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Samsangheile Nchang
Department of Horticulture, School of Agricultural Sciences and Rural Development, Medziphema Campus, Nagaland University, Nagaland, India

Santosh Lal
Department of Horticulture, School of Agricultural Sciences and Rural Development, Medziphema Campus, Nagaland University, Nagaland, India

Kuldeep Singh Rajawat
Department of Horticulture MPUAT, Udaipur, Rajasthan, India

Babu Singh Tanwar
Department of Horticulture SHIATS, Allahabad, Uttar Pradesh, India

Correspondence
Samsangheile Nchang
Department of Horticulture, School of Agricultural Sciences and Rural Development, Medziphema Campus, Nagaland University, Nagaland, India

Effect of integrated nutrient management on growth of chilli (*Capsicum annum* L.)

Samsangheile Nchang, Santosh Lal, Kuldeep Singh Rajawat and Babu Singh Tanwar

Abstract
The field experiment was conducted during 2010 - 2011 at the Experimental Farm of School of Agricultural Sciences and Rural Development, Medziphema Campus, Nagaland University, Nagaland to study the effect of different sources of manuring on growth, of Chilli (*Capsicum annum* L.) The experiment was laid out in a randomized block design with three replications. Integrated nutrient management (INM) is technically sound, economically viable, socially acceptable, practically feasible and ecologically sound system of production. The basic principle of INM is the maintenance of soil fertility, sustainable agricultural productivity and improving farmers' profitability. A field experiment was carried out at the experimental farm of SASRD, Medziphema Campus, Nagaland University, during October, 2010 to May, 2011 using Randomized Block Design to evaluate the integrated effect of chemical fertilizers, organic manures and biofertilizers on growth, of chilli under the foothill condition of Nagaland. Results of the twelve treatment combination field experiment revealed that integrated application of chemical fertilizers, organic manures and biofertilizers significantly increased the growth, characters of chilli over control. Maximum plant height (105.58 cm), number of branches plant^{-1} (104.36), number of leaves plant^{-1} (516.47), leaf area (55.65 cm^2).

Keywords: Chilli, INM, chemical fertilizers, organic manures, biofertilizers, growth

Introduction
Chilli (*Capsicum annum* L.) belongs to the family solanaceae. Chilli was known to Indian only about 400 years ago. This chilli was first introduced to India by the Portuguese towards the end of 15 century and the cultivation began popular from 17 century onwards (Indira *et al*., 2007) [12]. Chilli is reported to be a native of South America and its cultivation was known to be native of Peru since pre-historic times (Pruthi, 1993) [15]. Chilli is the richest source of vitamin C and its content is more than that of tomato. The hotness or hot flavour of chillies are due to presence of a group of seven closely related compound called capsaicinoids, but capsaicin and dihydrocapsaicin are responsible for their pungency. In capsaicin, fruits contain fixed fatty acids (60%) and little strain low-volatile oil (0.1-2.6%), pigments (0.1-0.8%), pungent principles (capsaicin and dihydrocapsaicin), resins, protein, cellulous, pentoses and mineral elements. The fresh fruit also have sufficient amount of vitamin B, C, E and Pro-vitamin A (Winton and Winton, 1939) [20].

In India, *Capsicum annum* L. is cultivated for fresh fruits (both sweet and hot types), oleoresin/colour extraction (paprika type) and processing (pickle type). It is consumed in various forms, fresh green chillies as vegetables to dried powders as spices. It is most widely used universal spice, named as 'wonder spice'. In daily life, chillies are integral and most important ingredient in many different cuisines around the world as it adds pungency, taste, flavor and colour to the dishes. Indian chilli is considered to be world famous for two important qualities- its colour and pungency level. It exports chillies in different forms like chilli powder, dried chilli, pickled chillies and chilli oleoresins. Countries like US, UK, Germany and Sweden use chilli for manufacture of oleoresins and extract on a large scale. Some varieties are famous for the red colour because of the pigment capsanthin and others are known for biting pungency attributed to capsaicin. Some accessions of *Capsicum annum* L with dark purple leaf, purple flower petals and dark purple fruit have higher antioxidant activity, ascorbic acid and phenol content. The active ingredient capsaicin (and the related capsaicinoids - dihydrocapsaicin, nordihydrocapsaicin and homocapsaicin) is found only in the fruits of the genus *Capsicum*.

Extracted carotenoids pigments are important colourants in the processed food industry as well as in cosmetic applications. Chilli is called by several others names like hot pepper, pepper, chilli, chilli pepper, chile, paprika, etc.

Chilli is cultivated in tropical and sub-tropical climates up to 2000 m altitude. A temperature ranging from 15ºC to 35ºC is optimum for its cultivation but 20-25ºC temperature is ideal for plant growth and fruit development. Peppers can grow in almost all types of soil but well drained loamy soil rich in organic matter is best for its cultivation. The best soil pH for pepper is 6-7. Chilli can be sown three (3) times in plains *i.e*. February-March, June-July and September-October and once in hills *i.e*. April-May.

Apart from temperature, soil moisture and photoperiod, nutrition is one of the paramount factors which the reproductive development in chilli (Cochran, 1936) [7]. Use of organic manures was suggested in pepper cultivation. The efficacies of cattle manure, poultry manure, sludge, farm compost, etc, in improving growth of the plants and increasing the yield was well documented. The use of organic manures corrects multiple deficiency and sectional elements improve physical, chemical and biological property of soil. Vermicompost (1.6%N: 5.04%P: 0.8%K), FYM (0.75%N: 0.17%P: 0.55%K) are good sources of organic manures (Jamir, 2005). FYM (0.5%N: 0.4%P: 0.5%K), poultry manure (2.8%N: 2.6%P: 1.2%K), goat manure (2.5%N: 0.9%P: 2%K) and sheep manure (2.1%N: 1.1%P: 2.2%K) are also a very good source of organic manure (Amanuliah *et al*., 2009).

Increased use of chemical fertilizers with hybrid seeds and irrigation facilities are major three components responsible for increased yield and food sufficiency in Indian agriculture. In the post-green revolution periods, the farmers in our country have dramatically increased the crop yields to meet the needs of ever growing population through the use of improved cultivars, inorganic fertilizers and chemicals. The escalating prices of chemical inputs and its impact on the environment urged the farmer to adopt alternative remedy practices for reducing the input costs in agriculture for protecting the human health, to reduce chemical loads in the earth and for conserving the natural resources (Senthivelu *et al*., 2007) [18].

Materialas and Methods

Experimental design

The experiment was laid out in Randomized Block Design, with 12(twelve) treatments and 3(three) replications.

Design	: RBD
Replication	: 3
Variety	: G-4 (Bhagyalakshmi)
Plot size	: 1.8m x1.5m
Spacing	: 45cm x 30cm
Number of treatments	: 12

Treatments

T_1 - Control
T_2 - FYM 20t ha $^{-1}$
T_3 - Pig manure 15 t ha^{-1}
T_4 - Vermicompost 10 t ha^{-1}
T_5 - 100% NPK (100:60:60 kg ha^{-1})
T_6 - 75% NPK + biofertilizers (*Azospirillum* and *phosphotika*)
T_7 - 50% NPK + 50% FYM
T_8 - 50% NPK + 50% pig manure
T_9 - 50% NPK + 50% vermicompost
T_{10} - 50% NPK + 50% FYM + biofertilizers (*Azospirillum* and *phosphotika*)
T_{11} - 50% NPK + 50% pig manure + biofertilizers (*Azospirillum* and *phosphotika*)
T_{12} - 50% NPK + 50% vermicompost + biofertilizers (*Azospirillum* and *phosphotika*)

Plant Materials

The variety G-4 (Bhagyalakshmi) has been developed at Regional Agricultural Research Station (RARS), Lam, Guntur; derived through selection in Thohian chilli from Sri Lanka. Plants bear narrow dark green leaves and are fairly tolerant to pests and diseases. Fruits are olive green, turn dark red on ripening. This variety is use in the experiment.

Nursery Raising

The experiment was started on 9th October, 2010. Nursery was raised under low cost polyhouse. Nursery bed was prepared by mixing FYM@ 5 Kg, SSP@ 30g and MOP@ 10g m^{-2} area. It was raised 15cm above the ground to avoid water logging condition. The seed were sown in line with 8-10cm distance in a bed of 1m x 1m; at depth of 1cm. Irrigation were given right after sowing. Seed took about 10 to 15 days to germinate. Intermittent irrigation at forth nightly interval was given till transplanting.

Agronomic Practices

Preparatory Tillage Operations

The experimental field was ploughed thoroughly by tractor drawn spike tooth cultivator followed by harrowing and leveling. Plant debris and stubbles were removed properly by manual labour.

Layout of the experiment

The plot was measured with measuring tape, than making three blocks for replication with block to block distance of 1.5m within the block, twelve individual plots each measuring (1.8 x 1.5 m²) were allotted for treatments.

Application of manures, fertilizer and biofertilizers

Quantities of different manures, fertilizer and biofertilizers were worked out first for each plant according to different treatment requirements. NPK is given through Urea, SSP and MOP respectively. Full dose of manures, P and K and half dose of N were applied at the time of final land preparation. Remaining half dose of N was given in two equal doses *ie*. 30 and 60 days after transplanting. Biofertilizers (*Azospirillum* and *Phosphotika)* were inoculated to seedlings before transplanting as seedling dip methods @ 2 kg ha^{-1} (400 g biofertilizers in 300 ml water).

Transplanting

Forty five to fifty days old healthy seedlings with uniform vigour and height were transplanted into the prepared main field. Irrigation was stopped a day before transplanting. Before pulling out the seedlings, light irrigation was given to loosen the soil. Transplanting was done in the afternoon. Immediately after transplanting light irrigation was given.

After care and interculture

After transplanting irrigation was given as and when required with the help of a rose can. The field was kept weeds free for initial 50 days to 60 days after transplanting. Weeding and intercultural operations were done manually with the help of kurpi and spade. Proper drainage was provided to drain out excess water to avoid water stagnation at all cost. Irrigation

was given at frequent intervals to each individual plant to ensure adequate soil moisture for the crop till harvest.

Harvesting
the maturity the crop was judged with individual fruits from light to dark green. Chilli is a climacteric fruit, thus harvesting at this stage is necessary if the fruits are to be use in green stage otherwise later it will turned to complete red colour. Individual fruits were hand-picked carefully with clean hand at different time intervals, as individual fruits of the same plant and also fruits in different plants matured at different times.

Sampling and observation recorded
Five plants in each plot were duly tagged for recording the observations.

Growth Parameters
Observations under growth parameters were recorded first at 45 days after transplanting thereafter at 20 days intervals till harvest.

Plant Height
Plant height of the sample plants was recorded in cm with measuring tape from the base of the stem to the apex of the longest leaf and average height was recorded.

Number of branches plant^{-1}
The number of both primary and secondary branches of individual sample plants was also counted. The average number of branches at different stages was than recorded and mean was worked out.

Number of leaves plant^{-1}
The number of functional leaves produced per plant was recorded from each sample plants. The average number of leaves at different stages was recorded and mean was worked out.

Results
Growth characteristics
The effect of integrated nutrient management on plant growth parameters were recorded at various growth stages viz., 45, 65, 85, 105, 125 and 145 DAT which are given in detail under the following heads-

Plant Height (cm)
There is significant difference in the plant height (cm) among various treatments. The maximum plant height of 35.81, 49.33, 66.76, 78.47, 89.17 and 105.58 cm were obtained from T_{10} (50% NPK + 50% FYM + Biofertilizers) at all stages of observation followed by T_{12} (50% NPK + 50% Vermicompost + Biofertilizers) and T_{11} (50% NPK + 50% Pig manure + Biofertilizer). T_2 (FYM 20 t ha^{-1}), T_5 (100% NPK), T_6 (75% NPK + Biofertilizers), T_9 (50% NPK + 50% Vermicompost) at 145 DAT were par to each other. Several other treatments were also found superior to control (T_1) with regard to height of plant. T_1 (Control) recorded minimum plant height of 22.60, 30.25, 38.59, 48.72, 57.24 and 66.51 cm at all stages of observation.

Number of branches per plant
That there was appreciable impact of chemical fertilizers, organic manures and biofertilizers on the number of branches of chilli. The number of branches per plant was recorded highest in the treatment T_{10} (50% NPK + 50% FYM + Biofertilizers) showing 12.80, 29.89, 51.63, 70.11, 89.24 and 104.36 respectively at all stages of observation followed by T_{12} (50% NPK + 50% Vermicompost + Biofertilizers) and T_{11} (50% NPK + 50% Pig manure + Biofertilizers). T_6 (75% NPK + Biofertilizers) and T_9 (50% NPK + 50% Vermicompost) at 145 DAT were also at par. T_1 (Control) had the minimum number of branches at all stages of observation showing 6.54, 19.04, 28.05, 37.29, 53.48 and 66.46 branches respectively.

Number of leaves per plant
That there is significant difference in the number of leaves among various treatments. The number of leaves were highest in T_{10} (50% NPK + 50% FYM + Biofertilizers) showing 55.60, 101.25, 183.10, 291.67, 385.35 and 516.47 respectively at all stages of observation followed by T_{12} (50% NPK + 50% Vermicompost + Biofertilizers) and T_{11} (50% NPK + 50% Pig manure + Biofertilizers). At 125 DAT, T_{10} (50% NPK + 50% FYM + Biofertilizers) and T_{12} (50% NPK + 50% Vermicompost + Biofertilizers) were found to be par but not at 45 DAT, 65DAT, 85 DAT, 105 DAT and 145 DAT. At 45 DAT, T_4 (Vermicompost 10 t ha^{-1}), T_6 (75% NPK + Biofertilizers), T_9 (50% NPK + 50% Vermicompost) and T_{11} (50% NPK + 50% Pig manure + Biofertilizers) were also found to be at par. At 65 DAT, the number of leaves plant^{-1} were found to be non-significant. While the minimum number of leaves 32.18, 67.73, 94.62, 117.29, 174.27 and 208.59 was recorded from the treatment T_1 (Control) at different stages of observation.

Leaf Area (cm^2)
The data on leaf area (cm^2) of individual plants has been depicted. T_{10} (50% NPK + 50% FYM + Biofertilizers) was recorded to be significantly better leaf area 21.12 cm^2, 44.59 cm^2, 47.05 cm^2, 50.60 cm^2, 52.62cm^2 and 55.65 cm^2 over other treatments. The leaf area in T_7 (50% NPK + 50% FYM) and T_8 (50% NPK + 50% Pig manure) at 145 DAT were also found to be at par with each other. The treatments with integration have been found significantly bigger in leaf area over other treatments. T_1 (Control) had the minimum or smallest leaf area at all stages of observation.

Discussions
It is evident from the present investigation that different types of manures viz., FYM, Pig manure, Vermicompost and various doses of NPK fertilization and their combinations with biofertilizers viz., *Azospirillum* and *Phosphotika* have differential positive effect on the growth attributes such as plant height, number of branches, number of leaves and leaf area of chilli. In general, most of the treatment was found effective in increasing the plant growth at all stages significantly as compared to control.
Plant height was recorded maximum with application of 50% NPK + 50% FYM + Biofertilizers (T_{10})at all stages of observation and was found significantly superior to treatments with integration with biofertilizers as well as those treatment without any integration. Cerna (1981) [5] reported that application of nitrogen (urea) and potassium (40% potassium salt) in absence of FYM retards the formation of vegetative organs and subsequently reproductive organs in capsicum. Similarly, Qiang *et al.* (2001) [16] also reported that mixed organic fertilizer greatly promoted the growth and development of sweet pepper. On the other hand, Sajan *et al.* (2002) [17] also reported that in chilli cv. Byadagi Dabba, plants inoculated with *Azotobacter*, *Azospirillum*, PSB and

VAM in combination with 75% NP + 100% K recorded maximum plant height (100.3 cm). Similarly, results were also obtained by Chumyani *et al.* (2012) [6] and Vimera *et al*. (2012), they reported that 50% NPK + 50% FYM + Biofertilizers recorded maximum plant height in tomato and king chilli.

Number of branches was recorded maximum with application of 50% NPK + 50% FYM + Biofertilizers (T_{10}) at all stages of observation. The increase branches may be as a result of the combined application due to higher absorption of nutrients especially nitrogen which enhanced the cell division and cell elongation and also increase in metabolic activity. Hangarge *et al*. (2001) [10] who also reported improved plant growth and development activities under integrated nutrient supply system in sweet pepper and chilli (*Capsicum annum* L.) cv. Parbhani Tejas respectively. Hossain *et al*. (2001) [11] also reported that plant height, number of branches per plant, flowering varies significantly with different fertilizer rates in chilli cv. Pusa Jwala. Similarly, Anburani and Manivannam (2005) also reported that the number of primary branches in brinjal was registered highest by combined application of FYM + press mud along with 75% of the recommended of N and P and biofertilizers.

The number of leaves like other growth characters was recorded maximum with the application of 50% NPK + 50% FYM + Biofertilizers (T_{10}) at all stages of observation except at 125 DAT which was found to be par with T_{12} (50% NPK + 50% Vermicompost) + Biofertilizers). The application of 50% NPK + 50% (FYM 'or' Pig manure 'or' Vermicompost) + Biofertilizers in T_{10} (50% NPK + 50% FYM + Biofertilizers), T_{11} (50% NPK + 50% Pig manure + Biofertilizers) and T_{12} (50% NPK + 50% Vermicompost) + Biofertilizers) were found to be significantly superior to other treatments particularly over those treatments without any integration. This result confirmed Ghoname and Shaffek (2005) [8] who reported that in sweet pepper (*Capsicum annum* L.) application of organic manure combined with biofertilizers and mineral N resulted in vigorous plant expressed as plant height, number of leaves and stem as well as shoot dry weight. Similarly, Alabi (2006) reported that in *Capsicum annum* L. levels of phosphorus (P_2O_5) up to 125 kg ha^{-1} significantly increased number of leaves per plant. He also reported that further application of organic waste and poultry droppings significantly increased the growth of pepper more than that of fertilizer phosphorus.

Leaves are the major site of photosynthesis and play an important role in plants for its growth, development, yield and quality. Therefore, the number of leaves and leaf area are important parameters to be considered. The integrated treatments were found superior over all other treatments at all stages of observation. Leaf area like other growth parameters was recorded maximum with the application of 50% NPK + 50% FYM + Biofertilizers (T_{10}) at all stages of observation except at 45 DAT which was found to be par with T_6 (75% NPK + Biofertilizers), T_{11} (50% NPK + 50% Pig manure + Biofertilizers) and T_{12} (50% NPK + 50% Vermicompost) + Biofertilizers) respectively. This may be due to slow leaf area expansion at initial growth stages when different soil nutrients are yet to be used up by the plant. Momirovic *et al*. (2000) [14] reported that lumbri – humus + soil (40:60) gives highest total leaf area (83.4 cm^2) in *Capsicum annum* cv. Macvanka. Hangare *et al*. (2004) [9] reported that in chilli – spinach cropping system, recommended rates of NPK and organic sources of nutrients each alone does not have any significant effect on plant growth and other biometrics. On the other hand, Aracon *et al*. (2005) [4] observed increased leaf area, plant shoot biomass with application of vermicompost produced from food waste, paper wastes and cattle manure @ 5, 10 and 20 t ha^{-1} in *Capsicum annum* var. King Arthur. Similarly, results were also obtained by Chumyani *et al.* (2012) [6] and Vimera *et al*. (2012), they reported that 50% NPK + 50% FYM + Biofertilizers recorded maximum leaf area in tomato and king chilli. Thus, the findings of these workers were in aligned with this conclusion.

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