PHYSIOLOGICAL STUDIES ON GROWTH, YIELD AND QUALITY ENHANCEMENT OF CHILLI (*Capsicum annum* L.) UNDER DIFFERENT NUTRIENT MANAGEMENT

By

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(2017-11-147)

THESIS

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DECLARATION

I hereby declare that the thesis entitled "Physiological studies on growth, yield and quality enhancement of chilli (*Capsicum annum* L.) under different nutrient management" is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Physiological studies on growth, yield and quality enhancement of chilli (*Capsicum annum* L.) under different nutrient management " is a bonafide record of research work done independently by **Amrutha E. A (2017-11-147)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associate ship or fellowship to her.

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We, the undersigned members of the advisory committee of Ms. **Amrutha E. A (2017-11-147)**, a candidate for the degree of **Master of Science in Agriculture**, with major field in **Plant Physiology**, agree that the thesis entitled "Physiological studies on growth, yield and quality enhancement of chilli (*Capsicum annum* L.) under different nutrient management" may be submitted by **Ms. Amrutha E. A (2017-11-147)**, in partial fulfillment of the requirement for the degree.

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ABBREVIATIONS

g	Gram
%	Per cent
Kg/ ha	Kilogram per hectare
SPAD	The Soil Plant Analyses Development
SCMR	SPAD chlorophyll meter reading
CEC	Cation exchange capacity
Ha	Hactare
DAS	Day after sowing
MOP	Murate of potash
TSS	Total soluble solids
DAT	Day after transplanting
FYM	Farm yard manure
LAI	Leaf area index
EDTA	Ethylenediaminetetracetic acid
PoP	Package of practices
RGR	Releative growth rate
SLW	Specific leaf weight
LAI	Leaf area index
LAD	Leaf area duration
Y(II)	Quantum yield
ETR	Electron transport rate

INTRODUCTION

1. INTRODUCTION

Chilli (*Capsicum annum* L.) is a spice crop, which is very important because of its pungency, used as green or at ripe stage. Chilli belongs to the family Solanaceae and genus *Capsicum*. Origin of chilli is southern parts of Mexico and Bolivia. Among the 400 chilli varieties seen all over the world, five important chilli species used for cultivation are *C. annum*, *C. baccatus*, *C. chinense*, *C. frutescens*, and *C. pubencens*. Considering the usage, *C. annum* is the most important species that is widely cultivated.

Chilli requires long and warm season for its proper growth and yield. So the commercial cultivation is mostly concentrated in the tropical region of the world. Chilli is grown in an area of 9.5 lakh hectares with production of 10.6 lakh tons (Mehraj *et al*., 2014). India is the largest producer of chilli followed by China and Pakistan. India is also the largest consumer of chilli. India contributes 30 per cent of chilli production with the highest production from Maharashtra which contributes 15 % followed by Karnataka (11 %), Orissa (11 %), Madhya Pradesh (7 %) and other states contribute 22 % (Bhuvaneswari *et al*., 2013).

In Indian diet, chilli has an important place, as a condiment in one or other form. Chilli is used as a spice and also in beverages and medicines. Depending on the location and type, chilli is known by different names such as chilli pepper, red or green chilli, sweet pepper and capsicum. The word chilli was originated from the Mexican word 'Nahuatl'. The pericarp and placenta of chilli contain an alkaloid 'capsaicin' which is responsible for the pungency. Capsaicin is used for the treatment for sensory nerve fibre disorder, diabetic neuropathy etc., green chilli contains vitamin C at the rate of 111 mg per 100 g. 100 g of chilli contains 24 kcal of energy, 1.3 g of protein, 4.3 g of carbohydrate and 0.3 g of fat. Vitamin C functions as immune system, stimulants and it repair the cellular damages also. Chilli has antibacterial action. According to folk medicine, chilli is used for the treatment against worms. It help to reduce high blood pressure and also lower the occurrence of heart attack and stroke. Fertilizers are an essential part of nutrients which contributes potential yield and quality of the crop. After the green revolution, we achieved self sufficiency in food production but in mean time we exploited the soil health.

Deficiency of nutrients adversely affects the physiological and biochemical functioning of the plant which leads to a reduction in growth and quality of the crop. Different combination of fertilizer leads to higher productivity without impairing the environment sustainability (Deepa, 2016). Therefore targeted and sufficient application of fertilizer is important for growing crops.

Conventional fertilizer generally applied as soil broadcasting or as spray, but the disadvantage is that only very less concentration reaches to plant due to loss of different nutrients by various processes, such as leaching, drift, runoff, evaporation and microbial degradation. Now a days we use a large amount of fertilizer in order to feed large population, which is very harmful to our environment (Verma *et al.*, 2017). Hence to meet the crop nutrient requirement, the optimal use of fertilizer is essential. Considering these points, the use of special chemicals that systemically releases chemicals at the targeted site in plants is very essential to increase the nutrient use efficiency of the plant. Also, nano structured fertilizer have a property of long duration of nutrient supply (Rai and Pandey, 2016). Nanoparticle also have the desired property of high solubility, effectiveness and less eco-toxicity.

Nano fertilizer is new emergent fertilizer which increases yield and growth by improving the nutrient use efficiency of the crop. It also reduces the wastage of nutrient from the soil through leaching (Liu *et* *al*., 2014). Nano fertilizer have a very small size that is less than 100 nm, which increases it penetration into plant, lead to increase the metabolic activity, yield and quality of the crop. Foliar fertilizer application increases the translocation efficiency which is more efficient than the soil application. 19:19:19 NPK is water soluble which leads to rapid crop growth and quickly eliminate the nutrient deficiency.

All these nutrient managements make the crop grow quickly and healthy which lead to reduce the pest and disease incidents. It also help to reduce the usage of insecticides and pesticides helps in uniform flowering which ultimately enhances the crop yield. Hence the objective of the study is to investigate the influence of soil and foliar application of nano NPK and compare with conventional fertilizer on enhancing growth, yield and quality attribute of chilli crop.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Agriculture sector presently use a high amount of fertilizer than optimum for getting a high crop yield from the unit crop area and leads to environmental problems and low nutrient use efficiency. Nanotechnology is a newly emerging tool for solving these problems without compromising the yield.

2.1. Nano fertilizer

Steward *et al.* (2005) suggested that nano fertilizer is a new emergent tool in agriculture which increase the crop growth, yield and quality characters of the crop. Due to its small size, the nano fertilizer has a large surface area which provides more space for metabolic activity which ultimately increases the photosynthesis, yield and dry matter production. The other benefit of nano fertilizer is that it increases the nutrient use efficiency and also reduces the nutrient wastage.

Cicek and Nadaroglu (2015) noted that nanofertilizer create a field of precision farming because effective use of nanofertilizer increases environmental safety and economic benefits. Nano fertilizer can be made by physical, chemical and biological method from conventional fertilizer or from a different plant parts.

2.1.1. Effect of nano fertilizer on morphological parameters

According to Tarafdar *et al.* (2014) the use of nanoparticle, improved shoot length, root length, leaf protein, chlorophyll content and dry matter. The grain yield at harvest was improved by 37 % because of the utilization of nano fertilizer in pearl millet. Roosta *et al.* (2015) demonstrated that leaf Fe content and plant development were altogether expanded by nano Fe-chelate application and the most sounding estimation of leaf Fe and vegetative development were recorded with plants treated with nano Fe chelate in lettuce.

Kale and Gawade (2016) observed that a mixing ratio of 25 % NPK with 75 % nano silica fertilizer increased morphological parameters like fresh weight, dry weight and height of rice.

Hasaneem *et al.* (2016) examined the impact of two distinct sorts of designed nanofertilizers, carbon nanotube converted NPK and nanoparticles NPK on french bean. It was speculated that nanoparticle had the capacity to enter the plant cell by endocytosis. Nano fertilizer either alone or in mixed combination, essentially improves plant development and biomass than control.

Yarmohammadzehi (2016) noted that the combination of nano bio and nano chemical fertilizer positively increase the flower number, plant height and flavonoid content in borage (*Borage officinalis* L.).

Rajonee *et al.* (2016) also demonstrated that a higher accumulation of N in plants developed with nano fertilizer. Post fertilizer impact of nano fertilizer application in soil demonstrated better pH, CEC and accessible nitrogen under nanofertilizer treatment than the conventional fertilizer.

Hagagg *et al.* (2018) noticed that the foliar application of the nanofertilizer NPK applied as foliar in olive seedling enhances vegetative growth parameters like plant height, dry weight, root length and root dry weight without causing nutrient deficiency. According to Ridoy (1706), nano chitosan @10 ppm showed best result with relatively more nutrient use efficiency, slow release of nutrient, reduced nutrient loss and increased growth of the crop olive.

2.1.2. Effect of nano fertilizer on Physiological parameter

Thirunavakkarasu (2014) reported in the groundnut. Increased chlorophyll a, chlorophyll b, total chlorophyll and soluble protein and increased yield attributes such as a number of pods, 100 kernel weight and shelling percentage with the application of nano S @ 30 kg/ha.

Hussien *et al.* (2015) conducted a study in spinach by using nano iron chelates. Results demonstrated that fresh weight and leaf area index were impacted by centralization of iron chelator nano fertilizer and dry weight was increased by nano fertilizer. Application nanofertilizer @ 4 kg/ha resulted in 58 and 47 % more in fresh weight and leaf area index respectively. Leaf area index and growth rate demonstrated that the positive effect of nanofertilizer on plant development.

Benzon *et al.* (2015) reported that the nanofertilizer enhanced the antioxidant activity of rice plant and total phenolic content which increased the chlorophyll content of the leaf. Grain yield and shoot biomass production indirectly related to the total phenolic content in rice. According to Solanki *et al.* (2015), nano fertilizer have a major role in "smart delivery system" which reduces nutrient loss, enhances photosynthesis activity, carbohydrate synthesis, protein synthesis and nitrogen metabolism, ultimately leading to increase in crop productivity.

Abdel Aziz *et al.* (2016) reported that nano NPK treated wheat plant had high relative water content, leaf area and fresh weight. They also reported that nano fertilizer treated wheat attained reproductive stage at 130 days while plants reproductive stage attained at 170 days in the control.

Baranzeli (2018) conducted a study in cowpea by using different recommended dose of nano NPK, from his study he concluded that by using 100 % recommended dose of nano NPK increased biochemical parameters like soluble carbohydrates, protein content, proline content and peroxidase activity. Wang and Nguyen (2018) reported that utilization of the nano fertilizer improved the uptake of zinc, nitrogen and phosphorous.

Sohair *et al.* (2018) conducted a study in cotton by using nano NPK and found that the nano NPK application at three times increased the physiological parameters like crop growth rate, relative growth rate, leaf area per plant and leaf area index compared to two-time application. Burhar and Hassan (2019) conducted a study in bread wheat, he noted that by using nano NPK fertilizer there was apposition increased in flag leaf area, total chlorophyll nitrogen, phosphorous and potassium content.

2.1.3. Effect of nano fertilizer on quality parameter

Thirunavakkarasu (2014) found that by using nanofertilizer nano S @ 30 kg S ha^{-1} increased the quality parameters like oil content, crude protein content, total free amino acid, methionine and cytosine content. Celsia and Mala (2014) reported that in *Vigna radiata*, amylase, protease, total carbohydrate and protein were enhanced due to nano NPK fertilizer application.

According to Benzon *et al.* (2015), nano fertilizer application increased the total phenolic content and also potential antioxidant content. These antioxidant helped to scavenge the free radical produced at the time of adverse condition in rice.

Davarpanah *et al.* (2017) reported that foliar N nano fertilizer application improved the quality parameters of pomegranate fruit aril juice and total soluble solids and also increased the fruit parameters like fruit yield and number of fruits per tree.

Abdel-Aziz *et al.* (2018) conducted a study in wheat by different types of NPK foliar spray. He noticed that nano NPK foliar spray increased the saccharide content, P and K content but protein and nitrogen content decreased. The level of increased in parameters noticed was more in clay soil than the sandy soil.

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According to Baranzeli (2018) 100 % recommended a dose of nano NPK enhanced grain yield, biomass yield, number of grains per plant and harvest index compared to 50 % recommended dose of fertilizer. The highest yield was obtained from 100 % recommended doses of nano NPK fertilizer application in cowpea. Sohair *et al.* (2018) found that three splits of foliar spray of nano NPK in cotton increased fibre strength and fibre length and also uniformity index

Burhar and Hassan (2019) noted that nano NPK fertilizer enhanced the quality parameters of bread wheat like protein percentage of 27.24 % and gluten content.

2.1.4. Effect of nano fertilizer on yield parameters

Sheykhaglou *et al.* (2010) conducted a study in soybean using nano-iron oxide particle, they noted that the nano-iron oxide particle had a great role in increased pod dry weight and the highest grain yield. Liu and Lal (2014) found that by using nano phosphorous particle biomass production increased by 41.2 % and seed yield by 20.4 %. They observed that using apatite nanoparticle enhanced the agronomic yield of the soyabean and reduced eutrophication.

Kale and Gawada (2016) observed that fertilizer with ZnO nanoparticle resulted more yield than a full dose of the recommended dose of fertilizer. From this, he concluded that by using nano fertilizer we can reduce the amount of full dose of the recommended dose of fertilizer in rice.

According to Mehta (2017), treatment with 100 % NPK with nano NPK spray at 20, 30 and 45 DAS increased the grain yield and carbohydrate content in wheat.

Qureshi *et al.* (2018) reported that nanofertilizer application increased the yield by increasing in growth of plant parts which led to increased in photosynthesis. So these photosynthates translocated to the economic part of the crop resulted in more yield.

Sohair *et al.* (2018) reported that nanofertilizer application in cotton increased the yield parameters like total and open boll per plant, boll weight and seed. It also increased the fibre strength and length.

2.2. 19:19:19 NPK foliar spray

2.2.1. Effect of 19:19:19 NPK foliar spray on morphological parameters

Gowda *et al.* (2008) observed that in grapes the treatment with 19:19:19 spray applied as three splits after pruning led to more growth *ie*, enhanced the production of more number of leaves, length of the cane, maximum productive canes, number of increased flower number and enhanced vase life compared to other treatments.

Kandil and Gal (2009) found that application of farmyard manure with 19:19:19 NPK spray increased the growth of the plant, yield, and quality parameters of broccoli and nutrient composition of fruit. But pure organic manure treatment gave the least yield in brocoli.

Abo-Rekab *et al.* (2010) conducted a study in date palm plantlets, 19:19:19 application @ of 2.5 g per litre had a significant role in morphological parameters like the height of the plant, leaf number per plantlet, root length and root number per plantlet.

Singh *et al.* (2013) noted that carnation (*Dianthus carphyllus*) cultivated with N and K fertigation 250 ppm as urea and MOP with 250 ppm and 19:19:19 foliar spray enhanced vegetative growth like plant height and stem length. It also increased flowering characters like the size of the flower and duration of flower.

Mamathashree *et al.* (2015) studied the effect of different water-soluble fertilizer on pigeon pea. From the study, he reported that 2 %

foliar application of 19:19:19 NPK spray had a positive effect on plant height, total dry matter production per plant, primary branches per plant compared to other treatments.

Kikani *et al.* (2018) noted that the foliar spray of 19:19:19 NPK in cotton at flowering, boll formation and boll development stage led to increased a number of sympodial branches per plant and number of the bolls per plant and seed yield compared to other treatments.

Battacharya and Ghosh (2018) found that chilli cultivated with Trichoderma enriched vermicompost, *Acetobacter* spp., neem cake and root tip treated with *Pseudomonas* and 19:19:19 NPK foliar spray at three times decreased the infestation of pests like thrips, mites and fruit borer.

2.2.2. Effect 19:19:19 NPK foliar spray on physiological parameter

Saleh *et al.* (2000) conducted study in Aureum plant (*Epipremnum pinnatum*) by using foliar spray of urea one gram per litre and 19:19:19 which showed an increased in the physiological parameters like chlorophyll a, chlorophyll b, total chlorophyll content, soluble sugar, insoluble sugar and total sugar content in leaf. The accumulation of N, P and K was the highest in treatment with 19:19:19 NPK foliar spray.

Shivamurthy *et al.* (2013) conducted a study on effect of yield in cotton with micro and macro fertilizer analyzing biochemical parameters. He concluded that soil application of $MgSO_4$ at 25 kg per ha with 1 % foliar spray of 19:19:19 at three times with a recommended dose of fertilizer had a positive effect on physiological parameters. An increased in chlorophyll a, chlorophyll b, total chlorophyll, proline content of the leaf was observed. Also, this treatment significantly influenced the yield of the crop.

Gowda *et al.* (2014) demonstrated that through the application of micronutrients and macronutrients, $ZnSO_4$ applied to soil at

25 kg per ha with 19:19:19 foliar spray at 0.4 % increased in leaf area per plant and chlorophyll content in pigeonpea.

Anju *et al.* (2017) observed the effect of 100 % NPK fertilizer with a foliar spray of 19:19:19 NPK on French bean (*Phaseolus vulgaris*). The results showed that a combination of 100 % NPK fertilizer in soil with 19:19:19 NPK spray had a positive effect on physiological parameters like leaf area index and leaf area per plant, morphological parameters like internodal length and number of functional leaves per plant

Vinodkumar and Salkinko (2017) reported the effect of different foliar nutrition in *Arachis hypogea* L. They noticed that 19:19:19 NPK foliar spray had direct correlation to the leaf area, leaf area index, chlorophyll content, net assimilation rate, total dry matter production, leaf area duration and crop growth rate.

2.2.3. Effect of 19:19:19 NPK foliar spray on the quality parameters

Gowda *et al.* (2008) observed that 0.1 percentage 19:19:19 NPK spray increased the juice content in grapes. Gowda *et al.* (2014) observed that the application of $ZnSO_4$ 0.4 % in soil with foliar application of 19:19:19 at the rate of 0.4 % resulted increased in the protein content by 22.47 % in pigeon pea compared to other treatments.

According to Somimol (2018), 19:19:19 spray at 60 % at 90 days after transplanting in chilli at one percentage concentration increased capsaicin content in chilli.

2.2.4. Effect of 19:19:19 on yield parameters

Chaurasia *et al.* (2005) conducted a study in tomato and concluded that good effect on fruit parameters like fruit number, the weight of average fruit, length of fruit, the diameter of fruit, total soluble sugar and net profit were high in treatment with 19:19:19 NPK spray.

Batra *et al.* (2006) studied different foliar fertilizers in brinjal and concluded that 19:19:19 foliar spray at concentration 5 g in one litre increased the fruit yield because of more assimilation of nutrients and also maintained NPK balance which led to increased the crop productivity.

Sharma and Ratnoo (2013) found that basal dose fertilizer application of N 75 kg and P 30 kg per ha with 1 % foliar spray of 19:19:19 NPK at flowering stage enhanced the seed yield in cluster bean.

Gowda *et al.* (2014) found that yield attributes like number of pods per plant, seed yield per hectare and seed yield per plant were enhanced by the application of $ZnSO_4$ 0.4 % with foliar application of 19:19:19 at the rate of 0.4 % with high benefit-cost ratio. Mamathashree *et al.* (2014) conducted a study in pigeonpea by using a different water-soluble fertilizer. The result depicted that the application of 19:19:19 as a foliar spray at 2 % positively increased the yield attributes like 100 seed weight, seed weight per plant followed by the foliar spray of 28:28:0.

According to Sharma (2015), in pearl millet, the application of 75 % recommended dose of fertilizer with 1% 19:19:19 NPK foliar spray at the flowering stage will gave 20-27 % more yield than the other treatments. From the economic analysis the highest benefit-cost ratio 11.25 was obtained from the 75 % recommended dose of fertilizer with 1 % 19:19:19 NPK foliar spray. Gajbhiye *et al.* (2017) found the influence of water-soluble fertilizer on fruiting attributes in cashew (*Anacardium occidentale* L.). He concluded that urea @ 2 % and 19:19:19 @ of 2 % had increased the number of nuts per panicle, more number of nuts at marble stage, high rate of fruit set, percentage of fruit retention and a maximum number of fruit harvest per panicle.

Singhal *et al.* (2015) noticed that foliar spray of 19:19:19 NPK at 0.5 % gave better benefit-cost ratio 3.4 compared to other treatments.

Das and Jana (2015) conducted an experiment in cowpea and they concluded that 19:19:19 foliar spray in pre-flowering stage at concentration 2 % increased yield.

Anju (2017) observed the effect of 19:19:19 NPK foliar spray in French bean. They noticed that foliar spray of 19:19:19 had a positive effect on yield parameter like number of pods per plant, number of seed per pod, average pod weight, average pod length and average pod thickness. Vinodkumar and Salakinko (2017) conducted a study in *Arachis hypogea* by using 19:19:19 foliar spray. Pod yield, kernel yield and harvest index was increased by applying a foliar spray of 19:19:19 NPK.

According to Somimol (2018), foliar application of 19:19:19 NPK one percentage concentration at 60 and 90 DAT in chilli gave more fruit yield.

2.3. Organic management

2.3.1. Effect of organic management on morphological parameters

Premsekhar and Rajashree (2009) concluded that farmyard manure application in okra at the rate of 20 t / ha increased the plant height, number of fruits per plant and yield of the crop. Alhrout and Spaner (2010) found that 20 t/ha cattle manure application in maize had a positive role in enhancing plant height, the diameter of ear, diameter of the stem, length of the ear, number of ears per plant.

Mahdi *et al.* (2010) reported that biofertilizer had a role in crop growth and development and also mobilized the fixed micro and macronutrient led to more availability of nutrients to the crop.

According to Ankaram *et al.* (2013), application of vermicompost in chilli had a positive effect in enhancing morphological parameters like the fruit number, plant height, leaf number and branch number per plant. The result showed that vermicompost with cow dung application enhanced growth and development and also improved the nitrogen, phosphorous and potassium percentage in chilli.

Bhaskarrao *et al.* (2014) noticed that 15 t / ha cowdung application had a positive effect on morphological parameters of Faba bean and peas like percentage of germination, dry matter production, height of the plant, length of shoot and root length. Biochemical parameters are also improved by the application of cow dung.

Krishnarao *et al.* (2015) conducted a study in chilli for evaluating the effect of vermicompost and panchagavya in soil treated with 40 kg vermicompost, Azospirillum 0.5 kg and 0.5 kg phosphobacter in one hectare. They concluded that panchagavya with vermicompost application enhances the morphological parameters like plant length, branch number, fruit number and fruit size.

Huner *et al.* (2015) studied the effect of different dose of vermicompost application on morphological and yield parameters. Vermicompost applied two tons per hectare had a positive role in enhancing the length of shoot, length of root, dry shoot weight and weight of dry root and yield parameters like fruit number per plant and yield in tomato.

According to Nasiri (2016), farmyard manure application @ 20 t/ ha had a positive effect on plant height, lateral stem number, biomass production and essential oil percentage in Dragonhead (*Dracocephalum moldavica*).

Prabhakari and Mogle (2017) conducted a study in spinach and concluded that leaf fresh weight and dry weight of leaf was maximum in vermicompost treatment of *Achyranthes aspera*. This manure contains micro and macronutrient for enhancing the growth and yield of the crop.

Afzal *et al.* (2017) noted that poultry litter and farmyard manure application in safflower had a positive effect on morphological parameters like the height of the plant (174.6 cm), number of heads per plant, number of seeds per head and maximum seed yield compared to other treatments.

2.3.2. Effect of organic management on physiological parameters

Rabari *et al.* (2006) found that in onion application of 75 % recommended dose of fertilizer with 1.25 t of vermicompost, which led to enhanced vegetative growth and carbohydrate formation. Nitrogen is a constituent of protein, amino acid and chlorophyll content which led to promotion of cell multiplication and elongation. Highest bulb yield, weight of the bulb, volume of the bulb was also noticed in the same treatment.

Premsekhar and Rajashree (2009) found that 20 t / ha farmyard manure in okra had a positive effect on chlorophyll content of the leaf and increased the photosynthesis. FYM also improved the physical and biological status of soil led to an increased in the nutrient supply which increased the growth and yield.

Sureshkumar *et al.* (2011) noted that panchagavya foliar spray increased the physiological parameters like leaf area index, leaf area, chlorophyll content and total dry matter production of the plant which led to enhancement in the yield of the crop. Baliah *et al.* (2016) reported that organic fertilizer application had a role in physiological parameters like chlorophyll content, glucose content, protein content and free amino acid in okra.

Prabhakari and Mogle (2017) in spinach concluded that vermicompost and manure had a positive effect on the content of chlorophyll a, chlorophyll b, total chlorophyll and crude protein by applying vermicompost.

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Muthalagu *et al.* (2018) studied the role of natural extracts like panchagavya, *Vetiveria zinzanioides* extract, *Moringa oleifera* leaves extract enhanced length of shoot and root, leaf number, shoot and root dry weight, chlorophyll content, carotenoid content, soluble protein, photosynthesis rate, transpiration rate, and chlorophyll fluorescence were studied. The highest value of physiological and growth parameters were obtained from three percentage moringa leaf extract and three percentage vetiver root extract in black pepper.

2.3.3. Effect of organic management on quality parameters

Granstedt and Kjellenberg (1997) concluded that in wheat and potato the crude protein content was lower in organic treatment, increased pure protein content and essential amino acid and lower the content of free amino acid. In potato, storage life was increased in organically treated crops and in the case of wheat the starch quality was increased.

Hemalatha *et al.* (2000) observed that incorporation of dhaincha 12 t / ha in rice field had a positive effect on quality attributes like optimum time of cooking, amylase content and crude protein content. Premsekhar and Rajashree (2009) reported that farmyard manure @ 20 t/ ha application in okra improved the quality parameters of the okra. Application of FYM reduced the crude fibre content compared to synthetic fertilizer. Khan *et al.* (2008) reported that 12 t / ha poultry manure application in maize enhanced the protein percentage compared to other treatments.

Shankar *et al.* (2009) reported that organic manure application in spinach had a positive role in quality parameters like vitamin C content, total carotenoid and have more antioxidant activity. Singh *et al.* (2010) found the effect of vermicompost in morphological – physiological characters of plant and quality of tomato. The result

31

revealed that application of vermicompost had 2.5 % more shelf life and total soluble sugar (4.5 %) compared to other treatments and both these quality are very important in summer season production of tomato.

Shankar *et al.* (2013) noted that vermicompost application in amaranthus increased the total carotene content, crude fibre content and vitamin C content of the crop.

2.3.4. Effect of organic management on yield parameters

Hemalatha *et al.* (2000), in rice he concluded that the organic manure application enhanced growth, yield and quality of the crop. Especially dhaincha increased the grain and straw yield parameters. According to Talanur (2003), in rabi sorghum-chickpea system the highest yield was obtained when 50% N was applied as manure and other 50 % nitrogen was applied as fertilizer.

Kumar *et al.* (2007) reported that farmyard manure with zinc amendment application enhanced the plant height, dry matter accumulation and yield parameters.

Khan *et al.* (2008) reported that 12 t / ha poultry manure application in maize enhanced length of the cob, the diameter of the cob and grain number per cob, due to more photosynthetic activity of the plant.

Singh *et al.* (2011) found that in French bean the application of vermicompost 2.5 - 3.75 t ha^{-1} with 4 cm thick mulch of crop residue enhanced pod formation and pod yield.

Abayomi and Adebayo (2014) reported that the application of organomineral fertilizer at the rate of 100 kg N/ ha in amaranthus gave yield about 18.9 t/ha than the NPK fertilizer which gave 17.6 t/ha. The organic mineral fertilizer was found to affect the morphological parameter like the height of the plant, leaf number and yield.

Adhikari *et al.* (2016), reported that in sweet pepper more growth and development was recorded in the treatment with vermicompost application followed by poultry manure application.

Khandarker *et al.* (2017) in okra found that the application of poultry manure enhanced the growth and yield, by improving the yield parameters like fruit weight, the number of fruit per plant, dry weight of fruit .

2.4. Soil test based nutrient management

Reddy and Ahamed (2004) conducted a study in maize by soil test based nutrient management. He concluded his study as the soil consist of 10, 50, and 17 percentage N, P_2O_5 and K_2O and nutrient supplied through fertilizer is 0.166, 0.112 and 0.155 kg^{-1} of N, P_2O_5 and K_2O respectively, which gave the highest yield of 4.5 ton per hectare. Mulvaney *et al.* (2005) reported that soil test based nutrient management increased the microbial N immobilization and uptake of mineralized soil N in corn.

Singh *et al.* (2016) reported that the soil test based nutrient fertilizer application provided balanced nutrition and increased the efficiency of fertilizer and found that soil test based nutrient recommendation produced the targeted yield of 40 t ha^{-1} in carrot.

Gayathri *et al.* (2009) reported that the higher value of benefit-cost ratio 1.5 was obtained from the soil test based nutrient compared to other treatment in potato. Sakarvadia *et al.* (2012) reported in garlic variety GG-3 that using soil test based nutrient management additional income and yield.

Singh *et al.* (2016) reported in mulberry that leaf yield was significantily high in soil test based nutrient management than farmers existing practices followed by recommended practices. Verma *et al.* (2017) reported in mustard (*Brassica juncea*) the treatment soil test based nutrient management in the soil will gave more grain and straw yield and enhanced nutrient uptake.

2.5. NPK Fertilizer

2.5.1. Effect of NPK Fertilizer on morphological parameters

Omotoso and shittu (2007) concluded that the application of NPK in okra enhanced the height of the crop and height of the plant was directly proportional to the productivity of the crop.

Singh *et al.* (2009) reported in tomato that the application of NPK fertilizer enhanced the height of the plant, area of the leaf, weight of the leaf, weight of the fruit, yield of the fruit, shelf life and total soluble sugar content. Olanji *et al.* (2010) reported the importance of inorganic fertilizer on growth, yield and quality of okra up to 200 kg per ha NPK application increased the plant height and the number of leaves per plant.

Bassiony *et al.* (2010) found that 100 % NPK application enhanced the morphological and yield parameters like the height of the plant, leaf number, number of branches, dry matter production, length of the pod, chlorophyll content and fibre content in okra. Prativa and Bhattari (2011) reported that Vermicompost and FYM gave maximum plant height, earlier production of 50 % flowering and number of leaves per plant.

Nafiu *et al.* (2011) reported that in eggplant the application of 200 kg NPK per ha gave more yield characters but shoot characters is were increased up to 300 kg NPK per ha. Above 200 kg, the yield parameters did not have a positive effect in dry matter production of the crop, yield and growth parameters.

Ketran *et al.* (2016) reported in evaluating the okra that fertilizer application had a direct positive effect in the height of the plant, a number of flowers per plant and length of the fruit. Soomro reported that

100% recommended inorganic NPK fertilizer application have a positive effect in morphological parameters like plant height, the girth of the stem, maximum tillers per plant.

According to Adiaba (2016), in maize the mineral nutrition application of NPK (15:15:15) at the rate of 15 to 20 kg per ha showed more response to growth and development of the crop.

2.5.2. Effect of NPK Fertilizer on physiological parameters

Asefa *et al.* (2014) reported that application of 14 N, 15 P_2O_5, 15 K_2O had a positive effect on grain yield, nutrient use efficiency, nutrient uptake, recovery of nutrient and also in agronomic efficiency.

Jena *et al.* (2013), reported that enhanced the quality protein maize by application of 240 kg N per ha and 100 kg P_2O_5 kg per ha and had a positive effect in LAI of the crop followed by 180 kg N per ha and 90 kg P_2O_5. Soomro (2004) reported that application of 100 % recommended a dose of inorganic NPK increased the physiological parameters like leaf area, leaf area index, crop growth rate and dry matter production.

Nasarudin *et al.* (2017) reported that NPK fertilizer had a role in chlorophyll content and antioxidant activity which played a role in development. Antioxidant had a great role at the time oxidative stress. Khandaker *et al.* (2017) noted that in okra inorganic NPK fertilizer at the rate of 190 kg per ha increased the physiological parameters like photosynthesis rate, chlorophyll content of the leaf, stomatal conductance of the leaf and total soluble solids (TSS) increased in pods when 190 kg per ha NPK application to the soil.

2.5.3. Effect of NPK Fertilizer on quality parameters

According to Barner (1964), reported that of 75 to 90 N, 50 - 60 P_2O_5 and 150 K_2O kg per ha increased the sugar content in sugarcane.

According to Hussain (2002), high protein content was observed at high NPK fertilizer ratio 105–75-75 kg per ha and concluded that protein content in wheat was directly proportional to the NPK fertilizer level.

Soomro (2004) reported that application of 100 % recommended a dose of NPK fertilizer had a positive effect in maximum purity, pol and brik reading compared to control. Rathi and Bist (2007) found that 250 g NPK per pear enhanced the fruit quality like total soluble sugar, reducing sugar and amount of non-reducing sugar) in pant pear-18.

Olanji *et al.* (2010) found that application of NPK up to 150 kg NPK per ha enhances the fibre content and vitamin C in bhindi. Akhtar *et al* (2010) reported that potassium application in tomato increased the vitamin C content but reduces the soluble sugar content.

2.5.4. Effect of NPK Fertilizer on yield parameters

Omotoso and Shittu (2001) reported that application of NPK at the rate of 150 kg per ha gave the optimum yield in okra. Oloyeda *et al.* (2013) observed that NPK fertilizer increases the fruit number from 7000 to 10000 per ha compared to control and also found that there was an increase in fruit weight from 9 to 17 t/ha.

Jacob *et al.* (2014) concluded that the application of 90 kg nitrogen fertilizer gave the highest yield 2533.3 kg per ha enhanced plant height and leaf area. Grain yield positively correlated to plant height and leaf area. Asefa *et al.* (2014) reported the maximum Teff grain yield 2147.7 kg per ha and straw yield 5852.8 kg per ha from the application of 14 N, 21 P_2O_5, 15 K_2O inorganic fertilizer.

Naeem *et al.* (2014) reported that highest grain yield (1104 kg per ha) from the inorganic NPK fertilizer and the yield parameters like the number of pods per plant, the number of seeds per plant and 1000 grain weight was increased with respect to increasing in inorganic fertilizer.

Usman *et al.* (2015) reported that application of NPK fertilizer increased the yield parameters in maize and soybean intercropping system. Chukwuka *et al.* (2015) reported that in maize the application of 90 N kg per ha, 60 P kg per ha and 60 kg K per ha gave better yield compared to other treatments.

Lawal *et al.* (2015) found that application of NPK fertilizer at the rate of 300 kg per ha increases the length and girth of the fruit, the number of fruit per plant in *Solanum melongena*. Vedpathak and Chavan (2016) reported that the yield parameters in fenugreek (*Trigonella foenum*) was maximum in treatment with straight fertilizer application.

Yaso *et al.* (2017) reported that the fertilizer recommendation of NPK 90:30:24 kg per ha gave better yield in case of onion.

MATERIALS AND METHODES

3. MATERIALS AND METHODS

The research work entitled "Physiological studies on growth, yield and quality enhancement of chilli (*Capsicum annum* L) under different nutrient management" was done at Regional Agricultural Research Station (RARS), Pilicode, Kerala Agricultural University. The objective of the study was to investigate the influence of soil and foliar application of nano NPK and compare with conventional fertilizer on enhancing growth, yield and quality attributes of chilli. The details regarding materials and methods used for the research work are furnished in this chapter.

3.1. GENERAL DETAILS

3.1.1. Experimental location

The experimental plot was located at Regional Agricultural Research Station (RARS), Pilicode. Geographically the field was situated at an altitude of 15 m above mean sea level. The latitude and longitude of the site were 12°12′ N and 75°10′E, respectively. The climatic condition was humid tropical condition.

3.1.2. Time of study

The field experiment was carried out from September 2018 to May 2019.

3.1.3. Soil

A composite soil sample from the experimentl plot at the depth of 15 cm was collected and sample was reduced to 0.5 kg soil by using quartering method. Air dried soil was then passed through 2 mm sieve. This soil sample was used for analysing physical and chemical properties of the soil.

3.1.4. Methods used for soil analysis

3.1.4.1. pH

The pH was measured by using pH meter by potentiometric method (Jackson, 1958). Ten gram of soil was taken in a 50 ml beaker and 25 ml distilled water was added. Intermittently stirred up to 30 min and after some time Electrode was diped in the soil water suspension and reading was taken.

3.1.4.2. Electrical conductivity

Electrical conductivity was measured by conductivity meter. The electrode was dipped in soil water suspension 1:25 ratio and the reading was taken (Jackson, 1958)

3.1.4.3. Organic carbon

Organic carbon in soil was estimated by wet oxidation method (Walkley and Black (1934). Organic matter present in soil is oxidized by potassium dichromate and sulphuric acid. By using ferrous ammonium sulphate, unreacted potassium dichromate is back titrated. From this method, we can estimate the amount of potassium dichromate used for the oxidation of carbon present in the organic matter

3.1.4.4. Available nitrogen

Available nitrogen present in soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956)

3.1.4.5. Available phosphorous

Available phosphorous present in soil was estimated by colorimetric method (Bray and Kurtz, 1945). The phosphorous was extracted by Bray No.1 reagent. Extracted phosphorus was estimated using spectrophotometer model Lambda 25.

3.1.4.6. Available potassium

The soil available potassium was extracted using neutral normal ammonium acetate. The total potassium present in the soil was estimated according to (Jackson, 1958) by using flame photometer model CL 308.

3.1.4.7. Available calcium and magnesium

Complexometric titration was used for the analysis of calcium and magnesium using EDTA. The extraction is by ammonium acetate (Jackson, 1958).

3.1.4.8. Available sulphur

Plant available sulphur was extracted by 0.15 % calcium chloride. From the extracted solution sulphur was estimated by using barium chloride turbidimetrically in spectrophotometer (Williams and Steinbergs, 1950).

3.1.4.9. Available iron, manganese, zinc and copper

The extraction was done by using 0.1 M hydrochloric acid and Fe, Mn, Zn and Cu was estimated by using Atomic absorption spectrophotometer (Sims and Johnson, 1991).

3.1.4.10. Available boron

Extraction of available boron was done by using hot water and estimated by photoelectric colorimetry (Berger and Truog, 1939).

3.2. EXPERIMENTAL STUDY

3.2.1. Experiment details

Variety : Ujwala

Season : September, 2018 to February, 2019

Spacing : 45 cm × 45 cm

Design : RBD

Treatments : 9

Replication : 3

Number of plants per replication : 25

Seeds of chilli variety ujwala collected from College of Horticulture, Department of Olericulture, Thrissur. The field layout plan is depicted in Fig.1

A. Treatments

T_1 : Control (soil test based nutrient management (47.25:10:6.25 NPK Kg/ha)

T_2 : Nano NPK 4 G granules (4 : 4 : 4)

T_3 : T_1 + Nano NPK 4 G foliar @ 0.5 %

T_4 : T_1 + NPK 19:19:19 foliar @ 0.5 %

T_5 : T_2 + Nano NPK 4 G foliar @ 0.5 %

T_6 : T_2 + NPK 19 :19:19 foliar @ 0.5 %

T_7 : Organic PoP (KAU, 2009)

T_8 : Organic PoP + Nano NPK 4 G foliar @ 0.5 %

T_9 : Absolute control

Nano NPK 4 G granules were applied at basal, 30 and 60 days after transplanting @ 0.33 g / plant for each dose. Foliar application of Nano-NPK and 19 :19:19 were done at 35, 65, 80 and 95 days after transplanting.

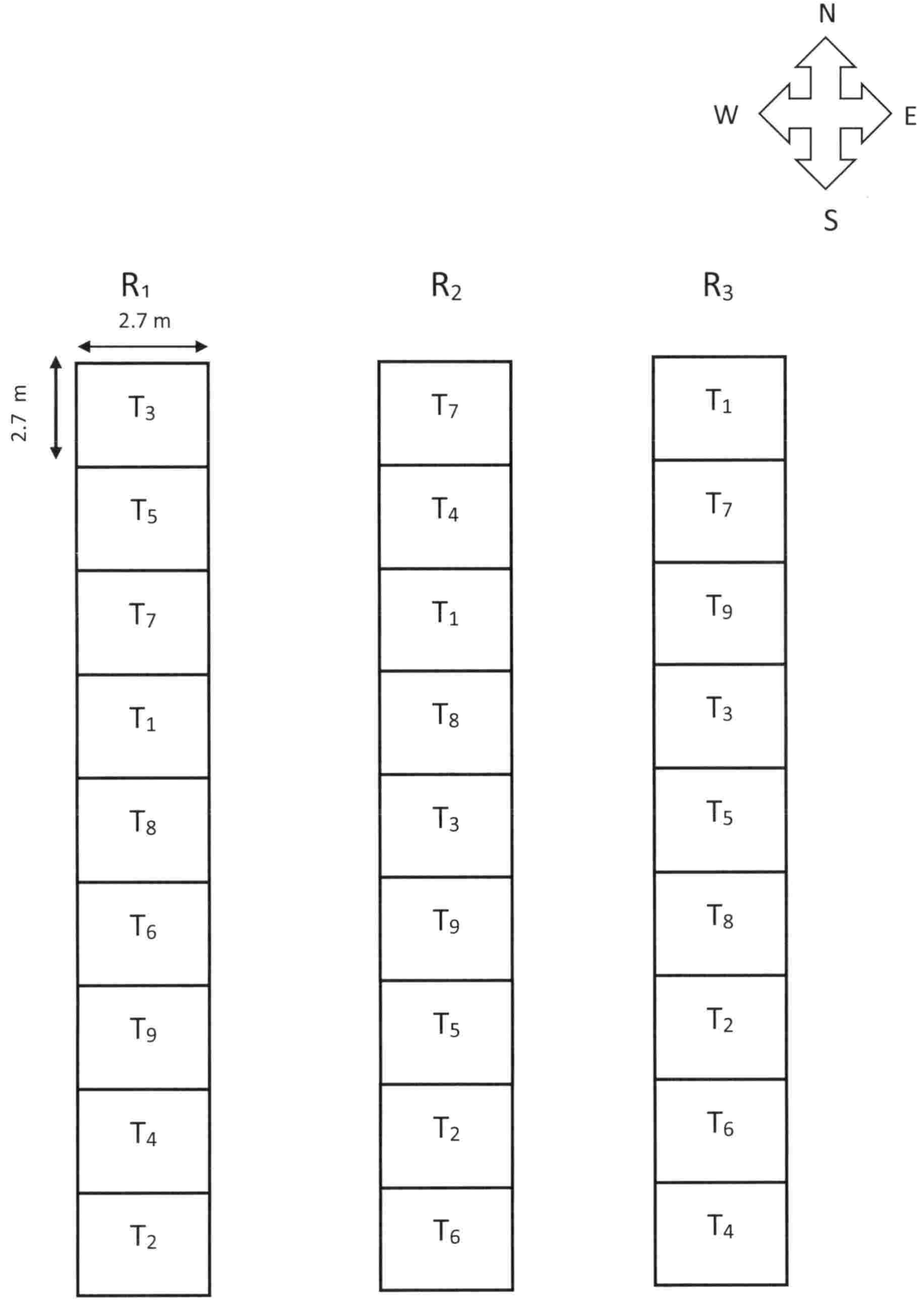


Fig. 1. : Layout of the field

Fertilizer details

Nano NPK granules and nano NPK liquid fertilizer - N -P_2O_5 - K_2O (4-4-4), fertilizer contains multiple organic acid like protein-lacto-gluconate micro-nutrients etc. manufactured by Tropical Agrosystem Pvt. Ltd .and technical collaboration from Prathista Industries Ltd. Hyderabad.

N- P_2O_5 . K_2O (19:19:19) - Manufactured by Rich Phytocare, Pvt Ltd, Thamilnadu.

Adhoc organic PoP recommendation- FYM at the rate of 25 t per ha applied as a basal dose. Trichoderma neem cake enriched cowdung mixture applied as a basal. Cowdung slurry applied at 7 day interval up to 95 DAT.

3.2.2. Nursery preparation

Seeds were sown in raised bed of one meter length and 1.00 m width. The soil was mixed well with decomposed FYM, after sowing the seeds, the seed bed was covered with green leaves and irrigated. One month old seedlings were used for transplanting.

3.2.3. Field operations

3.2.3.1. Land preparation and fertilizer application

Soil samples were collected from randomily four to five spots from experimental plot for analyzing macro and micro nutrients. Land was thorouly ploughed two times for making the soil fine tilth. The plot was divided into three blocks. Each block was again divided in to nine plots, with effective plot size of 3×3 m^2. In each plot, furrows were made and lime was applied. After one week, FYM was applied and throughly

Lay out

Making furrow

Lime application

FYM application

Transplanting

Plate 1. Main field preparation

mixed. Based on the soil test values, the basal dose was applied. One month old three to five leaves healthy seedlings were transplanted at spacing of 45cm × 45 cm. For shade, the teak leaves were covered in the north south direction.

3.2.4. Cultural practices

Cultural operation carried out in the experiment plot are listed in Table.1

Table:1 Details of cultural practices

SI.no	Cultural practices	
Nursery preparation		
1	Nursery bed preparation	09-08-2018
2	Seed sowing	13-08-2018
3	Preparation of cowdung, trichoderma and neem cake mixture	13-08-2018
Main field operations		
4	Layout	19-09-2018
5	Furrow and ridge making	20-09-2018
6	Lime application	21-09-2018
7	Incorporation of FYM in experimental plot	24-09-2018
8	seedlings Transplanting	01-10-2018
9	Mulching	02-10-2018
10	First time weeding	08-10-2018
11	First basal dose application	09-10-2018
12	Second time weeding	05-11-2018
13	Second dose of fertilizer application	08-11-2018
14	First dose of foliar application	13-11-2018
15	Third time weeding	05-12-2018

16	Third dose of fertilizer application	10-12-2018
17	Second dose of foliar application	15-12-2018
18	Fourth time weeding	30-12-2018
19	Third dose of foliar application	01-01-2019
20	Fourth weeding	05-01-2019
21	Fourth dose of foliar application	18-01-2019
22	Irrigation	At one day interval
23	Harvesting	December,2018 to May,2019

3.2.5. Seed rate

Chilli is a transplanting crop. One kg healthy seed is required for planting one ha area.

3.2.6. Seedling treatment

One month old seedling roots were dipped in Pseudomonas solution for 10 minutes and transplanted in to main field.

3.2.7. Irrigation

After transplanting immediate irrigation was given by using rosecan. Irrigation was continued daily up to 15 days. After 15 days irrigation was done once in two days.

3.2.8. Manures and fertilizer application

Trichoderma enriched cow dung neem cake mixture was given as a basal application. Based on the technical programme recommended quantity of different fertilizers like soil Nano NPK granule, Nano NPK foliar, 19:19:19 NPK foliar spray and organic PoP recommendation applied in respective treatments.

Fertilizer application

Insecticide spray

Harvesting

Irrigation

Plate 2. Different cultural practices adopted during the study

3.2.9. Plant protection

For managing sucking pest like chilli thrips and mite managed by Actara @ 2g per 10 liter of water. Nimbicidin @ 8 ml per litre was applied for managing sucking pests in absolute control (T_9). Leaf eating caterpillar was controlled by the mechanical method like hand picking.

3.2.10. Weeding

Hand weeding was adopted for maintaing the experimental plot weed free.

3.2.11. Harvesting

Harvesting was started from December, 2018 first week onwards Chilli fruits were harvested when fruit colour changed from light green to dark green colour and maximum fruit size. Harvesting was done at weekly intervals up to May, 2019.

3.2.12. Observations

In each plot, uniform sized five plants were tagged with a metal tag. Care was taken to avoid border and heterogeneous plants. The morphological ,physiological, yield and quality parameters were recorded from five tagged plants

3.2.13. Morphological parameters

3.2.13.1. Plant height

Plant height was measured with scale from ground level to the tip of the fully opened leaf on the main branch. The height was measured at 45, 75, and 105 day after transplanting. The plant height was expressed in centimeters

3.2.13.2. Leaf area per plant

Leaves were collected from each tagged plant. The leaf was wiped out using tissue paper for removing dust particles. Leaf area was directily measured using a portable automatic leaf area meter model LI3000 A.

3.2.13.3. Number of leaves per plant

From each tagged plant 20 leaves were collected and obtained the dry weight. The dry weight of all leaves of the plant was taken. the numer of leaves were calculated by using back calculation.

3.2.13.4. Number of branches per plant

Number of side branches produced from the main branch were counted from 5 representative plants of a plot and average number was taken. The observation was taken at 45, 75 and 105 days after transplanting.

3.2.13.5. Days to 50 % flowering

The number of days taken from first flower formation to 50 % of the total number of the plants in a plot, was taken as days to 50 % flowering. When the first flower was produced, then that plant was tagged by a coloured ribbon. This tagging was continued up to 50 % of the plants produced first flowering.

3.2.13.6. Days to first harvest

The days taken for first harvest from the day of transplanting was recorded

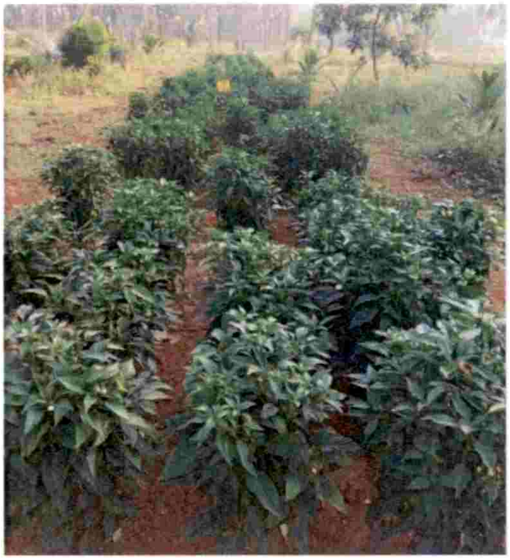
3.2.13.7. Duration of the crop

Duration of the crop was from sowing to final harvest of crop was taken as a duration of the crop.

Transplanting seedling

30 DAT

60 DAT



120 DAT

Plate 3. Different stages of crop during study

Plate 4. Field over view

3.2.13.8. Number of fruits per plant

In each plot 5 tagged plants plants were taken as a representative plant. The average number of fruits produced in each 5 plants was recorded.

3.2.13.9. Root volume

Root volume was measured by using the displacement method by taking a beaker filled with water then roots dipped in the beaker and noted quantity of water that had over flowed. It gives the root volume in cm^3.

3.2.14. PHYSILOGICAL PARAMETERS

The following physiological observation were taken at 45, 75 and 105 DAT

3.2.14.1. Relative growth rate **(mg^{-1} g^{-1} day^{-1})**

Relative growth rate is the increase in dry weight any instant of time per unit dry weight material (Black man,1919)

$$RGR = \frac{\log_e W_2 - \log_e W_1}{T_2 - T_1}$$

W_1 = Dry weight of plant at the time of T_1

W_2= Dry weight of plant at the time of T_2

3.2.14.2. Specific leaf weight **(mg/cm^2)**

On dry weight basis a measure of the leafiness of the plant was expressed

$$SLW = \frac{\text{Leaf dry weight}}{\text{Leaf area}}$$

3.2.14.3. Leaf area index

Leaf area index is the ratio of total leaf area to the ground area occupied.

$$LAI = \frac{\text{Total leaf area}}{\text{Ground area}}$$

3.2.14.4. Leaf area duration

Leaf area duration is a measure of leaf persistence on the plant.

$$LAD = \frac{(A_1 + A_2)}{2} \times (T_2 - T_1)$$

A_1 = Leaf area at the time interval of T_1

A_2 = Leaf area at the time interval of T_2

3.2.15.5. Leaf releative water content

Releative water content is expressed in percentage. The equation is given by the formula of Barrs and Weatherly,(1962)

$$RWC = \frac{FW - DW}{TW - DW} \times 100$$

FW = Leaf fresh weight

TW = Leaf turgid weight

DW = Leaf dry weight

3.2.15.6. Dry matter production

Average dry weight of three whole plants were taken.

3.2.15.7. Transpiration rate and Stomatal conductance

Transpiration rate and Stomatal conductance were measured by using steady state porometer model LI-COR-inc-111600. Reading was taken between 9.00 to 11.00 am.

3.2.15.8. Chlorophyll pigment estimation

80 % acetone used required for the extraction of pigments 250 mg. of leaf sample is macerated with 80 % acetone.and centrifuged the content at 4000 rpm for 20 minutes. Supernatents make up to 25 ml with 80 % acetone. The reading was taken from the spectrophotometer at three wave length 663, 652 and 645 nm (Hiscox and Israel, 1979)

$$\text{Chlorophyll a} = (\text{OD at } 663) \times 12.7 - (\text{OD at } 645)\ 2.69 \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll b} = (\text{OD at } 645) \times 2.29 - (\text{OD at } 663)\ 4.68 \times \frac{V}{1000 \times W}$$

$$\text{Total chlorophyll} = (\text{OD at } 663)\ 8.02 + (\text{OD at } 645)\ 20.2 \times \frac{V}{1000 \times W}$$

OD = Optical density

V = Final volume

W = Fresh weight of the sample

3.2.15.9. SPAD chlorophyll meter reading (SCMR)

SPAD chlorophyll meter model SPAD 502 was used for direct measurement of chlorophyll. The reading was taken at 45, 75 and 105 DAT.

3.2.15.10. F_V/F_m , Y (II) and ETR

Chlorophyll fluorescence, Quantum photosynthetic yield Y (II) and electron transport rate directly measured by using plant stress kit (ADC biosynthetic Ltd, Global house, Gedding Road),London.

Fv/Fm indicate the quantum efficiency of photosystem II. Y (II) indicate the amount of energy used by photosystem II in light reaction. ETC is the transfer of electrons in cellular respiration by oxidation reduction reaction.

3.2.15.11. N, P and K content of plant

3.2.15.11.1. Total Nitrogen in plant sample

The plant sample was digested using concentrated suphuric acid. The digest was transfered to Kjeldahl distillation flask, distillation process was carried out. After completion of distillation, distillate was titrated against sulphuric acid. End point was changing blue to pink (Jackson, 1958)

3.2.15.11.2. Total Phosphrous in plant sample

In nitric acid medium phosphate molecule react with vanadomolybdate, and yellow coloured heteropoly compound is formed at 420 nm and the intensity of yellow colour is measured.

3.2.15.11.3. Total Potassium in plant sample

Potassium containg liquid sample is burnt in flame. Photon emmited is directily propotional to the K content

3.2.15.12. N, P and K uptake

Nutrient uptake = nutrient concentration × whole plant drymatter production

3.2.16. QUALITY ANALYSIS OF FRUIT

3.2.16.1. Ascorbic acid content of fruit

One gram chilli fruit was macerated with 4 % oxalic acid. This was made up to 100 ml and centrifuged. From centrifuged solution 10 ml suspernnatant was pipetted out to conical flask and titrated against 2,6-dichlorophenol dye. Development of pink colour is the end point (Sadasivam and Manikhyam,1992)

3.2.16.2. Oleoresin

Oleoresin analysis was done by using soxlet apparatus. Chilli fruit was dried in hot air oven at the temperature of 50°C. Two gram fine chilli powder packed in filterpaper and placed in round bottom flask. The solvent acetone was used for the extraction. After extraction, the solvent was evaported to dryness under vaccum

$$\text{Oleoresin (\%)} = \frac{\text{weight of oleoresin}}{\text{Weight of sample}} \times 100$$

3.2.17. YIELD PARAMETERS

3.2.17.1. Fruit yield per plant/ plot (g)

Fresh weight of fruit was taken from five representative sample and average was taken. Also calculated total fresh fruit yield per plot.

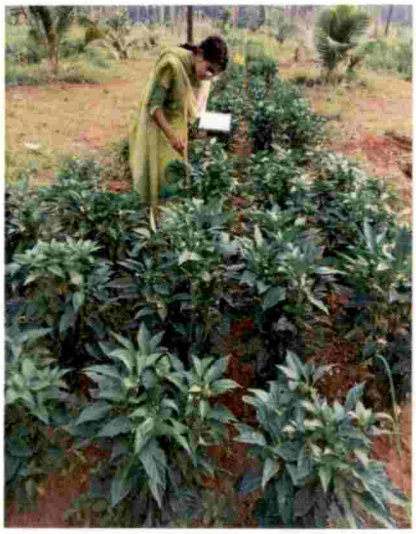
3.2.17.2. Fruit yield per ha (t/ha)

Yield per plot was taken. From this data fruit yield per ha was calculated.

3.3. Statistical analysis

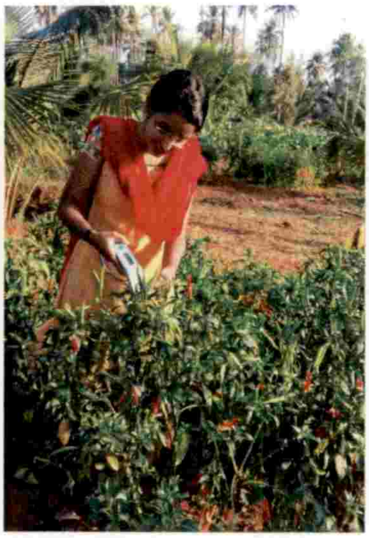
The experiment was laid out on a randomized block design. The Experimental data was analysed by one way analysis of variance where in, the least significant difference with a value less than 0.05 was accepted to be statistically significant. The analysis was done using statistical package, STAR.

Plate 5. Field visit of advisory committee members



A

B



C

D

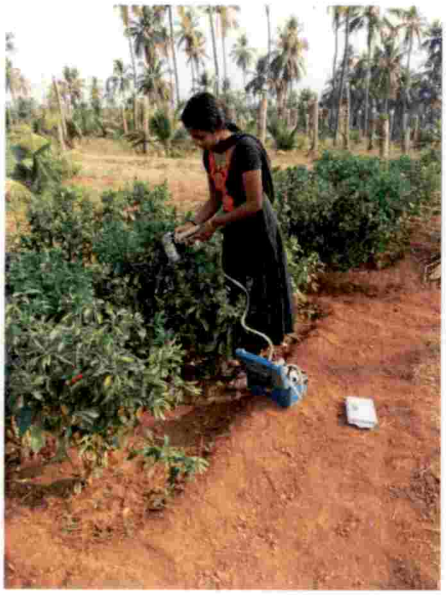


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Plate 6. Recording observartions from experimental plot using scale (A), SPAD chlorophyll meter (B), Stress kit (C), leaf area index meter (D) and porometer (E)

RESULTS

4. RESULTS

The research work was carried out at Regional Agricultural Research Station (RARS) Pillicode, Kerala Agricultural University during September 2018 to May 2019, to investigate the influence of soil and foliar application of nano NPK and compare with conventional fertilizer on enhancing growth, yield and quality attributes of chilli crop. The data was collected and statistically analysed. The result was presented below.

Before starting the experiment, the soil of the experimental plot was analysed for its nutritional status. It was found that the soil was acidic in nature, so the experimental plot was applied with lime at 250 kg/ acre.

Table 2. Soil test details of experiment plot

Parameters	Quality	Remarks
pH	4.9	Acidic
Electrical conductivity (dS/m)	0.17	Normal
Organic carbon (%)	1.4	High
Available nitrogen (kg /ha)	290.7	Medium
Available phosphorous (kg /ha)	44.1	High
Available potassium (kg /ha)	445.5	High
Available sulphur (mg /kg)	55.1	Sufficient
Available calcium (mg /kg)	400	Sufficient
Available magnesium (mg /kg)	60	Deficient
Micronutrients		
Copper (mg /kg)	1.13	Sufficient
Iron (mg /kg)	60	Sufficient
Zinc (mg /kg)	7.37	Sufficient
Manganese (mg /kg)	37.3	Sufficient
Boron (mg /kg)	0.24	Deficient

4.1. MORPHOLOGICAL OBSERVATIONS

4.1.1. Plant height (cm)

The data on plant height was presented in Table 3. The plant height was significantly enhanced under all nutrient managements from 45 DAT to 105 DAT.

Table 3. Effect of various treatments on the plant height (cm)

Treatments	Plant height (cm)		
	45 DAT	75 DAT	105 DAT
T_1 : Control (soil test based nutrient management)	52.0^{bcd}	73.8^{b}	81.0^{cd}
T_2 : Nano NPK granules	56.0^{bc}	74.0^{b}	82.8^{bcd}
T_3 : T_1 + Nano NPK foliar @ 0.5%	50.0^{cd}	74.9^{b}	84.0^{bcd}
T_4 : T_1 + NPK 19 : 19 : 19 foliar@ 0.5%	54.0^{bcd}	75.3^{b}	86.3^{bc}
T_5 : T_2 + Nano NPK foliar @ 0.5%	59.0^{ab}	78.0^{b}	88.7^{b}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	66.0^{a}	89.0^{a}	95.0^{a}
T_7 : Organic management	51.3^{cd}	69.9^{bc}	79.0^{d}
T_8 : Organic management+ Nano NPK foliar @ 0.5%	53.0^{bcd}	73.0^{bc}	81.0^{cd}
T_9 : Absolute control	48.2^{d}	65.0^{c}	72.0^{e}
SEd	1.9	2.3	1.7
CD (0.05)	7.0	8.3	6.2

At 45 DAT, the maximum plant height was observed from treatment T_6. The treatment T_6 was on par with T_5. The treatment T_5 was on par with T_4, T_2 and T_1. Signigicantily maximum plant height was recorded by T_6 at 75 DAT followed by treatment T_5. Significantily maximum plant hight at 105 DAT was noticed in T $_6$ followed by T_5.

Treatme nt T_5 was on par with treatments T_4, T_3 and T_2. At all three growth periods the maximum and minimum plant height were recorded in treatment T_6 and T_9 respectively. Nano NPK granule with 19:19:19 NPK foliar spray (T_6) was significantly superior to other treatments.

4.1.2. Leaf area per plant (cm^2)

The data on leaf area per plant is presented in Table 4.

Table 4. Effect of various treatments on leaf area per plant

Treatments	Average value of leaf area (cm^2)		
	45 DAT	75 DAT	105 DAT
T_1 : Control (soil test based nutrient management)	2970^f	9716^e	11089^e
T_2 : Nano NPK granules	3998^e	8153^f	10054^f
T_3 : T_1 + Nano NPK foliar @ 0.5%	4310^d	11295^c	12399^c
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	4410^c	10660^d	11399^d
T_5 : T_2 + Nano NPK foliar @ 0.5%	5754^b	11360^b	12980^b
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	7783^a	14980^a	16786^a
T_7 : Organic management	2106^h	5592^h	7989^h
T_8 : Organic management+ Nano NPK foliar @ 0.5%	2517^g	7025^g	8594^g
T_9 : Absolute control	1705^i	4203^i	6955^i
SEd	7.2	8.6	4.6
CD (0.05)	2.5	3.0	1.5

At 45 DAT, significantily maximum leaf area per plant was recorded in treatment T_6 (7783 cm^2) followed by T_5. The lowest leaf area per plant recorded with T_9 (1705 cm^2).

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At 75 DAT, the application of nano NPK granule with 19:19:19 foliar spray (T_6)had the significantly higher of leaf area (14980) follow by T_5. At 105 DAT, the maximum leaf area was recorded in T_6

4.1.3. Number of leaves per plant

The data on the number of leaves per plant is given in Table 5. At all stages of the crop the number of leaves per plant was affected by various nutrient management. An increasing trend was observed from 45 DAT to 105 DAT. Nano NPK granule with 19:19:19 foliar spray (T_6) was significantly superior to all other treatments in all stages.

Table 5. Effect of various treatments on the number of leaves per plant

Treatments	Number of leaves per plant		
	45 DAT	75 DAT	105 DAT
T_1 :Control (soil test based nutrient management)	99.00^{de}	347.00^{d}	515.00^{f}
T_2 : Nano NPK granules	105.50^{d}	354.50^{d}	538.00^{e}
T_3 : T_1 + Nano NPK foliar @ 0.5%	126.66^{c}	376.50^{c}	589.00^{c}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	131.66^{bc}	410.00^{b}	634.00^{b}
T_5 : T_2 + Nano NPK foliar @ 0.5%	137.50^{b}	355.00^{d}	548.00^{d}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	181.50^{a}	428.00^{a}	699.00^{a}
T_7 : Organic management	81.00^{fg}	233.50^{f}	415.00^{h}
T_8 : Organic management+ Nano NPK foliar @ 0.5%	90.00^{ef}	281.00^{e}	498.00^{g}
T_9 : Absolute control	77.50^{g}	186.00^{g}	379.00^{i}
SEd	2.91	3.14	2.52
CD (0.05)	10.56	11.34	9.16

At 45 DAT, the maximum number of leaves per plant was observed in obtained at 181.50 followed by T_5 and T_3.The lowest value was recorded in absolute control which was on par with T_7.

At 75 DAT, all the treatments significantly differed with each other. The maximum number of leaves per plant was recorded in T_6 followed by T_4, T_3,T_5, T_2 and T_1 . At 105 DAT the maximum number of leaves per plant recorded in T_6 followed by T_4, T_3 and T_5 treatments .

4.1.4. Number of branches per plant

The data on number of branches per plant is presented in Table 6. The number of branches per plant were significantly affected under the different nutrient managements. The number of branch per plant were increased from the 45 DAT to 105 DAT.

Table 6. Effect of various treatments on number of branches per plant

Treatments	Number of branches/ plant		
	45 DAT	75 DAT	105 DAT
T_1 : Control (soil test based nutrient management)	7^{bc}	29^{cd}	33^{c}
T_2 : Nano NPK granules	8^{bc}	33^{abc}	36^{c}
T_3 : T_1 + Nano NPK foliar @ 0.5%	10^{ab}	34^{abc}	45^{b}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	12^{ab}	35^{abc}	48^{ab}
T_5 : T_2 + Nano NPK foliar @ 0.5%	12^{ab}	37^{ab}	49^{ab}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	15^{a}	40^{a}	52^{a}
T_7 : Organic management	7^{bc}	20^{d}	23^{d}
T_8 : Organic management+ Nano NPK foliar @ 0.5%	7^{bc}	23^{d}	26^{d}
T_9 : Absolute control	4^{c}	11^{ecd}	15^{e}

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SEd	1.5	3.3	1.7
CD (0.05)	5.5	7.6	6.3

At 45 DAT, the maximum number of branches per plant was recorded in treatment T_6. The treatment T_6 was on par with treatment T_5, T_4 and T_3. The treatments T_1, T_2, T_7 and T_8 were on par. At 75 DAT, the maximum number of the branches per plant was recorded in T_6 which was on par with T_5, T_4 T_3 and T_2 but the lowest number of branches was recorded with T_8 and which was on par with T_9 and T_1.

At 105 DAT the maximum number of branches per plant as was recorded in T_6 and which was on par with T_5 and T_4. The lowest value was observed in T_9. The nano NPK granule with 19:19:19 NPK spray (T_6) was given better results followed by T_5 treatment.

4.1.5. Days to 50 % flowering, days to first harvest and duration of crop

The data regarding days to 50 % flowering, days to first harvest and duration of crop is presented in Table 7.

Table 7. Effect of various treatments on days to 50 % flowering, days to the first harvest and duration of crop

Treatments	Days to 50 % flowering	Days to the first harvest	Duration of crop
T_1 : Control (soil test based nutrient management)	61^{bc}	105^{ab}	189^{ef}
T_2 : Nano NPK granules	58^{cd}	99^{bc}	196^{de}
T_3 : T_1 + Nano NPK foliar @ 0.5%	52^{de}	95^{cd}	212^{bc}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	54^{cd}	89^{cd}	204^{cd}
T_5 : T_2 + Nano NPK foliar @ 0.5%	50^{de}	85^{de}	228^{a}

T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	45^{e}	85^{e}	216^{b}
T_7 : Organic management	67^{ab}	105^{a}	150^{g}
T_8 : Organic management+ Nano NPK foliar @ 0.5%	63^{ab}	102^{ab}	182^{f}
T_9 : Absolute control	73^{a}	108^{a}	127^{h}
SEd	2.2	1.8	3.3
CD (0.05)	8.17	5.36	11.83

The treatment T_6 recorded least number of days to 50 % flowering (45 days) followed by T_5 (50 days) 50 % flowering. In treatment. While it took 73 days for attaining 50 % flowering in absolute control. T_5 and T_3 treatments with nano NPK foliar application had recorded early flowering which was on par with T_6.

The days to the first harvest significantly differed among all the treatments. The different fertilizer managements had an influence on days to the first harvest of the crop. The minimum days taken for the first harvest was recorded in the treatment T_6 and T_5. The maximum number of days taken for the first harvest of the crop was T_9 (absolute control) which was on par with T_1 ,T_7 and T_8.

Different nutrient management were significantly different from each other on the duration of the crop. The various fertilizer managements affected the duration of the crop. The significantily maximum duration (228 days) of the crop was recorded in treatment T_5 followed by treatment T_6 (216 days).

The lowest crop duration was noted in absolute control (T_9). So the nano NPK granule with nano NPK foliar spray (T_5) significantly affected the duration of the crop and hence treatment T_5 was significantly superior to all other treatments.

4.1.6. Number of fruits per plant

The nano NPK granule with 19:19:19 NPK foliar spray (T_6) was recorded significantly maximum number of fruits per plant followed by treatment T_5. The minimum number of fruits per plant was recorded absolute control (T_9). So T_6 was significantly superior to all other treatments.

Table 8. Effect of various treatments on the number of fruits per plant

Treatments	Number of fruits per plant
T_1 : Control (soil test based nutrient management)	501^f
T_2 : Nano NPK granules	572^e
T_3 : T_1 + Nano NPK foliar @ 0.5%	675^d
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	700^c
T_5 : T_2 + Nano NPK foliar @ 0.5%	759^b
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	866^a
T_7 : Organic management	433^g
T_8 : Organic management+ Nano NPK 4 G foliar @0.5%	500^f
T_9 : Absolute control	150^h
SEd	3.8
CD (0.05)	13.86

4.1.7. Root volume (cm^3)

Table 9. Effect of various treatments on the root volume

Treatments	Root volume		
	45 DAT	75 DAT	105 DAT
T_1 : Control (soil test based nutrient management)	2.30^{abc}	16.83^{b}	22.32^{bcd}
T_2 : Nano NPK granules	2.40^{abc}	17.66^{b}	23.50^{bcd}
T_3 : T_1 + Nano NPK 4 G foliar @ 0.5%	3.90^{ab}	18.66^{b}	27.50^{ab}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	3.20^{abc}	18.16^{b}	26.00^{abc}
T_5 : T_2 + Nano NPK 4 G foliar @ 0.5%	4.30^{a}	26.00^{a}	29.90^{a}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	4.00^{ab}	21.00^{b}	27.50^{ab}
T_7 : Organic management	1.30^{bc}	10.33^{c}	20.32^{d}
T_8 : Organic management + Nano NPK foliar@ 0.5%	1.60^{abc}	16.66^{b}	21.95^{cd}
T_9 : Absolute control	1.00^{c}	11.50^{c}	18.33^{d}
SEd	0.77	1.29	1.48
CD (0.05)	2.76	4.61	5.27

The data on root volume is presented in Table 11. At 45 DAT, the maximum root volume was recorded in T_5. Treatment T_5 was on par with T_6 and T_3. The minimum root volume was recorded in absolute control which was also on par with T_7, T_8, T_4, T_2 and T_1. At 75 and 105 DAT, recorded maximum root volume in T_5 than T_6. The minimum reading was recorded at T_9 and T_7.

All three crop stage, the maximum root volume was recorded in T_5 (nano granule NPK with nano foliar) followd by T_6 and T_3 treatments.

4.1.8. Fruit length (cm)

The data on fruit length is presented in Table 12.

Table 10. Effect of various treatments on fruit length

Treatments	Fruit length
T_1 : Control (soil test based nutrient management)	6.1^{abc}
T_2 : Nano NPK granules	6.4^{abc}
T_3 : T_1 + Nano NPK foliar @ 0.5%	6.3^{abc}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	6.5^{abc}
T_5 : T_2 + Nano NPK foliar @ 0.5%	6.7^{ab}
T_6 :T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	7.1^{a}
T_7 : Organic management	5.7^{bc}
T_8 : Organic management+ Nano NPK 4 G foliar @ 0.5%	5.9^{bc}
T_9 : Absolute control	5.5^{c}
SEd	0.2
CD (0.05)	1.03

The maximum fruit length was observed in treatment T_6 followed by T_5. Treatment T_6 was on par with T_1, T_2, T_3, T_4 and T_5. The lowest fruit length was observed in T_9. Nano NPK granule with 19:19:19 NPK spray (T6) recorded higher fruit length compared to all other treatments. So the fruit length was range from 5.5 cm to 7.1 cm under different nutrient managements.

4.2. PHYSIOLOGICAL OBSERVATIONs

4.2.1. Relative growth rate ($mg^{-1} g^{-1} d^{-1}$)

The data on relative growth rate is presented in Table 11.

Table 11. Effect of various treatments on the relative growth rate

Treatments	01 – 45 DAT	45-75 DAT	75-105 DAT
T_1 : Control (soil test based nutrient management)	0.036	0.043^{b}	0.016^{d}
T_2 : Nano NPK granules	0.037	0.043^{b}	0.023^{c}
T_3 : T_1 + Nano NPK foliar @ 0.5%	0.039	0.044^{b}	0.028^{a}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	0.039	0.042^{b}	0.013^{d}
T_5 : T_2 + Nano NPK foliar @ 0.5%	0.041	0.047^{ab}	0.028^{a}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	0.044	0.052^{a}	0.022^{bc}
T_7 : Organic management	0.033	0.043^{b}	0.015^{d}
T_8 : Organic management+ Nano NPK foliar @ 0.5%	0.030	0.043^{b}	0.023^{b}
T_9 : Absolute control	0.027	0.036^{c}	0.016^{e}
SEd		0.003	0.0009
CD (0.05)	NS	0.007	0.002

During 01-45 DAT, the relative growth rate was non significant among all treatments. During 45 to 75 DAT, the maximum relative growth was recorded in treatment T_6 which was on par with T_5. Except for T_6 and T_9 all other treatments were on par. During 75-105 DAT, the maximum relative growth rate was observed in T_5 and T_3 followed by T_8 and T_2. The lowest value was recorded in T_9. The relative growth rate was increased from the initial stage of the growth period (1-45

DAT) to the second stage (45-75 DAT) of the growth period then it decreased during 75-105 DAT.

4.2.2. Specific leaf weight (SLW)

The data on specific leaf weight was presented in Table 12.

Table 12. Effect of various treatments on specific leaf weight

Treatments	Specific leaf weight (mg/cm^2)		
	45 DAT	75 DAT	105 DAT
T_1 : Control (soil test based nutrient management)	0.0009^{d}	0.0019^{c}	0.0061^{bc}
T_2 : Nano NPK granules	0.0040^{a}	0.0045^{a}	0.0051^{c}
T_3 : T_1 + Nano NPK foliar @ 0.5%	0.0024^{bcd}	0.0029^{bc}	0.0068^{ab}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	0.0023^{bcd}	0.0035^{ab}	0.0078^{a}
T_5 : T_2 + Nano NPK foliar @ 0.5%	0.0018^{cd}	0.0035^{ab}	0.0070^{ab}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	0.0036^{ab}	0.0040^{ab}	0.0081^{a}
T_7 : Organic management	0.0024^{bcd}	0.0036^{ab}	0.0060^{bc}
T_8 : Organic management+ Nano NPK foliar @ 0.5%	0.0028^{abc}	0.0040^{ab}	0.0060^{bc}
T_9 : Absolute control	0.0014^{cd}	0.0040^{ab}	0.0057^{bc}
SEd	0.0007	0.0007	0.0008
CD (0.05)	0.0015	0.0015	0.0017

At 45 DAT, maximum specific leaf weight was recorded in T_2. T_2 was on par with T_6 and T_8. The lowest value for specific leaf weight was the in the soil test based nutrient management (T_1). At 75 DAT, the maximum value was recorded in T_2 and which was on par with T_4, T_5, T_6, T_7, T_8 and T_9. At 105 DAT, maximum specific leaf weight was recorded in T_4 and T_6. Specific leaf weight was recorded maximum in T_2 at first

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two stages of crop. But at the third stage the maximum value was recorded in T_6. Minimum specific leaf weight was recorded in T_1 in the first two stages and in third stage it was recorded in T_2. The specific leaf weight increased from the initial growth stage (45 DAT) to the final growth stage (105 DAT) in all the treatments.

4.2.3. Leaf area index

The data regarding leaf area index is presented in Table 13.

Table 13. Effect of various treatments on leaf area index

Treatments	leaf area index		
	45 DAT	75 DAT	105 DAT
T_1 : Control (soil test based nutrient management)	3.09^{abc}	3.24^{ab}	3.39^{ab}
T_2 : Nano NPK granules	3.36^{abc}	3.51^{ab}	3.66^{ab}
T_3 : T_1 + Nano NPK foliar @ 0.5%	3.56^{ab}	3.69^{a}	3.90^{ab}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	3.62^{ab}	3.88^{a}	4.01^{ab}
T_5 : T_2 + Nano NPK foliar @ 0.5%	3.85^{a}	4.09^{a}	4.52^{ab}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	3.88^{a}	4.21^{a}	4.88^{a}
T_7 : Organic management	2.55^{c}	2.89^{ab}	3.01^{ab}
T_8 : Organic management + Nano NPK foliar @ 0.5%	2.80^{bc}	2.91^{ab}	3.15^{ab}
T_9 : Absolute control	2.41^{c}	2.04^{b}	2.29^{b}
SEd	0.25	0.36	0.65
CD (0.05)	0.95	0.58	0.47

At all three stages of the crop the maximum value of leaf area index was recorded in treatment T_6 which was on par with all treatment except T_9. Leaf area index increased from the initial growth stage (45 DAT) to the final growth stage (105 DAT). Nanao NPK granule with

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19:19:19 foliar spray did not had much effect on LAI of most of the treatments except T_9.

4.2.4. Leaf area duration

The data on leaf area duration is presented in Table 14. Leaf area duration was influenced by different nutrient managements.

Table 14. Effect of various treatments on leaf area duration

Treatment	01-45 DAT	45-75 DAT	75 – 105 DAT
T_1 : Control(soil test based nutrient management)	101^{e}	103.05^{bc}	100.65^{d}
T_2 : Nano NPK granules	92.25^{f}	94.95^{cd}	96.60^{e}
T_3 : T_1 + Nano NPK foliar @ 0.5%	104.38^{d}	108.75^{b}	105.15^{cd}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	110.75^{c}	112.50^{ab}	108.45^{bc}
T_5 : T_2 + Nano NPK foliar @ 0.5%	116.24^{b}	119.10^{a}	112.35^{b}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	119.39^{a}	121.35^{a}	118.65^{a}
T_7 : Organic management	86.46^{h}	81.60^{e}	81.00^{f}
T_8 : Organic management + Nano NPK 4 G foliar @ 0.5%	89.47^{g}	85.65^{de}	83.85^{f}
T_9 : Absolute control	70.54^{i}	66.75^{f}	65.10^{g}
SEd	1.42	4.51	2.85
CD (0.05)	2.97	10.26	5.94

During 1 to 45 DAT, leaf area duration recorded maximum in treatment T_6 followed by T_5. During 45-75 DAT, the maximum leaf area duration observed in T_5 and T_6. Which was on par with T_4. During 75-105 DAT significantily maximum leaf area duration was observed in T_6 followed by T_5 which was on par with T_4. The lowest leaf area duration was recorded in the treatment of absolute control (T_9). Nano NPK granule with 19:19:19 spray (T_6) recorded the highest leaf area duration compared to other treatments in all crop growth stages.

4.2.5. Leaf relative water content

The data on leaf releative water content is presented in Table 15. At 45 DAT, the highest relative water content was recorded in T_6 which was on par with T_5, T_4, T_3, T_2 and T_1. At 75 DAT, the highest leaf relative water content was observed in T_5 which was on par with treatments T_6, T_3, T_2 and T_7. At 105 DAT maximum value was recorded in T_5, T_3 and T_6 which was on par with T_4, T_2 and T_1. The lowest value was recorded in T_9. In T_1, T_3 and T_6 the relative water content increased from the initial stage to the final stage. But in other treatments,relative water content increased from the first growth stage to the second growth stage then decreased.

Table 15. Effect of various treatments on leaf relative water content

Treatments	Leaf relative water content (%)		
	45 DAT	75 DAT	105 DAT
T_1 :Control (soil test based nutrient management)	80.96^{bcd}	82.33^{cd}	83.00^{abc}
T_2 : Nano NPK granules	82.33^{abcd}	84.78^{abc}	83.00^{abc}
T_3 : T_1 + Nano NPK foliar @ 0.5%	84.22^{ab}	85.92^{ab}	86.72^{a}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	84.13^{abc}	83.15^{bcd}	84.38^{ab}
T_5 : T_2 + Nano NPK foliar @ 0.5%	86.00^{a}	87.01^{a}	86.78^{a}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	86.94^{ab}	86.21^{ab}	86.40^{a}
T_7 : Organic management	79.54^{cd}	83.76^{abc}	82.04^{bc}
T_8 : Organic management+ Nano NPK foliar @ 0.5%	81.39^{bcd}	81.89^{cd}	81.75^{bc}
T_9 : Absolute control	78.83^{d}	80.23^{d}	79.69^{c}
SEd	2.18	1.50	1.94

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CD (0.05)	4.63	3.31	4.13

4.2.6. Total dry matter production (g)

The data on total dry matter production of the plant recorded at 45, 75 and 105 DAT is presented in Table 16.

Table 16. Effect of various treatments on total dry matter production

Treatments	Total dry matter production (g)		
	45 DAT	75 DAT	105 DAT
T_1 : Control (soil test based nutrient management)	33.80^{bc}	123.79^{d}	187.26^{d}
T_2 : Nano NPK granules	34.99^{bc}	127.21^{cd}	195.42^{d}
T_3 : T_1 + Nano NPK foliar @ 0.5%	38.15^{b}	146.46^{b}	207.57^{c}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	39.21^{b}	140.41^{bc}	219.01^{b}
T_5 : T_2 + Nano NPK foliar @ 0.5%	39.68^{b}	163.47^{a}	231.32^{a}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	47.37^{a}	171.74^{a}	235.91^{a}
T_7 : Organic management	28.97^{cd}	93.36^{e}	148.56^{f}
T_8 : Organic management + Nano NPK foliar @ 0.5%	25.90^{d}	123.79^{d}	171.00^{e}
T_9 : Absolute control	22.05^{d}	65.95^{e}	82.07^{g}
SEd	2.00	4.02	2.60
CD (0.05)	7.11	14.32	9.62

Data recorded on total dry matter production was influenced by differentnutrient management. At 45 DAT significantily maximum dry matter production was recorded in T_6 followed by Treatment T_3, T_4 and T_5 which were on par. The lowest dry matter production was observed in T_8 and T_9. During 75 DAT the highest dry matter production was recorded in T_5 and T_6. At 105 DAT significantily maximum dry matter production was observed in T_5 and T_6 followed by T_4 and the minimum was recorded in T_9. In all treatments, dry matter production increased from 45 DAT to 105 DAT.

4.2.7. Transpiration rate

The data on the effect of different nutrient management on transpiration are presented in Table 17.

Table 17. Effect of various treatments on transpiration rate

Treatments	Transpiration rate (mmol H_2O m^{-2} s^{-1})		
	45 DAT	75 DAT	105 DAT
T_1 : Control (soil test based nutrient management)	3.21^{ab}	3.95^{ab}	6.85^{ab}
T_2 : Nano NPK granules	3.24^{ab}	4.08^{ab}	6.75^{ab}
T_3 : T_1 + Nano NPK foliar @ 0.5%	3.35^{ab}	4.18^{ab}	7.05^{ab}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	3.57^{a}	4.18^{ab}	6.88^{ab}
T_5 : T_2 + Nano NPK foliar @ 0.5%	3.68^{a}	4.60^{ab}	6.91^{ab}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	3.85^{a}	4.68^{a}	8.09^{a}
T_7 : Organic management	3.12^{ab}	3.83^{ab}	6.58^{ab}
T_8 : Organic management+ Nano NPK foliar @ 0.5%	2.97^{ab}	3.35^{ab}	7.36^{ab}
T_9 : Absolute control	2.32^{b}	3.35^{b}	5.83^{b}
SEd	0.28	0.64	0.88
CD (0.05)	1.03	1.36	1.87

During all crop growth stages 45,75 and 105 DAT the transpiration was observed highest in T_6 and T_5 which were on par with all other treatment except T_9. Transpiration rate was increased from the initial crop stage (45 DAT) to the final stage (105 DAT).

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4.2.8. Stomatal conductance

The data on the effect of various nutrient management on stomatal conductance is presented in Table 18.

Table 18. Effect of various treatments on stomatal conductance

Treatments	Stomatal conductance (mol H_2O m^{-2} s^{-1})		
	45 DAT	75 DAT	105 DAT
T_1 : Control (soil test based nutrient management)	0.13^{ab}	0.19^{ab}	0.17^{bc}
T_2 : Nano NPK granules	0.13^{ab}	0.14^{ab}	0.16^{bc}
T_3 : T_1 + Nano NPK foliar @ 0.5%	0.12^{ab}	0.17^{ab}	0.18^{b}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	0.16^{a}	0.19^{a}	0.21^{b}
T_5 : T_2 + Nano NPK foliar @ 0.5%	0.15^{ab}	0.16^{ab}	0.21^{b}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	0.19^{a}	0.25^{a}	0.28^{a}
T_7 : Organic management	0.14^{ab}	0.14^{ab}	0.19^{b}
T_8 : Organic management + Nano NPK foliar @ 0.5%	0.11^{ab}	0.14^{ab}	0.16^{bc}
T_9 : Absolute control	0.08^{b}	0.11^{b}	0.12^{c}
SEd	0.02	0.02	0.01
CD (0.05)	0.07	0.07	0.05

At 45and 75 DAT the highest stomatal conductance was observed in T_4 and T_6, which was on par with all other treatment except T_9. During 105 DAT, the maximum value recorded in T_6. Except T_9, all other treatments are on par.

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4.2.9. Chlorophyll content

The data on chlorophyll content is presented in Table 19. The different nutrient management influenced the chlorophyll content in all the treatments.

Table 19. Effect of various treatments on total chlorophyll content

Treatments	Total chlorophyll content (mg. g^{-1})		
	45 DAT	75 DAT	105 DAT
T_1 : Control(soil test based nutrient management)	1.20^{abc}	1.54^{ab}	1.50^{bc}
T_2 : Nano NPK 4 G granules (4:4:4)	1.17^{bc}	1.58^{ab}	1.52^{bc}
T_3 : T_1 + Nano NPK 4 G foliar @ 0.5%	1.30^{bc}	1.59^{ab}	1.59^{bc}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	1.40^{ab}	1.60^{ab}	1.74^{ab}
T_5 : T_2 + Nano NPK 4 G foliar @ 0.5%	1.50^{ab}	1.60^{ab}	1.80^{ab}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	1.90^{a}	2.00^{a}	2.20^{a}
T_7 : Organic POP (KAU, 2009)	0.99^{bc}	1.46^{ab}	1.35^{bc}
T_8 : Organic POP + Nano NPK foliar @ 0.5%	1.15^{c}	1.49^{ab}	1.52^{bc}
T_9 : Absolute control	0.96^{bc}	1.03^{b}	1.11^{c}
SEd	0.18	0.31	0.23
CD (0.05)	0.70	0.66	0.50

At 45 DAT the maximum chlorophyll content was noted in T_6 which was on par with T_5, T_4 and T_1. The least chlorophyll content was recorded in T_9. At 75 DAT, the maximum chlorophyll content was recorded in T_6 followed by T_5 and T_4 which were on par with all other treatments except T_9. At 105 DAT, maximum chlorophyll content was observed in T_6. which was on par with T_4 and T_5.

4.2.10. SPAD Chlorophyll meter reading (SCMR)

The data on SCMR is presented in Table 20.

Table 20. Effect of various treatments on SCMR

Treatments	SCMR		
	45 DAT	75 DAT	105 DAT
T_1 : Control(soil test based nutrient management)	58.06^{ab}	59.08^{ab}	57.30^{b}
T_2 : Nano NPK granules	62.26^{ab}	63.38^{ab}	60.60^{b}
T_3 : T_1 + Nano NPK foliar @ 0.5%	59.93^{ab}	60.98^{ab}	60.96^{b}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	61.80^{ab}	63.56^{ab}	68.20^{a}
T_5 : T_2 + Nano NPK foliar @ 0.5%	63.99^{ab}	64.12^{ab}	68.00^{a}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	66.00^{a}	67.85^{a}	73.19^{a}
T_7 : Organic management	58.30^{ab}	58.30^{b}	56.95^{bc}
T_8 : Organic management + Nano NPK foliar @ 0.5%	59.03^{ab}	58.03^{b}	59.91^{bc}
T_9 : Absolute control	55.93^{b}	56.88^{b}	53.75^{c}
SEd	2.32	2.56	1.56
CD (0.05)	8.30	9.12	5.59

At 45 and 75 DAT the maximum SCMR was recorded in T_6 followed by T_5 which were on par with all other treatment except T_9. At 105 DAT significantly maximum SCMR were recorded in T_4, T_5 and T_6 treatments followed by T_3, T_2 and T_1. The minimum value of SCMR was observed in T_9.

4.2.11. Quantum yield (Y (II))

The observation on Y(II) under different nutrient management is presented in Table 21.

Table 21. Effect of various treatments on quantum yield Y(II)

Treatments	Y (II)		
	45 DAT	75 DAT	105 DAT
T_1 : Control(soil test based nutrient management)	0.61	0.622^{ab}	0.574^{ab}
T_2 : Nano NPK granules	0.62	0.639^{a}	0.596^{ab}
T_3 : T_1 + Nano NPK foliar @ 0.5%	0.59	0.601^{ab}	0.625^{ab}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	0.58	0.626^{ab}	0.642^{ab}
T_5 : T_2 + Nano NPK foliar @ 0.5%	0.65	0.663^{ab}	0.622^{ab}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	0.67	0.677^{a}	0.655^{a}
T_7 : Organic management	0.59	0.567^{ab}	0.566^{ab}
T_8 : Organic management + Nano NPK foliar @ 0.5%	0.59	0.589^{ab}	0.575^{ab}
T_9 : Absolute control	0.58	0.522^{b}	0.543^{b}
SEd	NS	0.03	0.02
CD (0.05)		0.11	0.10

At 45 DAT all treatments non significant on Y(II). During 75 DAT, the highest Y(II) value was reported in T_6 and T_2 was on par with all other treatment except T_9. At 105 DAT, the maximum Y(II) value was recorded in T_6 which was on par with all other treatments except the absolute control.

4.2.12. Fv/Fm

The observation on Fv / Fm under different nutrient management is presented in Table 22.

Table 22. Effect of various treatments on Fv/Fm ratio

Treatments	Fv/Fm		
	45 DAT	75 DAT	105 DAT
T_1 : Control(soil test based nutrient management)	0.72	0.74^{ab}	0.75^{ab}
T_2 : Nano NPK granules	0.74	0.72^{ab}	0.74^{ab}
T_3 : T_1 + Nano NPK foliar @ 0.5%	0.77	0.79^{ab}	0.82^{ab}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	0.72	0.74^{ab}	0.75^{ab}
T_5 : T_2 + Nano NPK foliar @ 0.5%	0.78	0.80^{a}	0.89^{a}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	0.75	0.75^{ab}	0.79^{ab}
T_7 : Organic management	0.74	0.79^{ab}	0.80^{ab}
T_8 : Organic management + Nano NPK foliar @ 0.5%	0.73	0.74^{ab}	0.74^{ab}
T_9 : Absolute control	0.71	0.69^{b}	0.72^{b}
SEd	NS	0.03	0.05
CD (0.05)		0.10	0.17

The data on Fv/Fm is present in table 22. At 45 DAT, all treatment were non-significant. During 75 DAT maximum Fv/Fm value was recorded in treatment T_5 which was on par with all other treatments except T_9. The least value of Fv/Fm ratio was recorded in T_9. At 105 DAT, the maximum value of Fv/Fm ratio was recorded in T_5 which was on par with all other treatments except T_9.

4.2.13. Electron transport rate (ETR)

The data on ETR is presented given in the Table 23 .

Table 23. Effect of various treatments on ETR

Treatment	ETR		
	45 DAT	75 DAT	105 DAT
T_1 : Control (soil test based nutrient management)	77.5^{e}	104.0^{c}	129.2^{de}
T_2 : Nano NPK granules	103.2^{c}	87.9^{e}	131.0^{d}
T_3 : T_1 + Nano NPK foliar @ 0.5%	107.0^{bc}	120.2^{a}	128.3^{e}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	114.2^{ab}	118.7^{ab}	131.5^{d}
T_5 : T_2 + Nano NPK foliar @ 0.5%	115.5^{ab}	113.0^{b}	141.6^{c}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	119.1^{a}	115.0^{ab}	148.9^{b}
T_7 : Organic management	87.8^{d}	93.9^{de}	128.2^{e}
T_8 : Organic management + Nano NPK foliar @ 0.5%	100.0^{c}	96.0^{d}	155.0^{a}
T_9 : Absolute control	78.9^{de}	92.5^{de}	81.3^{f}
SEd	2.6	1.9	1.5
CD (0.05)	9.3	7.0	1.80

At 45 DAT the maximum ETR was recorded in T_6 which was on par with T_5 and T_4. The minimum value was recorded in treatment T_1 (soil test based nutrient management). Treatment T_1 was on par with T_9. At 75 DAT, maximum ETR was recorded in T_3 which was on par with T_4 and T_6 followed by treatment T_5. Minimum ETR was recorded in treatment T_2 which was on par with T_9. At 105 DAT maximum value was recorded in T_8 treatment .

4.2.14. N, P and K content of whole plant

The N, P and K contents of the plants at 105 DAT are presented in Table 24.

Table 24. Effect of various treatments on N, P and K content of whole plant

Treatment	N, P and K content of whole plant		
	N	P	K
T_1 : Control (soil test based nutrient management)	2.1^{d}	0.30^{ab}	2.19^{b}
T_2 : Nano NPK granules	2.2^{d}	0.31^{ab}	2.35^{b}
T_3 : T_1 + Nano NPK foliar @ 0.5%	2.5^{c}	0.33^{ab}	2.71^{ab}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	2.7^{b}	0.32^{ab}	3.35^{a}
T_5 : T_2 + Nano NPK foliar @ 0.5%	2.6^{c}	0.32^{ab}	2.78^{ab}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	2.9^{a}	0.38^{a}	3.32^{a}
T_7 : Organic management	2.1^{d}	0.29^{ab}	2.14^{b}
T_8 : Organic management+ Nano NPK foliar @ 0.5%	1.9^{e}	0.28^{b}	2.19^{b}
T_9 : Absolute control	1.3^{f}	0.27^{b}	2.01^{b}
SEd	0.39	0.02	0.21
CD (0.05)	0.22	0.09	0.78

Nitrogen content was recorded significantily maximum in treatment nanogranule with 19:19:19 foliar spray (T_6). Which was on par with T_5, T_4, T_3 and T_2 followed by T_1, T_7 and T_8. The lowest nitrogen content was recorded in absolute control (T_9). Maximum phosphorous content was recorded in T_6. Which was on par with all other treatments except T_8 and T_9. In the case of potassium content of whole plant maximum value was observed in T_4 and T_6 which were on par with T_3 and

T_5. Nano NPK granule with 19:19:19 spray (T_6) has a significant effect in N, P, K contents in whole plant.

4.2.15. N, P and K uptake

The data on N, P and K uptake is presented Table 25. Different nutrient management had a significant effect in N, P and K uptake at all crop growth stages.

Table 25. Effect of various treatments on N, P and K uptake (kg/ ha)

Treatment	N, P and K uptake		
	N uptake	P uptake	K uptake
T_1 : Control (soil test based nutrient management)	116.23^{f}	17.04^{cd}	125.64^{de}
T_2 : Nano NPK 4 G granules (4:4:4)	125.73^{e}	17.83^{cd}	134.30^{d}
T_3 : T_1 + Nano NPK 4 G foliar @ 0.5%	164.25^{d}	20.79^{bc}	170.73^{c}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	170.10^{c}	21.35^{bc}	220.09^{b}
T_5 : T_2 + Nano NPK 4 G foliar @ 0.5%	190.71^{b}	23.91^{b}	203.91^{b}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	223.15^{a}	29.93^{a}	255.47^{a}
T_7 : Organic POP (KAU, 2009)	83.70^{h}	12.47^{de}	89.55^{f}
T_8 : Organic POP + Nano NPK foliar @ 0.5%	105.10^{g}	14.30^{de}	110.37^{e}
T_9 : Absolute control	55.35^{i}	10.03^{e}	74.16^{f}
SEd	3.78	2.64	8.51
CD (0.05)	8.02	5.61	18.02

All the treatments differed significantly with each other. Nitrogen uptake was significantily maximum in T_6 followed by T_5. Minimum N uptake was recorded in T_9 (Absolute control). Phosphorous uptake was maximum in T_6 followed T_5. Minimum value was recorded absolute control (T_9). Potassium uptake was significantily maximum in treatment T_6 followed by T_4 which was on par with T_5. The minimum value was recorded in absolute control (T_9). N, P and K uptake maximum and the minimum were recorded in T_6 and T_9 respectively, Nano NPK granule with 19:19:19 foliar was spray significantly superior to other treatments.

4.3. QUALITY ANALYSIS OF FRUIT

The data on ascorbic acid and oleoresin content are presented in Table 26.

Table 26. Effect of various treatments on ascorbic acid and oleoresin content of fruit

Treatments	Ascorbic acid content (mg 100g)	Oleoresin content (%)
T_1 : Control(soil test based nutrient management)	49.62^{d}	10.09^{cde}
T_2 : Nano NPK granules	63.70^{bc}	9.94^{de}
T_3 : T_1 + Nano NPK foliar @ 0.5%	70.20^{ab}	11.40^{bcd}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	68.90^{ab}	10.29^{cde}
T_5 : T_2 + Nano NPK foliar @ 0.5%	71.50^{ab}	12.20^{ab}
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	69.70^{ab}	11.44^{abc}
T_7 : Organic management	65.00^{ab}	9.11^{ef}
T_8 : Organic management + Nano NPK 4 G foliar @ 0.5%	72.20^{a}	12.90^{a}
T_9 : Absolute control	56.00^{cd}	7.89^{f}
SEd	2.31	1.35
CD (0.05)	8.23	1.47

The maximum ascorbic acid content was recorded in organic PoP with nano NPK foliar spray (T_8) which was on par with T_3, T_4, T_5, T_6 and T_7. The lowest value was recorded in soil test based nutrient management (T_1) which was on par with absolute control (T_9).

The maximum oleoresin content was recorded in organic PoP with nano NPK foliar spray (T_8) which was on par with nano NPK granule with nano NPK foliar spray (T_5). The lowest oleoresin content was recorded in absolute control (T_9).

4.4. YIELD PARAMETERS

The data on fruit yield parameters is presented in table 27. All the treatments had a significant effect on fruit yield parameters.

Table 27. Effect of various treatments on fruit yield per plant, fruit yield per plot and fruit yield per plot

Treatments	Fruit yield per plant (Kg/plant)	Fruit yield per plot (Kg/ plot)	Fruit yield per ha (t/ha)	% yield over control (%)
T_1 : Control(soil test based nutrient management)	2.0^{d}	24.0^{c}	14.21^{bc}	0
T_2 : Nano NPK granules	2.1^{d}	25.2^{c}	15.11^{b}	6.3
T_3 : T_1 + Nano NPK foliar @ 0.5%	2.3^{c}	27.5^{b}	15.86^{ab}	14.9
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	2.4^{c}	28.8^{b}	16.34^{ab}	11.6
T_5 : T_2 + Nano NPK foliar @ 0.5%	2.6^{b}	31.29^{a}	17.94^{a}	26.5
T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	2.9^{a}	34.69^{a}	18.25^{a}	28.0
T_7 : Organic management	1.3^{f}	15.5^{e}	10.58^{de}	-25
T_8 : Organic management + Nano NPK foliar @ 0.5%	1.5^{e}	18.6^{d}	11.93^{cd}	-16.1
T_9 : Absolute control	0.45^{g}	5.4^{f}	9.00^{e}	-43.5
SEd	0.72	0.81	0.74	

CD (0.05)	2.1	2.96	2.65	

The various nutrient management had a significant effect on fruit yield per plant. Maximum value of fruit yield per plant was recorded in treatment nano NPK granule with 19:19:19 foliar spray (T_6) followed by treatment T_5. The lowest value of fruit yield per plant was recorded in the absolute control (T_9). Nano NPK granule with 19:19:19 foliar spray was significantly superior to other treatments.

The significantly maximum value of fruit yield per plot and hectare was recorded in nano NPK granules with 19:19:19 foliar spray which was on par with nano NPK granule with nano NPK foliar spray.

Differential application of 19:19:19 foliar spray (T_6) and nano NPK foliar spray (T_5) along with nano NPK granules increased the fruit yield 28.07 % and 26.54 % respectively over control (T_1). Foliar application of NPK 19:19:19 and nano NPK alone increased the fruit yield by 14.9 and 11.6% respectively over control. Organic management (T_8) and organic management with nano foliar spray (T_7) recorded 25.54 and 16.04 % lesser fruit yield than control (T_1)

4.5. BENEFIT COST RATIO

Data on benefit cost ratio is presented in table 28. Different treatments had a significant effect on benefit cost ratio.

Table 28. Effect of various treatments on benefit cost ratio

Treatment	Benefit cost raio
T_1 : Control(soil test based nutrient management)	1.1^{e}
T_2 : Nano NPK granules	1.25^{d}
T_3 : T_1 + Nano NPK foliar @ 0.5%	1.49^{c}
T_4 : T_1 + NPK 19 : 19 : 19 foliar @ 0.5%	1.21^{c}
T_5 : T_2 + Nano NPK foliar @ 0.5%	1.61^{b}

T_6 : T_2 + NPK 19 : 19 : 19 foliar @ 0.5%	1.73[a]
T_7 : Organic management	0.63[g]
T_8 : Organic management + Nano NPK 4 G foliar @ 0.5%	0.79[f]
T_9 : Absolute control	0.48[h]
SEd	0.02
CD (0.05)	0.06

Significantily maximum benefit cost ratio (1.73) was recorded in treatment T_6 (nano granule with 19:19:19 foliar spray) followed by treatment T_5 1.61 (nano granule with nano NPK foliar spray) compared to control.

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DISCUSSION

5. DISCUSSION

The results of the influence of different nutrient managements on morphological, physiological, yield and fruit quality parameters of chilli were presented in the previous chapter. The significant experimental results obtained are discussed in this chapter with a possible explanations.

5.1. Effect of treatments on morphological characters

Plant height was significantly affected by various nutrient management. At all growth stages the maximum and minimum plant height were recorded in treatment T_6 and T_9 respectively (Fig.2). Nano NPK granule with 19:19:19 NPK foliar spray (T_6) was significantly superior to other treatments followed by nano NPK granule application with nano NPK foliar spray (T_5). Treatment T_6 showed 18 per cent increase in plant height compared to control. These results are in conformation with Meena *et al.,* 2017, Plant height is an important morphological parameter which is directly influenced by nano fertilizer. The nano fertilizer has an influence on the modification of plant gene expression and biological pathways that affect the plant hight. Nano fertilizer was shown to have a direct trend in the increase in plant height in cotton (Rochester *et al*., 2001). The foliar application of 19:19:19 NPK enhanced various physiological and metabolic activity which increased the plant height in orange (Hipps, 1997 ; Tredes, 2012).

During all three crop stages, the maximum leaf area per plant was noted in treatment T_6 followed by treatment T_5 (Fig. 3). Leaf area per plant increased from 45 days after transplanting (DAT) to 105 DAT. Nano NPK granule with 19:19:19 NPK foliar spray (T_6) was significantly superior to other treatments followed by nano NPK granule application with nano NPK foliar spray (T_5). This result is in conformity with Sabir *et al*. (2014) where increase in the absorption of nitrogen by using nano

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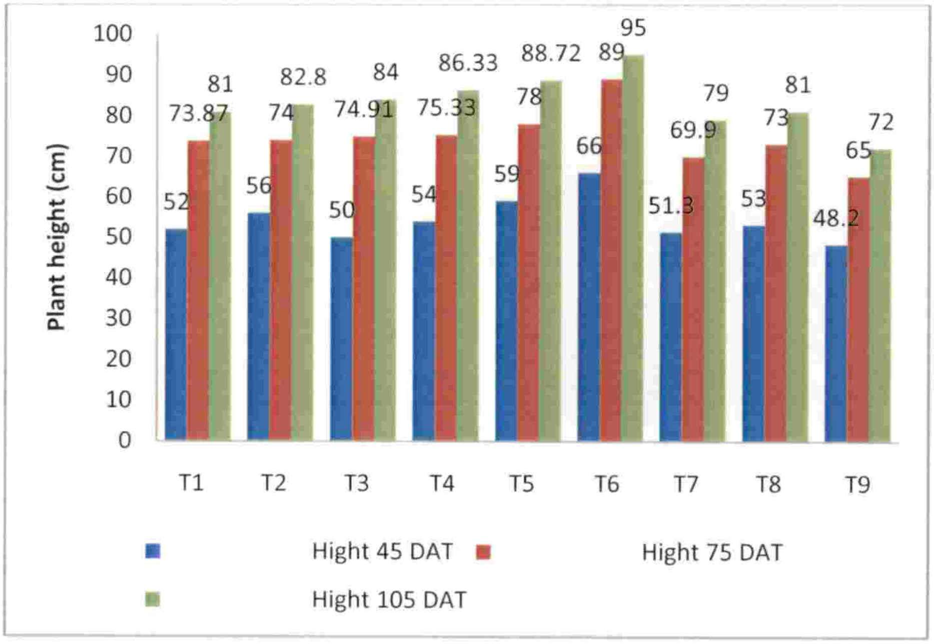

Fig. 2. Effect of treatments on plant height

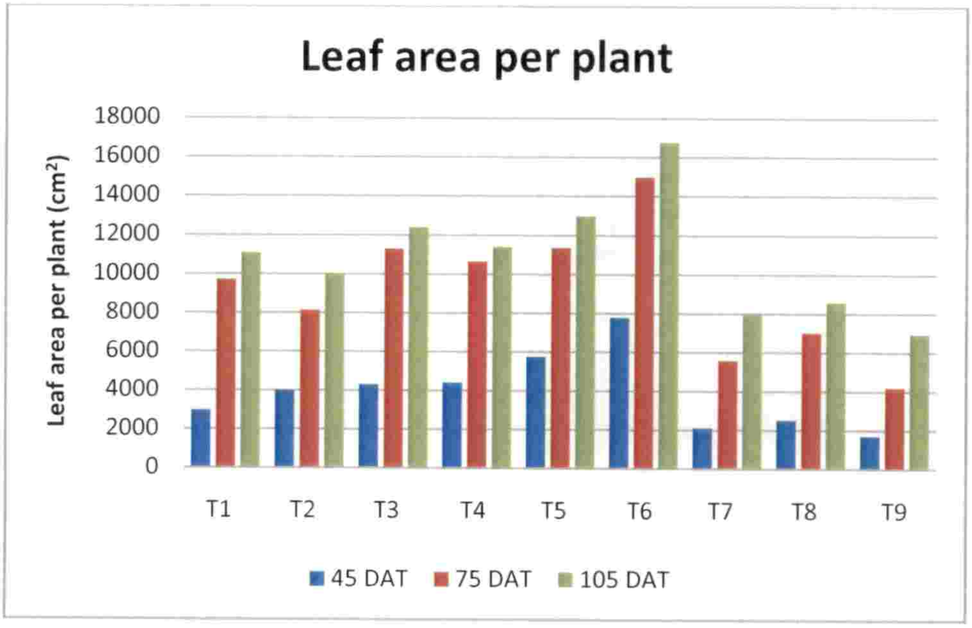

Fig. 3. Effect of treatments on leaf area per plant

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NPK fertilizer enhanced the vegetative growth which leds to an increase in the leaf area per plant. Increase leaf area per plant was due to the availability of NPK at a critical stage and more concentration in carrot (Naik *et al.,* 2002).

In all growth periods, the maximum and the minimum number of leaves per plant was recorded in T_6 and T_9 respectively (Fig. 4), also an increasing trend was observed from the initial stage to the final stage of the crop growth. Nano NPK granule with 19:19:19 foliar spray (T_6) was significantly superior to control in all stages. Similar result was also noticed by Sabir *et al.* (2014). These result is in conformity with Abedo *et al.* (2012) where they noticed that increased number of leaves with increased in the nitrogen uptake which was a major factor for yield determinant.

Number of branches per plant increased from the initial growth phase to the final growth phase. Nano NPK granule with 19:19:19 NPK spray (T_6) registered better result followed by treatment T_5 than control.

Nano NPK granule with 19:19:19 NPK spray (T_6) first attained 50 % flowering which had take only 45 days for attaining 50 % flowering followed by treatment T_5 (50 days). Similar results was also noticed by Tredes (2012) in wheat application of nano fertilizer enhanced physiological and metabolic activity and also changed the gene expression which led the transition from vegetative to floral characters.

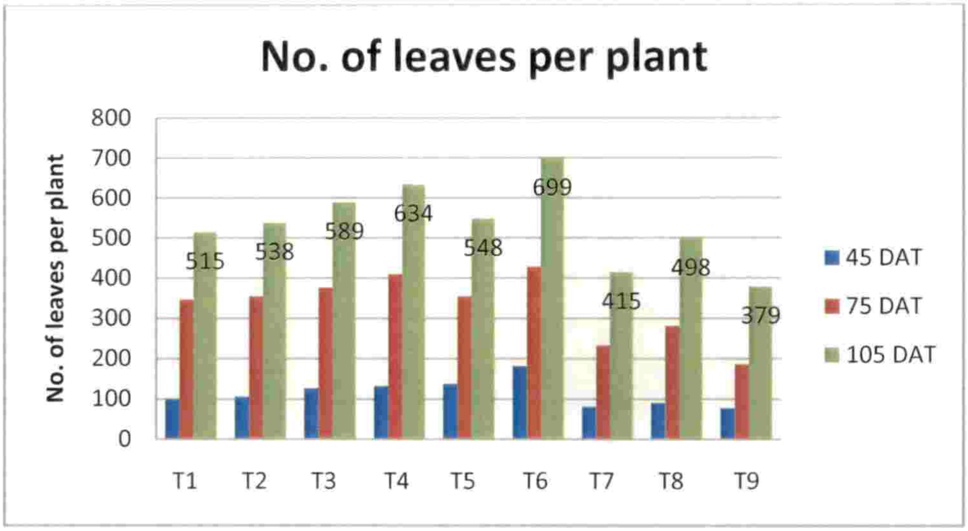

Fig. 4. Effect of treatments on the number of leaves per plant

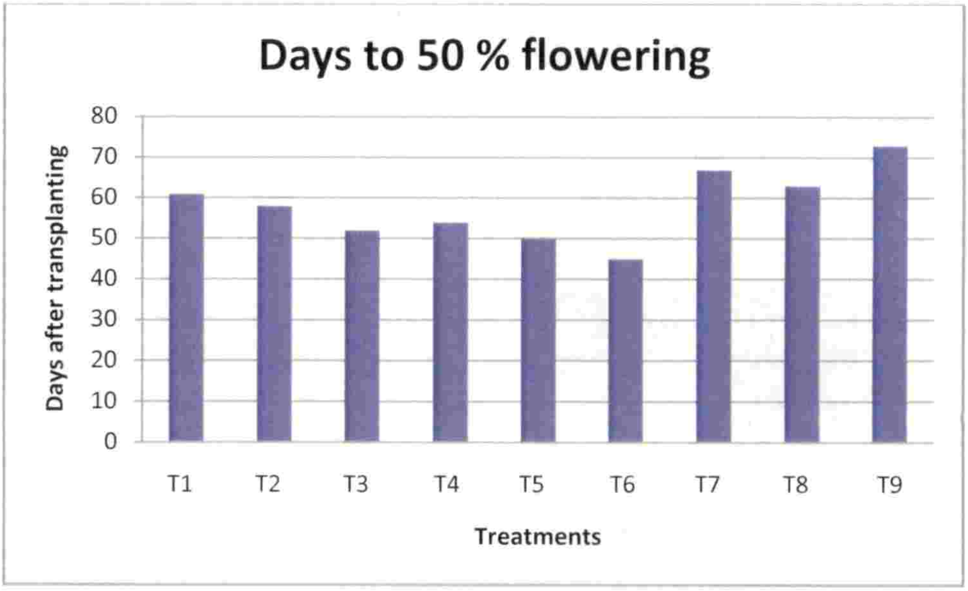

Fig. 5. Effect of treatments on days to 50 % flowering

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Minimum number of days for the first harvest was required in the treatment T_6 which was significantly superior to other treatments followed by T_5 (Fig.6). So nano NPK granule with 19:19:19 NPK foliar spray influenced early harvest of the crop. Similar results were also noticed by Liu and Lal, 2014 in cabbage, tomato and egg plant indicated that the nano fertilizer had a role in the early harvest of the vegetables that comes to the market 5 to 7 days ahead. The foliar application of nano NPK enhanced the earliness of harvest in sunflower (Savan *et al* ., 2018). Nano granules with foliar application of 19:19:19 NPK spray helped for early harvest, this might be due to the effect of phosphorous which led to enhanced the maturity in rice (Bhowmick *et al.,* 2014).

The maximum duration of the crop was recorded in treatment T_5 followed by T_6. So the nano NPK granule with nano NPK foliar spray (T_5) significantly enhanced the duration of the crop (Fig.7). Similar result was also noticed by Subramanian and Rahale, (2000) nano NPK fertilizer is slow releasing fertilizer. Nano fertilizer release nitrate form of nitrogen 50 days slower than conventional fertilizer. Increased nitrogen application enhances the vegetative growth which increases the duration of the black gram crop (Kumar and Ratna, 2003). Bhowmick *et al.*, 2014 also reported that the nano foliar application has an impact on physiological activities which reduced the leaf senescence and improved the growth duration of the rice crop.

Nano NPK granule with 19:19:19 NPK foliar spray (T_6) significantly enhanced the number of fruits per plant (Fig.8). The maximum number of fruits per plant was recorded in T_6 followed by T_5. These results are in conformity with Phandi, 2010 in bhindi increases in the number of fruits per plant was due to more assimilation of nutrients which increased uptake of nutrients and water which lead to increase photosynthesis enhancing assimilates to accumulate into more number of fruits per plant.

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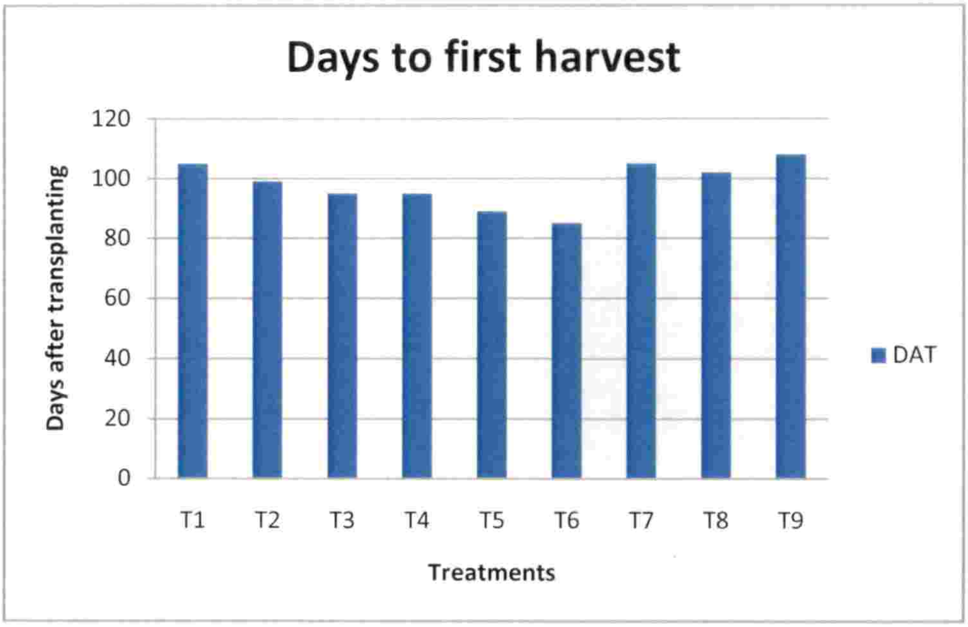

Fig. 6. Effect of treatments on days to the first harvest

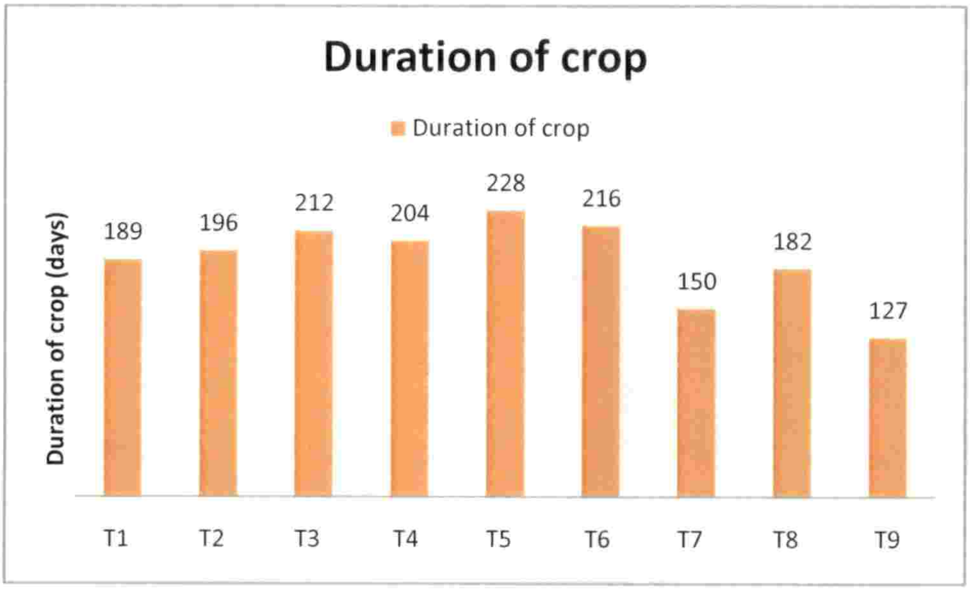

Fig. 7. Effect of treatments on the duration of crop

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At all three crop development stages, the maximum and minimum value of root volume was recorded in T_5 and T_9 respectively. So nano granules with nano foliar spray (T_5) was recorded significantly superior to other treatments followed by (T_6). The root volume increased from the initial growth stage to the final growth stage. The same result noticed by Ghosh and Malic, 2001, in *Nigella sativa* nano Potassium fertilizer had a prominent role in the increase root volume which resulted in higher plant growth. Nano fertilizer enhanced the root fresh weight, dry weight and volume due to more response of root for nutrient uptake from the soil.

The maximum fruit length was observed in treatment T_6 (nano NPK granule with 19:19:19 NPK spray) was superior in compared with other treatments. These result is in conformity with Armin *et al.* (2014) in okra application of nano nitrogen, phosphorous and potassium helped to attain more vigour, early flowering and large size fruits, potassium had a major role in increasing the diameter and length of fruit.

The low pest and disease infection were recorded in treatment with Nano NPK granule with 19:19:19 NPK spray (T_6) and Nano NPK granule with nano NPK spray (T_5) than other treatments. The same result noticed by Basu *et al.*, 2012 in rice, nano fertilizer was responsible for the production of total phenolic content which is a secondary metabolite, responsible for enhancing pest and disease resistance.

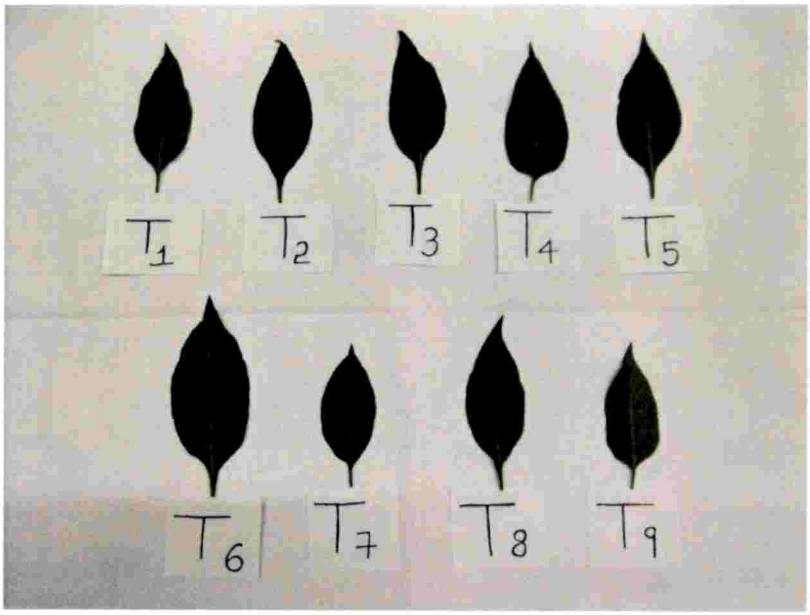
Leaf eating caterpillar

White fiy attack

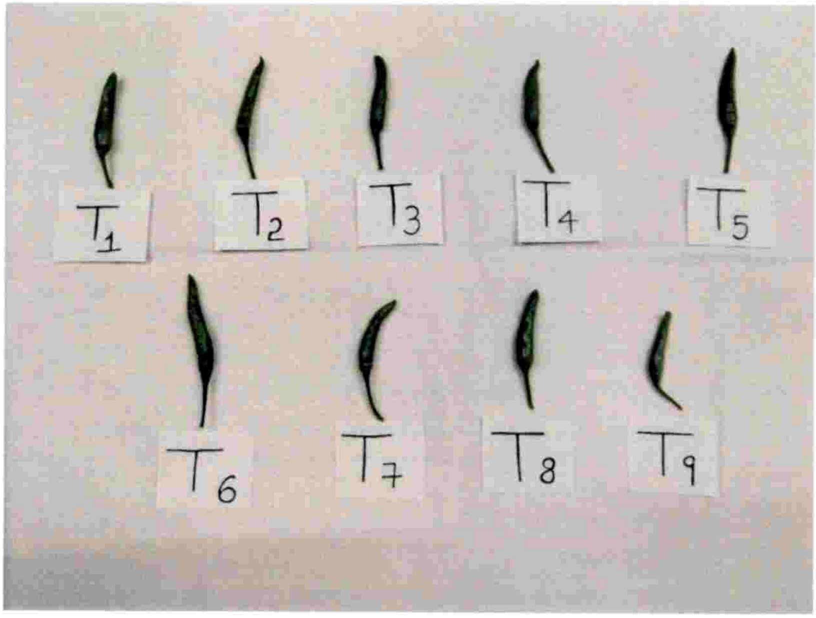
Grasshopper attack

Anthracnose fruit rot

Plate 7. Pest and disease infection on chilli observed during study



A. Effect of different treatments on leaf morphology



B. Effect of different treatments on Fruit morphology

Plate 8. Effect of different treatments on leaf morphology (A) and fruit Morphology (B)

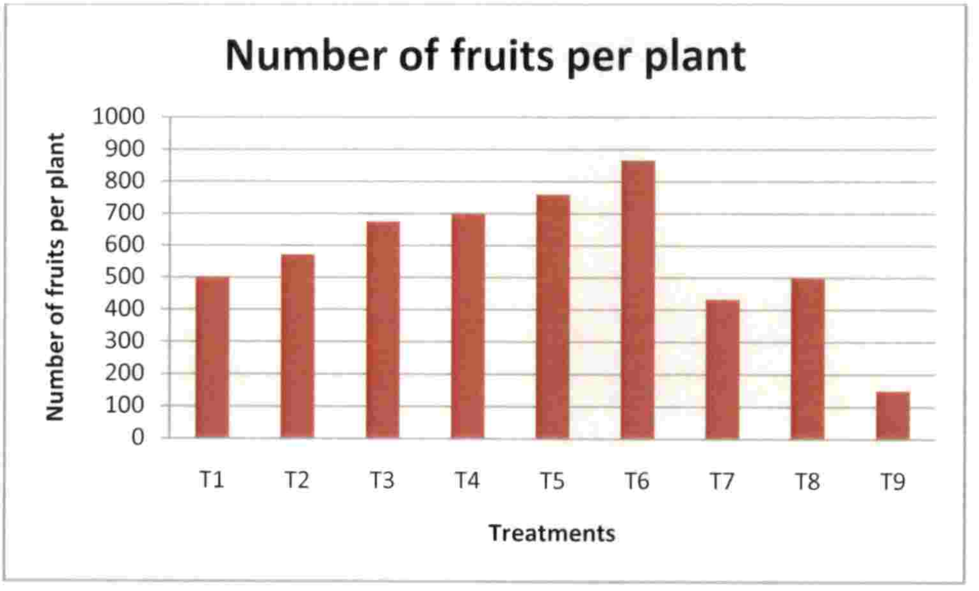


Fig. 8. Effect of treatments on the number of fruits per plant

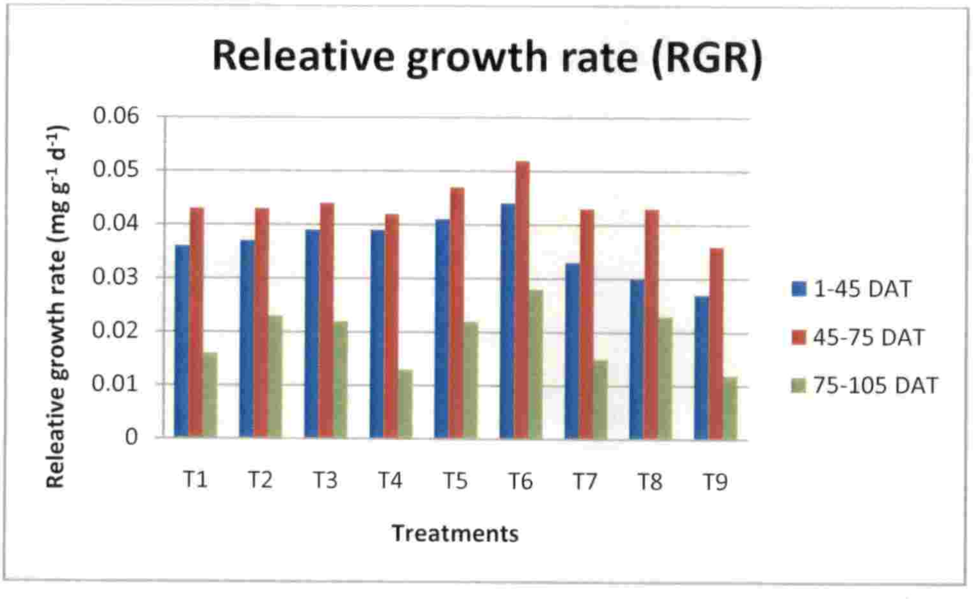


Fig. 9. Effect of treatments on the relative growth rate (RGR)

5.2. Effect of treatments on physiological characters

During 1 - 45 DAT, the relative growth rate was non significant in all treatments. Maximum relative growth was recorded in treatment T_6 during the growth period range to 45 to 75 DAT (Fig. 9). At 75-105 DAT, the maximum relative growth rate was observed in T_5 and T_3. The relative growth rate increased from the initial stage of the second growth period then decreased to the final stage of the growth period. Relative growth rate was relatively higher at the early stage of the growth period then it will decreased. Janki *et al.*, 2006 also reported that better relative growth rate in cotton results from better absorption and utilization of nutrients at the critical stage of the crop growth.

At 45 and 75 DAT, the maximum specific leaf weight was recorded in treatment with the application of nano granule with 19:19:19 NPK fertilizer application (T_6). At 105 DAT the maximum specific leaf weight was recorded in T_4 and T_6. Sabir *et al.*, 2014 in sunflower also reported that specific leaf weight increases from the initial growth stage to the final growth stage. Nano NPK fertilizer reduces the fertilizer losses which led to better the absorption and translocation which enhanced the specific leaf weight.

In all growth stages the maximum leaf area index was recorded in T_6. Leaf area index increases from the initial growth stage to the final growth stage. These result in conformation with Wajid *et al.*, 2017, in *Vigna radiata* nitrogen availability enhanced the photosynthesis, leaf expansion and leaf persistence. LAI hardly nitrogen sensitive and directly related to the leaf expansion. More leaf area index may be due to effect of nano fertilizer on specific leaf area and density in mung bean (Dhoke *et al.*, 2013).

Nano NPK granule with 19:19:19 spray (T_6) gave the highest leaf area duration followed by treatment T_5 compared to other treatments in all stages of the growth period (Fig 10). Wajd *et al.*, 2017 also supported that in *Vigna radiata* nano NPK granule with 19:19:19 spray enhances the availability and utilization efficiency of nitrogen fertilizer which enhanced the leaf area duration.

Nano NPK granule with foliar nano NPK spray (T_5) significantly affected leaf relative water content at all crop stages. These same results also observed in Shabala and Lana, 2011, in tomato reported that foliar application of NPK maintained the water content in the plant by osmotic adjustment.

In all treatments the dry matter production was increased from the initial growth stage to the final growth stage (Fig. 11). Nano NPK granule with 19:19:19 NPK spray (T_6) and Nano NPK foliar spray with nano NPK granule application (T_5) significantly affected the total dry matter production compared to other treatments. Wajid *et al.*,2017, in *Vigna radiata* supported that nano N, P and K influences the dry matter production directly compared to conventional fertilizer. The leaf growth was directly related to the nitrogen content, Phosphorous promotes root growth and shoot growth in wheat (Ge *et al.*, 2009). Higher dry matter production indicates higher plant height, more number of tillers per unit crop area and leaf area index. More leaf area index will harvest more solar radiation which is essential for dry matter production in wheat (Armin *et al.*, 2014). Supply of water soluble 19:19:19 fertilizer enhanced the dry matter production. Prabhavathi *et al.* (2009) in chilli due to higher uptake of nutrients. Similar results were also observed by Rahman and Venkataramana (2006) in green gram. Increase in the metabolic and physiological process enhanced the vegetative growth and dry matter production in apple (Hipps, 1997; Tredes, 2012).

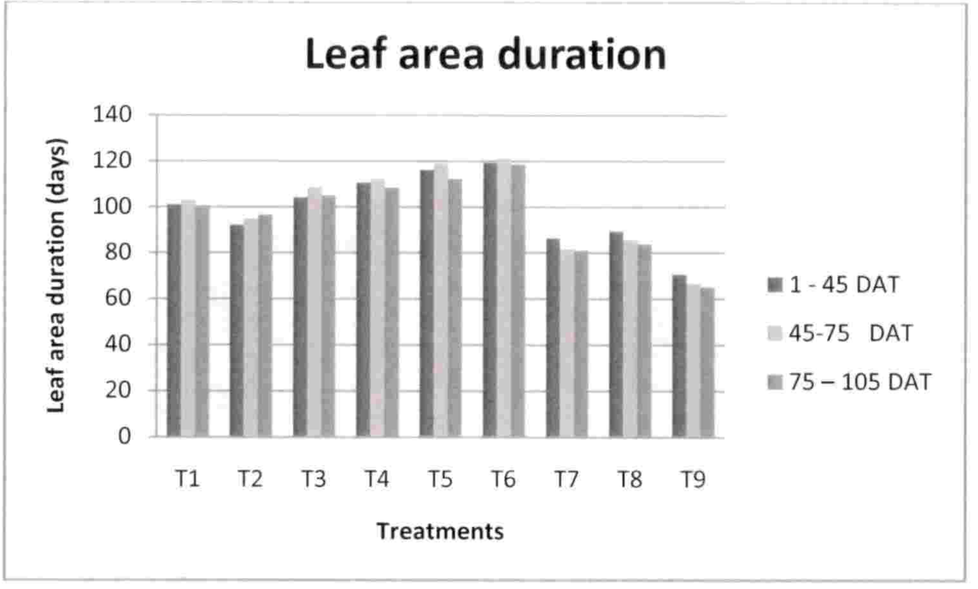


Fig. 10. Effect of treatments on leaf area duration

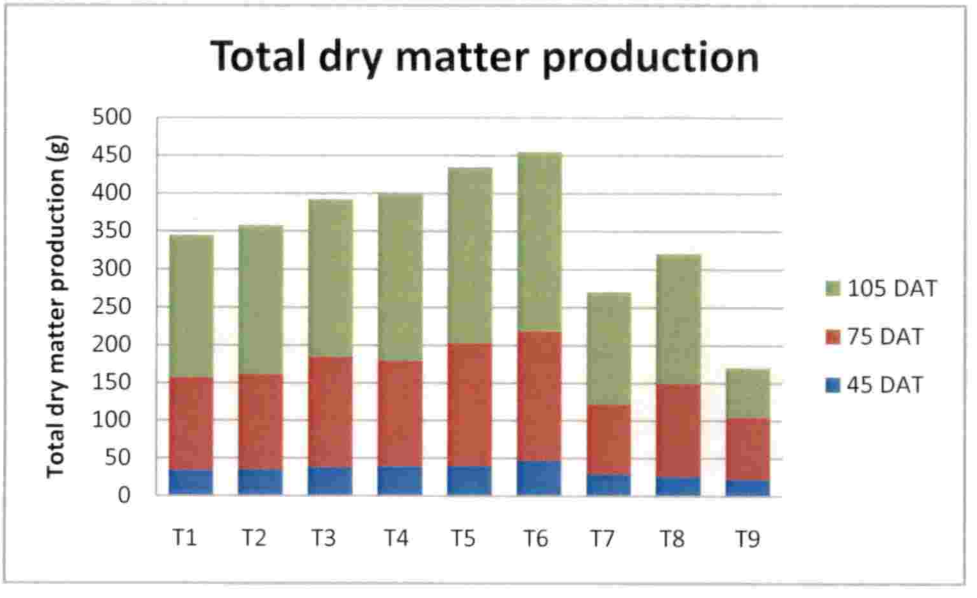


Fig. 11. Effect of treatments on total dry matter production

In case of transpiration, all treatments were on par except T_9. Different fertilizer application had affected stomatal conductance. At 45 and 75 DAT, the highest stomatal conductance observed in T_4 and T_6. At 105 DAT, the maximum transpiration recorded in T_6. In case of stomatal conductance, the nanogranule with 19:19:19 NPK spray (T_6) had higher value compared to other treatments. Leuning, 2005 reported that the rate of photosynthesis depends on supply of CO_2 and higher stomatal conductance which was increased by leaf temperature and intensity of light. Application of nano NPK fertilizer enhanced the transpiration rate and stomatal conductance (Zoni *et al.*, 2006), there by enhancing the photosynthesis. Low accessibility of NPK reduced the activity of ATP synthase and Rubisco. It reduces the transpiration rate and stomatal conductance (Toth *et al.*, 2002). Stomatal closure leads to reduce the carbon uptake by leaves, it reduces the photosynthesis (Cornic and Massacci,1990). Potassium has a role in closing and opening of stomata which control the CO_2 movement in and out of the stomata (Bednarz *et al.*, 1998). Potassium fertilizer application improves photosynthesis by enhancing intercellular CO_2 concentration (Zhu *et al.*, 2012). Phosphorous fertilizer encourages stomatal conductance and water use efficiency (Dos-Santos *et al.*, 2004)

The different fertilizer management sinfluenced the chlorophyll content (Fig. 12). Nano NPK granule with 19:19:19 foliar spray (T6) significantly affected the chlorophyll content followed by (T_5) than other treatments. At first two stages of growth, chlorophyll content increased then decreased. But in the case of foliar sprayed treatments (T_3, T_4, T_5 and T_6), the chlorophyll content increased at all three stages of the crop growth. Hopkins and Huner, 2004 in tomato reported that chlorophyll is a light harvesting pigment which is responsible for photosynthesis. Higher nitrogen content means higher chlorophyll content which prevents premature senescence. Nitrogen is an important constituent of many components like protein, chlorophyll, enzymes and nucleic acids which are integral components for growth and development in pear (Sah *et al.*, 2014).

Data revealed that the different fertilizer managements had an influence on quantum yield (Y (II)). So the nano NPK granule with 19:19:19 foliar spray (T_6) had a significant effect in the last two growth stage of the crop compared to other treatments. Y II represents the amount of energy used by photosystem II under steady state photosynthetic light condition which indicates the photosynthesis efficiency of PS II under light. Nano NPK granule with 19:19:19 foliar spray (T_6) was found to significantly affect the Fv/Fm value. Maxwell and Johnson, 2000 reported that Fv/Fm represents the maximum quantum efficiency of photosystem II. Nano granule with 19:19:19 foliar spray (T_6) had a significant effect ETR value compared to other treatments. ETR is a indicator to evaluate the photosynthetic activity of leaves (Haimeiong *et al.*, 2002)

Nano NPK granule with 19:19:19 spray (T_6) had a significant effect in N, P, K content in the whole plant. N, P and K uptake were recorded maximum in T_6 followed by T_5. Nano NPK granule with 19:19:19 foliar spray (T_6) was significantly superior to other treatments followed by nano NPK granule with nano NPK foliar spray (T_5). These result is in conformity with Jinghua, 2004, application of nano fertilizer consists of N, P, K, micronutrients, mannose and amino acid which enhances the nutrient uptake and nutrient use efficiency of fertilizer. Nano NPK fertilizer dissolved in water more efficientily which enhanced the nutrient uptake in rice (Liscano *et al.*, 2000). Nano sized fertilizer increases fertilizer use efficiency and uptake rate of the soil nutrients in crop production. This is due to the high surface area to the volume ratio, the solubility of fertilizer is high, small size and high mobility which lead to high specific targeting (Sasson *et al.*, 2007). Foliar fertilization enhanced uptake of nutrients, translocation and utilization (Beaton and

Espinosa,1996)

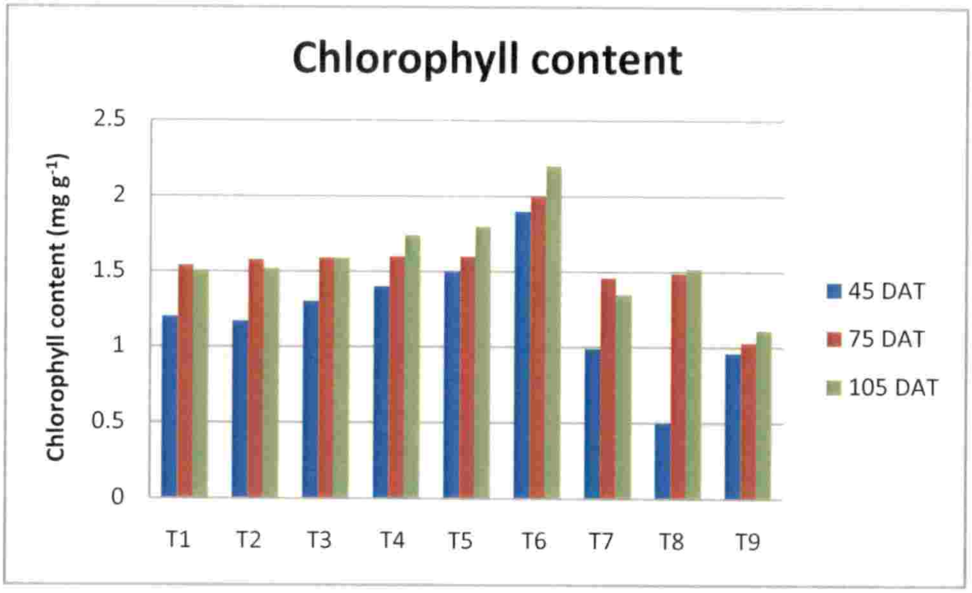


Fig. 12. Effect of treatments on chlorophyll content

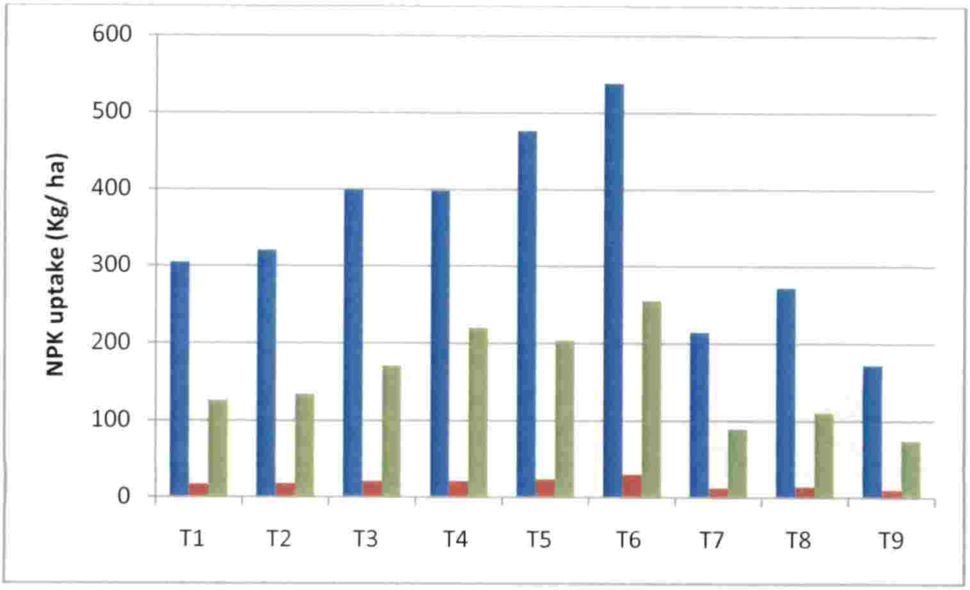


Fig. 13. Effect of treatments on NPK uptake

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5.3. Effect of treatments on fruit quality parameters

The maximum value of ascorbic acid and oleoresin was recorded in treatment T_8 (organic management with nano NPK foliar) was on par with T_3, T_4, T_5, T_6 and T_7. The lowest value was recorded in soil test based nutrient management (T_1) which was on par with absolute control (T_9). So the organic management with nano NPK (T_8) foliar spray have a significant effect on oleoresin content (Fig. 14).

The important quality parameter in chilli is ascorbic acid and oleoresin content. Sanctez *et al.* (1993) reported that ascorbic acid is an antioxidant which acts as a natural protector of pigment stability. The application of organic manure with inorganic fertilizer increases the ascorbic acid content in green chilli. This might be due to an increase in the availability and utilization of plant available nutrients and favourable condition due to the applied FYM. A positive correation between potassium content of capsicum fruit and ascorbic acid was supported (Kaminwar and Rajagopal, 1993). Application of FYM, enhanced the ascorbic acid content as reported by Chavan *et al.* (1997) and Sashidara (2000) in chilli crop. The application of FYM and vermicompost increases the ascorbic acid content (Vijayakumar *et al.,* 2007). Balakrishna (1990) and Hassan *et al.* (2019) reported that organic cultivation of chilli enhances the organic matter content in the soil which enhances ascorbic acid content in chilli.

Oleoresin content was significantily effected the FYM content. Oleoresin content was attributed by more uptake of potassium in chilli (Malawadi *et al.*, 2003).Sandhoshkumar and Shashidara (2006) reported that higher FYM application increases the ascorbic acid and oleoresin content. Thimma *et al.* (2006) reported that FYM and vermicompost application enhances the oleoresin content from 2.30 % to

14 % in carrot. Application of nutrient particularly potassium have a major role in oleoresin content of fruit (Hosmani, 1993).

5.4. Effect of treatments on yield parameters

The different treatment had a significant effect on fruit yield per plant. The maximum fruit yield per plant was recorded in treatment nano NPK granule with 19:19:19 foliar spray (T_6) followed by treatment T_5 (Nano granule with nano foliar spray). The lowest value of fruit yield per plant was recorded in treatment absolute control. Nano NPK granule with 19:19:19 foliar spray (T_6) was significantly superior to other treatments. The maximum value of fruit yield per plot and per hectare was recorded in nano NPK granules with 19:19:19 foliar spray (T_6) which was on par with nano NPK granule with nano NPK foliar spray (T_5).

Qiang *et al.*, (2008) reported that, the slow release of nano NPK increased the fruit yield. Nano NPK fertilizer enhanced the number of fruiting branches, photosynthetic rate, chlorophyll content and dry matter production resulted in an overall improvement in fruit yield. Foliar application of 19:19:19 enhanced the fertilizer use efficiency that leads to an increase in the photosynthesis rate which enhanced the yield of the rice crop (Sarkar and Roychoudhery, 2003). A similar response in tomato was reported by Palaniappan *et al.*, (1999). The present findings are in agreement with Rahman *et al.*, 2014 and Kumar *et al.*, (2008).

Maximum benefit cost ratio (1.73)was recorded in treatment T_6 (nano granule with 19:19:19 foliar spray) followed by treatment T_5 (nano granule with nano NPK foliar spray (1.61) compared to other treatments. The same result also observed by Afzal *et. al.* (2017) in wheat, small amount of nano fertilizer needed for the sufficient metabolic activity in plant and also had high nutrient uptake and nutrient use efficiency,led to increase the benefic cost ratio

Plate 9. Effect of different treatments on fruit yield

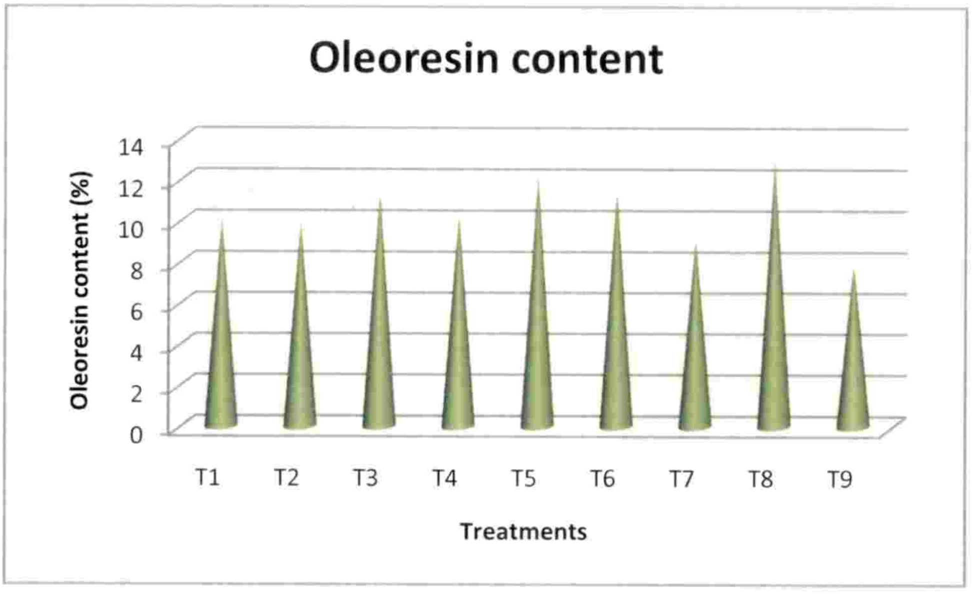

Fig. 14. Effect of treatments on oleoresin content

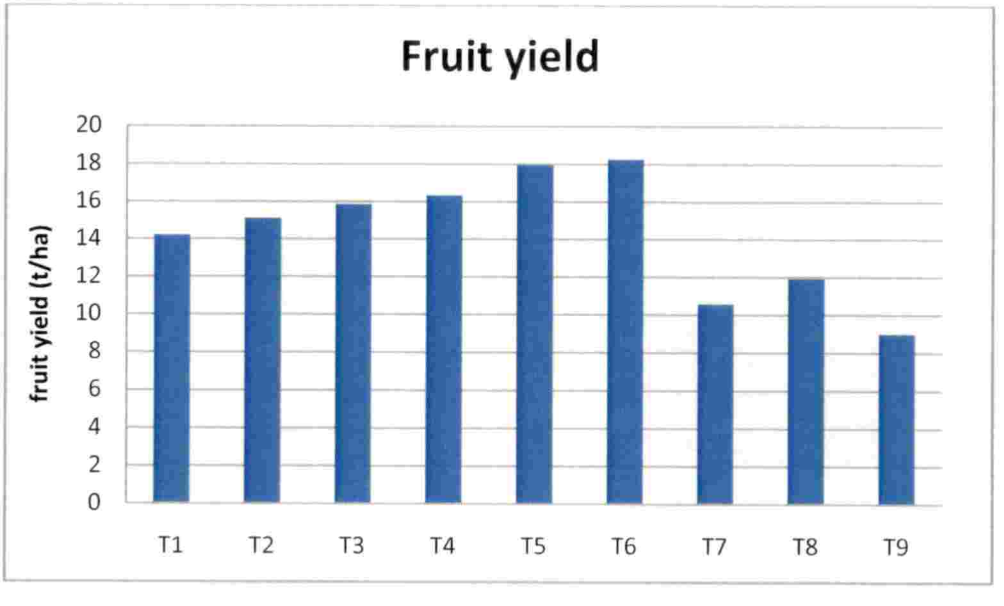

Fig. 14. Effect of treatments on fruit yield per plant

SUMMARY

6. SUMMARY

Agriculture sector presently using a high amount of fertilizer than optimum dose for getting a high yield from the unit area crop leads to environmental problems and low nutrient use efficiency. Overuse of this chemical fertilizer does not guarantee more yield but affects the soil quality and lead to underground water pollution. This problem can be solved by increasing the nutrient use efficiency and reducing the application of the overdose of chemicals. Nanotechnology is a newly emerging tool for solving these problems without compromising the yield. Nano fertilizer has less than 100 nm size, due to small size they have a higher surface area. It is also highly soluble in water and plant can easily absorb the nutrients. Encapsulated nano fertilizer increases the uptake of nutrients which releases the nutrient slowly and nutrient can be used for a longer time and reduce the nutrient losses from leaching and volatilization losses.

The research work titled "Physiological studies on growth, yield and quality enhancement of chilli (*Capsicum annum* L.) under different nutrient management" was carried out at Regional Agricultural Research Station, Pillicode, Kerala Agricultural University from September 2018 to May 2019.

The results indicated that the application of nano NPK granule with 19:19:19 foliar spray (T_6) and nano NPK granule with nano NPK foliar spray (T_5) improve morphological, physiological, yield and quality parameters compared to other treatments.

The salient finding of the study

- Morphological characters like plant height and number of leaves per plant were maximum in T_6 (nano NPK granule with 19:19:19 foliar spray) followed by T_5 (nano NPK granule with nano NPK foliar spray)

- Integrated use of nano NPK granules with nano NPK foliar spray application (T_5) enhanced the duration of crop and increased the root volume followed by T_6 .

- Crop duration was increased by 20.6 % in T_5 (228 days) followed by treatment T_6 over control (189 days)

- Higher values of growth indices such as releative growth rate (RGR), specific leaf weight (SLW), leaf area index (LAI) and total dry matter production were observed in T_6 followed by T_5

- Physiological parameters such as transpiration rate, stomatal conductance, chlorophyll content, leaf relative water content, Y(II), Fv/Fm and ETR were recorded maximum in T_6 compared to other treatment.

- Yield parameters such as number of branches per plant, number of fruits per plant and fruit length were recorded higher in T_6 followed by T_5

- Combined application of nano NPK granules with NPK 19:19:19 foliar spray (T_6) increased the fruit yield by 28 %, while nano granule with nano foliar spray (T_5) contributed to 26 % increased over yield control (T_1).

- Treatment T_7 (organic management) and T_8 (organic management with nano foliar spray) decreased fruit yield by 25 % and 16 % respectively than control (T_1).

- The fruit quality parameters like ascorbic acid and oleoresin were higher in T_8

Future line of work

- Study the effect of nano fertilizer on drought tolerance
- Optimizing dose and time of nano fertilizer
- Study the degradation process of nano fertilizer to identify the environmental hazardous
- Elucidate the mode of action of nano fertilizer

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Abstract

PHYSIOLOGICAL STUDIES ON GROWTH, YIELD AND QUALITY ENHANCEMENT OF CHILLI (*Capsicum annum* L.) UNDER DIFFERENT NUTRIENT MANAGEMENT

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ABSTRACT OF THE THESIS

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Physiological studies on growth, yield and quality enhancement of chilli (*Capsicum annum* L.) under different nutrient management

Abstract

Chilli is a very important vegetable crop and has a great demand in the processing industry and export market. Chilli crop is more responsive to fertilizer application. Application of fertilizers in excess not only causes environmental problems but also reduces nutrient use efficiency, increases the cost of production and reduces the benefit-cost ratio. Nanotechnology is a newly emerging tool for solving these problems. Nano fertilizer has a particle size less than 100 nm. Due to its small size and water soluble nature it is easily absorbed by plants. The present study was carried out to understand the influence of soil and foliar application of nano NPK fertilizer and to compare with conventional fertilizers on growth, yield and quality attributes of chilli.

The investigation on " Physiological studies on growth, yield and quality enhancement of chilli (*Capsicum annum* L.) under different nutrient management " was conducted at Regional Agricultural Research Station, Pillicode from September, 2018 to February, 2019. The experiment consisted of nine treatments with three replications laid out in randomized block design. The treatments were T_1 : Control (soil test based nutrient management); T_2 : Nano NPK granules (4:4:4); T_3 : T_1 + Nano NPK foliar @ 0.5 %; T_4 : T_1 + NPK 19:19:19 foliar @ 0.5 %; T_5 : T_2 + Nano NPK foliar @ 0.5 %; T_6 : T_2 + NPK 19:19:19 foliar @ 0.5 %; T_7 : Organic POP (KAU, 2009); T_8 : Organic POP + Nano NPK foliar @ 0.5 % and T_9 : Absolute control. Nano NPK granules were applied as a basal dose and also as top dressing at 30 and 60 days after transplanting @ 0.33 g/plant. Foliar spray of Nano NPK and NPK 19:19:19 were given at 35, 65, 80 and 95 days after transplanting.

Morphological observations namely plant height, leaf area per plant, number of leaves per plant, number of branches per plant, number of fruits per plant and fruit length were recorded to be maximum in the treatment, nano NPK granule

with NPK 19:19:19 foliar spray (T_6) followed by nano NPK granule with nano NPK foliar spray (T_5). Integrated use of nano NPK granules with nano NPK foliar spray application (T_5) enhanced the duration of crop and increased the root volume followed by T_6 .

Higher values of growth indices such as RGR, LAI and total dry matter production was observed in T_6 (nano NPK granule and NPK 19:19:19 foliar spray) followed by T_5 (nano NPK granules with nano NPK foliar spray). Physiological parameters such as transpiration rate, stomatal conductance, chlorophyll content, leaf relative water content, specific leaf weight, quantum yield (Y(II)), Fv/Fm and electron transport rate (ETR) were statistically on par in all the treatments and was significantly higher than absolute control (T_9).

Differential application of NPK 19:19:19 foliar spray (T_6) and nano NPK foliar spray (T_5) along with nano NPK granules increased the fruit yield by 28.07 % and 26.54 % respectively over control (T_1).

Organic management (T_7) alone and organic management with nano NPK foliar spray (T_8) recorded 25.54 % and 16.04 % lesser fruit yield than control (T_1). However fruit quality parameters like ascorbic acid and oleoresin contents were maximum in the treatment receiving an organic management with a foliar spray of Nano NPK (T_8). Maximum benefit cost ratio (1.73) was recorded in treatment T_6 (nano granule with 19:19:19 foliar spray) followed by treatment T_5 (nano granule with nano NPK foliar spray (1.61) compared to other treatments.

The results obtained from the experiments indicated that the application of nano NPK fertilizer both as soil and foliar treatments has a direct positive effect on morphological and yield parameters, which is on par with the treatment involving soil application of nano NPK granules and NPK 19:19:19 foliar spray.

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