grown chillies and found higher P rates increased plant height, dry matter, and yield.

Waseem *et al.,* (2008) reported that 100 kg N/ha had significantly maximized cucumber fruit length, fruit weight and vine length, which are indirectly related to the yield, but 80 kg N/ha was the most economical dose for minimizing the days to flowering, days to fruit setting and days to fruit maturity and getting higher number of fruits and ultimately higher yield.

Zhang *et al.*, (2009) found that both green fruit and blossom-end rot fruit yield decreased with increasing application of K fertilizer when no drip irrigation was applied. However, with drip irrigation, increasing K fertilization rates created an increase in marketable yield.

CHAPTER 3
MATERIALS AND METHODS

This chapter describes the materials and methods that were used in carrying out the experiment. It includes a brief description of the experimental site, climate, soil, planting materials, treatments and design of the experiment, fertilizing, and transplantation of seedlings, intercultural operations, weed and pest management, harvesting, method of data collection, statistical analyses.

3.1 Description of the Study Area

The research work was conducted at the Citrus Research Station, Bangladesh Agricultural Research Institute, Jaintapur, Sylhet. The experimental site is situated at $25^{o}8$N latitude and $92^{o}8$E longitude having an altitude of 36 m.

3.2 Climate

The investigation was carried out during the period from January, 2014 to June 2014. Annual average rainfall ranges from 6000-6500 mm, the mean maximum and minimum temperatures are 36 ^{o}C and 6 ^{o}C in the month of April-January respectively. The climate of the experimental site is subtropical in nature, which is characterized by three distinct seasons, the monsoon extending from May to October, the winter or dry season from November to February and pre-monsoon period hot season from March to April. The seasonal condition comprises of sufficient precipitation during the months from April to September and scant or no rainfall during the rest of the months of the year. Plenty of sunshine and moderately low temperature prevails during Rabi season from October to March which is suitable for growing of naga chilli. Average monthly relative humidity, sunshine hours, air and soil temperature for the period of the study were collected from the weather forecasting unit, Citrus Research Station, Bangladesh Agricultural Research Institute, Jaintapur, Sylhet and presented in Appendix 1.

3.3 Characteristics of soil

The soil of the experimental plot belongs to northern and eastern piedmont plains (AEZ-22) having sandy loam textured soil. The physico-chemical properties of the soil were analyzed before the start of experimentation using standard procedures. Soil samples were collected from the depth of 0-15 cm of experimental field. At the very beginning of the study the soil was with pH 4.8 and organic carbon 1.28 per cent. Total N, exchangeable K, Ca, Mg, and available Zn were also found to be below the critical level. Dolomite 4kg/decimal was applied to regulate the pH level of the soil. The soil test results for the study year were presented under Appendix 2.

3.4 Plant materials used

The local Naga chilli variety was used for the study. The seeds were collected from farmers' field of Jaintapur upazila under Sylhet district. There after collected seeds were sown under ambient condition at Citrus Research Station nursery, Bangladesh Agricultural Research institute, Jaintapur, Sylhet.

3.5 Treatments of the experiment

There were 14 treatment combinations comprising four nutrients element. The four nutrients viz N, P, K and S were applied in the field as Urea, TSP, MoP and Gypsum respectively. The treatment combinations are illustrated below.

$T_1 = N_0\ P_{75}\ K_{120}\ S_{20}$ kg/ha	$T_8 = N_{100}\ P_{75}\ K_0\ S_{20}$ kg/ha
$T_2 = N_{80}\ P_{75}\ K_{120}\ S_{20}$ kg/ha	$T_9 = N_{100}\ P_{75}\ K_{100}\ S_{20}$ kg/ha
$T_3 = N_{100}\ P_{75}\ K_{120}\ S_{20}$ kg/ha	$T_{10} = N_{100}\ P_{75}\ K_{140}\ S_{20}$ kg/ha
$T_4 = N_{120}\ P_{75}\ K_{120}\ S_{20}$ kg/ha	$T_{11} = N_{100}\ P_{75}\ K_{120}\ S_0$ kg/ha
$T_5 = N_{100}\ P_0\ K_{120}\ S_{20}$ kg/ha	$T_{12} = N_{100}\ P_{75}\ K_{120}S_{10}$ kg/ha
$T_6 = N_{100}\ P_{50}\ K_{120}\ S_{20}$ kg/ha	$T_{13} = N_{100}\ P_{75}\ K_{120}\ S_{30}$ kg/ha
$T_7 = N_{100}\ P_{100}\ K_{120}S_{20}$ kg/ha	$T_{14} = N_0\ P_0\ K_0\ S_0$ kg/ha (Native Nutrient)

3.6 Experimental Design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Fourteen treatments including one control were assigned randomly to the unit plot of 2m × 1.2 m in size. The experimental area was divided into three blocks. Each block consisted of 14 unit plots. Thus the total number of unit plots was 42; the blocks and plots were spaced at 0.5 m respectively which ultimately used as drain.

3.7 Naga Chilli Production Procedures

3.7.1 Land preparation

The land of the experimental field was first opened on 18 December, 2013 with a power tiller. Then it was exposed to the sun for 15 days prior to the next ploughing. Thereafter, the land was deeply ploughed and cross-ploughed to obtain good tilth. To get better yield of naga chilli, levelling was done in order to break the soil clods followed by each ploughing. All the weeds and stubbles were removed from the experimental field. The soil was treated with nematicides at the time of final ploughing.

3.7.2 Manuring and fertilization

A blanket dose of 10 ton/ha cow dung, 4 ton/ha dolomite lime, 2 kg B/ha and 4 kg Zn/ha were used. Chemical fertilizers were used as per treatment. Dolomite lime was applied after first ploughing and the plot was left for fifteen days. A general application of Cow dung @ 10 t/ha, full dose of TSP and Gypsum, half dose of MoP was applied during final land preparation. Urea and half of MoP fertilizer were applied in three instalments as first after 7 days of transplanting, second after 28 days of transplanting and third after 60 days of transplanting.

3.7.3 Seedling raising

Naga chilli seeds take too long to germinate if the seeds were dried. There fully ripe fruit was collected from farmers' field in order to seedling raising. The pods were cut and the seeds were taken out and sown directly in line in the nursery poly tub at a depth of 1.5 cm and three seeds per tub. The date of sowing was 21 December, 2013. After sowing, the seeds were covered with loose soil. Emergence of seedling was completed within 10 days after sowing. Over crowded seedlings were thinned out. Thinning of the seedlings was done after 15 days of sowing.

3.7.4 Seedling Transplantation

After land preparation the prepared seedlings were transplanted in the main filed maintaining 60 cm row to row and 65 cm plant to plant distance forming 252 plant populations in the experimental plot. The transplanting was done on 31January 2014 when the age of the seedling reached to 30 days.

3.7.5 Intercultural operations

3.7.5.1 Gap filling

After seven days of transplanting about five per cent seedling was died due to damping off diseases and new seedling was transplanted at those places.

3.7.5.2 Weeding

Weeds compete with the plants for nutrients and space. Therefore three weeding was done at 20, 50 and 80 days of transplanting to keep the plots free from weeds and to keep the soil loose and well aerated.

3.7.5.3 Irrigation

Irrigation needed especially at early stage of growth therefore, irrigation by watering cane was performed. Flood irrigation was done three times following fertilization.

3.7.5.4 Stalking

Naga chilli plants attain a height about 1 meter. Therefore bamboo sticks were used for stalking the plants when necessary.

3.7.5.5 Disease and pest management

The experimental crop was not infected by any diseases and no fungicide was used. Mole cricket and cutworm attacked the crop during the early growing stages of seedlings. Those insects were controlled by spraying of Pyriphos at 14, 21, and 28 DAT.

3.8 Harvesting

Harvesting of the crop was done after 90 days of transplanting for data collection when the pod colour turns from green to light red. Three randomly selected plants were harvested from each plant ten pods were collected for data recording. Together with rest of entire plot for yield data collection. Harvesting was done very carefully for avoiding the plants from any injury.

Plate 1. General view of the experimental Plot

Plate 2. At 90 DAT of Naga chilli

Plate 3. At 120 DAT of Naga chilli

Plate 4. Full matured of Naga chilli

Plate 5. Naga chilli harvested for collecting yield and qualitative data.

3.9 Data Collection

Three plants were selected randomly and tagged in each plot for recording various morphological observations at 60, 90, 120 days after transplanting and final harvest and ten randomly selected pods were also taken these plants for fruit quality data recording. The following observations were recorded at different stages of crop growth and the average was computed.

3.9.1 Growth parameters

Plant height (cm):

Plant height was measured at 30, 60, 90 DAT and final harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of fully opened leaf on the main shoot and the mean plant height was expressed in centimetres.

Canopy Spreading (cm):

The mean values of three selected plants were taken at 30, 60, 90 DAT and final harvest. The canopy spreading was measuring diameter of the plant (North to South and East to West dimension of the above ground part of sample plants).

Number of branches per plant:

The number of primary branches arising on the main stem in the three randomly selected and tagged plants was recorded at different growth stages. The mean number of branches per plant was worked out and expressed in number.

Stem diameter (cm):

To measure the diameter of stem, a slide callipers was used .The diameter of the stem was measured at the top part, middle part and bottom part then its average value was recorded.

Plant volume (cm^3):

Canopy volume were measured following (Castle, 1983) with slight modification by the formula V (m3) = 1/6× π× height ×D2 where, D was the average value of north-south and east west spreading of the canopy.

Days to 50% flowering:

Daily observations were made on the three randomly selected and tagged plants for flowering.The day on which 50 per cent of plants showed flower initiation were considered as 50 per cent flowering. The number of days taken from the date of transplanting to flowering was recorded and expressed in number as days taken for 50 per cent flowering.

Days to first harvest:

The number of days from transplanting to the date of first harvest was recorded from three sample plants.

Days to complete harvest:

The number of days from transplanting to the date of full maturity of fruits or final harvest was recorded from three selected plants.

3.9.2 Yield and yield related parameters

Number of fruits per plant:

The numbers of red colour fruit harvested on three randomly tagged plants in each treatment were counted from different pickings and average was worked out and expressed as number of fruits per plant.

Fruit weight (g):

Fruits of three selected plants were collected and weighed and its weight was recorded in grams.

Yield/Plant (g):

The marked fruits from three tagged plants of all the pickings were harvested and sun dried till they attained constant weight. The total weight of dried fruits was recorded and mean fruit yield per plant was calculated and expressed in grams.

Fruit Yield (t/ha):

The fruit yield obtained from each picking from the net plot area was sun dried till they attained constant weight and the total dry weight of fruits was recorded. Based on the dry fruit yield from the net plot area, the yield per hectare was computed and expressed in tones.

3.9.3 Quality parameters

Fruit length (cm):

Before drying, the length of ten randomly selected fruits was measured from the base of pedicel to the tip of the fruit and average was worked out and expressed in centimetres.

Fruit diameter (cm):

Ten selected fruits of three randomly selected plants taken for measuring the fruit length were used for measuring fruit diameter. The diameter was measured at the centre of the fruit with the help of vernier callipers. The mean fruit diameter was computed and expressed in centimetres.

Fruit pericarp weight (g):

The pericarp of ten randomly selected fruits was weighed and its weight was recorded in grams.

1000 seed weight (g):

1000 seeds were counted manually from each picking and weight was recorded as per the procedure given by ISTA Rules (Anon., 1996). The average was worked out and expressed in grams.

Fruit dry weight (g):

Ten selected fruits of three randomly selected plants from each plots was taken. The samples were dried in an oven at 105^{o}C until constant weight was reached.

3.10 Statistical analysis

The data obtained from experiment on various parameters were statistically analyzed using MSTAT computer program. The mean values for all the parameters were calculated and the analysis of variance for the characters was accomplished by F variance test. The significance of difference between pair of means was tested by the Duncan Multiple Range Test (DMRT) test at 5 % and 1 % levels of probability (Gomez and Gomez, 1984).

CHAPTER 4
RESULTS AND DISCUSSION

The experiment was conducted to determine the effect of different levels of NPKS on the growth and yield of Naga chilli. The growth, yield and quality component characters such as plant height with canopy, Number of branches, Stem diameter, Days to 50% Flowering, Number of flowers /plant, Days to first harvest, Days to last harvest, Number of fruit/plant, Average individual Fruit weight, Fruit Size, Pericarp weight, Number of seeds/fruit, 1000 seed weight, Fruit dry Weight and Yield of naga chilli as influenced by different levels of NPKS are presented in this chapter. The results of each parameter have been discussed and possible interpretations whenever necessary have been elaborated below:

4.1 GROWTH PARAMETERS

4.1.1 Plant height (cm)

Plant height is one of the important growth characters for naga chilli. There was a significant variation among the plants by the application different levels of NPKS on plant height recorded at different DAT. The plant height was increased gradually with the advancement of crop growth up to harvest. Effect of NPKS on plant height at different growth stages were presented at figure 1 and appendix V.

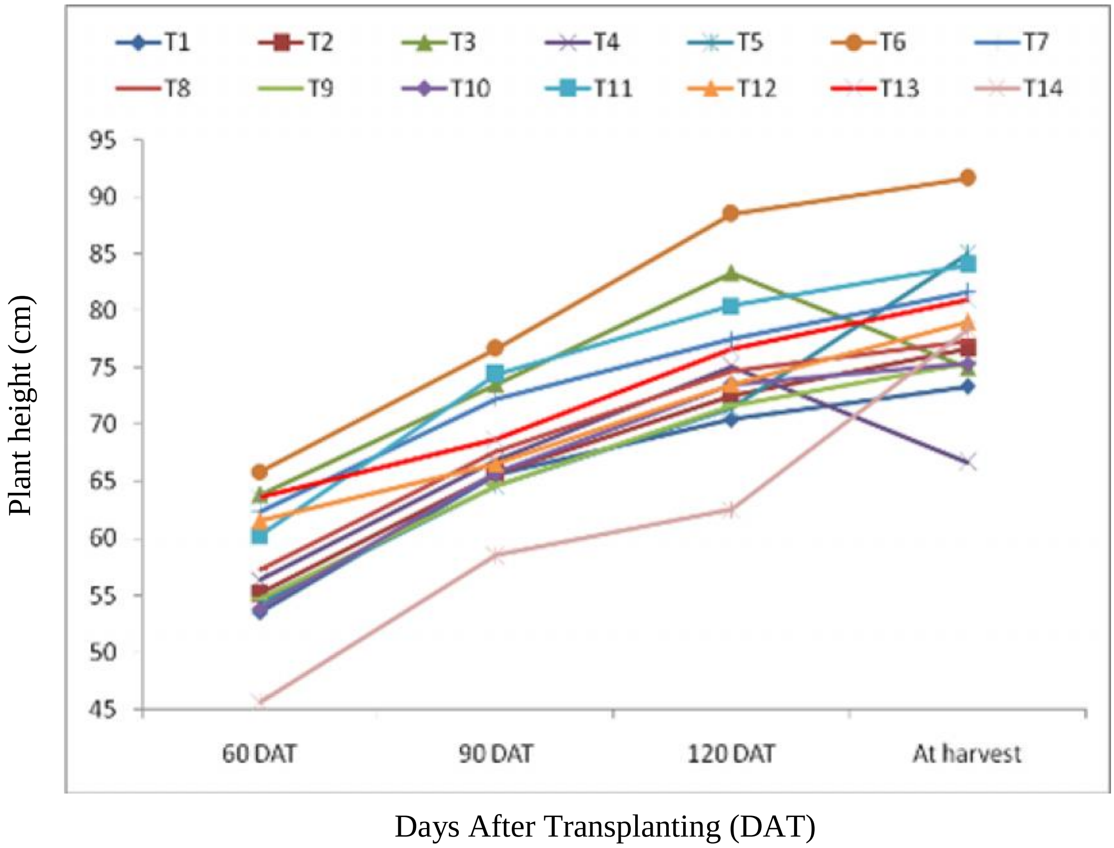
At 60 DAT, the plant receiving the fertilizer treatment N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) was the tallest (65.85 cm per plant) which was significantly different from other treatment. The Shortest plant height (45.58 cm per plant) was found in control where no fertilizer was used.

At 90 DAT, Significantly highest plant height (76.66 cm per plant) was observed in N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) treatment combination which was statistically different from other treatment combination followed by N_{100} P_{75} K_{120} S_0 kg/ha (74.42 cm per plant). Whereas, the lowest plant height (58.52 cm per plant) was recorded in control.

At 120 DAT, Among the treatment combination, N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) was recorded significantly higher plant height (88.50 cm per plant) which was statistically different from other treatment combination followed by N_{100} P_{75} K_{120} S_{20} kg/ha (83.35 cm per plant) while, significantly lower plant height (62.52 cm per plant) was recorded in control treatment.

Finally, the highest plant height (91.67 cm per plant) was found in the treatment combination of N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) and this result was statistically different from other treatment combination. The lowest plant height (69.31 cm per plant) was found in the control.

This might be due to the fact that proper dose of NPKS fertilizers supplied plant nutrients for efficient growth of naga chilli. Plant height is influenced by genetic as well as environmental conditions. The increase in plant height also could be due to better availability of soil nutrients in the growing areas, especially nitrogen and phosphorus which have enhancing effect on the vegetative growth of plants by increasing cell division and elongation and the varietal variability to absorb the nutrients from the soil (Vos and Frinking, 1997; El-Tohamy *et al*., 2006). The result revealed that combined application of Zn, B, in presence of NPKS fertilizers was found to produce the better yield of naga chili. Similar result was found by Schuch *et al*. (1999) in Brazil. They observed that plant height was increased gradually with the advancement of time. i.e. vegetative growth and development. The result of this study confirms the finding of Gonzalez *et al.* (2001) who reported that organic manure and inorganic fertilizer supplied most of the essential nutrients at growth stage resulting in increase of growth variables including plant height. Since nitrogen increases the vegetative growth of the plants (Baloch, 2008), thus it increased with incremental increase in nitrogen, While Hassan (1995) found no significant increase in plant height of chillies with increasing potash levels.



Legend:

$T_1 = N_0\ P_{75}\ K_{120}\ S_{20}$ kg/ha

$T_2 = N_{80}\ P_{75}\ K_{120}\ S_{20}$ kg/ha

$T_3 = N_{100}\ P_{75}\ K_{120}\ S_{20}$ kg/ha

$T_4 = N_{120}\ P_{75} K_{120}\ S_{20}$ kg/ha

$T_5 = N_{100}\ P_0\ K_{120}\ S_{20}$ kg/ha

$T_6 = N_{100}\ P_{50}\ K_{120}\ S_{20}$ kg/ha

$T_7 = N_{100}\ P_{100}\ K_{120}\ S_{20}$ kg/ha

$T_8 = N_{100}\ P_{75}\ K_0\ S_{20}$ kg/ha

$T_9 = N_{100}\ P_{75}\ K_{100}\ S_{20}$ kg/ha

$T_{10} = N_{100}\ P_{75}\ K_{140}\ S_{20}$ kg/ha

$T_{11} = N_{100}\ P_{75}\ K_{120}\ S_0$ kg/ha

$T_{12} = N_{100}\ P_{75}\ K_{120}\ S_{10}$ kg/ha

$T_{13} = N_{100}\ P_{75} K_{120}\ S_{30}$ kg/ha

$T_{14} = N_0\ P_0\ K_0\ S_0$ kg/ha (Native Nutrient)

Figure 1. Effect of NPKS Treatments on Plant height (cm) of Naga chilli at different stages of plant growth

4.1.2 Canopy Spreading (cm)

Canopy spreading is the most important growth contributing characters for Naga chilli. There was a significant effect by the application of different levels of NPKS on canopy spreading which was recorded at different DAT. The canopy spreading was increased gradually with the advancement of crop growth up to harvest.

At 60 DAT, the analysis of variance showed that there was a significant variation on canopy spreading (Table 1). The result indicated that the highest spreading (45.9 cm × 47.8 cm) were obtained from the treatment combination of N_{100} P_{50} K_{120} S_{20} kg/ha (T_6).Where the lowest spreading (31.5 cm × 31.7 cm) was found from control.

At 90 DAT, the maximum spreading (68 cm × 69.2 cm) were obtained from the treatment combination of N_{100} P_{50} K_{120} S_{20} kg/ha (T_6).Where the minimum spreading (48.2 cm × 48.1 cm) found from control.

At 120 DAT, the highest spreading (88 cm × 88.2 cm) were obtained from the treatment combination of N_{100} P_{50} K_{120} S_{20} kg/ha (T_6).Where the lowest spreading (58 cm × 58 cm) found from control.

Finally, the maximum spreading (91.0 cm × 94.7 cm) were obtained from the treatment combination of N_{100} P_{50} K_{120} S_{20} kg/ha (T_6).Where the minimum canopy size (63.7 cm × 61.7 cm) found from control.

These variations in canopy spreading might be due to fertilizer requirement, the growing environment’s soil type, and rainfall and soil pH. This variation on the other hand, may determine the yielding potential of the crop, since, varieties with wider canopy diameter could produce more fruit (pods) than varieties with narrow canopy due to increased number of secondary and tertiary branches which are the locations for fruit bud formation. This is in conformity with the work of Faby (1997) who has reported that plants with wider crown produced higher early season yield than those with small crown. Aliyu *et al*. (2002) used the crown diameter as the main variable to identify the quality of transplants.

Table 1. Effect of NPKS on Canopy Spreading at different growth stages in naga chilli

Treatments	Canopy Spreading (cm)							
	60 DAT		90 DAT		120 DAT		At harvest	
	N/S	E/W	N/S	E/W	N/S	E/W	N/S	E/W
T_1	37.6 cd	39.9 c-e	52.6 de	54.8 cd	63.7 d-g	65.8 d-f	68.3 c-f	70.0 d-f
T_2	37.2 c-e	37.7c-e	56.4 cd	52.7 de	70.7 c	74.8 bc	83.3 b	87.3 ab
T_3	42.6 ab	45.7 ab	60.9 b	60.0 b	77.7 b	64.8 d-g	68.7 c-f	68.3 ef
T_4	35.6 d-f	36.6 d-g	52.8 de	48.5 e	66.5 c-f	59.5 fg	65.6 ef	68.3 ef
T_5	40.4 bc	41.6 bc	56.4 cd	57.8 bc	68.8 c-f	68.7 c-e	72.0 c-e	72.0 c-e
T_6	45.9 a	47.8 a	68.0 a	69.2 a	88.0 a	88.2 a	91.0 a	94.7 a
T_7	35.9 d-f	37.7 c-e	58.2 bc	58.8 bc	68.7 c-e	70.8 b-d	75.3 c	75.3 c-e
T_8	34.6 e-g	37.5 c-e	56.6 cd	52.9 d	68.8 c-e	68.2 c-e	72.7 c-e	71.7 de
T_9	33.5 fg	35.9e-g	51.5e-g	59.4 bc	62.5 fg	68.6 c-e	69.3 c-f	79.3 b-d
T_{10}	38.6cd	32.8 fg	48.7 fg	51.5 de	59.6 g	65.6 d-f	74.7 cd	74.3 c-e
T_{11}	38.1 cd	36.4 d-f	56.4 cd	58.0 bc	68.8 cd	70.7b-d	74.3 cd	76.7 c-e
T_{12}	33.5 fg	34.5 e-g	52.2 d-f	51.3 de	62.8 e-g	62.4 e-g	66.7 d-f	66.7 ef
T_{13}	42.5 ab	40.2 cd	50.0 e-g	58.5 bc	63.4 d-g	75.7 b	85.0 ab	81.7 bc
T_{14}	31.5 g	31.7 g	48.2 g	48.1 e	58.0 g	58.4 g	63.7 f	61.7 f
LSD	**3.035**	**4.100**	**3.652**	**4.280**	**5.224**	**6.270**	**7.189**	**8.717**
CV (%)	**4.81**	**6.42**	**3.97**	**4.58**	**4.60**	**5.45**	**5.82**	**6.94**

In a column means followed by common letters are not significantly different from each other at 5 % level of probability by DMRT.

Legend:

$T_1 = N_0\ P_{75}\ K_{120}\ S_{20}$ kg/ha	$T_6 = N_{100}\ P_{50}\ K_{120}\ S_{20}$ kg/ha	$T_{11} = N_{100}\ P_{75}\ K_{120}\ S_0$ kg/ha
$T_2 = N_{80}\ P_{75}\ K_{120}\ S_{20}$ kg/ha	$T_7 = N_{100}\ P_{100}\ K_{120}\ S_{20}$ kg/ha	$T_{12} = N_{100}\ P_{75}\ K_{120}\ S_{10}$ kg/ha
$T_3 = N_{100}\ P_{75}\ K_{120}\ S_{20}$ kg/ha	$T_8 = N_{100}\ P_{75}\ K_0\ S_{20}$ kg/ha	$T_{13} = N_{100}\ P_{75} K_{120}\ S_{30}$ kg/ha
$T_4 = N_{120}\ P_{75} K_{120}\ S_{20}$ kg/ha	$T_9 = N_{100}\ P_{75}\ K_{100}\ S_{20}$ kg/ha	$T_{14} = N_0\ P_0\ K_0\ S_0$ kg/ha (Native Nutrient)
$T_5 = N_{100}\ P_0\ K_{120}\ S_{20}$ kg/ha	$T_{10} = N_{100}\ P_{75}\ K_{140}\ S_{20}$ kg/ha	

4.1.3 Number of branches per plant

Application of NPKS showed significant effect on the number of branches production per plant at different stages of growth (60, 90 and 120 DAT) and final harvest (Figure 2 and Appendix VI). The maximum number of branches (33.48) was produced from N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) treatment combination and lowest number of branches (25.18) was produced in no fertilizer treatment at harvest. At earlier stages, the number of branches per plant was increased rapidly but slowed at later stage. The results clearly showed that number of branches per plant was gradually increased with increase in different levels of NPKS.

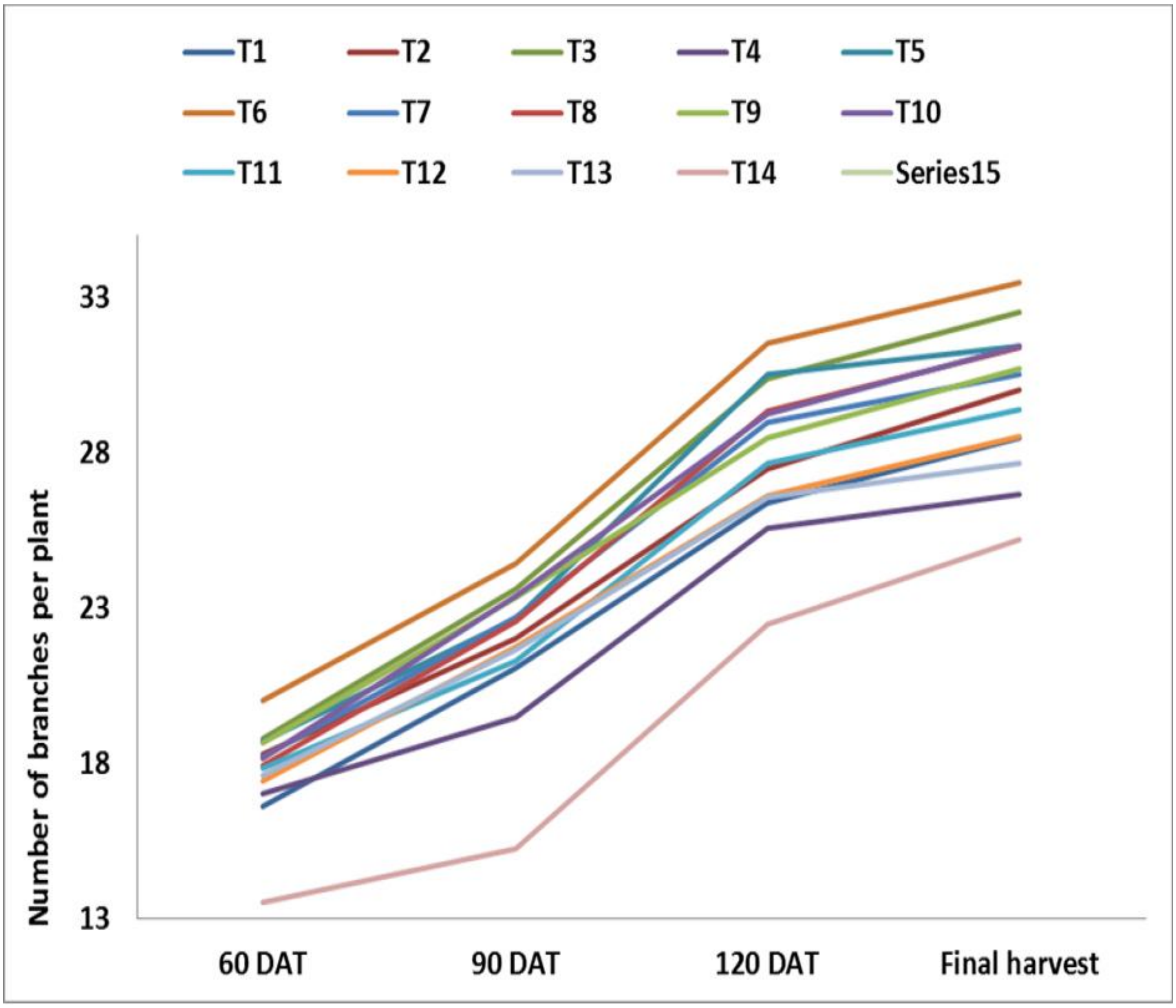
At 60 DAT, Significantly higher number of branches (20) was observed in N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) over all other treatments followed by N_{100} P_{75} K_{120} S_{20} kg/ha **(**18.80**)** and lower number of branches (13.52 was recorded in control

At 90 DAT, among the treatments, N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) recorded significantly higher number of branches (24.42) followed by N_{100} P_{75} K_{120} S_{20} kg/ha (23.58) and the control treatment had the lower number of branches per plant (15.22).

At 120 DAT, the number of branches was significantly higher (31.50) in N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) over all other treatments followed by N_{100} P_0 K_{120} S_{20} (30.50) kg/ha and lower number of branches (22.46) was recorded in control treatment.

Finally, Among the treatments N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) recorded significantly higher (33.48) number of branches over all other treatments, followed by N_{100} P_{75} K_{120} S_{20} kg/ha (32.50) and was on par with N_{100} P_0 K_{120} S_{20} kg per ha (31.44), N_{100} P_{75} K_{140} S_{20} kg per ha (31.41) and N_{100} P_{75} K_0 S_{20} kg per ha (31.38) while, the control had the lower number branches (25.18).

NPKS has a significant effect on number of branches plant^{-1} as it activates vegetative growth. These results agree with the findings of Manchanda and Singh (1991). Similarly, a linear increase in the number of branches plant^{-1} in chilies with increase in nitrogen levels was also noticed by Khan and Suryanarayana (1977). They conclude that branches plant^{-1} increasing with increasing nitrogen rate. Number of branches plant^{-1} ranged from 12.9 to 13.2 in case of potassium.



$T_1 = N_0\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_2 = N_{80}\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_3 = N_{100}\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_4 = N_{120}\ P_{75} K_{120}\ S_{20}$ kg/ha
$T_5 = N_{100}\ P_0\ K_{120}\ S_{20}$ kg/ha
$T_6 = N_{100}\ P_{50}\ K_{120}\ S_{20}$ kg/ha
$T_7 = N_{100}\ P_{100}\ K_{120}\ S_{20}$ kg/ha
$T_8 = N_{100}\ P_{75}\ K_0\ S_{20}$ kg/ha
$T_9 = N_{100}\ P_{75}\ K_{100}\ S_{20}$ kg/ha
$T_{10} = N_{100}\ P_{75}\ K_{140}\ S_{20}$ kg/ha
$T_{11} = N_{100}\ P_{75}\ K_{120}\ S_0$ kg/ha
$T_{12} = N_{100}\ P_{75}\ K_{120}\ S_{10}$ kg/ha
$T_{13} = N_{100}\ P_{75} K_{120}\ S_{30}$ kg/ha
$T_{14} = N_0\ P_0\ K_0\ S_0$ kg/ha (Native Nutrient)

Figure 2. Effect of NPKS on Number of branches per plant at different growth stages in Naga chilli

4.1.4 Stem diameter

Data regarding stem diameter (cm) as affected by NPKS levels are given in Table 2. Analysis of variance reflected that levels of NPKS affected the stem diameter. The mean data showed that N_{100} P_{50} K_{120} S_{20} kg /ha (T_6) resulted in the maximum stem diameter (6.50 cm) as compared to control plots (4.00 cm). Stem diameter increased as a result of higher N dose, it might be attributed to the positive effect of nitrogen on vegetative growth of plants. Our results are in accordance with the findings of Sundstrom (1984), who reported that increasing N application rate, increased stem diameter on tabasco pepper in linear passion.

4.1.5 Plant volume (cm^3)

Plant volume showed very highly significant variation under this study (Table 2). Accordingly, maximum plant volume (4511.72 cm^3) was recorded from N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) whereas, the minimum plant volume (2057.37 cm^3) was also observed from the control treatment.

4.1.6 Days to 50 per cent flowering

The number of days to fifty percent flowering showed very highly significant difference among the treatments (Table 2). Earliest numbers of days (50.37 days) to reach 50% flowering was observed from N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) even though it is statistically different from other treatment.While the longest days (72.53 days) to attain 50% flowering was recorded from control treatment.

4.1.7 Days to first harvest

The treatment combination indicated highly significant variation on naga chilli (Table 2) on days to first harvest. Accordingly, the shortest number of days to first harvest (91 days) was recorded from N_{100} P_{75} K_{120} S_{20} kg/ha (T_6) and the longest day to attain days to first harvest (140.5 days) was recorded from control treatment. This might be due to the fact that the plants getting proper nutrition flowers earlier thus matured earlier.

4.1.8 Days to complete harvest

The combined effect of NPKS had a significant effect on the days to complete harvest in Naga chilli. Earliest numbers of days to reach full maturity (115.9 days) was observed from N_{120} P_{50} K_{120} S_{20} kg/ha even though it is statistically different from other treatment combination, while the longest days (135.4 days) to attain full maturity was recorded from control treatment (Table 2).

Table 2. Effect of NPKS on stem diameter, plant volume, days to 50% flowering days to first harvest and days to complete harvest.

Treatment	Stem diameter (cm)	Plant Volume (cm^3)	Days to 50% flowering	Days to first harvest	Days to complete harvest
T_1	4.83 c	2502.43 f	59.48 c-f	95.59 ef	126.2 e
T_2	5.60 a-c	3807.82 b	58.02 d-f	96.49 de	127.9 d
T_3	5.83 ab	2455.61 f	55.28 d-f	91.04 h	123.1 f
T_4	5.00 bc	2345.73 g	61.55 bc	92.09 gh	115.9 g
T_5	5.67 a-c	2712.96 e	69.61 ab	102.1 b	135.6 a
T_6	6.50 a	4511.72 a	50.37 f	100.6 bc	132.9 b
T_7	4.83 c	2967.34 d	60.35 cd	99.32 b-d	130.3 c
T_8	5.00 bc	2728.05 e	68.12 bc	102.0 b	133.3 b
T_9	5.00 bc	2889.05 d	57.27 d-f	96.55 de	131.1 c
T_{10}	4.87 bc	2904.63 d	55.09 ef	97.63 c-e	128.6 d
T_{11}	5.70 a-c	2983.13 d	59.68 c-e	96.61 de	131.4 c
T_{12}	5.00 bc	2328.25 g	58.33 d-f	95.27 e-g	127.9 d
T_{13}	4.93 bc	3635.71 c	55.58 ef	92.54 f-h	125.4 e
T_{14}	4.00 d	2057.37 h	72.53 a	140.5 a	135.4 a
LSD	**0.8471**	**66.46**	**3.653**	**3.211**	**1.460**
CV(%)	**11.39**	**1.35**	**3.37**	**1.94**	**0.67**

In a column means followed by common letters are not significantly different from each other at 5 % level of probability by DMRT.

Legend:

$T_1 = N_0 P_{75} K_{120} S_{20}$ kg/ha
$T_2 = N_{80} P_{75} K_{120} S_{20}$ kg/ha
$T_3 = N_{100} P_{75} K_{120} S_{20}$ kg/ha
$T_4 = N_{120} P_{75} K_{120} S_{20}$ kg/ha
$T_5 = N_{100} P_0 K_{120} S_{20}$ kg/ha
$T_6 = N_{100} P_{50} K_{120} S_{20}$ kg/ha
$T_7 = N_{100} P_{100} K_{120} S_{20}$ kg/ha
$T_8 = N_{100} P_{75} K_0 S_{20}$ kg/ha
$T_9 = N_{100} P_{75} K_{100} S_{20}$ kg/ha
$T_{10} = N_{100} P_{75} K_{140} S_{20}$ kg/ha
$T_{11} = N_{100} P_{75} K_{120} S_0$ kg/ha
$T_{12} = N_{100} P_{75} K_{120} S_{10}$ kg/ha
$T_{13} = N_{100} P_{75} K_{120} S_{30}$ kg/ha
$T_{14} = N_0 P_0 K_0 S_0$ kg/ha (Native Nutrient)

4.2 YIELD PARAMETERS

4.2.1 Number of fruits per plant

The number of fruit/plant was significantly affected by NPKS (Table 3). The mean analysis shows that maximum number of fruits/plant (208) were recorded from N_{100} P_{50} K_{120} S_{20} kg/ha, followed by N_{100} P_{75} K_{120} S_{20} kg/ha (200) and minimum (90.3) was recorded from control plots. The highest number of fruits plant^{-1} might be due to vigor of plant and more number of leaves plant^{-1}. The results are in agreement with those of Roychaudhury (1990), who reported that the number of fruit plant-^{1} increased with increasing nitrogen application.

4.2.2 Fruit weight (g)

The fruit weight was significantly influenced by different levels of NPKS applied. Among the treatments, the treatment combination of N_{100} P_{50} K_{120} S_{20} kg/ha recorded significantly highest average fruit weight per plant (5.50 g) followed by N_{100} $P_{75}K_{120}$ S_{30} kg/ha (5.42 g) While, significantly lowest average fruit weight per plant was recorded with control (3.5 g) treatment (Table 3).

4.2.3 Yield/Plant (g)

The combined effect of NPKS on yield/plant was significant. The highest yield/plant (927.8 g/plant) was obtained from the treatment combination of N_{100} P_{50} K_{120} S_{20} kg/ha which was statistically different from other treatment combination. On the other hand, the lowest yield/plant (315.1 g/plant) was found from control treatment (Table 3).

4.2.3 Yield/Plot (kg)

The yield/plot of Naga chili was significantly influenced by different treatments. The fruit yield/plot varied from 2.10 to 6.20 kg/plot. The maximum yield/plot of fruits (6.20 kg/plot) was obtained in the treatment of N_{100} P_{50} K_{120} S_{20} kg/ha which was followed by N_{80} P_{75} K_{120} S_{20} kg/ha and N_{100} P_{75} K_{120} S_{20} kg/ha. In contrast,the minimum fruit yield/plot (2.10 kg/plot) was recorded from the control treatment which no received fertilizer (Table 3).

Table 3. Effect of NPKS on Average number of fruits, Average individual Fruit weight, Yield/ Plant and Yield/ Plot (kg) of Naga chilli.

Treatment	Average no. of fruits/plant	Average individual Fruit weight (g)	Yield/ Plant (g)	Yield/ Plot (kg)
T_1	141.3 h	3.91 j	552.5 k	3.68 i
T_2	180.0 c	4.88 d	878.4 c	5.86 b
T_3	200.0 b	4.47 g	894.0 b	5.96 b
T_4	122.5 j	5.50 a	673.8 g	4.49 f
T_5	150.0 f	4.05 i	607.6 j	4.05 h
T_6	208.0 a	4.47 g	927.8 a	6.19 a
T_7	146.7 fg	4.27 h	626.5 h	4.18 g
T_8	120.5 j	4.00 ij	482.2 l	3.21 j
T_9	169.0 d	4.56 f	770.6 e	5.14 d
T_{10}	132.2 i	4.66 e	616.6 i	4.11 gh
T_{11}	165.0 e	5.02 c	826.6 d	5.51 c
T_{12}	140.0 h	5.26 b	737.7 f	4.92 e
T_{13}	143.4 gh	5.42 a	777.2 e	5.18 d
T_{14}	90.3 k	3.50 k	315.1 m	2.10 k
LSD	**4.146**	**0.092**	**8.419**	**0.1061**
CV (%)	**1.64**	**1.14**	**0.72**	**1.29**

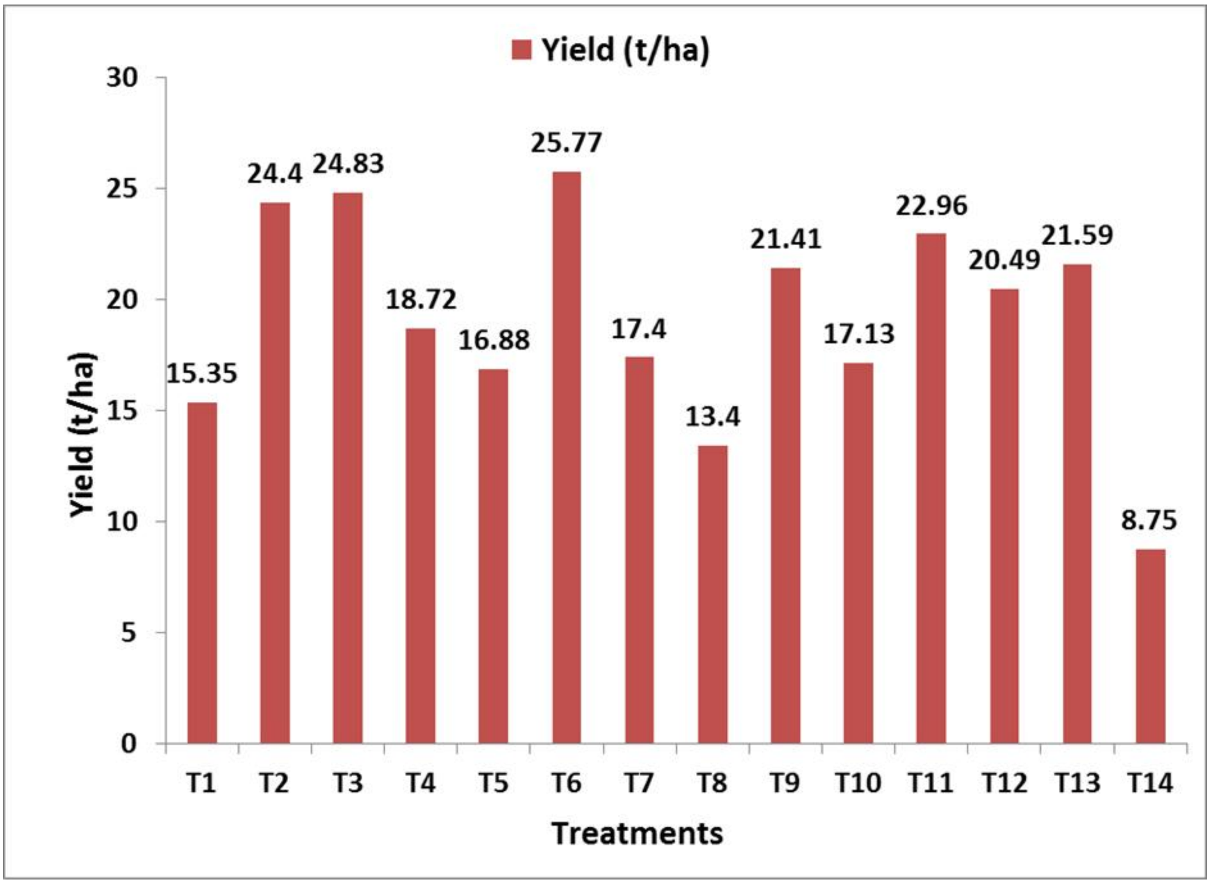
In a column means followed by common letters are not significantly different from each other at 5 % level of probability by DMRT.

Legend:

$T_1 = N_0\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_2 = N_{80}\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_3 = N_{100}\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_4 = N_{120}\ P_{75} K_{120}\ S_{20}$ kg/ha
$T_5 = N_{100}\ P_0\ K_{120}\ S_{20}$ kg/ha
$T_6 = N_{100}\ P_{50}\ K_{120}\ S_{20}$ kg/ha
$T_7 = N_{100}\ P_{100}\ K_{120}\ S_{20}$ kg/ha
$T_8 = N_{100}\ P_{75}\ K_0\ S_{20}$ kg/ha
$T_9 = N_{100}\ P_{75}\ K_{100}\ S_{20}$ kg/ha
$T_{10} = N_{100}\ P_{75}\ K_{140}\ S_{20}$ kg/ha
$T_{11} = N_{100}\ P_{75}\ K_{120}\ S_0$ kg/ha
$T_{12} = N_{100}\ P_{75}\ K_{120}\ S_{10}$ kg/ha
$T_{13} = N_{100}\ P_{75} K_{120}\ S_{30}$ kg/ha
$T_{14} = N_0\ P_0\ K_0\ S_0$ kg/ha (Native Nutrient)

4.2.4 Fruit Yield (t/ha)

A very highly significant effect was observed on fruit yield. The fruit yield varied from 8.71 to 25.84 t/ha. The maximum fruit yield (25.84 t/ha) was obtained from the treatment combination of N_{100} P_{50} K_{120} S_{20} kg/ha which was statistically different from other treatment combination. On the other hand, the minimum fruit yield (8.71 t/ha) was found from control treatment. Also, the results are in harmony with those obtained by Padem and Ocal (1999) who demonstrated that increasing K-humate application dose led to a significant increase in fruit weight and total yield (Figure 3 and Appendix VII).



$T_1 = N_0\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_2 = N_{80}\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_3 = N_{100}\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_4 = N_{120}\ P_{75}K_{120}\ S_{20}$ kg/ha
$T_5 = N_{100}\ P_0\ K_{120}\ S_{20}$ kg/ha
$T_6 = N_{100}\ P_{50}\ K_{120}\ S_{20}$ kg/ha
$T_7 = N_{100}\ P_{100}\ K_{120}\ S_{20}$ kg/ha
$T_8 = N_{100}\ P_{75}\ K_0\ S_{20}$ kg/ha
$T_9 = N_{100}\ P_{75}\ K_{100}\ S_{20}$ kg/ha
$T_{10} = N_{100}\ P_{75}\ K_{140}\ S_{20}$ kg/ha
$T_{11} = N_{100}\ P_{75}\ K_{120}\ S_0$ kg/ha
$T_{12} = N_{100}\ P_{75}\ K_{120}\ S_{10}$ kg/ha
$T_{13} = N_{100}\ P_{75}K_{120}\ S_{30}$ kg/ha
$T_{14} = N_0\ P_0\ K_0\ S_0$ kg/ha (Native Nutrient)

Figure 3. Yield (t/ha) of Naga chilli as influenced by different NPKS doses

4.3 Correlation Study

A positive correlation between number of fruits/plant and average individual fruit weight (g) was observed when different levels of NPKS was applied to naga chilli plants. The relationship between number of fruits/plant and average individual fruit weight (g) could be expressed by the equation y=0.004x-5.17 (R^2=0.042) where, y= average individual fruit weight, x= number of fruits/plant. The R^2 value indicates that 4.2% of the average individual fruit weight (g) is attributed to the number of fruits/plant (Figure 4).

A positive correlation between plant volume (cm^3) and Yield/Plant (g) was observed when different levels of NPKS were applied to naga chilli plants (Figure 5). The relationship between plant volume (cm^3) and Yield/Plant (g) could be expressed by the equation y=0.163x+215.6 (R^2=0.394) where, y= Yield/Plant (g) average, x= plant volume (cm^3). The R^2 value indicates that 39.4% of the average Yield/Plant (g) is attributed to the plant volume (cm^3).

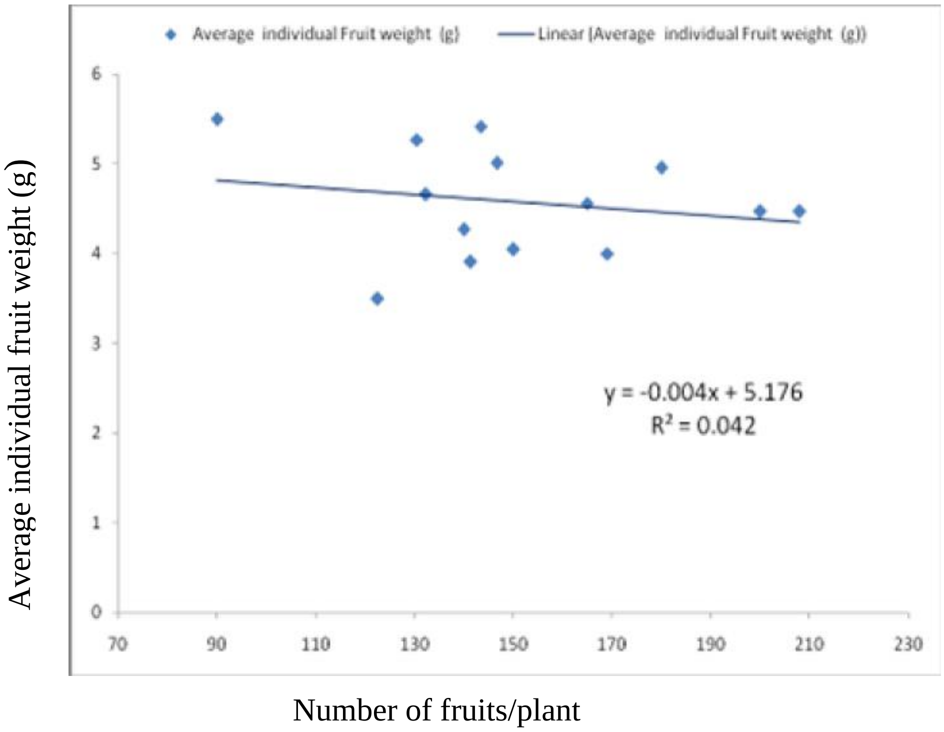


Figure 4. Relationship between number of fruits/plant with average individual fruit weight as influence by different levels of NPKS

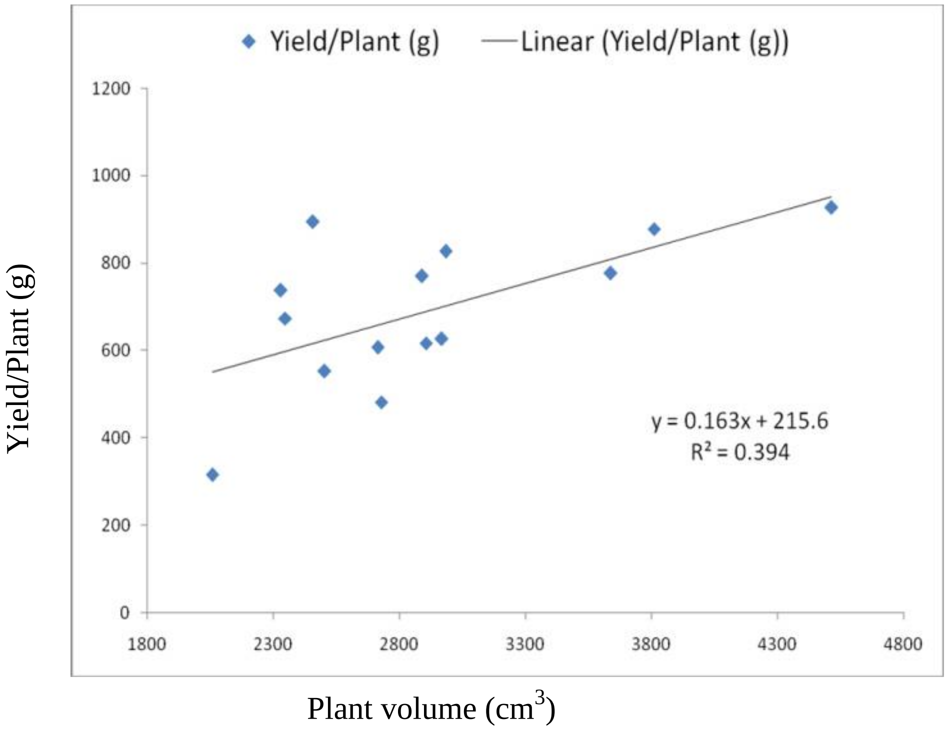


Figure 5. Relationship between plant volume with yield/plant as influence by different levels of NPKS

4.4 QUALITY PARAMETERS

4.4.1 Fruit length (cm)

The combined effect of NPKS had a significant effect on the fruit length in naga chilli (Table 4). The highest fruit length (6.63 cm per plant) was produced by the plants having received the doses of N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) followed by N_{100} P_{75} K_{100} S_{20} kg/ha (T_3) treatment combination and lowest fruit length (5.43 cm per plant) was observed from control treatment (no fertilizer). The result revealed that fruit length increased with the increasing levels of NPKS. The effect of N_{100} P_{50} K_{120} S_{20} kg/ha and N_{100} P_{75} K_{100} S_{20} kg/ha treatment on fruit length were statically similar from the other treatments and the treatment combinations of N_{80} P_{75} K_{120} S_{20} kg/ha, N_{100} P_{75} K_{120} S_{20} kg/ha and N_{100} $P_{75}K_{120}$ S_{30} kg/ha were statically similar. The result agrees with that of MARC (2005) which reported that the long fruit length of (7 cm) and the short fruit length with (4 cm) at similar NPK fertilizer application. Beyene and David (2007) reported that the application of NPK significantly increased the fruit diameter per plant of naga chilli.

The results are to some extent in agreement with Lal and Pundrik (1971) who observed an improvement in fruit size with increasing nitrogen application. The obtained results might be due to the role of potassium in fruit quality, where it is known as the quality nutrient because of its important effects on fruit quality parameters (Imas and Bansal, 1999 and Lester, 2006).

4.4.2 Fruit diameter (cm)

The results showed that the fruit diameters were significantly influenced by different levels of NPKS applied (Table 4). The maximum fruit diameter (3.03 cm per plant) was found from N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) treatment combinations and the minimum fruit diameter (2.25 cm per plant) were recorded from the control treatment (no manure and fertilizer). Beyene and David (2007) reported that the application of NPK significantly increased the fruit diameter per plant of naga chilli.

4.4.3 Pericarp weight (g/fruit)

The significant difference in pericarp weight per fruit was noticed due to treatments (Table 4). Among the treatment combination, N_{120} $P_{75}K_{120}$ S_{20} kg/ha (T_4) recorded significantly higher (4.99 g) pericarp weight per fruit, followed by N_{100} P_{75} K_{120} S_0 kg/ha (4.57 g) which was statistically similar with N_{100} P_{75} K_{120} S_{10} kg/ha and N_{100} $P_{75}K_{120}$ S_{30} kg/ha. The lower pericarp weight per fruit (2.97 g) was recorded with control.

4.4.4 Number of seeds per fruit

Effect of treatment combination on number of seeds per fruit was found significant (Table 4). Among the treatments, N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) recorded significantly higher number of seeds per fruit (39.54), while, control (31.05) had the lower seeds of fruit. The increase in number of seeds fruit-1 might be attributed to increase in fruit length with an optimum dose of nitrogen. The results are up to some extent in agreement with the findings of Subhani (1990) who obtained maximum number of seeds fruit-^{1} when the highest rate of nitrogen and potassium were applied. In context of potassium, highest seeds fruit-^{1} (109) were recorded from 50 kg K ha-^{1} which was statistically at par with 40 kg K ha-^{1} (107.99) and 30 kg K ha-^{1} (107.88) while minimum seed fruit-^{1} (105) were recorded from plots having no potassium.

4.4.5 1000 Seed weight (g)

The 1000 seed weight was found significant due to treatments. Among the treatments, significantly highest 1000 seed weight (12.20 g) was noticed in N_{100} P_{50} K_{120} S_{20} kg/ha (T_6), while, the control had the lowest (9.07 g) 1000 seed weight (Table 4).

4.4.6 Dry fruit weight (g)

The analysis of variance on Dry fruit weight showed a very highly significant difference (Table 4). The highest fruit dry weight per plant (0.67 g) was obtained from N_{120} $P_{75}K_{120}$ S_{20} kg/ha (T_6) while the least fruit dry weight (0.35 g) was obtained from the control treatment.

The increase in pod dry weight in this study is in conformity with the work of Hedge (1997) and Guerpinar and Mordogan (2002) who reported that pod dry matter content of peppers was directly related to the amount of nutrient taken from the soil, which was proportional to the nutrients present in the soil or the amount of organic and inorganic fertilizers applied to the soil.

Table 4. Effect of NPKS on fruit length, fruit diameter, pericarp weight, number of seeds/fruit, 1000 seed weight and dry fruit weight of naga chilli

Treatment	Fruit Size (cm)		Pericarp weight (g/fruit)	Number of seeds/fruit	1000 seed weight (g)	Single Fruit dry Weight (g)
	Length	Diameter				
T_1	4.67 f	2.39 c-f	3.42 h	35.30 de	11.14 d	0.40 ef
T_2	5.47 de	2.80 ab	4.38 c	37.01 c	10.06 f	0.53 b-d
T_3	5.56 de	2.43 c-f	3.92 ef	38.07 b	11.15 d	0.45 c-e
T_4	4.66 f	2.65 bc	4.99 a	35.88 d	10.56 e	0.67 a
T_5	5.77 c-e	2.35 def	3.54 g	35.37 d	11.70 bc	0.40 ef
T_6	6.63 a	3.03 a	3.91ef	39.54 a	12.20 a	0.45 c-e
T_7	6.00 bc	2.30 ef	3.83 f	38.52 b	10.02 f	0.43 d-f
T_8	5.80 c-e	2.57 b-e	3.99 de	34.50 ef	9.483 g	0.47 b-e
T_9	6.37 a	2.40 c-f	3.57 gh	37.97 b	10.00 f	0.40 ef
T_{10}	5.60 de	2.59 b-d	4.07 d	34.00 f	11.01 d	0.47 b-e
T_{11}	6.33 ab	2.30 ef	4.57 b	32.10 h	11.60 c	0.50 b-d
T_{12}	5.83 cd	2.60 b-d	4.97 a	33.00 g	12.00 ab	0.53 a-c
T_{13}	5.50 de	2.70 b	4.95 a	37.11 c	11.79 bc	0.54 ab
T_{14}	5.43 e	2.25 f	2.97 i	31.05 i	9.07 h	0.35 f
LSD	**0.3357**	**0.2374**	**0.1187**	**0.8188**	**0.302**	**0.075**
CV (%)	**3.51**	**5.63**	**1.69**	**1.37**	**1.65**	**10.31**

In a column means followed by common letters are not significantly different from each other at 5 % level of probability by DMRT.

Legend:

$T_1 = N_0\ P_{75}\ K_{120}\ S_{20}$ kg/ha	$T_6 = N_{100}\ P_{50}\ K_{120}\ S_{20}$ kg/ha	$T_{11} = N_{100}\ P_{75}\ K_{120}\ S_0$ kg/ha
$T_2 = N_{80}\ P_{75}\ K_{120}\ S_{20}$ kg/ha	$T_7 = N_{100}\ P_{100}\ K_{120}\ S_{20}$ kg/ha	$T_{12} = N_{100}\ P_{75}\ K_{120}\ S_{10}$ kg/ha
$T_3 = N_{100}\ P_{75}\ K_{120}\ S_{20}$ kg/ha	$T_8 = N_{100}\ P_{75}\ K_0\ S_{20}$ kg/ha	$T_{13} = N_{100}\ P_{75} K_{120}\ S_{30}$ kg/ha
$T_4 = N_{120}\ P_{75} K_{120}\ S_{20}$ kg/ha	$T_9 = N_{100}\ P_{75}\ K_{100}\ S_{20}$ kg/ha	$T_{14} = N_0\ P_0\ K_0\ S_0$ kg/ha (Native Nutrient)
$T_5 = N_{100}\ P_0\ K_{120}\ S_{20}$ kg/ha	$T_{10} = N_{100}\ P_{75}\ K_{140}\ S_{20}$ kg/ha	

4.5 Economic evaluation

Gross return was calculated from the price of naga chilli. Variable cost was calculated from the costs involved for fertilizer used for the experimental treatments. The partial budget analysis of fertilizer showed that the gross return from the control plot was Tk. 395.06 /m^2 and the application of fertilizer increased the gross return up to Tk.910.00/ m^2. The gross margin ranged from Tk. 395.06 /m^2 to Tk. 907.99/m^2. The maximum mean gross margin of Tk. 907.99/m^2 was achieved with the treatment of N_{100} P_{50} K_{120} S_{20} kg/ha (Table 5).

Dominance analysis shows that the treatments of N_0 P_{75} K_{120} S_{20} kg/ha, N_{80} P_{75} K_{120} S_{20} kg/ha, N_{100} P_{75} K_{120} S_{20} kg/ha, N_{120} P_{75} K_{120} S_{20} kg/ha, N_{100} P_{100} $K_{120}S_{20}$ kg/ha, N_{100} P_{75} K_0 S_{20} kg/ha, N_{100} P_{75} K_{100} S_{20} kg/ha, N_{100} P_{75} K_{140} S_{20} kg/ha, N_{100} P_{75} K_{120} S_0 kg/ha, N_{100} P_{75} $K_{120}S_{10}$ kg/ha, and N_{100} P_{75} K_{120} S_{30} kg/ha are cost dominated irrespective of this experiment.

Marginal analysis (Table 6) showed that the highest marginal rate of return (MRR) of 33833.33% was obtained from the treatment of N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) followed by that of N_{100} P_{75} K_{120} S_0 kg/ha 20729.37%. Hence, application of N_{100} P_{50} K_{120} S_{20} kg/ha would be economically acceptable for the naga chilli production in the hilly region of Piedmont plains soil.

Table 5. Partial budget and dominance analysis for different fertilizer response data of naga chilli

Treatment	Gross return (Tk./m^2)	Variable cost (Tk./m^2)	Gross margin (Tk./m^2)	Remarks
T_1	618.19	1.98	616.21	CD
T_2	787.50	2.31	785.19	CD
T_3	875.00	2.41	872.59	CD
T_4	535.94	2.5	533.44	CD
T_5	656.25	1.26	654.99	CU
T_6	910.00	2.01	907.99	CU
T_7	641.81	2.76	639.05	CD
T_8	527.19	2.06	525.13	CD
T_9	739.38	2.48	736.9	CD
T_{10}	578.38	2.6	575.78	CD
T_{11}	722.00	2.06	719.94	CD
T_{12}	612.50	2.23	610.27	CD
T_{13}	627.38	2.56	624.82	CD
T_{14}	395.06	0	395.06	CU

Legend:
$T_1 = N_0\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_2 = N_{80}\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_3 = N_{100}\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_4 = N_{120}\ P_{75}K_{120}\ S_{20}$ kg/ha
$T_5 = N_{100}\ P_0\ K_{120}\ S_{20}$ kg/ha
$T_6 = N_{100}\ P_{50}\ K_{120}\ S_{20}$ kg/ha
$T_7 = N_{100}\ P_{100}\ K_{120}\ S_{20}$ kg/ha
$T_8 = N_{100}\ P_{75}\ K_0\ S_{20}$ kg/ha
$T_9 = N_{100}\ P_{75}\ K_{100}\ S_{20}$ kg/ha
$T_{10} = N_{100}\ P_{75}\ K_{140}\ S_{20}$ kg/ha
$T_{11} = N_{100}\ P_{75}\ K_{120}\ S_0$ kg/ha
$T_{12} = N_{100}\ P_{75}\ K_{120}\ S_{10}$ kg/ha
$T_{13} = N_{100}\ P_{75}K_{120}\ S_{30}$ kg/ha
$T_{14} = N_0\ P_0\ K_0\ S_0$ (Native Nutrient)
CU= Cost undominated
CD= Cost dominated.

Table 6.Marginal analysis of undominated fertilizers response data of Naga chilli

Treatment	Gross return (Tk./m^2)	Variable cost (Tk./ m^2)	Marginal increase in Gross return (Tk./m^2)	Marginal increase in variable cost (Tk./m^2)	Marginal rate of return (%)
T_6	910	2.01	253.75	0.75	33833.33
T_5	656.25	1.26	261.19	1.26	20729.37
T_{14}	395.06	0	395.06	0	0

Legend:
$T_1 = N_0\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_2 = N_{80}\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_3 = N_{100}\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_4 = N_{120}\ P_{75}K_{120}\ S_{20}$ kg/ha
$T_5 = N_{100}\ P_0\ K_{120}\ S_{20}$ kg/ha
$T_6 = N_{100}\ P_{50}\ K_{120}\ S_{20}$ kg/ha
$T_7 = N_{100}\ P_{100}\ K_{120}\ S_{20}$ kg/ha
$T_8 = N_{100}\ P_{75}\ K_0\ S_{20}$ kg/ha
$T_9 = N_{100}\ P_{75}\ K_{100}\ S_{20}$ kg/ha
$T_{10} = N_{100}\ P_{75}\ K_{140}\ S_{20}$ kg/ha
$T_{11} = N_{100}\ P_{75}\ K_{120}\ S_0$ kg/ha
$T_{12} = N_{100}\ P_{75}\ K_{120}\ S_{10}$ kg/ha
$T_{13} = N_{100}\ P_{75}K_{120}\ S_{30}$ kg/ha
$T_{14} = N_0\ P_0\ K_0\ S_0$ kg/ha (Native Nutrient)

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted at Citrus Research Station, Bangladesh Agricultural Research Institute, Jaintapur, Sylhet during the period from January, 2014 to June 2014 to evaluate the effect of different levels of NPKS on the growth and yield of naga chilli. The experiment consisted of four nutrient elements (NPKS) which were tested in 14 treatment combinations viz. T_1= N_0 P_{75} K_{120} S_{20} kg/ha, T_2= N_{80} P_{75} K_{120} S_{20} kg/ha, T_3= N_{100} P_{75} K_{120} S_{20} kg/ha, T_4= N_{120} P_{75} K_{120} S_{20} kg/ha, T_5= N_{100} P_0 K_{120} S_{20} kg/ha, T_6= N_{100} P_{50} K_{120} S_{20} kg/ha, T_7 = N_{100} P_{100} $K_{120}S_{20}$ kg/ha, T_8= N_{100} P_{75} K_0 S_{20} kg/ha, T_9 = N_{100} P_{75} K_{100} S_{20} kg/ha, T_{10} = N_{100} P_{75} K_{140} S_{20} kg/ha, T_{11}= N_{100} P_{75} K_{120} S_0 kg/ha, T_{12} = N_{100} P_{75} $K_{120}S_{10}$ kg/ha, T_{13} = N_{100} P_{75} K_{120} S_{30} kg/ha and T_{14}= N_0 P_0 K_0 S_0 kg/ha (Native Nutrient).

The experiment was set up in Randomized Complete Block Design (RCBD) with three replications. The size of each unit plot was 2.0 m × 1.2 m and the treatments were distributed randomly in each block. There were 252 plants in each unit plot maintaining a spacing of 60 cm x 65 cm. The seeds of naga chilli variety were sown on 21 December, 2013 under nursery condition which was transplanted in the main field as on 31 January, 2014 and the final chilli pod was harvested on 15 June. Data were collected from 3 randomly selected plants of each unit plot on plant height, Canopy Spreading, Number of branches per plant, Stem diameter, Plant volume, Days to 50 per cent flowering, Days to first harvest, Days to complete harvest, Number of fruits per plant and yield, while the single fruit weight, fruit length, fruit diameter, fruit Pericarp weight, Number of seeds per fruit, 1000 Seed weight were measured from randomly selected ten fruits from each plants. The collected data were analyzed statistically and the differences between the means were evaluated by Duncan's Multiple Range Test (DMRT).

The results of the experiment showed that the different levels of NPKS had significant effect on all the parameters tested. The highest plant height, stem diameter, plant volume, spreading and maximum number of branches per plant were increased with increasing the amount of NPKS. Final harvest, maximum plant height (91.40 cm per plant), Stem diameter (6.50 cm), plant volume (4511.72 cm^3), spreading (91.0 cm × 94.7 cm) and branches (33.48 per plant) were observed in the treatment of N_{100} P_{50} K_{120} S_{20} kg/ha which was significantly different from other treatments. At harvest, the minimum plant height (69.31cm per plant), Stem diameter (4 cm), plant volume (2057.37 cm^3), spreading (63.7 cm × 61.7 cm) and branches (25.18 per plant) were observed from control (no manure and fertilizer) treatment.

Among the treatments, N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) was found to be superior with earlier flowering takes 50.37 days for fifty per cent flowering while the lowest 91.04 days and 115.9 days were taken to first harvest and to complete harvesting from the treatment N_{100} P_{75} K_{120} S_{20} kg/ha (T_3) and N_{120} $P_{75}K_{120}$ S_{20} (T_4) respectively.

Respect to yield parameters, application of N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) recorded higher values for average number of fruits per plant (208), fruit yield per plant (927 g), fruit yield per plot (6.19 kg) and fruit yield per ha (25.77 tonnes) while control (T_{14}) recorded lower values for all the characters (90.3, 315 g, 2.10 kg and 25.77 tons respectively). Maximum individual fruit weight (5.5 g) was observed in the treatment of N_{120} P_{75} K_{120} S_{20} kg/ha (T_4) while minimum fruit weight (3.5 g) was found in the control.

The treatment N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) was superior for producing higher fruit length (6.63 cm), fruit diameter (3.03 cm) with more number of seeds per fruit (39.54) and 1000 seed weight (12.20 g). The control treatment exhibited lower values for the above characters (4.66 cm, 2.25 g, 31.05 g, and 9.07 g respectively). The pericarp weight (4.99 g) and Dry single fruit weight (0.67 g) was significantly highest with N_{120} P_{75} K_{120} S_{20} kg/ha (T_4) and lowest was recorded in control treatment.

Application of N_{80} P_{75} K_{120} S_{20} kg/ha and N_{100} P_{75} K_{120} S_{20} kg/ha produced 24.40 t/ha and 24.83 t/ha yields respectively which was lower than N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) treatment combinations. So, the treatment combination of N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) is the best among other treatments.

The economic evaluation showed that the highest gross return (Tk. 910.00 /m^2) was obtained from the treatment combination of N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) while the lowest gross return (Tk. 393.77/m^2) was obtained from the control treatment. The highest marginal rate of return (33833.33%) was obtained from N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) treatment.

From the above results it may be concluded that NPKS significantly influenced the growth and yield of naga chilli and the treatment combination of N_{100} P_{50} K_{120} S_{20} kg/ha (T_6) may be recommended for the profitable production of naga chilli.

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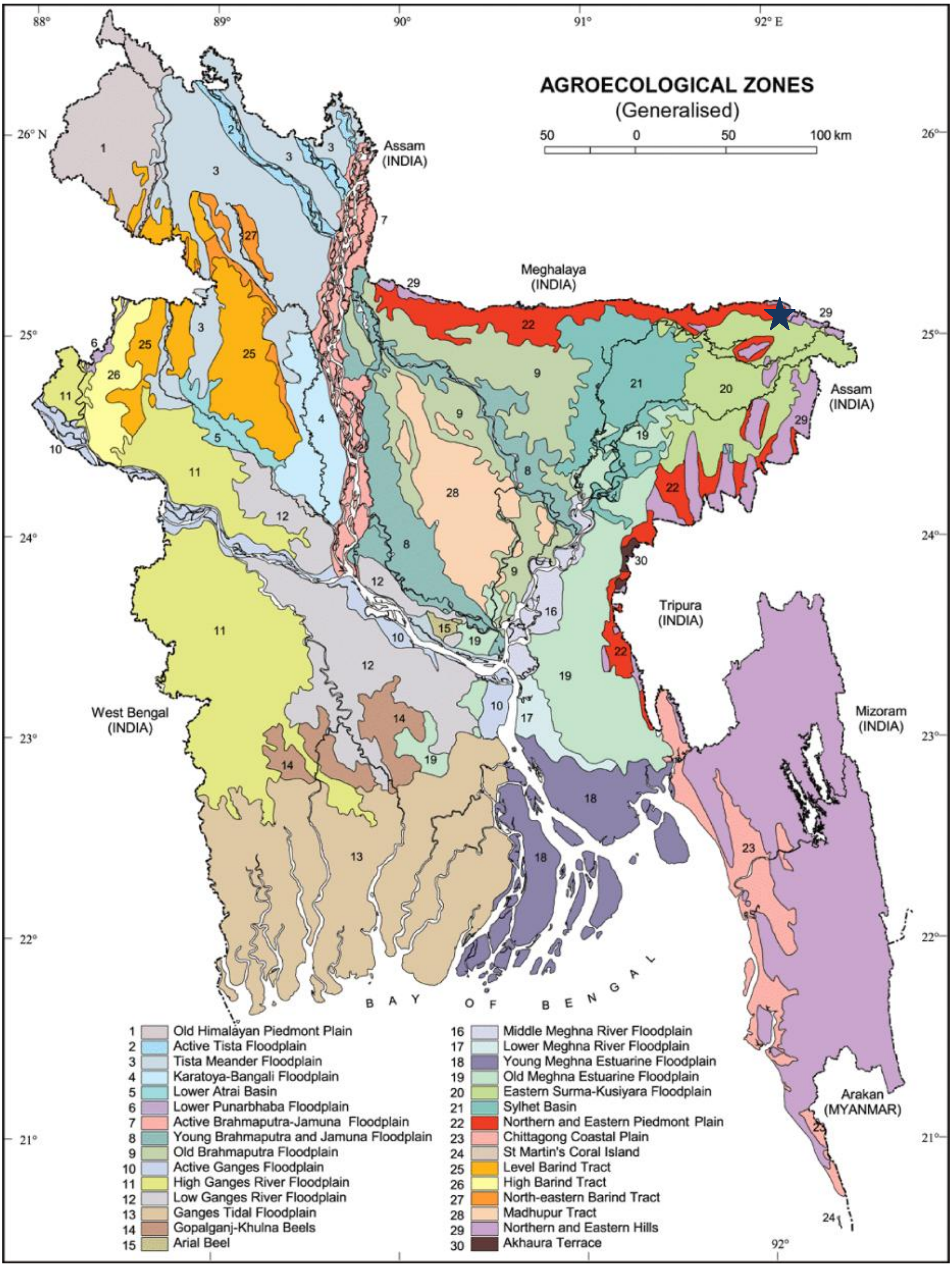
APPENDICES

Appendix I. Map showing the experimental sites under study



★ **The experimental site under study**

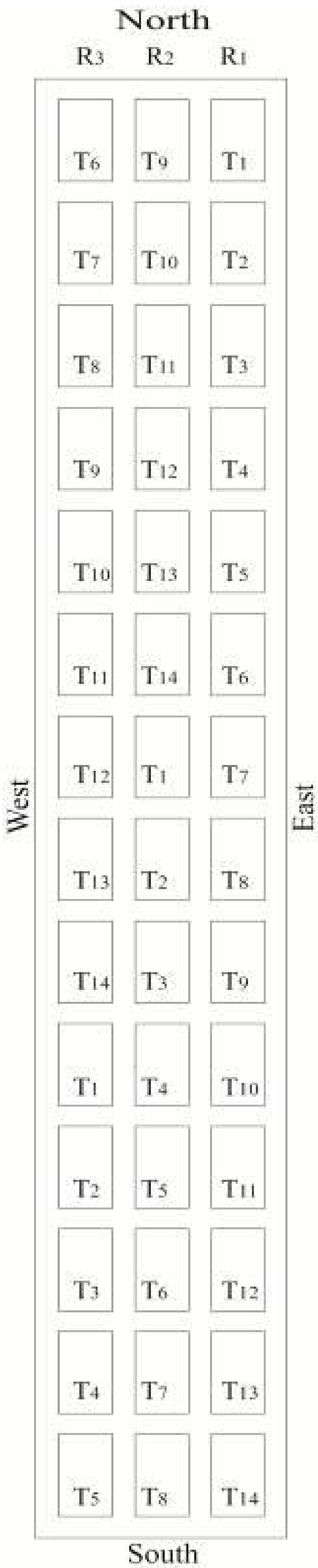
Appendix II. Weather data for the experimental period

Month	Temperature		Precipitation	Relative humidity
	Maximum	Minimum		
October’ 2012	33.9	14.7	472	73
November’ 2012	33.2	8.1	37	65
December’2012	26.5	7.8	2	70
January’ 2013	28.7	13.7	0	62
February’ 2013	32.0	16.4	8	57
March’ 2013	33.3	19.0	60	60
April’ 2013	33.8	21.2	271	70
May’ 2013	36.6	24.4	1065	81

Appendix III. Soil test results of the experimental plot for the experimental year

Parameters	Value	Remarks
pH	4.8	Extreamly acidic
OM (%)	1.67	
N (% Total)	0.05	Very low
P (µg/ml)	18.1	Optimum
K (meq/100ml)	0.07	Low
S (µg/ml)	12.0	Low
Ca (meq/100ml)	1.6	Low
Mg (meq/100ml)	0.68	Low
B (µg/ml)	0.26	Medium
Zn (µg/ml)	1.25	Optimum
Cu (µg/ml)	0.45	Optimum
Fe (µg/ml)	12.2	Very high
Mn (µg/ml)	2.2	Optimum

Appendix IV. Field layout of the experimental plot



Appendix V. Effect of NPKS on plant height (cm) at different growth stages in naga chilli

Treatment	Plant height			
	60 DAT	90 DAT	120 DAT	Final harvest
T_1	53.52 e	65.60 fg	70.48 g	73.43 bc
T_2	55.20 de	65.71fg	72.51 e-g	76.63 bc
T_3	63.86 ab	73.54 bc	83.35 b	85.30 ab
T_4	56.37 de	66.85 ef	75.10 d-f	78.59 bc
T_5	54.34 de	64.63 g	71.45 fg	85.45 ab
T_6	65.85 a	76.66 a	88.50 a	91.40 a
T_7	62.40 ab	72.26 c	77.51cd	81.63 a-c
T_8	57.30 cd	67.67de	74.70 d-g	77.45 bc
T_9	54.70 de	64.62 g	71.66 fg	75.21 bc
T_{10}	53.81de	65.77 fg	73.54 d-g	76.57 bc
T_{11}	60.29 bc	74.42 b	80.45 bc	70.87 c
T_{12}	61.53 b	66.56 ef	73.53 d-g	79.28 a-c
T_{13}	63.60 ab	68.69 d	76.61 c-e	80.31 a-c
T_{14}	45.58 f	58.52 h	62.52 h	69.31 c
LSD	**3.258**	**1.417**	**3.946**	**10.95**
CV(%)	**3.36**	**1.24**	**3.13**	**8.29**

In a column means followed by common letters are not significantly different from each other at 5 % level of probability by DMRT.

Legend:

$T_1 = N_0\ P_{75}\ K_{120}\ S_{20}$	$T_8 = N_{100}\ P_{75}\ K_0\ S_{20}$
$T_2 = N_{80}\ P_{75}\ K_{120}\ S_{20}$	$T_9 = N_{100}\ P_{75}\ K_{100}\ S_{20}$
$T_3 = N_{100}\ P_{75}\ K_{120}\ S_{20}$	$T_{10} = N_{100}\ P_{75}\ K_{140}\ S_{20}$
$T_4 = N_{120}\ P_{75}K_{120}\ S_{20}$	$T_{11} = N_{100}\ P_{75}\ K_{120}\ S_0$
$T_5 = N_{100}\ P_0\ K_{120}\ S_{20}$	$T_{12} = N_{100}\ P_{75}\ K_{120}\ S_{10}$
$T_6 = N_{100}\ P_{50}\ K_{120}\ S_{20}$	$T_{13} = N_{100}\ P_{75}K_{120}\ S_{30}$
$T_7 = N_{100}\ P_{100}\ K_{120}\ S_{20}$	$T_{14} = N_0\ P_0\ K_0\ S_0$ (Native Nutrient)

Appendix VI. Effect of NPKS on Number of branches per plant at different growth stages in Naga chilli

Treatment	Number of branches per plant			
	60 DAT	90 DAT	120 DAT	Final harvest
T_1	16.60 g	21.07 e	26.39 de	28.45 ef
T_2	18.30 b-d	21.99 c-e	27.48 c-e	30.03 cd
T_3	18.80 b	23.58 ab	30.39 ab	32.50 ab
T_4	17.00 fg	19.48 f	25.54 e	26.65 g
T_5	18.70 b	22.63 b-d	30.50 ab	31.44 bc
T_6	20.00 a	24.42 a	31.50 a	33.48 a
T_7	18.20 b-d	22.67 b-d	28.96 a-d	30.50 cd
T_8	17.90 c-e	22.55 b-d	29.35 a-c	31.38 bc
T_9	18.67 bc	23.33 a-c	28.48 b-d	30.71cd
T_{10}	18.17 b-e	23.37 a-c	29.24 a-c	31.41 bc
T_{11}	17.83 de	21.27 de	27.65 c-e	29.38 de
T_{12}	17.40 ef	21.72 de	26.62 de	28.53 ef
T_{13}	17.60 d-f	21.64 de	26.54 de	27.63 fg
T_{14}	13.52 h	15.22 g	22.46 f	25.18 h
LSD	**0.708**	**1.273**	**2.288**	**1.362**
CV(%)	**2.38**	**3.48**	**4.88**	**2.72**

In a column means followed by common letters are not significantly different from each other at 5 % level of probability by DMRT.

Legend:

$T_1 = N_0\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_2 = N_{80}\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_3 = N_{100}\ P_{75}\ K_{120}\ S_{20}$ kg/ha
$T_4 = N_{120}\ P_{75} K_{120}\ S_{20}$ kg/ha
$T_5 = N_{100}\ P_0\ K_{120}\ S_{20}$ kg/ha
$T_6 = N_{100}\ P_{50}\ K_{120}\ S_{20}$ kg/ha
$T_7 = N_{100}\ P_{100}\ K_{120}\ S_{20}$ kg/ha
$T_8 = N_{100}\ P_{75}\ K_0\ S_{20}$ kg/ha
$T_9 = N_{100}\ P_{75}\ K_{100}\ S_{20}$ kg/ha
$T_{10} = N_{100}\ P_{75}\ K_{140}\ S_{20}$ kg/ha
$T_{11} = N_{100}\ P_{75}\ K_{120}\ S_0$ kg/ha
$T_{12} = N_{100}\ P_{75}\ K_{120}\ S_{10}$ kg/ha
$T_{13} = N_{100}\ P_{75} K_{120}\ S_{30}$ kg/ha
$T_{14} = N_0\ P_0\ K_0\ S_0$ kg/ha (Native Nutrient)

Appendix VII. Effect of NPKS on Yield (t/ha) of Naga chilli.

Treatments	Yield (t/ha)
$T_1 = N_0 P_{75} K_{120} S_{20}$ kg/ha	15.35 h
$T_2 = N_{80} P_{75} K_{120} S_{20}$ kg/ha	24.40 b
$T_3 = N_{100} P_{75} K_{120} S_{20}$ kg/ha	24.83 b
$T_4 = N_{120} P_{75} K_{120} S_{20}$ kg/ha	18.72 f
$T_5 = N_{100} P_0 K_{120} S_{20}$ kg/ha	16.88 g
$T_6 = N_{100} P_{50} K_{120} S_{20}$ kg/ha	25.77 a
$T_7 = N_{100} P_{100} K_{120} S_{20}$ kg/ha	17.40 g
$T_8 = N_{100} P_{75} K_0 S_{20}$ kg/ha	13.40 i
$T_9 = N_{100} P_{75} K_{100} S_{20}$ kg/ha	21.41 d
$T_{10} = N_{100} P_{75} K_{140} S_{20}$ kg/ha	17.13 g
$T_{11} = N_{100} P_{75} K_{120} S_0$ kg/ha	22.96 c
$T_{12} = N_{100} P_{75} K_{120} S_{10}$ kg/ha	20.49 e
$T_{13} = N_{100} P_{75} K_{120} S_{30}$ kg/ha	21.59 d
$T_{14} = N_0 P_0 K_0 S_0$ kg/ha (Native Nutrient)	8.75 j
LSD	**0.8944**
CV (%)	**2.77**

In a column means followed by common letters are not significantly different from each other at 5 % level of probability by DMRT.