International Journal of Fauna and Biological Studies
Available online at www.faunajournal.com

IJFBS International Journal of Fauna And Biological Studies

ISSN 2347-2677
IJFBS 2016; 3(2): 126-130
Received: 07-01-2016
Accepted: 09-02-2016

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Studies on integrated nutrient management on yield and quality of chilli (*Capsicum annum* L.)

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Abstract
A field experiment was carried out at the experimental farm of Experimental Farm, Division of Vegetable Science, SKUAST-K during Kharif 2013 and 2014 using Randomized Block Design to evaluate the integrated effect of chemical fertilizers, organic manures and biofertilizers on yield and quality of chilli. Results of the eighteen treatment combination revealed that integrated application of chemical fertilizers, organic manures and biofertilizers significantly increased the yield and quality characters of chilli. The efficacies of Vermicompost, poultry manure, farmyard manure, biofertilizer (Azospirillum and PSB), NPK improved the yield and quality of fruit. Increased fruit yield per plant (512.28 g), red ripe fruit yield per hectare (173.42 q),dry matter content (24.52%), ascorbic acid (106.96 mg/100g), total phenols (7.66 ml/100g),capsanthin (139.75ASTA units) and capsacin (0.34%) were recorded with T17(RFD 75% +Farmyard manure + Sheep manure + Poultry manure + Vermicompost + Biofertilizers).

Keywords: Chilli, Integrated nutrient management, quality, yield

Introduction
Chilli is one of the commercial high value crops in our country. India is the largest producer, consumer and exporter of chilli, which contributes to 25% of total world's production. In India the most important chilli growing states are Karnataka, Tamil Nadu, Odisha, Maharashtra, Rajasthan and West Bengal. Chilli, being a long duration crop, requires proper manuring and fertilizing in the surface soil is because of its shallow root system, for attaining high yields and quality produce (Bidari, 2000) [3]. Chillies are excellent source of vitamin A, C and E with minerals like molybdenum, magnesium, potassium and copper. It is an essential ingredient of Indian curry, which is characterized by tempting colour and exciting pungency. It is predominantly popular for its green pungent fruits, which is used for culinary purpose. It is commercially important for the two qualities, the red colour due to the pigment capsanthin and the biting taste due to the chemical constituent capsaicin. Adequate and balanced fertilizer management in association with manures is very much essential to exploit the full yield potential of Chilli. After the green revolution, increase in production was achieved at the cost of soil health. It has been proved that indiscriminate use of inorganic fertilizers results in decrease in soil fertility and increase in soil acidity with depletion of organic humus content in addition to poor crop quality. Use of organic manures to meet the nutrient requirements of crop would be an inevitable practice in the years to come for sustainable agriculture since organic manures not only improve the physical, chemical and biological properties of soil. Eco friendly, scientific method of crop production envisages use of organics in the soil as a source of nutrients. Inorganic nutrients play an important, direct role in yield and its attributes, as well as uptake of nutrients. However, use of organics along with inorganic nutrients not only helps increase the yield of crops, but also acts as a storehouse of nutrients, besides improving physical condition of the soil and quality of the produce. The escalating cost of fertilizers, their hazardous polluting effects on environment and quality of the produce, there is a growing awareness among the farming community of the advantages of organic fertilizers. Therefore the present investigation was undertaken to study the effect of organic, inorganic and biofertilizers for yield and quality improvement in chillies.

Materials and Methods
Experimental design
The experiment was laid out in Randomized Block Design, with eighteen treatments and

3(three) replications.
Plot size: 3m x3m
Spacing: 30cm x 45cm
Number of treatments: 18

Treatments
T1 Control No Organic/Chemical fertilizers
T2 Farmyard manure
T3 Sheep manure
T4 Poultry manure
T5 Vermicompost
T6 Recommended fertilizer dose 50% + Farmyard manure
T7 Recommended fertilizer dose 50% + Sheep manure
T8 Recommended fertilizer dose 50% + Poultry manure
T9 Recommended fertilizer dose 50% + Vermicompost
T10 Recommended fertilizer dose 50% + Biofertilizers
T11 Recommended fertilizer dose 50% + Farmyard manure + Sheep manure + Poultry manure + Vermicompost + Biofertilizers
T12 Recommended fertilizer dose 75% + Farmyard manure
T13 Recommended fertilizer dose 75% + Sheep manure
T14 Recommended fertilizer dose 75% + Poultry manure
T15 Recommended fertilizer dose 75% + Vermicompost
T16 Recommended fertilizer dose75 % + Biofertilizers
T17 Recommended fertilizer dose 75% + Farmyard manure + Sheep manure + Poultry manure + Vermicompost + Biofertilizers
T18 Recommended fertilizer dose

Experimental material
The organic manures viz. farmyard manure (FYM), sheep manure (SM), poultry manure (PM), vermicompost (VC), biofertilizers (*Azospirillum*, *Phosphobacteria*) and chemical fertilizers (urea, diammonium phosphate, murate of potash) were used as source of plant nutrients. Organic manures and Chemical fertilizers were provided by the Division of Vegetable Science, SKUAST-Kashmir, Shalimar while as biofertilizers were obtained from Division of FAO, Wadura. The seeds of chilli Kashmir Long-1 were provided and maintained by Division of Vegetable Science, SKUAST-Kashmir, Shalimar.

Nursery raising
The soil of nursery beds was brought to fine tilth and raised seed beds were prepared. Chilli seeds were sown in rows 5 cm apart and covered with a thin layer of soil. The beds were covered with dry grass till germination was completed. Light irrigation was provided every morning and evening with rose can.

Land preparation
The experimental field was tractorized and the soil was brought to a fine tilth. The hard compact soil clods were broken to bring the soil to pulverized mass and land was leveled well. The field was then divided into 54 plots of size 3 x 3 m separating each plot from the adjacent plots by 30 cm wide small earthen bunds. The field was also provided with one main channel and two sub irrigation channels to facilitate plot to plot irrigation. The plots were leveled before planting.

Fertilizer application
Organic manures were applied as basal dose and were thoroughly incorporated in the soil as per treatments where as in integration of chemical fertilizers where either 50 or 75 percent chemical fertilizers was to be applied, half dose of nitrogen and full dose of phosphorus through urea and diammonium phosphate respectively was applied as basal dose. The remaining half of nitrogen of nitrogen in both the cases was top dressed after 30 days of transplanting. However, in treatments where conjugation of biofertilizers with chemical fertilizers were practiced they were thoroughly mixed with 30 kg fine soil and applied in soil 48 hours before application of chemical fertilizers.

Transplanting and irrigation
The nursery beds were irrigated before uprooting of seedlings. Vigorous and healthy seedlings of uniform size were transplanted in well prepared and fertilized plots at spacing of 30 cm x 45 cm during evening hours to prevent excessive transpiration. Immediately after transplanting the seedlings were watered with a rose can individually. After establishment of crop light irrigation was given as and when required throughout the growing season. In order to maintain requisite plant population, gap filling was done upto 7 days after transplanting.

Intercultural operations
Intercultural operations like weeding, hoeing was done as per the requirements.

Harvesting
During both the years of experimentation, the fruits were harvested at red ripe stage in three pickings.

Observations recorded
Observations were recorded on various yield and quality attributes of chilli plants. Ten competitive plants were selected at random from each replication and tagged for recording observations. Mean values for all the characters were worked out. Observations were recorded at the appropriate developmental stages of plant growth as per the description given below.
The observations were recorded on the following parameters:

Yield parameters
Red ripe fruit yield per plant (g)
Fresh weight of red ripe chilli fruits from ten randomly selected plants at each picking from each treatment were added to work out the total weight of fruits and average was worked out to get red ripe fruit yield per plant for all the treatment combinations in all replications.

Red ripe fruit yield per hectare (q)
The yield per plot for each treatment was converted into quintals per hectare by multiplication factor for each treatment for all the treatment combinations in all replications.

Quality parameters
Dry matter content (%)
Dry matter content was determined by sun drying of 100 grams of red ripe chilli fruits followed by oven drying at 60±5oC till the material recorded a constant weight. The dried material was weighed and expressed as dry matter in per cent for all the treatment combinations in all replications.

Ascorbic acid (mg/100g)

The ascorbic acid content of red ripe fruits from each treatment was determined by 2, 6 dichlorophenol indophenols visual titration method suggested by AOAC (1975) [1] and expressed in milligram per 100 g of fresh weight for all the treatment combinations in all replications.

Total phenols (ml/100g)

Total phenols in red ripe fruits were determined by spectophotometric measurement of blue coloured complex formed by reaction of phenols with phosphomolybedic acid in Folin ciocalteu reagent in alkaline medium (Bray and Thorpe, 1954) [2].

Capsanthin (ASTA) units

Extractable colour value in red ripe chilli fruits was determined by method suggested by A.O.A.C., 1984 [2].

Capsaicin (%)

Capsaicin content of red ripe chilli fruits was determined by using colorometric method (Thimmaiah, 2006) [11].

Statistical analysis

The data collected on different characters were analyzed statistically using procedure given by Gomez and Gomez (1984) [5]. The results are presented at 5 per cent level of significance. Wherever the 'F' test was found significant at 5 per cent probability, critical difference value was used to compare the treatment mea.

Results and Discussion

Yield

The findings of the experiment indicated beneficial effect of integrating NPK fertilization with various organic manures as well as biofertilizers on yield.

Fruit yield per plant (g)

Integration of organic manure with inorganic sources registered an increase in fruit yield per plant over sole application of organic sources as well as control.

Among sole applications of organic sources, highest fruit yield per plant was recorded in treatment T4 (Poultry manure) *i.e.,* 418.24, 417.23 and 417.76 g during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. These were followed by treatment T3 (Sheep manure) which recorded fruit yield per plant of 413.32, 415.56 and 414.46 g during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Lowest fruit yield per plant was recorded in treatment T2 (Farmyard manure) *i.e.,* 409.82, 408.96 and 409.40 g during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Superiority of poultry manure over farmyard manure, sheep manure, vermicompost and biofertilizers in increasing yield and yield attributes of chilli over rest of organic sources (sheep manure, farmyard manure, vermicompost) can be attributed to its nutritional richness, quick mineralization, efficient microbial activity leading to sustainable nutrient availability and improvement in soil physical conditions. All these might have led to better root proliferation, better translocation of plant nutrients and accelerated carbohydrate synthesis finally leading to better yields. These results obtained in present study are in line with those of Harikrishna *et al*. 2002 [6].

Among integration of organic sources with inorganic sources, maximum fruit yield per plant of 512.13, 513.71 and 512.28 g was recorded with treatment T17 (RFD 75% + Farmyard manure + Sheep manure + Poultry manure + Vermicompost +Biofertilizers) during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. These were followed by treatment T14 (RFD 75% + Poultry manure) which recorded fruit yield per plant of 490.41, 480.78 and 485.32 g during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Lowest fruit yield per plant was recorded in treatment T1 (control) *i.e.,* 386.36, 385.39 and 385.88 g during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively.

Fruit yield per hectare (q)

Integration of organic sources with inorganic sources of plant nutrients proved to be superior over sole applications.

Among sole applications of organic sources, highest fruit yield per hectare was recorded in treatment T4 (Poultry manure) *i.e.,* 148.12, 148.43 and 148.25 q during *Kharief* 2013 and *Kharief* 2014 and in pooled analysis respectively. These were followed by treatment T3(Sheep manure) which recorded fruit yield per hectare of 147.33,147.64 and 147.47 q during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Lowest fruit yield per hectare was recorded in treatment T2 (Farmyard manure) *i.e.,* 146.22, 146.66 and 146.42 q during *Kharief 2013*, *Kharief* 2014 and in pooled analysis respectively.

Among integration of organic sources with inorganic sources, under study, maximum fruit yield per hectare of 173.96, 172.89 and 173.43 q was recorded with treatment T17 (RFD 75% + Farmyard manure + Sheep manure + Poultry manure + Vermicompost + Biofertilizers) during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. These were followed by treatment T14 (RFD 75% + Poultry manure) which recorded fruit yield per hectare of 163.33, 162.33 and 162.82 q during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Lowest fruit yield per hectare was recorded in treatment T1 (control) *i.e.,* 141.36, 143.22 and 142.25 q during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Increase in yield can be due to quick release of nutrients in sufficient amount. These results obtained in present study are in line with those of Malik *et al*. 2009 [9].

Quality attributes

The findings of the experiment indicated beneficial effect of integrating NPK fertilization with various organic manures as well as biofertilizers on quality attributing characters of chilli.

Dry matter (%)

Integration of organic manures with inorganic sources of plant nutrients proved to be superior over sole applications.

Among individual applications of organic sources, highest dry matter was registered in treatment T4 (Poultry manure) *i.e.,* 22.69%, 22.66% and 22.67% during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. These were followed by treatment T3 (Sheep manure) which registered dry matter of 22.66%, 22.63% and 22.64% during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Lowest dry matter was registered in treatment T2 (Farmyard manure) *i.e.,* 22.64%, 22.61% and 22.60% during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively.

Among integration of organic manures with inorganic sources, maximum dry matter of 24.57%, 24.43% and 24.52% was registered with treatment T17 (RFD75% + Farmyard manure + Sheep manure + Poultry manure + Vermicompost

+Biofertilizers) during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. These were followed by treatment T14 (RFD 75% + Poultry manure) which registered as dry matter content of 24.12%, 23.92% and 24.12% during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Lowest dry matter was registered in treatment T1 (control) *i.e.,* 22.60%, 22.56% and 22.57% during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. The significant increase in the dry matter content was attributed to increase in nutrient availability especially nitrogen, phosphorus and potassium. Nitrogen being an essential constituent of chlorophyll increased chlorophyll formation and ultimately effect photosynthesis, thus resulted for greater dry matter accumulation and improvement in dry matter production. These findings are in conformity with those of Manchanda and Singh 1987 [10].

Ascorbic acid (mg/100g)

Integration of organic sources with inorganic sources registered an increase in ascorbic acid content over sole application of organic sources as well as control.

Among sole applications of organic sources, highest ascorbic acid content was recorded in treatment T4 (Poultry manure) *i.e.,* 102.22, 102.12 and 102.11 mg/100g during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. These were followed by treatment T3 (Sheep manure) which recorded ascorbic acid content of 101.96,101.98 and 101.96 mg/100g during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Lowest ascorbic acid content was recorded in treatment T2 (Farmyard manure) *i.e.,* 101.72, 101.75 and 101.74 mg/100g during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively.

Among all treatments under study, maximum ascorbic acid content of 107.03, 106.88 and 106.96 mg/100g was recorded with treatment T17 (RFD 75% + Farmyard manure + Sheep manure + Poultry manure +Vermicompost + Biofertilizers) during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. These were followed by treatment T14 (RFD 75% + Poultry manure) which recorded ascorbic acid content of 105.49, 105.69 and 105.58 mg/100g during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Lowest ascorbic acid content was recorded in treatment T1 (control) *i.e.,* 101.60, 101.62 and 101.63 mg/100g during *Kharief* 2013, *Kharief 2014* and in pooled analysis respectively. The increase in ascorbic acid content may be due to higher assimilation of micronutrients which are made available to plants due to decomposing of organic matter. The increased activity of ascorbic acid oxidase enzyme in presence of micronutrients increases the ascorbic acid content of fruits. These findings are in conformity with those of Malewar, *et al.,* 1998 [8].

Total phenol (ml/100g)

Integration of organic sources with inorganic sources of plant nutrients proved to be superior over sole applications. Among individual applications of organic sources, highest total phenol content was registered in treatment T4 (Poultry manure) *i.e.,* 7.57, 7.56 and 7.57 ml/100g during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. These were followed by treatment T3 (Sheep manure) which registered total phenol content of 7.56, 7.54 and 7.56 ml/100g during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively which was statistically at par with T5 (Vermicompost).Lowest total phenol content was registered in treatment T2(Farmyard manure) *i.e.,*7.54, 7.53 and 7.55 ml/100g during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Among integrated use of organic sources with inorganic sources, maximum total phenol content of 7.66, 7.67 and 7.66 ml/100g was registered with treatment T17(RFD 75% + Farmyard manure + Sheep manure + Poultry manure + Vermicompost +Biofertilizers) during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. These were followed by treatment T14 (RFD 75% + Poultry manure) which registered total phenol content of 7.65, 7.66 and 7.65 ml/100g during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Lowest total phenol content was registered in treatment T1 (control) *i.e.,* 7.52, 7.51 and 7.53 ml/100g during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. A possible explantation for increase in total phenol due to organic manure may be due to accumulation of substances and availability of nutrients for longer period and reduced loss of nutrients through leaching. The increased microbial activity improves the availability of soil nitrogen and also due to better development of fruits, increased uptake of nitrogen in plants takes place leading to increase in phenol content.

Capsanthin (ASTA units)

Integration of organic sources with inorganic sources registered an increase in capsanthin content over sole application of organic as well as control. Among sole applications of organic sources, highest capsanthin content was recorded in treatment T4 (poultry manure) *i.e.,* 132.62, 132.86 and 132.75 ASTA units during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. These were followed by treatment T3(Sheep manure) which recorded capsanthin content of 132.59, 132.80 and 132.68 ASTA units during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Lowest capsanthin content was recorded in treatment T2 (Farmyard manure) *i.e.,* 132.24, 132.62 and 132.42 ASTA units during *Kharief* 2013, *Kharief* 2014 and pooled analysis respectively.

Among conjugation of organic sources with inorganic sources, maximum capsanthin content of 139.72, 139.82 and 139.75 ASTA units was recorded with treatment T17 (RFD 75% + Farmyard manure + Sheep manure + Poultry manure + Vermicompost + Biofertilizers) during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. These were followed by treatment T14(Treatment RFD 75% + Poultry manure) which recorded capsanthin content of 137.67, 137.12 and 137.39 ASTA units during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Lowest capsanthin content was recorded in treatment T1 (control) *i.e.,* 130.24, 131.62 and 130.92 ASTA units during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. The increase in capsanthin content may be due to steady availability of nutrients by the combined application of organic and inorganic sources and hence, higher uptake of nutrients. These findings are in conformity with those of Jose *et al.,* 1988.

Capsaicin (%)

Among sole applications of organic sources, highest capsaicin content was registered in treatment T4 (Poultry manure) *i.e.,* 0.34, 0.33 and 0.34% during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. These were followed by treatment T3 (Sheep manure) which registered capsaicin content of 0.33, 0.32 and 0.34% *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively which was statistically at par with treatment T5(Vermicompost). Lowest capsaicin content was registered in treatment T2 (Farmyard manure) *i.e.*, 0.31, 0.32 and 0.31% during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Integration of organic sources with inorganic sources of plant nutrients proved to be superior over sole applications. Maximum capsaicin content of 0.39, 0.40 and 0.40% was registered with treatment T17 (RFD 75% + Farmyard manure + Sheep manure + Poultry manure + Vermicompost + Biofertilizers) during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. These were followed by treatment T14 (Treatment RFD 75% + Poultry manure) which registered capsaicin content of 0.37, 0.38 and 0.37% during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Lowest capsaicin content was registered in treatment T1 (control) *i.e.*, 0.30, 0.31 and 0.30% units during *Kharief* 2013, *Kharief* 2014 and in pooled analysis respectively. Increase in capsaicin content may be due to higher nutrient availability and increased nitrogen from organic manures along with inorganic fertilizer which had profound influence in mobilizing the nutrients from the unavailable form of nutrients mainly due to improved physical, chemical and biological properties of the soil. The increased availability of nitrogen to the crop leads to increase in capsaicin content. These findings are in conformity with those of Manchanda and Singh 1987 [10].

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