CUSTOMIZED FERTILIZER AND NUTRIENT SCHEDULING FOR OKRA (*Abelmoschus esculentus* (L.) Moench)

By

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(2014-11-215)

THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Customized fertilizer and nutrient scheduling for okra (*Abelmoschus esculentus* (L.) Moench)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University and Society.

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Yansing Luikham

LIST OF ABBREVIATIONS

%	-	per cent
@	-	at the rate of
B : C	-	Benefit Cost ratio
CF	-	Customized fertilizer
DAS	-	Days after sowing
et al	-	and others
FYM	-	Farm yard manure
i.e	-	that is
MOP	-	Muriate of potash
MSL	-	Mean Sea Level
NS	-	Non significant
OC	-	Organic Carbon
POP	-	Package of practices
RBD	-	Randomized Block Design
RDF	-	Recommended dose of fertilizer
STB	-	Soil test based

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INTRODUCTION

1. INTRODUCTION

Soil fertility depletion is now occurring at an alarming rate due to extensive mining of nutrient reserves. In order to maintain equivalent crop yields as in the preceding years, farmers apply more fertilizers each season specifying the decreasing response of crops to fertilizer (Rakshit *et al.,* 2012). The disproportionate rate of supplying fertilizers to obtain higher yield has proved to degrade the nutrient supplying capacity of the soil. The nutrient recommendation followed by farmers has been reported with nutrient depletion in long run especially micronutrients due to application of primary nutrients alone. This recommendation is based mainly on the nutrient deficiency magnitude of the soil and does not take into account the yield targets. The lack of recommendations on secondary and micro nutrients limits crop productivity and affects nutrient use efficiency of the crops.

Secondary and micronutrients are being depleted continuously mainly due to imbalanced application and mining of nutrients from the soil. Thus from single-plant nutrient deficiency in the past, multi-nutrient deficiencies in Indian soils has escalated, which have led to decline in soil and crop productivity. Thus, the concept of 'site-specific nutrient management' (SSNM) and development of customized and value-added fertilizers, especially micronutrient fortified fertilizers are required in this scenario (Prasad, 2012). Customized fertilizers (CF) are multi- nutrient carriers facilitating the application of the complete range of plant nutrients in right proportion to suit the specific requirements of a crop during its growth stages. It is formulated by combination of primary, secondary and micro-nutrients based on soil testing and crop requirement. The use of customized fertilizer aggravates the scope of site specific nutrient management and precision agriculture. The Central Fertilizer Committee has included customized fertilizers in the Fertilizer (Control) Order 1985 as a new category of fertilizers that are area/soil/crop specific (Dwivedi *et al.*, 2014). Nutrient management based on soil and crop is a repackaging of management concepts that have been developed and promoted for many years.

Balanced and efficient use of plant nutrients through value added customized fertilizers can help expanding the concept of nutrient management planning in improving soil health and soil productivity (Tiwari, 2010).

Okra is one of the most preferred vegetable crops used mainly for tender green pods. It is cultivated throughout the growing seasons in Kerala and is well adapted to sub-tropical and tropical regions of the world. Yield maximization of okra can be achieved by adequate application of fertilizers in right proportion and by scheduling of nutrients. Nutrient scheduling by split application of nutrient especially soluble fertilizers is an efficient way to reduce the nutrient losses and it further promotes the application of nutrients in a need based manner. The N, P and K availability for the plants has increased with application of split doses of nutrients over the conventional one time application. Application of N in split doses at every third picking is advantageous for getting high yield, for increasing number of harvest and to maintain size of okra fruit towards last harvest (Gopalakrishnan, 2007)

The use of customized fertilizer is limited in Kerala and other parts of the country are due to lack of awareness on its uses. The effect of split application of CF on improving the nutrient use efficiency and minimizing the nutrient loss from the soil needs to be studied. It is high time to experiment and test the use of CF in our situation. The present study is proposed against this backdrop with the following objectives:

1. To develop a customized fertilizer and nutrient schedule in okra.
2. To study techno-economic feasibility of customized fertilizer and nutrient scheduling in okra.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Multi nutrient deficiencies are becoming common in soil and the concept of balanced fertilization has travelled beyond their application of major nutrients alone. Customized fertilizers are multi nutrient carriers facilitating the complete range of plant nutrients in the right proportion to suit the specific requirement of a crop. The negative balance in soil due to deficiency of nutrients to attain higher future yield targets can be minimalized by implementing balanced fertilization, site-specific nutrient management and application of customized fertilizers. The nutrient scheduling by split application of nutrients helps to supply nutrients in need based manner.

Results of research available on effect of customized fertilizer and split application of nutrients on soil, crop growth and crop productivity, nutrient uptake, soil fertility changes, and economics are reviewed in this chapter.

2.1. Customized fertilizer

The decline in soil and crop productivity could be attributed to imbalanced use and mining of nutrients. Depletion of secondary and micronutrients has also led to deficiency of single nutrients in the past to multinutrient deficiency in Indian soils at present. The use of customized fertilizer to combat the problem of huge gap in nutrient supply could be achieved. Customized fertilizers are crop, soil and area specific fertilizers that ensure appropriate fertilization by maintaining soil health (Tiwari, 2010). The customized fertilizer may include 100 per cent water soluble fertilizers grades by combination of nutrients based on soil testing and requirement of crop and the formulation may be of primary, secondary and micro-nutrients (Rakshit *et al.*, 2012).The multi-micronutrient mixture application is more relevant under site specific nutrient management practices which will facilitate the application of a wide range of plant nutrients in right proportion required for different stages of crop growth (Hegde *et al.*, 2007). The priority areas for CF includes the areas with low yield, nutrient deficient areas, imbalanced use of fertilizers, large mining of soils nutrient reserves and those areas reported with multi-micronutrient deficiencies (Shivay, 2011).Customized fertilizers can maximize nutrient use efficiency and are ultimately programmed to improve soil fertility. Hence, they fall under the category of environmental friendly fertilizers (Rao and Rahman, 2011).

2.2. Preparation of customized fertilizer

Bulk blending is the simplest and the cheapest option for the preparation of customized fertilizer, which involves pure mixing of solid fertilizers in the ratio required to get the desired nutrient ratio. Compound granulation' or 'steam granulation' is another method to manufacture customized fertilizer which is formed purely by agglomeration process by using water, steam and heat in the dryer and the raw materials are in its solid form. This type is an intermediate between chemical route and bulk blending with higher investment costs than that required for bulk blending. In India, the compound granulation route is the most effective way for the promotion of customized fertilizer availability. Chemical granulation or complex granulation is a method for production of customized fertilizer where NPK's are produced primarily by a chemical reaction between ammonia and acid to form an ammonium sulphate or ammonium nitrate salt and then granulated with the addition of discrete K_2O either in solid form or even in some plants in a liquid form (FA1, 2011).

2.3. Balanced fertilization

Balanced fertilizer use is a profit maximizing approach in intensive irrigated farming. Balanced application of fertilizers supports soil fertility maintenance by supplying the required nutrients in proportion and thereby enhances soil physical, chemical and biological properties, thus providing superior base for plant growth and development. The disproportionate rate of supplying fertilizers to soil for the growth of plants to obtain higher yield has proved to degrade the nutrient supplying capacity of the soil.

Rakshit *et al.* (2012) reported that in order to maintain same crop yields as in the preceding years farmers are forced to apply more fertilizers each season, indicating the decreasing response of crops to fertilizer. Less fertile soil irrespective of the variety/hybrid, the farmer chooses could not produce better yield. The use of customized fertilizers is likely to boost crop yield and maintain the fertility of the soil in the long run. Balanced fertilization improves the nutrient use efficiency of the crops by preventing the loss of nutrients from soil. The balanced application of N, P, K, S and Zn through fertilizers heightens the yield attributes by inducing the activity of cell division by improving the meristematic activity, photosynthetic efficiency and by regulating the water intake of the cells (Singh *et al.*, 2008). According to Patel *et al.* (2009) reduction in crude fibre content might be due to high photosynthetic activity on application of the integrated form of organic and inorganic nitrogen fertilizers and enhanced availability of nitrogen by balancing the C: N ratio thereby improving the vegetative growth in okra.

2.4. Water soluble fertilizer

The recommended dose of NPK fertilizers along with water soluble fertilizer formulations viz., starter (11: 36: 24 NPK) and booster (8: 16: 39 NPK) recorded the tallest plant in tomato due to cell division and elongation (Krishnan *et al.*, 2014). Similarly increase in fruit weight and fruit volume were recorded which may be attributed to effective utilization and accumulation of photosynthates in the economic part of the plant. Similar results of higher yield parameters in brinjal were reported by Narayanamma *et al.* (2006). Water soluble fertilizer (19: 19: 19) at 1.0 per cent foliar spray at peak flowering and pod development stages of *Cajanus cajan* recorded highest yield of 1661 kg ha^{-1}, which is associated with increase in number of pods per plant, pod weight per plant and yield per plant with higher dry matter production (Mallesha *et al.*, 2014). Better branching on application of water soluble fertilizers (NPK 19 : 09: 19) was observed at early stages of growth as higher number of axillary buds were encouraged due to higher doses of nitrogen and phosphorus in tomato and carrot, with higher yield (Chaurasia *et al.*, 2006 ; Naik *et al.*, 2002)

2.5. Effect of customized fertilizer on growth and yield parameters

Omotoso and Shittu (2008) reported an increase in the pod length, leaf and stem fresh weight of okra on application of 150 kg ha^{-1} of NPK grade 15: 15: 15. The growth and yield attributes *i.e.,* plant height, leaf area, number of ears per hill and ear length were higher for CF dose (562.50 kg ha^{-1}) in finger millet owing to improved sink development thereby leading to better grain yield (Goud *et al*., 2013). On application of 150 per cent of CF dose 143.7N: 79.7P_2O_5: 51.6K_2O: 14.0S: 1.8Zn kg ha^{-1}, the mean number of tillers $hill^{-1}$increased from 2.46 to 7.11 against control with higher dry matter production in finger millet which may be in accordance with the higher nutrient application (Mudalagiriyappa *et al*., 2015). According to Dwivedi *et al.* (2014), on supplying 150 per cent of CF grade 11 N: 18P: 9K: 5.3S: 0.7Zn %, enhancement in growth and yield parameters *viz*., plant height (89.4 cm), total number of effective tillers m^{-2} (372.70), spikelet length (10.02 cm), total number of grains/ spikelet (76.17.) and test weight (37.80 g) was reported. Similarly, Sekhon *et al.* (2012) reported that on application of CF grade 16N: 24P: 9K: 5 S: 0.7 Zn% increased the plant height but did not show any significant change in plant height on further increasing the levels of CF. In this particular study of evaluation of CF in wheat showed more effective tillers, spike length, spike weight, no. of grains/spike, 1000 grain test weight, additional grain and straw yield were recorded against the recommended dose of fertilizer. Irfan *et al.* (2015) demonstrated the suitability of CF grade 8N: 18 P: 26 K: 1 Zn: 0.1 B: 6S on potato where the growth characters *i.e.* plant height, number of leaves, number of haulms, fresh and dry weight of haulms were found to be significantly higher when compared to the recommended dose of fertilizer. This CF grade improved the yield attributes *viz*., total number , total weight of tubers hill $^{-1}$ were found to be significantly higher. No significant variation on the quality parameters of potato such as specific gravity, dry matter and starch content was observed on application of CF. Several other studies reported similar positive interactions of combination of N, P, K, S and Zn on yield (Das *et al*., 2003 ; Singh, 2006). Kamble and Kathmale (2015) demonstrated that there was significant variation in the yield parameters of onion such as plant height, diameter of the stem and bulb due to effect of different levels of CF.

2.6. Effect of customized fertilizer on yield

Kaleeswari (2013) reported an increased in yield of 15.1 per cent in lowland rice ecosystem with application of customized fertilizer over the application of straight fertilizers which could be credited to the use of $ZnSO_4$ as a fertilizer source that reduced the spikelet sterility and increased the number of tillers. Similarly Mudalagiriyappa *et al.* (2015) reported that treatment of 150 per cent CF dose 143.7N: 79.7P_2O_5: 51.6K_2O: 14.0S: 1.8Zn kg ha^{-1} was credited with highest grain yield (3279 kg ha^{-1}) and straw yield (4510 kg ha^{-1}) mainly due to the soil ability to meet the nutrient demand and better translocation of photosynthates to reproductive part from vegetative part of finger millet. Dwivedi *et al.* (2014) reported higher grain (4.40 t ha^{-1}) and straw yield (5.56 t ha^{-1}) in wheat on application of 150 per cent of CF grade 11 N: 18P: 9K: 5.3S: 0.7Zn% owing to customized application of combined doses of nutrients which promoted better nutrient uptake by the roots. Goel *et al.* (2011) reported an increase in yield and quality of fruits in pomegranate on application of customized fertilizer grade 20N: 10P: 10K: 5S: 2Mg: 0.5Zn: 0.3B: 0.2Fe at 1000 kg ha^{-1}due to various metabolic processes on application of macro and secondary nutrients. Increase in yield per unit area was reported on increasing the nitrogen levels in okra (Ambare *et al.*, 2005). The variation in yield could be attributed to better yield attributing factors in customized fertilizer applied plots. Satpute *et al.* (2013) reported an increased plant height, number of nodes per plant and significantly higher yield on soil application of $FeSO_4$+ $ZnSO_4$ @ 20 kg ha^{-1} each + borax @ 5kg ha^{-1} in summer okra (cv. Phule Utkarsha).

2.7. Effect of customized fertilizer on soil properties and soil fertility

Sadatulla and Shyla (2013) reported that as the doses of CF increased, it influenced the soil reaction, electrical conductivity and organic carbon status of the soil. The availability of organic carbon could be attributed to favourable physical properties of soil. Change in soil pH could be attributed to the mineralization process and utilisation of the organic acids by maintaining the ideal pH (Jimenez and Garcia, 1992). Rajput *et al.* (2014) reported that in wheat-maize sequence the bulk density decreased on increasing available N and P.

Kaleeswari (2013) reported that on application of customized fertilizer, there was no significant influence on the electrical conductivity of the soil and organic carbon status. Kamble and Kathmale (2015) reported no significant change in pH on application of customized fertilizer in soil which could be attributed to high buffering capacity to the clay soil by releasing free cations to the soil on dissolution of carbonates and bicarbonates.

Singh *et al.* (2013) reported increased in fertility levels of soil on application of NPK fertilizer 150: 100: 80 kg N, P_2O_5 and K_2O ha^{-1} in okra (cv. Mahyco-12). The changes in soil nutrient ecosystem on availability of macronutrients could be attributed to mineralization, decomposition, chemical complexation, plant uptake and action of microorganism (Marrs, 1993). Rajput *et al.* (2014) reported the residual effect of rock phosphate at higher grade of 31 per cent and 34 per cent increased the availability of P in maize. This is attributed to low carbonate gangue which converts P into available form on application of high grade rock phosphate. The P status of the soil improved on combined effect of Udaipur rock phosphate and FYM. Similarly, the increased in availability of nutrients in soil was noticed due to balanced application of N, P, K, and Zn fertilizers (Mehlal *et al.*, 2006).

Kaleeswari (2013) reported no significant variation in DTPA extractable Fe, Cu and Mn contents on application of customized fertilizer on higher dose in paddy. Kamble and Kathmale (2015) reported that on treatment of CF, there was no significant difference in the status of soil DTPA micronutrients *viz.*, Fe, Zn, Mn and Cu.

2.8. Effect of combined application of fertilizer and FYM on crop growth and productivity

Several workers reported that yield attributing characters like fruits per plant, fruit weight, fruit yield per plant and productivity in okra showed significant increase with integrated application of inorganic and organic form of nutrients with higher uptake by the plant. Marked increment in the height of plant, number of branches, number of nodes, fruit length, fruit diameter and total fruit yield on combination of organic and inorganic fertilizers in okra could be accredited to stimulation of plant growth promoting substances like auxins, kinetin, gibberellins and vitamins (Singh *et al.*, 2008 ; Wagh *et al.*, 2014). There was significant increase in nutrient uptake by okra on application of 100: 50: 50 NPK kg ha^{-1} along with organic manure and there was interactive advantage on integrating these nutrient sources (Wagh *et al.*, 2014). The uptake of nitrogen and phosphorus in okra increased by the application of half inorganic and organic nitrogen and thereby maintained the balanced nutrition for growth and yield improvement (Abulesha, 1992). The available phosphorus status of the soil was found to be improved on integrating FYM and inorganic fertilizers and this could be attributed to solubilisation and release of organic acids on direct addition of phosphorus (Sharma *et al.*, 2009). The combined application of ground rock phosphate with poultry manure promotes growth and yield attributes of okra due to higher nutrient use efficiency (Akande *et al.*, 2003).

The use of NPK fertilizers improved the yield in okra, and also application of proper nitrogen fertilization through organic and inorganic sources promoted the food accumulation by proper root proliferation, uptake of both nutrients and water, hence increasing the yield attributing characters (Babatola, 2006 ; Singh *et al.*, 2008). This corroborate the finding of Olaniyi *et al.* (2010) that combined effect of NPK fertilizer and organomineral fertilizer resulted in better growth and yield parameters of okra. Akande *et al.* (2010) demonstrated that combined application of organic and inorganic fertilization favoured the growth and yield parameters of okra thereby obtained higher yield. Bashir and Qureshi (2014) reported an increase in tuber yield with better tuberization in potato on application of 180 kg ha^{-1} inorganic N and 24 t ha^{-1} FYM due to balanced C/N ratio, improvement in physico-chemical properties of soil with better root proliferation. Higher nitrogen uptake was also observed in tubers with the addition of farm yard manure allowing the steady supply of nutrients throughout the crop growth. These findings are in conformity with the reports in maize by Brar *et al.* (2001). Sharma *et al.* (2009) reported an increase in yield of okra and onion on the conjoint application of both organic and chemical fertilizers which could be credited to the effective uptake of nutrients due to better solubilisation. Several workers reported a better performance in growth and yield components of okra on combined application of 50 per cent NPK fertilizer and organic manure. Similarly a significant increase in straw and grain yield in wheat when N was substituted with urea and FYM in 75:25 ratio was noticed. The difference in growth, yield and fruit quality of okra could be attributed to difference in their genetic character and also the supplementation of organic manure. This substitution of organic form of nitrogen would also increase the efficiency of inorganic fertilizers (Shah and Ahmad, 2006 ; Kibria *et al.*, 2013). Sharma *et al.* (2009) reported an increase in organic carbon content on conjoint application of farm yard manure in okra and onion along with inorganic fertilizers owing to better root growth.

Sajid e*t al.* (2012) reported a significant increase in pod yield plant $^{-1}$ due to combined application of nitrogenous and phosphatic fertilizers allowing higher vigour in plants. Along with these yield parameters, seed number and average seed weight pod^{-1} determines the seed yield in okra. Similar results were reported by Khan *et al.* (2000) and Sadat (2000). Singh *et al.* (2008) reported an increase in yield due of balanced fertilization of nutrients. Jana *et al.* (2010) reported an increase in growth parameters, yield attributes and fruit quality in okra cultivar Arka Anamika on application of 150 kg N ha^{-1} at planting geometry of 45 cm x 30 cm. Similar dose of fertilizer at a spacing 45 cm x 15 cm recorded with maximum plant height in okra variety Akola Bahar and HRB-108-2 was also reported (Singh *et al.*, 2005; Soni *et al.*, 2006). Similar findings were reported with highest plant height in okra (cv Parbhani Kranti) on application with 125 kg N ha^{-1} (Shanke *et al.*, 2003).

Mubashir *et al.* (2010) reported an increase in plant height, pod length, pod number $plant^{-1}$ and pod yield $^{-1}$ with150 kg N ha^{-1}, but at higher rate of 200 kg N ha^{-1} it was found to have a detrimental effect with yield reduction of 3 per cent and 8 per cent in carrot and okra. The high level of nitrogen fertilization increased the nitrate accumulation in okra especially on the early season picked pods. The nitrate accumulation in okra is higher by 1.7 times than carrot on applying the same fertilizer levels. High soil nitrate levels after harvest on excessive application of nitrogenous fertilizer had been reported (Gordon *et al.*, 1993; Aarnio *et al.*, 2003) The reduction in yield on excessive supply of N fertilizers were reported due to excessive vegetative growth affecting the fruit development of okra (Jambhale and Narkar, 1990 ; Lee *et al.*, 1990).

2.9. Effect of soil test based recommendation on crop growth, productivity and nutrient uptake

Soil test based recommendation provides supply of nutrients in accurate doses minimising the problems from either inadequate or excessive fertilization. The determination of available nutrients in the soil before planting the crops allowed filling the gap of nutrients required to obtain optimum yield.

The soil test recommendations for the area were based mainly on the nutrient status and interpreting the deficiency of the required nutrients and failed to provide the yield targets. Ramesh *et al.* (2013) reported that application of fertilizers based on soil test crop response resulted in 16 -17 per cent improvement in the system productivity and economic return compared to recommended dose of fertilizers in castor-sorghum cropping system. The combined application of primary nutrients along with Zn and FYM has proved to have positive impact on plant nutrients uptake based on soil test based recommendation over the recommended fertilizer doses (Mandal *et al.*, 2004 ; Reddy *et al.*, 2009).

2.10. Effect of recommended dose of fertilizer (POP) on crop growth, productivity and nutrient uptake

Krishnan *et al.* (2014) reported that recommended dose of NPK fertilizers along with three sprays of two per cent water soluble fertilizer formulations *viz.*, starter (11: 36: 24 NPK) and booster (8:16: 39 NPK) improved fruit weight, yield plant^{-1} and dry weight plant^{-1} leading to higher dry matter yield. Gayathri and Reddy (2013) reported that the days to 50 per cent flowering in recommended dose of NPK (100:50:50 kg ha^{-1}) applied plots showed significant superiority over control plot due to increased photosynthetic activity and uptake of food nutrients which resulted in early flowering. This was in accordance with the results of Sharma and Bhalla (1995) and Patel *et al.* (2009) in bhendi. The quick release of nutrients to the soil and quick uptake by the plants on both vegetative and reproductive growth phases on application of inorganic fertilizers might favoured in earliness in flowering when compared to integrated application of inorganic and organic form of nutrients (Chaterjee *et al.*, 2005).

Paliwal *et al.* (1999) reported that on application of N @ 120 kg ha^{-1} and sulphur 160 kg ha^{-1} in okra (cv. Pusa Sawani) showed highest yield as well as better yield attributing characters *viz.*, number of fruits per plant, length of fruit, diameter of fruit, mean fruit weight per plant and yield. Similarly, Singh *et al.* (2005) reported that application of higher level of N (150 kg ha^{-1}), P (90 kg ha^{-1}) and gibberellic acid (150 ppm) showed significantly higher plant height (137.75 cm), number of branches per plant (3.60) and yield (167.61 q ha^{-1}) in okra (cv. Pusa Sawani) when compared to lower doses of fertilizers. Gowda *et al.* (2001) reported that application of recommended dose of NPK @ 175: 125: 100 kg ha^{-1}, significantly increased the dry matter production in leaf (20.40 g), stem (5.17 g), root (18.03 g), fruit (31.11 g) and whole plant (104.71 g) respectively were recorded in okra (cv. Arka Anamika). Sontakke *et al.* (1996) reported that application of increased levels of N increased the plant height, numbers of leaves per plant with higher pod yield (28.30 q ha^{-1}) and seed yield (5.43 q ha^{-1}) in okra (cv. Parbhani Kranti).

A variable effect in potassium uptake by vegetables on application through various potassic fertilizer source showed was also reported. Akhtar *et al.* (2008) reported positive effect on yield and yield parameters on application of muriate of potash at the rate of 100 kg ha^{-1} due to availability of adequate amount of K nutrient. Addition of K induced more content and uptake of N and P in chilli and brinjal (Subbiah, 1994 ; Selvi *et al.*, 2004). Similar effect of P addition based on recommended dose of fertilizer showed significant effect on the content and uptake by okra and cluster bean (Pandey and Dubey, 1996 ; Sunder *et al.*, 2003). Makinde (2013) reported the highest pod yield in okra on application of 100 kg ha^{-1} rock phosphate + 10 t ha^{-1} cowdung over unfertilized plant. Firoz (2009) reported that application of RDF in okra with 100 kg N ha^{-1} along with 120 kg P_2O_5 ha^{-1} recorded the highest yield (16.73 t ha^{-1}) compared to control.

Rekha *et al.* (2005) reported that the agronomic efficiency for extra fertilizer N declined with increased doses of N from 60 to 120 kg ha^{-1} implying progressively higher N losses. Similarly Patel and Rajput (2003) recorded higher agronomic efficiency in okra when drip-fertigated with 60 per cent RDF than at 80 per cent RDF.

2.11. Effect of application of FYM alone on crop growth, productivity and soil fertility

The use of FYM has been identified as one of the potential processes in managing waste being a natural process, cost effective and environmental friendly. The better response by the crops due to organic forms of nutrients could be due to stability of soil environment by improving the soil properties.

Amran *et al.* (2014) reported that the maximum plant height (127.6 cm), fruits per plant (23.15), fruit yield per plant (287.61 g) were obtained on addition of 25 tons ha^{-1} FYM and the minimum was recorded in the control plot without FYM in okra. Similar results by Ibrahim and Hamma (2013) revealed that FYM at 12 t ha^{-1} supplied adequate nutrients for better plant height (44.98 cm), pods yield (4.35 g plant^{-1}), and number of branches (4.25) compared to control. This could be credited to solubilization effect of nutrients required by the plants on addition of FYM leading to increased NPK uptake (Sendurkumaran *et al.*, 1998). Similar results were also reported by Muhammad *et al.* (2001). Gulshan *et al.* (2013) reported an improvement in growth and yield attributes in okra by substituting organic source demonstrated that the presence of substantial quantities of magnesium increased the rate of photosynthesis since it had significant role in chlorophyll synthesis. The results were in agreement with the findings of Nehra *et al.* (2001) and Sanwal *et al.* (2007).

The nutrients contained in organic manure are stored for a longer time in the soil ensuring improved root development and higher crop yield (Sharma and Mittra, 1991 ; El-Magd *et al.*, 2005). The lack of additional nutrients in untreated control besides from the residual nutrients in the soil resulted in lower performance in yield due to more competition of limited resources by the crops and weeds (Dada and Fayiminnu, 2010).

In order to maintain the soil productivity, the inclusion of FYM helped in increasing the organic matter content of the soil (Bayu *et al.*, 2006 ; Kumar *et al.*, 2011). Besides presence of plant nutrients in lesser concentration than the fertilizers, the presence of growth promoting substances like enzymes and hormones, made them indispensable for improvement of soil fertility and productivity (Bhuma, 2001). Incorporation of FYM at higher rates increased the availability of N and P due to residual effects, thereby increased the growth and yield of succeeding crops was reported (Mahala *et al.*, 2006 ; Makinde and Ayoola, 2008). It activated soil microbial biomass and sustain cropping system through better nutrient recycling (Ayuso *et al.*, 1996 ; El-Shakweer *et al.*, 1998). The recovery of P from organic manure was reported to be higher than from fertilizers as CO_2 released by decomposition improved the availability from the soil (Gopalakrishnan, 2007). The presence of nutrients at optimum quantity such as of Zn, Cu, Fe, Mn and Mg ensured the better efficiency of FYM (Anburani and Manivannan, 2002). The capacity to supply wide range of nutrients boosted the uptake of NPK by keeping in check on the losses of nutrient and hence contributed in improving the nutrient use efficiency (Chaterjee *et al.*, 2005 ; El-Magd *et al.*, 2006). The positive effects of organic manures on soil properties such as bulk density, water-holding capacity and soil moisture content were also reported (Adeleye *et al.*, 2010 ; Fawole *et al.*, 2010).

2.12. Effect of customized fertilizer and other nutrients on nutrient uptake

According to Dwivedi and Meshram (2014) on application of 150 per cent dose of customized fertilizer 65.6N: 98.4P: 37.5K: 2.81 Zn kg ha^{-1} in paddy during kharif season, the uptake of primary nutrients such as N (146.6 kg ha^{-1}), P (28.8 kg ha^{-1}) and K (341.1 kg ha^{-1}) were significantly higher than the recommended dose of fertilizer. Similarly different levels of CF dose 172.5N: 95.8P_2O_5: 61.9K_2O kg ha^{-1} had higher nutrient uptake with increased protein and carbohydrate content of 9.2 per cent and 75.1 per cent followed by higher dry matter in finger millet due to increased availability of nutrients to plants (Goud *et al.*, 2013). Dwivedi *et al.* (2014) reported an increased total uptake of N (117.3 kg ha^{-1}), P (21.4 kg ha^{-1}), K (150.5 kg ha^{-1}), S (96.1 kg ha^{-1}) and Zn (229.9 g ha^{-1}) in grain and straw of wheat on application of 150 per cent of CF grade 11 N: 18P: 9K: 5.3S: 0.7Zn. Sadatulla and Shyla (2013) reported an increased N, P and K uptake in mulberry leaves with increased doses of customized fertilizer over the recommended dose of nutrients which reflected with better quality of the leaves and higher output of the leaves. Dewal and Pareek (2004) reported that application of higher concentration of customized fertilizer containing N, P, K, S and Zn increased the nutrient content in rhizosphere region thereby improving the plant systems due to higher uptake by wheat.

Higher content of N, P, K, Mg and Ca content in okra was noticed on application of nutrients source when grown at wider spacing. Reduction in nitrogen content of okra as the crop growth advances was noticed and was reported to be higher at vegetative stage due to higher nutrient availability in the root zone and uptake at this stage (Rajaraman and Pugalendhi, 2013). Olowoake *et al.* (2015) reported that on application of organomineral and NPK grade 15: 15: 15, a significant increase in growth parameters and yield parameters of okra was noticed over sole organic source due to higher plant uptake. Similar studies on growth of okra by application of organomineral source and fertiliser was reported by Akanbi *et al.* (2004). There was significant increase in uptake of N, P, K and Ca by okra on application of 150 kg ha^{-1} NPK grade 15: 15: 15 over the treatments applied with poultry manure alone was reported by Otomoso and Shittu (2008).

Potassium plays an important role in improving protein synthesis, enzyme activity and regulates the translocation of photosynthates and also induces pest and disease resistance on proper potassium nutrition. Potassium application enhances cell division and elongation by promoting vegetative growth and increases the plant height in okra (Singh *et al.*, 1998 ; Mehdi *et al.*, 2007). Similarly Odeleye *et al.* (2005) reported an increased plant height in okra on addition of potassium employing its major role in growth and development by activating enzymes by proper uptake and utilization of nutrients from potassium source. The efficiency of the plant for proper utilization of nitrogen depended on the application of potassium (Al-Abdulsalam and Hamaiel, 2004). Several studies reported an increase in pod length of okra on application of potassic fertilizers enhancing the vegetative growth since the uptake was higher at this stage by improving the mobility of photosynthates enabling translocation from source to sink (Ananthi *et al.*, 2004 ; Omotoso and Johnson, 2015).

Sadatulla and Shyla (2013) reported an increased in Ca, Mg and S uptake in mulberry on higher levels of customized fertilizer doses over the recommended dose of fertilizers owing to increased availability of these nutrients. Similarly Omotoso and Shittu (2008) reported significant increased uptake of Ca and Mg in okra on application of NPK grade 15: 15: 15. The calcium content in soil would regulate the intake of plant nutrients such as N, Fe, Zn, Cu and Mn. Higher levels of Ca in soil would impede the uptake of boron by the plants (Osiname, 2000).

Micronutrients are required for optimal growth for its major role in metabolic activities and biochemical process. Soil application of multi-micronutrient mixtures grade containing Fe, Mn, Zn, Cu, B at 20 kg ha^{-1} increased the nutrient uptake and yield in okra and mustard (Patel and Singh, 2010). Similarly, the response of multi-micronutrient mixtures on the growth and yield of crops were also reported in tomato and soybean (Thiyageshwari and Ramanathan, 2001). Sadatulla and Shyla (2013) demonstrated that the higher doses of customized fertilizer resulted higher uptake of Zn from the soil. Dwivedi and Meshram (2014) reported that total Zn uptake in straw and grain was significantly influenced by addition of higher doses of customized fertilizer in paddy. According to Kaleeswari (2013), the highest DTPA-Zn content (5.30 mg kg^{-1}) was recorded in soil after the application of higher doses of CF 150N: 50P: 50K: 25Z nSO_4 kg ha^{-1} which could be attributed to balanced fertilization of these nutrients. Patel *et al.* (2008) reported an increased in uptake of micronutrients by okra with increased fruit yield on soil application of CF grade 2Fe: 0.5Zn: 5Mn: 0.2: 0.5Cu.

Application of Borax at 0.4 per cent increased the uptake of N, P and K nutrients in okra which might be due to the activity of enzymes in metabolic process (Rani *et al.*, 2013). Boron plays an active role in formation and stabilization of cell wall in maintaining membrane integrity, carbohydrate utilization and pollen tube formation (Marschner, 1995). The uptake of boron by the crops was less in light textured acidic Entisols and Inceptisols soils due to high precipitation (Mandal and De, 1993 ; Sarkar, 2006). Similar results were reported on elevation of nitrogen uptake in application of micronutrients (Singh *et al.*, 1978). Hatwar *et al.* (2003) reported that the higher uptake of micronutrients enhanced the photosynthetic and metabolic activities which favoured the vegetative growth and increased the production. Micronutrients application improved the growth and yield of plants by stimulating the enzyme activity, chlorophyll formation and stomatal regulation (Asad and Rafique, 2000). Patil *et al.* (2008) reported that on foliar application of boric acid in tomato gave maximum number of primary branches with higher fruit yield. This could be attributed to the function of boron in cell differentiation by improving the shoot and root development. Mehraj *et al.* (2015) reported that on foliar application of 100 ppm of micronutrients mixtures twice (Zn, B, Fe, Cu, Mn and Mo) in okra were recorded with higher plant height, longest petiole, number of internodes, number of branches, fresh weight, dry weight and pod yield over the control. Micronutrient added along with recommended NPK in brinjal showed positive response of content and uptake of N, P, K, Zn and Fe (Selvi *et al.*, 2004).

On excess application of borax at 30 kg ha^{-1}, toxic effect on okra was observed which resulted in lesser yield (Kumar and Sen, 2005). This finding were in accordance with the results by Sharma *et al.* (1994) and Ghosh and Hassan (1997). Srivastava *et al.* (2009) reported an increased fruit yield of okra and total B uptake on application of 0.60 per cent boron as 100 per cent basal (Granubor- 15% B) and as the B doses increased, the apparent recovery of P also increased. Bard and Wolstenholme (1999) reported an increased in boron concentration in avocado leaf on soil application over the control. However, increased B concentration over 100 mg kg^{-1} showed toxicity symptoms.

2.13. Effect of split application of nutrients on crop growth, productivity, nutrient uptake and soil fertility

Untimely application of fertilizers leads to its losses in various ways. In order to reduce the fertilizer loss, proper choice of fertilizer suited for condition and split applications of fertilizers by reducing the amount of pre-plant fertilizers in the soil are required.

To increase the early plant growth, supplementation of starter fertilization was reported to be effective (Mascagni and Boquet, 1996 ; Vetsch and Randall, 2002). Customized fertilizer on split doses of nitrogen at crown root initiation and first node stages resulted in greater plant height in wheat. This contributes to the better availability of nutrients particularly nitrogen which has simulative effect on the cell division and enlargement thereby promoting the number of leaves. The prolonged availability due to split doses of N was widely reported (Oscarson *et al.*, 1995; Bhardwaj *et al.*, 2010).

Soil application and foliar application of boron @ 1.5 kg ha^{-1} and 0.25 kg ha^{-1} in split doses improved the yield parameters such as increase in tillers m^{-2} and 1000 grain weight in wheat. Plant height and tuber yield increased with split application of customized fertilizer in potato was also reported by Irfan *et al.* (2015). Split application of N in soil at every third picking was advantageous for getting high yield, for increasing number of harvest and to maintain the size of okra fruit towards last harvest (Gopalakrishnan, 2007). Islam *et al.* (2008) demonstrated the advantage of split application over the conventional method of application by obtaining higher bulb yield in onion on application of 120 kg ha^{-1} potassic fertilizer in three splits.

Kamble and Kathmale (2015) reported that application of CF in two and three split doses increased the nutrient uptake effectively, hence enhancing the bulb yield of onion. The N, P and K availability for plants on split doses CF was noticed over the conventional one time application. Delay in nitrogen application improved the nitrogen use recovery by crops which might be due to lesser exposure to losses of nitrogen through leaching, denitrification, immobilization and clay fixation on split application (Jokela and Randall, 1997). Hassan *et al.* (2010) reported an increase in growth parameters in maize on split application of nitrogen with higher biomass production and N uptake. Split application in three stages could be attributed to better nutrient utilization at different stages of the crop. Gerwing and Woodard (1998) reported an increase in N uptake on split pre-plant application and side dressing of fertilizer. Gehl *et al.* (2005) reported an increase in grain yield over single application of N on split application at two splits of 250 kg ha^{-1} of N. The concentration of boron in plants also increased on soil application in split doses (Sarkar *et al.*, 2007).

Randall and Schmitt (1998) reported an increase in yield and nutrient use efficiency on split application of nitrogenous fertilizers in medium and fine textured soils. Sithaphanit *et al.* (2009) reported that the fertilizer use efficiency was higher on split application of fertilizers, due to efficient uptake of nutrients and reduction in leaching loss. Brauer and Shelp (2010) reported that the improvement in nitrogen use efficiency could result in the capture of a greater proportion of the applied nitrogen while still maintaining crop yield targets and also decreased the NO_3 content which is hazardous to the environment. Nitrogen losses are observed in every type of soil and management of such losses through leaching, volatilization, denitrification, soil erosion and microbial consumption and only 30 to 40 per cent of the nitrogen applied to the soil are taken up by the crop (Glass, 2003 ; Salazar *et al.*, 2011). The incorporation of CF grade 20 N: 12 P: 10K:4 S: 0.25 Mg: 0.50 Zn: 0.50 Fe % at different levels in split application was have significant increase in the available N, P and K status of the soil (Kamble and Kathmale, 2015). Sanchez and Doerge (1999) reported that split application of fertilizers minimized the nutrient loss from the soil.

2.14. Economics

Dwivedi and Meshram (2014) revealed that application of 150 per cent CF higher dose of customized fertilizer containing 65.6 N: 98.4P_2O_5: 37.5K_2O: 2.81 Zn kg ha^{-1} produced higher yield, nutrient uptake and highest net return (₹ 60,062 ha^{-1}) of BCR (2.31) in rice. Economic efficiency of customized fertilizer were recorded higher due to better yield- attributing characters such as grain yield with higher harvest index of 46.39 per cent compared to control. Similarly Goud *et al.* (2013) reported that CF grade 143.7N: 79.7P_2O_5: 51.6K_2O kg ha^{-1} resulted with higher net returns (₹ 24,750 ha^{-1}) and BCR (2.3) in finger millet. Mudalagiriyappa *et al.* (2015) reported that 125 per cent of customized fertilizer grade 20N: 17P_2O_5: 11K_2O: 3S: 0.4Zn % showed higher mean BCR (2.53) over absolute control (1.26) in finger millet. Dwivedi *et al.* (2014) reported that 150 per cent of CF grade 11N: 18P: 9K: 5.3S: 0.7Zn % showed maximum mean net returns (₹ 37,676 ha^{-1}) and BCR (2.7) due to higher grain and straw yield. Kamble and Kathmale (2015) reported the gross returns, net returns and BC ratio were higher for the treatment supplied with CF grade 20N: 12 P: 10K: 4S: 0.25Mg: 0.50 Zn: 0.50Fe %, in onion due to higher bulb yield. Patel *et al.* (2008) reported maximum net realisation and highest BCR (2.02) on application of micronutrients CF grade through soil application in okra. Sekhon *et al.* (2012) reported that on increasing the CF level to 125 per cent of the recommended dose in wheat resulted higher BC ratio of 2.84 and 3.78 in Gurdaspur and Rupnagar station of Punjab. Chaurasia *et al.* (2006) reported maximum BCR (1: 4.1) in tomato on application with water soluble fertilizer 19N: 09P: 19K. Yogita *et al.* (2012) reported higher BCR on integrated application of organic and inorganic fertilizers in okra where N was applied in three split doses *i. e.,* basal dose, top dressing at 30 and 45 days of sowing. Mubashir *et al.* (2010) reported that on optimum application of nitrogen fertilization improved the marketable yield and obtain a BCR (2.9). Several studies on effect of borax at 20 kg ha^{-1} improves the yield attributes and higher BCR (2.12) in okra due to active photosynthesis and higher uptake resulted in higher yield (Singh and Verma, 1991 ; Medhi and Kakati, 1994; Kumar and Sen, 2005). Patil *et al.* (2008) reported the maximum BCR (1.80) on application of boric acid @ 100 ppm in tomato compared to control (1.40).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation entitled "customized fertilizer and nutrient scheduling for okra" was conducted to develop a customized fertilizer grade and nutrient schedule for okra and to study its techno-economic feasibility. The details of materials and methods adopted for the study are briefly described below.

3.1. Location

The experiment was conducted at the Water Management Research Unit, Vellanikkara, Thrissur. The station is geographically located at 13^{0} 32′ N latitude and 76^{0} 26′ E longitude. The experimental site lies at an altitude of 40.3 m above MSL.

3.1.1. Weather condition during the experimental period

The area possesses a typical humid tropical climate. The meteorological data for the period of investigation are given in Fig. 1 and 2 and Appendix 1. The weather which prevailed during the cropping period was normal. The maximum and minimum temperature recorded during the cropping period were 33.3 ^{0} C and 23.2 ^{0} C respectively. The average relative humidity recorded was 85.88 per cent. Total rainfall recorded during the cropping period was 1578.38 mm for 73 rainy days.

3.1.2. Soil

Soil of the experimental site is texturally classified as sandy clay loam, belonging to the taxonomical order oxisol. The soil is acidic in reaction with a pH of 5.3. The basic physical properties of the soil are presented in Table 3.1.

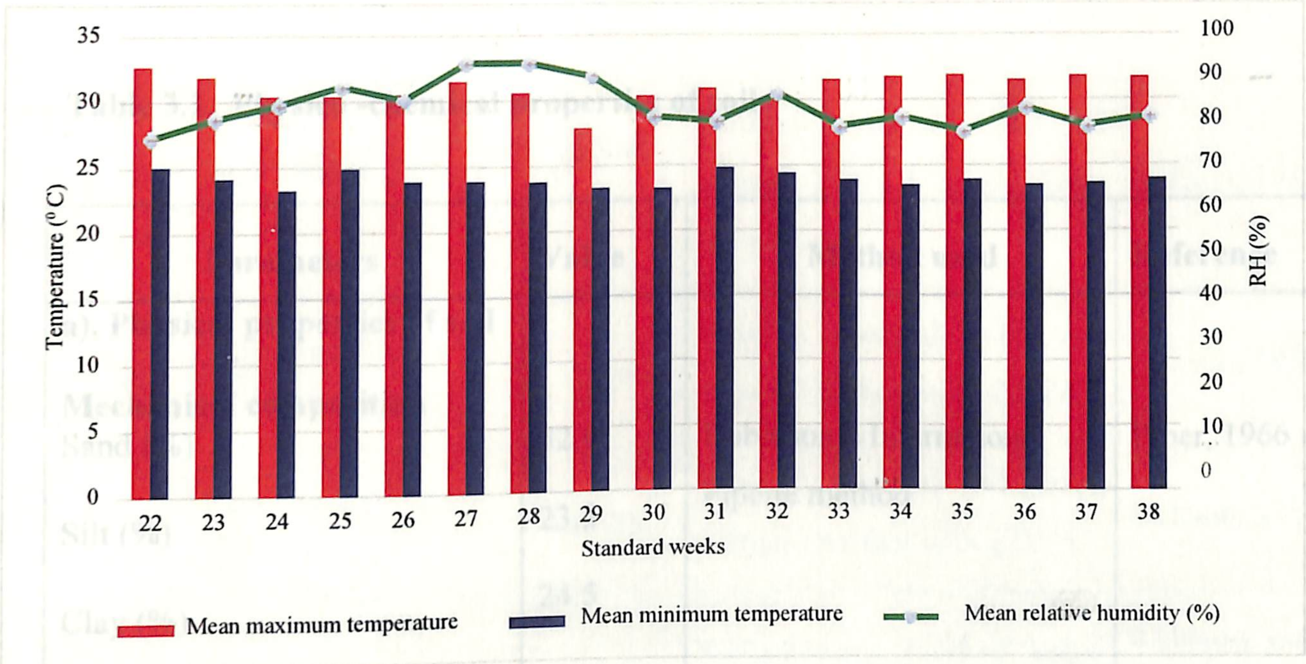

Fig.1 Mean weekly weather data of mean maximum and maximum temperature and relative humidity during crop period

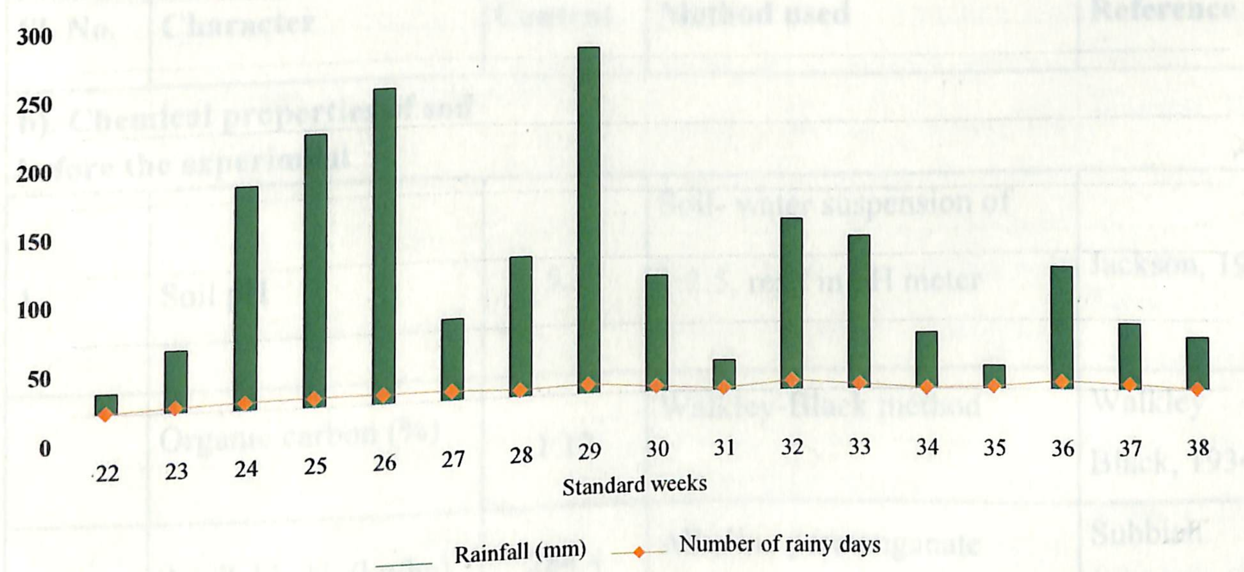

Fig.2 Mean weekly weather data of rainfall and number of rainy days

Table 3.1. Physico -chemical properties of soil

Parameters	Value	Method used	Reference
a). Physical properties of soil			
Mechanical composition			
Sand (%)	52.0	Robinson's International Pipette method	Piper, 1966
Silt (%)	23.5		
Clay (%)	24.5		
Physical characteristics			
Bulk density (g cm^{-3})	1.1 - 1.2	Core sampler method	Piper, 1966
Water holding capacity (%)	56.4		

Sl. No.	Character	Content	Method used	Reference
b). Chemical properties of soil before the experiment				
1	Soil pH	5.3	Soil- water suspension of 1:2:5, read in pH meter	Jackson, 1958
	Organic carbon (%)	1.13	Walkley-Black method	Walkley and Black, 1934
3	Available N (kg/ha)	284.4	Alkaline permanganate method	Subbiah and Asija, 1956
4	Available P (kg/ha)	115.1	Ascorbic acid reduced molybdo phosphoric blue colour method	Bray and Kurtz, 1945; Watanabe and Olsen, 1965

5	Available K (kg/ha)	293.44	Neutral Normal NH_4OAC extract method using flame photometer	Jackson, 1958
6	Exchangeable Ca (mg/kg)	330.50	Neutral Normal NH_4OAC extract titration with EDTA	Jackson, 1958
7	Exchangeable Mg (mg/kg)	41.25	Neutral Normal NH_4OAC extract titration with EDTA	Jackson, 1958
8	Available S (mg/kg)	5.47	Turbidimetry method using Spectronic 20	Williams and Steinbergs, 1958
9	Available Fe (mg/kg)	40.88	0.1M HCl extract method using atomic absorption spectrophotometer	Sims and Johnson, 1991
10	Available Mn (mg/kg)	35.56	0.1M HCl extract method using atomic absorption spectrophotometer	Sims and Johnson, 1991
11	Available Zn (mg/kg)	1.22	0.1M HCl extract method using atomic absorption spectrophotometer	Sims and Johnson, 1991
12	Available Cu (mg/kg)	3.73	0.1M HCl extract method using atomic absorption spectrophotometer	Sims and Johnson, 1991
13	Available B (mg/kg)	0.17	Hot water extraction method	Berger and Troug, 1939

3.1.3. Season

The field trial on 'Customized fertilizer and nutrient scheduling for okra' was conducted during the kharif season (May - September) of 2015.

3.1.4. Cropping history

The experimental area was under amaranthus cultivation during the summer season prior to the present experiment.

3.2. MATERIALS USED

3.2.1. Crop

The crop used for the field experiment was okra. The variety selected for field experiment was 'Arka Anamika'. The plants are tall, well branched and the stem is green with purple shade. Purple pigment is present on both sides of the petals. The fruits are long and green in colour. The variety is known for its green fruits, duration of 110 days and resistance to yellow vein mosaic virus.

3.2.2. Seed rate

A seed rate of 7 kg ha^{-1} was adopted as per POP recommendation of Kerala Agricultural University (KAU, 2011).

3.2.3. Manure

Farm yard manure was used as the organic source with a content of 0.5% N, 0.4% P, and 0.3% K.

3.2.4. Lime

Liming was done one week before sowing. Lime @ 350 kg ha^{-1} was applied uniformly to all the treatments plots.

3.2.5. Fertilizers

Straight and water soluble fertilizers containing the following nutrients source were used for the study.

Urea	-	46 % N
Rajphos	-	20% P_2O_5
Muriate of Potash (MOP)	-	60% K_2O
19:19:19	-	19% N : 19% P_2O_5 : 19% K_2O
Potassium nitrate	-	13% N : 45%K_2O
Magnesium carbonate	-	24% Mg
Dilubor	-	20% B

3.2.6. Plant protection chemicals

Need based application of the following plant protection chemicals were used to control pest and diseases: Chlorpyriphos (Dursban 20% EC), Quinalphos (Ekalux 25% EC), Dimethoate (Rogor 30% EC), Difenoconazole (Score 25% EC).

3.3. METHODS

3.3.1. Development of customized fertilizer grade

Soil samples were collected from the experimental field where the crop was to be raised and analyzed to determine the macro and micro nutrient status of the soil. Based on the soil test rating and nutrient recommendation of okra, the nutrient requirement of growing okra in that particular field was worked out. The details are presented in Table 3.2. Compatible straight and water soluble fertilizers were selected and the quantity of these fertilizers required was worked out based on the nutrient requirement. The details are presented in Table 3.3.

To supply the required primary, secondary and micronutrients, a customized fertilizer grade was arrived. Straight or water soluble fertilizers were selected based on the compatibility of the fertilizers.

Table 3. 2. Nutrients required for developing CF (100%) for okra

Nutrients required	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Mg (kg ha^{-1})	B (kg ha^{-1})
CF- 100%	59	9	34	16	1

Table 3.3. Quantities of fertilizers required for 100% CF

Fertilizers	19: 19: 19 (kg ha^{-1})	KNO_3 (kg ha^{-1})	Urea (kg ha^{-1})	$MgCO_3$ (kg ha^{-1})	Dilubor (kg ha^{-1})	Total fertilizer (kg ha^{-1})
Quantity (100% CF)	47.36	55.55	93.15	66.67	5.0	267.7

The total quantity of fertilizer was worked out by adding the weight of all the individual fertilizers used for the preparation of CF. The CF grade was developed by calculating the percentage of nutrients present in the total quantity of CF. The grade developed is given in Table 3.4.

Table. 3.4. CF grade

CF dose	CF grade				
	N	P	K	Mg	B
100%	22.01	3.35	12.68	5.97	0.37

3.3.2. Experimental details

Treatments	- 12
Design	- Randomized Block Design
Replications	- 3

Plot size

The gross plot size for the experiment was 3 m x 3 m.

3.3.3. Design and layout

The lay out plan is given in Fig. 3.

3.3.4. Details of the treatments in the experiment

T1	FYM + 75% CF (2 splits at 30 days interval)
T2	FYM + 75% CF (4 splits at 15 days interval)
T3	FYM + 100% CF (2 splits at 30 days interval)
T4	FYM + 100% CF (4 splits at 15 days interval)
T5	FYM + 125% CF (2 splits at 30 days interval)
T6	FYM + 125% CF (4 splits at 15 days interval)
T7	FYM + soil test based NPK application (N & K as 2 splits at 30 days interval)
T8	FYM + soil test based NPK application (N & K as 4 splits at 15 days interval)
T9	FYM + NPK as per POP (N & K as 2 splits at 30 days interval)
T10	FYM + NPK as per POP (N & K as 4 splits at 15 days interval)
T11	FYM alone based on N recommendation of POP (2 splits at 30 days interval)
T12	Absolute control

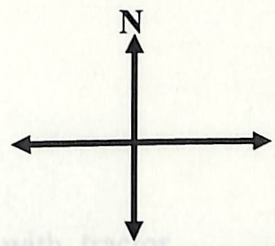

Fig.3. Lay out of experiment

R_1T_2	R_1T_7	R_1T_1	R_1T_{11}	R_1T_8	R_1T_7
R_1T_3	R_1T_4	R_1T_{10}	R_1T_6	R_1T_5	R_1T_9
R_2T_8	R_2T_{10}	R_2T_5	R_2T_1	R_2T_9	R_2T_2
R_2T_{12}	R_2T_6	R_2T_7	R_2T_3	R_2T_4	R_2T_{11}
R_3T_1	R_3T_{11}	R_3T_4	R_3T_8	R_3T_2	R_3T_{10}
R_3T_5	R_3T_3	R_3T_6	R_3T_9	R_3T_7	R_3T_{12}

3.4. Field Experiment

3.4.1. Crop husbandry

3.4.1.1. Land preparation

The experimental plot was prepared initially by ploughing with tractor drawn disc plough before sowing. The field was laid out in three blocks and the blocks were further subdivided into 12 plots. The plots were formed by taking ridges and furrows with 30 cm width. The individual plots were levelled perfectly.

3.4.1.2. Sowing

Pre-soaked okra seeds were dibbled uniformly in the furrows, made at a spacing of 65 cm X 45 cm. Sowing was done on 29-05-2015.

3.4.1.3. Gap filling

Gap filling was done at 10 days after sowing using the seedling raised in pot trays grown on the same day of planting to maintain optimum population in the field. Gap filling was done on 10th June 2015.

3.4.1.4. Irrigation

The field was irrigated after sowing. Irrigations were given regularly till the onset of monsoon.

3.4.1.5. Manures and fertilizer application

FYM @12 t ha^{-1} was incorporated in all the plots except the control plot before sowing. The fertilizers (Table 3.7) were applied in split doses based on the treatments allotted.

Plate 1: General view of the field

Table 3. 5. Fertilizer recommendation

Treatment	Recommendation(kg ha^{-1})				
	N	P	K	Mg	B
75% CF	44.25	6.75	25.50	12.00	0.75
100% CF	59.00	9.00	34.00	16.00	1.00
125% CF	73.75	11.25	42.50	20.00	1.25
Soil test based NPK	59.40	8.75	33.60	-	-
NPK as per POP	110.00	35.00	70.00	-	-

Table 3. 6. Schedule of fertilizer application

Treatment	Schedule of nutrient application
CF (75%, 100%, 125%)	2 splits at 30 days interval for T_1, T_3 and T_5 4 splits at 15 days interval for T_2, T_4 and T_6
Soil test based NPK	N & K as 2 splits and P as basal at 30 days interval for T_7 N & K as 4 splits and P as basal at 15 days interval for T_8
NPK as per POP	N & K as 2 splits and P as basal at 30 days interval for T_9 N & K as 4 splits and P as basal at 15 days interval for T_{10}
FYM	2 splits at 30 days interval for T_{11}

3.4.1.6. Weeding

Hand weeding was given at 15, 30 and 60 days after sowing uniformly to all the treatments.

3.4.1.7. Earthing up

Earthing up was done after every fertilizer application.

3.4.1.8. Plant protection measures

Plant protection measures were taken as and when necessary to control Yellow vein mosaic virus, leaf spot disease and for sucking pest.

3.4.1.9. Harvesting of pods

The tender pods of okra were harvested manually after 60 days at alternate days interval.

3.5. Observations

Three plants were selected at random from each plot and labelled. From these plants, biometric observations were recorded at 30 DAS, 60 DAS and 90 DAS.

3.5.1 Observation on growth characters

3.5.1.1. Plant height

Plant height of labelled plants was measured from the base to the tip of the growing point at 30 DAS, 60 DAS and 90 DAS. The mean height was computed and was expressed in cm.

3.5.1.2. Number of leaves per plant

Total number of green leaves produced was recorded on labelled plants in each plot and the average was taken.

3.5.1.3. Number of branches per plant

Number of branches of labelled plants was recorded and the mean number of branches was computed.

3.5.1.4. Dry matter production (kg ha^{-1})

One plant was uprooted from the plot and was oven dried at 80 ^{0}C. Weight of the biomass produced was recorded and expressed on per hectare basis at different growth stages.

3.5.2. Observations on yield and yield attributes

3.5.2.1. Days to 1st flowering

Number of days taken to 1st flowering from the date of sowing was recorded from each plot.

3.5.2.2. Fruits per plant

Fruits produced per plant for all harvests were recorded and the mean was calculated.

3.5.2.3. Fruit weight per plant

The weight of fruits produced per plant for all harvests was recorded and expressed in kg.

3.5.2.4. Yield per plant

Fruits harvested from net plot were recorded and was expressed in kg $plot^{-1}$.

3.5.3. Plant analysis

Plant samples collected from each plot at 30, 60 and 90 DAS were shade dried and then oven dried at 70^0 C. The samples were ground properly. Then 0.5 g of plant samples was weighed, digested and nutrient contents were estimated as per standard procedure.

Table 3. 7. Methods used for analysis of plant samples

Sl. No.	Nutrient	Method	Reference
1	N	Microkjeldhal method	Jackson, 1958
2	P	Diacid extract estimated colorimetrically in Spectrophotometer	Jackson, 1958
3	K	Diacid extract method using Flame Photometer	Jackson, 1958
4	Ca, Mg	Titration with EDTA	Page *et al.*, 1982
5	S	Turbidimetry method using Spectronic 20	Williams and Steinbergs, 1958
6	Fe, Mn, Zn, Cu	Diacid method using atomic absorption spectrophotometer	Jackson, 1958
11	B	Dry ashing method	Williams and Vlamis, 1961

3.5.4. Uptake of macronutrients and micronutrients

The uptake of macronutrients and micronutrients by the plants were calculated by multiplying respective values of the nutrients with total dry weight of the plant. The uptake values were expressed in kg ha^{-1}.

3.5.5. Soil analysis

Soil samples were collected from the experimental area before and after the experiment from each plot, shade dried, powdered and sieved through 2 mm sieve and analysed for macro and micronutrients. To estimate soil organic matter content the soil samples were passed through 0.5 mm sieve. The soil pH was read in a pH using soil-water suspension of 1: 2.5. The macronutrients and micronutrients were analysed using standard procedures (Table 3.1). The available N, P, and K were expressed in kg ha^{-1}, and exchangeable Ca and Mg, available S, Fe, Mn, Zn, Cu and B as mg kg^{-1}.

3.5.6. Economics

The labour charges for the field operations, cost of inputs and treatment costs were included to compute the gross expenditure, which was expressed in Rupees ha^{-1}. The gross return was calculated based on the local market prices of okra, and expressed on per hectare basis. Net return was calculated by subtracting total cost of cultivation from gross return. The Benefit: Cost ratio was worked out by dividing the gross return with the gross expenditure per hectare.

3.5.7. Statistical analysis

Data relating to different characters were compiled, tabulated and analysed statistically by applying the technique of analysis of variance using the statistical package WASP 2.0 and the significance of the difference among the treatments was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

RESULTS

4. RESULT

The investigation entitled 'customized fertilizer and nutrient scheduling for okra' was carried out at the Water Management Research Unit, Vellanikkara with the objective of developing a customized fertilizer and nutrient schedule for okra and to study its techno-economic feasibility. The experimental data collected were statistically analysed and the results obtained are presented under the following sections.

4.1. Growth characters of okra

4.1.1. Plant height

Plant height at 30 DAS, 60 DAS and 90 DAS showed significant variation due to nutrient management and scheduling of nutrients (Table 4.1). The highest plant height at 30 DAS was recorded in 125% CF applied as two splits (12.40 cm) followed by treatments receiving NPK as per POP applied as two splits (12.30 cm) and 75% CF as two splits (12.03 cm) respectively. The control plot recorded the lowest plant height (8.53 cm). At 60 DAS, all the treatments were equally effective and significantly different from the control with respect to plant height. Lower plant height was recorded in untreated control (51.13 cm). At 90 DAS, 125% CF applied in four splits recorded the highest plant height (217.77 cm).Treatments receiving the customized fertilizer at different doses applied either as two splits or four splits, application of recommended doses of NPK at two splits and application of farm yard manure alone performed equally well with respect to plant height. The lowest plant height was recorded in the control plot (132.13 cm).

4.1.2. Number of branches

The treatments showed no significant influence on number of branches of okra at 30 DAS and 60 DAS (Table 4.2.). At 90 DAS, the treatments receiving 75% CF either as two splits (2.33) or four splits (2.33) and 125% CF applied as two splits (2.33) were equally effective and significantly higher in the production

Table 4. 1. Effect of customized fertilizer and nutrient scheduling on plant height of okra at different growth stages

Treatment No.	Treatments	Plant height (cm)		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	12.03^{a}	97.70^{a}	194.87^{ab}
T_2	75% CF (4 splits)	9.43^{de}	89.27^{a}	184.00^{ab}
T_3	100% CF (2 splits)	11.83^{ab}	96.47^{a}	186.33^{ab}
T_4	100% CF (4 splits)	10.80^{abcd}	89.10^{a}	195.23^{ab}
T_5	125% CF (2 splits)	12.40^{a}	103.73^{a}	197.00^{ab}
T_6	125% CF (4 splits)	11.67^{abc}	101.20^{a}	217.77^{a}
T_7	Soil test based NPK(2 splits)	9.87^{cde}	79.17^{a}	181.90^{b}
T_8	Soil test based NPK(4 splits)	11.80^{abc}	88.33^{a}	176.00^{b}
T_9	NPK as per POP (2 splits)	12.30^{a}	97.03^{a}	200.33^{ab}
T_{10}	NPK as per POP (4 splits)	10.77^{abcd}	91.27^{a}	173.90^{b}
T_{11}	FYM (2 splits)	10.03^{bcde}	86.47^{a}	187.33^{ab}
T_{12}	Absolute control	8.53^{e}	51.13^{b}	132.13^{c}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4.2. Effect of customized fertilizer and nutrient scheduling on number of branches of okra at different growth stages

Treatment No.	Treatments	No. of branches		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	2.67 ^{a}	2.67 ^{a}	2.33 ^{a}
T_2	75% CF (4 splits)	3.00 ^{a}	2.33 ^{a}	2.33 ^{a}
T_3	100% CF (2 splits)	2.33 ^{a}	1.67 ^{a}	1.33 ^{bcd}
T_4	100% CF (4 splits)	2.00 ^{a}	2.00 ^{a}	1.67 ^{abc}
T_5	125% CF (2 splits)	3.00 ^{a}	2.00 ^{a}	2.33 ^{a}
T_6	125% CF (4 splits)	2.67 ^{a}	2.33 ^{a}	1.67 ^{abc}
T_7	Soil test based NPK (2 splits)	1.67 ^{a}	1.33 ^{a}	1.33 ^{bcd}
T_8	Soil test based NPK (4 splits)	2.67 ^{a}	2.00 ^{a}	1.33 ^{bcd}
T_9	NPK as per POP (2 splits)	3.00 ^{a}	2.33 ^{a}	2.00 ^{ab}
T_{10}	NPK as per POP (4 splits)	2.33 ^{a}	2.00 ^{a}	1.00 ^{cd}
T_{11}	FYM (2 splits)	1.67 ^{a}	1.33 ^{a}	1.67 ^{abc}
T_{12}	Absolute control	1.67 ^{a}	2.33 ^{a}	0.67 ^{d}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

of branches compared to other treatments. The control plot recorded the lowest number of branches (0.67).

4.1.3. Number of leaves

The treatments comprising customized fertilizer, soil test based NPK and NPK as per POP application in different splits had no significant influence on number of leaves of okra at 30 DAS, 60 DAS and 90 DAS (Table 4.3).

4.1.4. Dry matter production

The dry matter production was influenced significantly by the nutrients applied and nutrient scheduling (Table 4.4.). At 30 DAS, dry matter production was significantly higher in125% CF applied as four splits (1049.63kg ha^{-1}) and application of recommended dose of NPK as two splits (1022.96 kg ha^{-1}). The successive increase in customized fertilizers from 75% CF to 125% CF with both splits had marked influence on dry matter production. Significant increase in dry matter production was recorded in CF applied treatments, treatments receiving recommended dose of fertilizers and soil test based NPK at 60 DAS. In CF applied treatments, dry matter production showed an increasing trend when the fertilizers were applied in more split doses. Highest dry matter was recorded in 100% CF applied in four splits. It was also observed that the nutrients applied in four equal splits produced higher dry matter when compared to two equal splits at 90 DAS. Except in 125% CF applied in two splits and control, all the other treatments recorded almost similar dry matter production at 90 DAS. The dry matter production showed an increasing trend as the crop matured.

4.2. Yield and yield attributes of okra

4.2.1. Days to first flowering

Various treatments of nutrient management involving customized fertilizers, soil test based NPK, NPK as per POP and FYM showed no significant effect on days to first flowering (Table 4.5).

Table 4.3. Effect of customized fertilizer and nutrient scheduling on number of leaves of okra at different growth stages

Treatment No.	Treatments	No. of leaves		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	6.00 [a]	18.33 [a]	18.00 [a]
T_2	75% CF (4 splits)	5.33 [a]	17.67 [a]	18.67 [a]
T_3	100 % CF (2 splits)	6.00 [a]	18.33 [a]	15.00 [a]
T_4	100 % CF (4 splits)	6.00 [a]	14.00 [a]	13.00 [a]
T_5	125% CF (2 splits)	6.33 [a]	19.33 [a]	19.00 [a]
T_6	125% CF (4 splits)	6.00 [a]	17.67 [a]	19.00 [a]
T_7	Soil test based NPK(2 splits)	5.00 [a]	12.00 [a]	16.67 [a]
T_8	Soil test based NPK(4 splits)	6.00 [a]	20.00 [a]	20.33 [a]
T_9	NPK as per POP (2 splits)	6.00 [a]	20.00 [a]	19.67 [a]
T_{10}	NPK as per POP (4 splits)	5.67 [a]	18.33 [a]	12.00 [a]
T_{11}	FYM (2 splits)	5.67 [a]	14.33 [a]	19.67 [a]
T_{12}	Absolute control	5.00 [a]	12.33 [a]	16.00 [a]

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4.4.Effect of customized fertilizer and nutrient scheduling on dry matter production of okra at different growth stages

Treatment No.	Treatments	Dry matter (kg ha^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	929.87 ^{bc}	1692.59 ^{ab}	3282.71 ^{b}
T_2	75% CF (4 splits)	949.63 ^{bc}	1745.92 ^{a}	3702.46 ^{ab}
T_3	100% CF (2 splits)	942.22 ^{bc}	1751.85 ^{a}	3833.33 ^{ab}
T_4	100% CF (4 splits)	983.95 ^{ab}	1765.68 ^{a}	4119.75 ^{a}
T_5	125% CF (2 splits)	996.91 ^{ab}	1782.71 ^{a}	3670.37 ^{ab}
T_6	125% CF (4 splits)	1049.63^{a}	1754.32 ^{a}	3982.71 ^{ab}
T_7	Soil test based NPK (2 splits)	903.83 ^{cd}	1559.26 ^{cd}	3546.91 ^{ab}
T_8	Soil test based NPK (4 splits)	836.17 ^{de}	1490.62 ^{d}	3988.88 ^{ab}
T_9	NPK as per POP (2 splits)	1022.96 ^{a}	1625.92 ^{bc}	3830.86 ^{ab}
T_{10}	NPK as per POP (4 splits)	935.31 ^{bc}	1556.79 ^{cd}	3551.85 ^{ab}
T_{11}	FYM (2 splits)	809.26 ^{e}	1507.28 ^{d}	3511.11 ^{ab}
T_{12}	Absolute control	614.32 ^{f}	858.02 ^{e}	1630.86 ^{c}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

4.2.2. Number of fruits per plant

The number of fruits obtained by customized fertilizer doses in different splits was significantly higher compared with the control plot (Table 4.5). The number of fruits per plant of okra was significantly higher in treatments receiving 125% CF applied as two splits (31.43) followed by four splits (28.47). Lower doses of customized fertilizers and application of soil test based NPK application and recommended fertilizer dose were significantly inferior and performed similarly in fruit production. The control plot recorded the lowest number of fruits (14.39).

4.2.3. Fruit yield per plant

Per plant fruit yield of okra was significantly influenced by the treatments (Table 4.5). Application of 125% CF either in two splits (0.41 kg plant^{-1}) or four splits (0.38 kg plant^{-1}) were equally effective in the production of fruit and was found superior to all the treatments. It was followed by 100% CF applied as four splits (0.32 kg plant^{-1}). The lowest yield was recorded in the control plot (0.16 kg plant^{-1}).

4.2.4. Yield per hectare

Application of different treatments had significant influence on the total yield of okra (Table 4.6). The highest yield was recorded in 125% CF applied as two splits(14.46 Mg ha^{-1}) and found equally effective as that of 125% CF as four splits (13.69 Mg ha^{-1}). Lower doses of CF and soil test based NPK and recommended dose behaved similarly in the case yield of okra. Control plot recorded the lowest yield (5.67 Mg ha^{-1}). Application of FYM alone gave significantly lesser yield compared to other treatments except control.

Table 4. 5. Effect of customized fertilizer and nutrient scheduling for okra on yield and yield attributes of okra

Treatment No.	Treatments	Days to first flowering	No. of fruits plant $^{-1}$	Yield plant $^{-1}$
T_1	75% CF (2 splits)	30.33 ^{a}	21.98 ^{de}	0.292 ^{bcd}
T_2	75% CF (4 splits)	31.33 ^{a}	24.15 ^{cde}	0.300 ^{bcd}
T_3	100% CF (2 splits)	31.33 ^{a}	25.63 ^{bcde}	0.316 ^{bc}
T_4	100% CF (4 splits)	31.00 ^{a}	25.81 ^{bcd}	0.324 ^{b}
T_5	125% CF (2 splits)	30.67 ^{a}	31.43 ^{a}	0.407 ^{a}
T_6	125% CF (4 splits)	30.67 ^{a}	28.43 ^{ab}	0.385 ^{a}
T_7	Soil test based NPK (2 splits)	30.33 ^{a}	24.44 ^{cde}	0.290 ^{bcd}
T_8	Soil test based NPK (4 splits)	30.00 ^{a}	26.46 ^{bc}	0.309 ^{bc}
T_9	NPK as per POP (2 splits)	30.33 ^{a}	25.39 ^{bcde}	0.305 ^{bc}
T_{10}	NPK as per POP (4 splits)	30.67 ^{a}	21.97 ^{de}	0.281 ^{cd}
T_{11}	FYM (2 splits)	31.33 ^{a}	21.72 ^{e}	0.264 ^{d}
T_{12}	Absolute control	32.00 ^{a}	14.39 ^{f}	0.160 ^{e}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4. 6. Effect of customized fertilizer and nutrient scheduling for okra on yield (Mg ha^{-1})

Treatment No.	Treatments	Yield (Mg ha^{-1})
T_1	75% CF (2 splits)	10.37^{bcd}
T_2	75% CF (4 splits)	10.65^{bcd}
T_3	100% CF (2 splits)	11.22^{bc}
T_4	100% CF (4 splits)	11.52^{b}
T_5	125% CF (2 splits)	14.46^{a}
T_6	125% CF (4 splits)	13.69^{a}
T_7	Soil test based NPK(2 splits)	10.33^{bcd}
T_8	Soil test based NPK(4 splits)	10.97^{bc}
T_9	NPK as per POP (2 splits)	10.84^{bc}
T_{10}	NPK as per POP (4 splits)	9.98^{cd}
T_{11}	FYM (2 splits)	9.39^{d}
T_{12}	Absolute control	5.67^{e}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

4.3. Plant analysis

4.3.1. Nitrogen content

The N content of plants showed a decreasing trend from vegetative to harvesting stage (Table 4.7).The N content at 30 DAS was significantly higher in CF 125% applied in two splits (2.56%). Application of CF and soil test based NPK application resulted in higher N content compared to other treatments.

The application of 100% CF as two splits showed the highest N content (1.96%) at 60 DAS. Application of CF at different dose in different splits recorded higher N content compared to other treatments at 90 DAS. The lowest content of N was recorded in control plot. The N content showed a declining trend as the crop matures from vegetative to harvesting stage.

4.3.2. Phosphorus content

Significant variation in P content was noticed among the nutrients applied in split doses in different stages of the crop (Table 4.8) with higher content in 125% CF applied as two splits (0.65%) and four splits (0.55%) at 30 DAS. The least P content was noticed in control plot (0.28%). At 60 DAS, P content was recorded the highest in soil test based NPK received as four splits (0.44%) followed by two splits (0.39%) and recommended dose of NPK as two splits (0.39%). The lowest P content was observed in control plot (0.26%). At 90 DAS, soil test based NPK as two splits (0.40%) recorded higher P content followed by 125% CF applied as two splits (0.36%). The control plot recorded the lowest content (0.18%). It was observed that the P content in the plant decreased as the crop attained maturity.

4.3.3. Potassium content

Application of 125% customized fertilizer in two splits (5.06%) and four splits (5.04%) recorded significantly higher K content at 30 DAS (Table 4.9).The lowest content was recorded in control plot (3.23%).The K content at 60 DAS was

Table 4. 7. Effect of customized fertilizer and nutrient scheduling on nitrogen content of okra at different growth stages

Treatment No.	Treatments	N (%)		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	2.27^{abc}	1.69^{ab}	1.29^{ab}
T_2	75% CF (4 splits)	1.86^{cd}	1.39^{bcd}	1.11^{bcd}
T_3	100% CF (2 splits)	2.39^{ab}	1.96^{a}	1.46^{a}
T_4	100% CF (4 splits)	2.04^{bcd}	1.46^{bc}	1.17^{bc}
T_5	125% CF (2 splits)	2.56^{a}	1.81^{ab}	1.17^{bc}
T_6	125% CF (4 splits)	2.04^{bcd}	1.52^{bc}	1.11^{bcd}
T_7	Soil test based NPK (2 splits)	2.33^{ab}	0.99^{def}	0.99^{cde}
T_8	Soil test based NPK (4 splits)	2.04^{bcd}	0.68^{efg}	1.23^{b}
T_9	NPK as per POP (2 splits)	1.8^{d}	0.64^{fg}	0.99^{cde}
T_{10}	NPK as per POP (4 splits)	1.28^{e}	0.56^{fg}	0.93^{def}
T_{11}	FYM (2 splits)	1.28^{e}	1.11^{cde}	0.81^{ef}
T_{12}	Absolute control	0.93^{e}	0.53^{g}	0.76^{f}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4. 8. Effect of customized fertilizer and nutrient scheduling on phosphorus content of okra at different growth stages

Treatment No.	Treatments	P (%)		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	0.29^{g}	0.33^{cde}	0.35^{bc}
T_2	75% CF (4 splits)	0.29^{g}	0.31^{def}	0.32^{bc}
T_3	100% CF (2 splits)	0.36^{f}	0.33^{cde}	0.34^{bc}
T_4	100% CF (4 splits)	0.44^{d}	0.28^{efg}	0.32^{bc}
T_5	125% CF (2 splits)	0.65^{a}	0.33^{cd}	0.36^{ab}
T_6	125% CF (4 splits)	0.55^{b}	0.32^{cdef}	0.27^{de}
T_7	Soil test based NPK (2 splits)	0.38^{ef}	0.39^{b}	0.40^{a}
T_8	Soil test based NPK (4 splits)	0.35^{f}	0.44^{a}	0.35^{bc}
T_9	NPK as per POP (2 splits)	0.42^{de}	0.39^{b}	0.31^{cd}
T_{10}	NPK as per POP (4 splits)	0.37^{f}	0.28^{fg}	0.26^{e}
T_{11}	FYM (2 splits)	0.50^{c}	0.36^{bc}	0.21^{f}
T_{12}	Absolute control	0.28^{g}	0.26^{g}	0.18^{f}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4. 9. Effect of customized fertilizer and nutrient scheduling on potassium content of okra at different growth stages

Treatment No.	Treatments	K (%)		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	4.59^{bc}	3.95^{bc}	2.33^{bc}
T_2	75% CF (4 splits)	4.26^{cd}	4,07^{ab}	2.45^{a}
T_3	100% CF (2 splits)	4.59^{bc}	3.66^{d}	2.46^{a}
T_4	100% CF (4 splits)	4.84^{ab}	3.66^{d}	1.79^{g}
T_5	125% CF (2 splits)	5.04^{a}	3.74^{cd}	2.40^{ab}
T_6	125% CF (4 splits)	5.06^{a}	3.87^{bcd}	2.21^{d}
T_7	Soil test based NPK (2 splits)	4.78^{ab}	3.64^{d}	1.90^{f}
T_8	Soil test based NPK (4 splits)	4.50^{bcd}	2.72^{fg}	2.15^{d}
T_9	NPK as per POP (2 splits)	4.70^{ab}	3.34^{e}	2.31^{c}
T_{10}	NPK as per POP (4 splits)	4.16^{d}	2.95^{f}	2.01^{e}
T_{11}	FYM (2 splits)	4.15^{d}	4.20^{a}	2.42^{a}
T_{12}	Absolute control	3.23^{e}	2.56^{g}	1.66^{h}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

highest in FYM alone applied as two splits (4.20%). The least was noticed in control plot (2.56%). The higher content of K at 90 DAS were recorded in 100% CF applied as two splits (2.46%) followed by 75% CF applied as four splits (2.45%) and FYM alone (2.42%).The lowest K content was recorded in the control plot (1.66%). The K content in okra plant showed a declining trend as the crop reached maturity.

4.3.4. Calcium content

Treatments applied to the crop have significant influence on the content of Ca in okra (Table 4.10). Highest Ca content was recorded in 75% CF applied as two splits both at 30 DAS (1.59%) and60 DAS (1.54%). At 90 DAS, the highest Ca content was recorded in 125% CF applied as two splits (1.61%). The least content of Ca was recorded in the untreated control in all the stages of the crop.

4.3.5. Magnesium content

The Mg content of okra showed a declining trend as the crop matured (Table 4.11).The highest Mg content was recorded in 75% CF applied as four splits (0.58 %) followed by 100% CF (0.56%) and 125% CF (0.56%) in four equal splits at 30 DAS. At 60 DAS, the Mg content was highest in 100% CF (0.53%) followed by 125% CF (0.53%) both in two splits. The lowest Mg content was recorded in untreated control for both stages. There was no significant difference in the Mg content at 90 DAS due to the different customized fertilizers doses and other nutrients applied in different splits.

4.3.6. Sulphur content

The S content was significantly affected by the different nutrient management and scheduling and was found highest in soil test based NPK applied as two splits(0.30%) and 100% CF as four splits (0.30%) at 30 DAS (Table 4.12). The least S content was recorded in control (0.17%). The S content at 60 DAS was higher in 125% CF applied as two splits (0.42%) followed by 75% CF as four

Table 4. 10. Effect of customized fertilizer and nutrient scheduling on calcium content of okra at different growth stages

Treatment No.	Treatments	Ca (%)		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	1.59^{a}	1.54^{a}	1.45^{bcd}
T_2	75% CF (4 splits)	1.46^{d}	1.51^{ab}	1.51^{ab}
T_3	100% CF (2 splits)	1.44^{d}	1.52^{ab}	1.55^{ab}
T_4	100% CF (4 splits)	1.49^{cd}	1.43^{cdef}	1.55^{ab}
T_5	125% CF (2 splits)	1.49^{cd}	1.44^{bcde}	1.61^{a}
T_6	125% CF (4 splits)	1.51^{abcd}	1.36^{fg}	1.29^{ef}
T_7	Soil test based NPK (2 splits)	1.59^{ab}	1.46^{bcd}	1.55^{ab}
T_8	Soil test based NPK (4 splits)	1.51^{bcd}	1.41^{def}	1.49^{bc}
T_9	NPK as per POP (2 splits)	1.50^{bcd}	1.49^{abc}	1.46^{bcd}
T_{10}	NPK as per POP (4 splits)	1.33^{e}	1.38^{efg}	1.39^{cde}
T_{11}	FYM (2 splits)	1.57^{abc}	1.52^{ab}	1.37^{de}
T_{12}	Absolute control	1.28^{e}	1.33^{g}	1.24^{f}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4. 11. Effect of customized fertilizer and nutrient scheduling on magnesium content of okra at different growth stages

Treatment No.	Treatments	Mg (%)		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	0.56^{b}	0.51^{abc}	0.49^{a}
T_2	75% CF (4 splits)	0.58^{a}	0.51^{abc}	0.49^{a}
T_3	100% CF (2 splits)	0.55^{b}	0.53^{a}	0.48^{a}
T_4	100% CF (4 splits)	0.56^{ab}	0.50^{cd}	0.49^{a}
T_5	125% CF (2 splits)	0.55^{b}	0.52^{ab}	0.49^{a}
T_6	125% CF (4 splits)	0.56^{ab}	0.52^{abc}	0.49^{a}
T_7	Soil test based NPK (2 splits)	0.55^{b}	0.50^{bcd}	0.48^{a}
T_8	Soil test based NPK (4 splits)	0.54^{bc}	0.50^{cd}	0.48^{a}
T_9	NPK as per POP (2 splits)	0.54^{bc}	0.50^{abcd}	0.48^{a}
T_{10}	NPK as per POP (4 splits)	0.52^{cd}	0.51^{abc}	0.48^{a}
T_{11}	FYM (2 splits)	0.51^{d}	0.51^{abc}	0.47^{a}
T_{12}	Absolute control	0.51^{d}	0.48^{d}	0.47^{a}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4. 12. Effect of customized fertilizer and nutrient scheduling on sulphur content of okra at different growth stages

Treatment No.	Treatments	S (%)		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	0.25^{cd}	0.26^{f}	0.19^{ef}
T_2	75% CF (4 splits)	0.26^{c}	0.39^{b}	0.19^{ef}
T_3	100% CF (2 splits)	0.26^{c}	0.28^{e}	0.20^{de}
T_4	100% CF (4 splits)	0.30^{a}	0.27^{ef}	0.19^{ef}
T_5	125% CF (2 splits)	0.24^{d}	0.42^{a}	0.31^{a}
T_6	125% CF (4 splits)	0.28^{b}	0.35^{c}	0.32^{a}
T_7	Soil test based NPK (2 splits)	0.30^{a}	0.37^{c}	0.17^{f}
T_8	Soil test based NPK (4 splits)	0.21^{e}	0.31^{d}	0.20^{de}
T_9	NPK as per POP (2 splits)	0.18^{fg}	0.32^{d}	0.23^{cd}
T_{10}	NPK as per POP (4 splits)	0.19^{f}	0.27^{ef}	0.27^{b}
T_{11}	FYM (2 splits)	0.29^{ab}	0.37^{c}	0.24^{bc}
T_{12}	Absolute control	0.17^{g}	0.25^{f}	0.12^{g}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

splits (0.39%). The lowest content of S was noticed in 75% CF as two splits (0.26%) and absolute control (0.25%). At 90 DAS, 125% CF either in four splits (0.32%) or two splits (0.31%) showed higher S content. The least S content was recorded in control (0.12%).

4.3.7. Zinc content

The Zn content was significantly affected by customized fertilizer and nutrient scheduling (Table 4.13).The highest Zn content was recorded in 125% CF applied as four splits (50.00 mg kg^{-1}) and two splits (49.33mg kg^{-1}) followed by application of 100% CF as four splits (49.25mg kg^{-1}) at 30 DAS. Similarly the Zn content was significantly higher at 125% CF applied as four splits (39.75 mg kg^{-1}) followed by 100% CF as two splits (35.83 mg kg^{-1}) and 125% CF applied as two splits(34 mg kg^{-1}) at 60 DAS. At 90 DAS, the highest Zn content was recorded in 100% CF as two splits (34.42 mg kg^{-1}) followed by 100% CF as four splits (34.00 mg kg^{-1})and soil test based NPK as two splits (33.50 mg kg^{-1}) respectively and were on par. The lowest Zn content was observed in all the stages in okra without any nutrients. The customized fertilizer doses in both the splits were found to be equally effective on the Zn content.

4.3.8. Manganese content

The customized fertilizer doses of 125% applied either as two splits (218.00 mg kg^{-1}) or four splits (206.83 mg kg^{-1}) were found to be significantly higher in Mn content at 30 DAS than lower doses of customized fertilizer applied (Table 4.14) . The least Mn content was in absolute control (155.33mg kg^{-1}). At 60 DAS, the highest Mn content was in lower doses of customized fertilizers and found equally effective in100% CF as four splits (190.25 mg kg^{-1}) and 75% CF as two splits (189.383 mg kg^{-1}). The lowest Mn content was in FYM alone (118.08 mg kg^{-1}) and untreated control (108.17 mg kg^{-1}). At 90 DAS, the treatments failed to show any significant influence on the Mn content.

Table 4. 13. Effect of customized fertilizer and nutrient scheduling on zinc content of okra at different growth stages

Treatment No.	Treatments	Zn (mg kg^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	31.00^{de}	27.00^{fg}	29.08^{bcde}
T_2	75% CF (4 splits)	36.67^{c}	33.33^{bcd}	30.75 ^{abc}
T_3	100% CF (2 splits)	44.17^{b}	35.83^{b}	34.42 ^{a}
T_4	100% CF (4 splits)	49.25^{a}	32.75^{bcd}	34.00 ^{a}
T_5	125% CF (2 splits)	49.33 ^{a}	34.00^{bc}	30.33 ^{abcd}
T_6	125% CF (4 splits)	50.00 ^{a}	39.75 ^{a}	31.08 ^{abc}
T_7	Soil test based NPK (2 splits)	35.58^{cd}	31.42^{cde}	33.50 ^{a}
T_8	Soil test based NPK (4 splits)	31.50^{de}	28.25^{efg}	32.58 ^{ab}
T_9	NPK as per POP (2 splits)	32.33^{cde}	30.17^{def}	28.17^{cde}
T_{10}	NPK as per POP (4 splits)	29.75^{e}	30.33^{def}	26.50^{de}
T_{11}	FYM (2 splits)	29.83^{e}	28.75^{efg}	28.67^{bcde}
T_{12}	Absolute control	27.58^{e}	25.17^{g}	25.16^{e}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

4.3.9. Iron content

The treatments had significant influence on the Fe content at 30 DAS and 60 DAS (Table 4.15). The highest content of Fe at 30 DAS was recorded in soil test based NPK application at four splits(141.92 mg kg^{-1}) followed by application of 125% CF as two splits (136.23 mg kg^{-1}). The lowest Fe content was in untreated control (106.02 mg kg^{-1}). At 60 DAS, the highest Fe content was recorded in 125% CF applied at two splits (106.10 mg kg^{-1}) followed by application of 100% CF at four splits (104.59 mg kg^{-1}) and recommended dose of NPK at four splits (102.93 mg kg^{-1}. The untreated control recorded the lowest Fe content (73.62 mg kg^{-1}). There was no significant effect of treatments applied on Fe content at 90 DAS.

4.3.10. Copper content

Customized fertilizer doses and scheduling of nutrients had no significant influence on Cu content of the plants both at 30 DAS and 60 DAS (Table 4.16). At 90 DAS, the highest Cu content was recorded in 100% CF applied as four splits (15.83 mg kg^{-1}) followed by 75% CF applied as four splits (13.33 mg kg^{-1}). The lowest content of Cu was recorded in untreated control (7.50 mg kg^{-1}).

4.3.11. Boron content

Customized fertilizer treated plots obtained significantly higher B content than other nutrients advocated (Table 4.17). At 30 DAS, okra receiving 125% CF applied either as two splits or as four splits recorded higher B content. These treatments recorded significantly higher B content throughout the growth stages. Boron content was significantly higher in all the customized fertilizer applied treatments compared to other nutrients. The least content of B was observed in untreated control in all the stages of the crop.

Table 4. 14. Effect of customized fertilizer and nutrient scheduling on manganese content of okra at different growth stages

Treatment No.	Treatments	Mn (mg kg^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	191.00^{bc}	189.38^{a}	142.35^{a}
T_2	75% CF (4 splits)	193.58^{bc}	182.08^{abc}	143.47^{a}
T_3	100% CF (2 splits)	169.08^{de}	162.42^{bcd}	147.52^{a}
T_4	100% CF (4 splits)	186.58^{cd}	190.25^{a}	147.77^{a}
T_5	125% CF (2 splits)	218.00^{a}	183.83^{ab}	146.67^{a}
T_6	125% CF (4 splits)	206.83^{ab}	162.58^{bcd}	148.45^{a}
T_7	Soil test based NPK (2 splits)	179.08^{cd}	166.50^{bcd}	146.00^{a}
T_8	Soil test based NPK (4 splits)	197.75^{bc}	162.25^{cd}	143.93^{a}
T_9	NPK as per POP (2 splits)	184.92^{cd}	183.33^{abc}	145.67^{a}
T_{10}	NPK as per POP (4 splits)	192.03^{bc}	160.17^{d}	142.67^{a}
T_{11}	FYM (2 splits)	194.58^{bc}	118.08^{e}	141.83^{a}
T_{12}	Absolute control	155.83^{e}	108.17^{e}	142.20^{a}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4. 15. Effect of customized fertilizer and nutrient scheduling on iron content of okra at different growth stages

Treatment No.	Treatments	Fe (mg kg^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	122.19^{cd}	93.85^{bcde}	82.78^{a}
T_2	75% CF (4 splits)	115.46^{def}	81.99^{fgh}	79.76^{a}
T_3	100% CF (2 splits)	108.36^{ef}	92.59^{cdef}	83.48^{a}
T_4	100% CF (4 splits)	130.68^{abc}	104.59^{ab}	86.79^{a}
T_5	125% CF (2 splits)	136.23^{ab}	106.10^{a}	84.46^{a}
T_6	125% CF (4 splits)	130.40^{abc}	91.53^{def}	85.63^{a}
T_7	Soil test based NPK (2 splits)	127.48^{bc}	88.56^{defg}	77.55^{a}
T_8	Soil test based NPK (4 splits)	141.92^{a}	86.27^{efg}	80.09^{a}
T_9	NPK as per POP (2 splits)	118.95^{cde}	98.77^{abcd}	84.68^{a}
T_{10}	NPK as per POP (4 splits)	125.47^{bcd}	102.93^{abc}	83.35^{a}
T_{11}	FYM (2 splits)	124.07^{cd}	77.49^{gh}	81.71^{a}
T_{12}	Absolute control	106.02	73.62^{h}	80.11^{a}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4. 16. Effect of customized fertilizer and nutrient scheduling on copper content of okra at different growth stages

Treatment No.	Treatments	Cu (mg kg^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	25.00^{a}	20.00^{a}	10.00^{bcd}
T_2	75% CF (4 splits)	17.50^{a}	24.17^{a}	13.33^{ab}
T_3	100 % CF (2 splits)	21.25^{a}	21.25^{a}	11.67^{bc}
T_4	100 % CF (4 splits)	21.25^{a}	16.25^{a}	15.83^{a}
T_5	125% CF (2 splits)	23.75^{a}	13.33^{a}	8.33^{cd}
T_6	125% CF (4 splits)	23.75^{a}	17.08^{a}	8.33^{cd}
T_7	Soil test based NPK (2 splits)	24.58^{a}	19.58^{a}	10.00^{bcd}
T_8	Soil test based NPK (4 splits)	22.92^{a}	19.17^{a}	9.17^{cd}
T_9	NPK as per POP (2 splits)	22.50^{a}	22.50^{a}	10.00^{bcd}
T_{10}	NPK as per POP (4 splits)	24.17^{a}	15.83^{a}	8.33^{cd}
T_{11}	FYM (2 splits)	26.67^{a}	14.17^{a}	9.17^{cd}
T_{12}	Absolute control	20.00^{a}	17.08^{a}	7.50^{d}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4. 17. Effect of customized fertilizer and nutrient scheduling on boron content of okra at different growth stages

Treatment No.	Treatments	B (mg kg^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	30.95^{c}	28.33^{a}	15.95^{cd}
T_2	75% CF (4 splits)	31.19^{c}	29.04^{a}	16.19^{cd}
T_3	100% CF (2 splits)	32.14^{ab}	29.99^{a}	17.85^{abc}
T_4	100% CF (4 splits)	31.43^{bc}	30.95^{a}	17.38^{bc}
T_5	125% CF (2 splits)	32.38^{a}	30.24^{a}	19.52^{a}
T_6	125% CF (4 splits)	32.38^{a}	29.99^{a}	18.57^{ab}
T_7	Soil test based NPK (2 splits)	28.81^{e}	24.76^{abc}	12.38^{f}
T_8	Soil test based NPK (4 splits)	29.04^{de}	24.28^{abc}	13.33^{ef}
T_9	NPK as per POP (2 splits)	29.76^{d}	24.52^{abc}	14.76^{de}
T_{10}	NPK as per POP (4 splits)	29.52^{de}	18.93^{c}	15.24^{de}
T_{11}	FYM (2 splits)	29.28^{de}	26.67^{ab}	15.95^{cd}
T_{12}	Absolute control	25.47^{f}	20.24^{bc}	11.67^{f}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

4.4. Nutrient uptake by okra

4.4.1. Nitrogen uptake

Significant variation was recorded among the treatments on N uptake of the plant at 30 DAS, 60 DAS and 90 DAS (Table 4.18). The N uptake was the highest in CF 125% applied as two splits (25.55 kg ha^{-1}). The least N uptake was noticed in untreated control (5.71 kg ha^{-1}) at 30 DAS. The application of 100% CF as two splits has significant influence on uptake of N both at 60 DAS (34.39 kg ha^{-1}) and 90 DAS (55.84 kg ha^{-1}). The lowest uptake of N was recorded in control plot at 60 DAS (4.83 kg ha^{-1}) and 90 DAS (12.34 kg ha^{-1}). The uptake of N by the plants showed an increasing trend as the crop matures from vegetative to harvesting stage.

4.3.2. Phosphorus uptake

Significant variation in P uptake was noticed among the nutrients applied in split doses (Table 4.19). Highest P uptake was observed in 125% CF applied as two splits (6.49kg ha $^{-1}$) followed by four splits (5.79 kg ha $^{-1}$) at 30 DAS. Higher P uptake was noticed in FYM alone as two splits (7.61 kg ha^{-1}) at 60 DAS. At 90 DAS, the highest P uptake was noticed in soil test based NPK in two splits (14.93 kg ha^{-1}) and four splits (13.62kg ha^{-1}). The least P uptake was noticed in control plots.

4.3.3. Potassium uptake

The uptake of K by okra due to application of customized fertilizers and other nutrients showed significant effect at 30, 60 and 90 DAS (Table 4.20). Application of 125% CF as four splits recorded significantly higher uptake (53.15kg ha $^{-1}$) and treatment without any nutrients showed the least uptake of K (19.86 kg ha $^{-1}$) at 30 DAS. The highest K uptake was observed in 75% CF applied as four splits (70.49 kg ha $^{-1}$) at 60 DAS and the same treatment recorded the highest K uptake at 90 DAS with 110.55kg ha $^{-1}$ followed by 100% CF applied as

Table 4.18. Effect of customized fertilizer and nutrient scheduling on nitrogen uptake of okra at different growth stages

Treatment No.	Treatments	N uptake (kg ha^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	21.14 ^{bc}	28.55 ^{abc}	45.26 ^{b}
T_2	75% CF (4 splits)	17.69 ^{cd}	24.21 ^{c}	40.55 ^{bcd}
T_3	100 % CF (2 splits)	22.49 ^{ab}	34.39 ^{a}	55.84 ^{a}
T_4	100 % CF (4 splits)	20.07 ^{bcd}	25.72 ^{bc}	45.04 ^{bc}
T_5	125% CF (2 splits)	25.55 ^{a}	32.21 ^{ab}	45.69 ^{b}
T_6	125% CF (4 splits)	22.01 ^{ab}	26.61 ^{bc}	44.21 ^{bc}
T_7	Soil test based NPK (2 splits)	21.06 ^{bcd}	15.44 ^{de}	35.11 ^{def}
T_8	Soil test based NPK (4 splits)	17.06 ^{d}	10.09 ^{def}	43.48 ^{bc}
T_9	NPK as per POP (2 splits)	18.48 ^{bcd}	10.49 ^{def}	37.93 ^{cde}
T_{10}	NPK as per POP (4 splits)	11.97 ^{e}	8.25 ^{ef}	33.03 ^{ef}
T_{11}	FYM (2 splits)	10.36 ^{e}	16.34 ^{d}	28.56 ^{f}
T_{12}	Absolute control	5.71 ^{f}	4.83 ^{f}	12.34 ^{g}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4.19. Effect of customized fertilizer and nutrient scheduling on phosphorus uptake of okra at different growth stages

Treatment No.	Treatments	P uptake (kg ha^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	2.58 ^{f}	5.54 ^{de}	12.23 ^{bcd}
T_2	75% CF (4 splits)	2.80 ^{ef}	5.36 ^{de}	11.65 ^{cd}
T_3	100% CF (2 splits)	3.35 ^{d}	5.73 ^{cde}	12.39 ^{bcd}
T_4	100% CF (4 splits)	4.31 ^{c}	4.98 ^{ef}	11.39 ^{d}
T_5	125% CF (2 splits)	6.49 ^{a}	5.84 ^{bcd}	13.25 ^{abc}
T_6	125% CF (4 splits)	5.79 ^{b}	5.67 ^{cde}	10.62 ^{de}
T_7	Soil test based NPK (2 splits)	3.41 ^{d}	6.07 ^{bcd}	14.93 ^{a}
T_8	Soil test based NPK (4 splits)	2.89 ^{e}	6.54 ^{b}	13.62 ^{ab}
T_9	NPK as per POP (2 splits)	4.30 ^{c}	6.34 ^{bc}	11.76 ^{cd}
T_{10}	NPK as per POP (4 splits)	3.45 ^{d}	4.39 ^{f}	9.22 ^{e}
T_{11}	FYM (2 splits)	4.48 ^{c}	7.61 ^{a}	7.24 ^{f}
T_{12}	Absolute control	1.78 ^{g}	2.31 ^{g}	3.16 ^{g}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4. 20. Effect of customized fertilizer and nutrient scheduling on potassium uptake of okra at different growth stages

Treatment No.	Treatments	K uptake (kg ha^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	42.72 ^{cd}	66.82 ^{ab}	93.65 ^{c}
T_2	75% CF (4 splits)	40.45 ^{de}	70.49 ^{a}	110.55 ^{a}
T_3	100% CF (2 splits)	43.29 ^{c}	64.04 ^{bc}	109.49 ^{a}
T_4	100% CF (4 splits)	47.59 ^{b}	64.55 ^{bc}	69.45 ^{e}
T_5	125% CF (2 splits)	50.28 ^{b}	66.76 ^{ab}	93.74 ^{c}
T_6	125% CF (4 splits)	53.15 ^{a}	67.98 ^{ab}	88.07 ^{d}
T_7	Soil test based NPK (2 splits)	43.20 ^{cd}	56.81 ^{d}	67.49 ^{e}
T_8	Soil test based NPK (4 splits)	37.66 ^{e}	40.50 ^{f}	102.61 ^{b}
T_9	NPK as per POP (2 splits)	48.13 ^{b}	54.28 ^{d}	96.08 ^{c}
T_{10}	NPK as per POP (4 splits)	38.87 ^{e}	45.99 ^{e}	71.47 ^{e}
T_{11}	FYM (2 splits)	33.59 ^{f}	62.08 ^{c}	105.03 ^{b}
T_{12}	Absolute control	19.86 ^{g}	21.96 ^{g}	27.03 ^{f}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

two splits (109.49 kg ha $^{-1}$) and with the lowest K uptake in control plots. The result showed an increasing pattern of K uptake from vegetative to harvest stage.

4.3.4. Calcium uptake

The Ca uptake showed significant variation in nutrients supplied treatments compared to control (Table 4.21). The Ca uptake was the highest at 125% CF applied as four splits (15.89 kg ha $^{-1}$) followed by application of recommended dose of NPK as two splits (15.37 kg ha $^{-1}$) at 30 DAS. The highest Ca uptake was observed in treatments with the application of 100% CF applied as two splits (26.61 kg ha^{-1}) at 60 DAS. The maximum Ca uptake was recorded in 125% CF applied as two splits (62.73 kg ha^{-1}) in 90 DAS. In all the growth stages CF applied treatments recorded higher Ca uptake.

4.3.5. Magnesium uptake

Application of customized fertilizer showed significant influence in Mg uptake of okra (Table 4.22). The Mg uptake was significantly higher with the application of higher doses of customized fertilizer. The highest Mg uptake was recorded in 125% CF applied at four splits in 30 DAS (5.84 kg ha^{-1}) and 90 DAS (19.53 kg ha^{-1}). At 60 DAS, highest Mg uptake was recorded in 125% CF as two splits (9.36 kg ha^{-1}). The least Mg uptake was recorded in untreated control.

4.3.6. Sulphur uptake

The treatments showed significant variation in S uptake by the plants (Table 4.23). Application of customized fertilizer at 125% CF as four splits (2.98 kg ha^{-1}) and 100% CF as four splits (2.95 kg ha^{-1}) recorded significantly higher uptake of S than other treatments at 30 DAS. At 60 DAS, the S uptake was the highest with 125% CF applied as two splits (7.49 kg ha^{-1}). The S uptake was found equal and significantly higher when 125% CF applied either as four splits (12.96%) and two

Table 4.21. Effect of customized fertilizer and nutrient scheduling on calcium uptake of okra at different growth stages

Treatment No.	Treatments	Ca uptake (kg ha^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	14.87^{bc}	26.16^{ab}	50.87^{e}
T_2	75% CF (4 splits)	13.91^{d}	26.12^{ab}	55.12^{cd}
T_3	100% CF (2 splits)	13.59^{d}	26.61^{a}	59.43^{ab}
T_4	100% CF (4 splits)	14.74^{bc}	25.19^{bc}	59.72^{ab}
T_5	125% CF (2 splits)	14.91^{bc}	25.77^{ab}	62.73^{a}
T_6	125% CF (4 splits)	15.89^{a}	23.86^{de}	51.68^{de}
T_7	Soil test based NPK (2 splits)	14.36^{cd}	22.74^{ef}	54.92^{cd}
T_8	Soil test based NPK (4 splits)	12.59^{e}	21.05^{h}	58.71^{bc}
T_9	NPK as per POP (2 splits)	15.37^{ab}	24.36^{cd}	56.07^{bc}
T_{10}	NPK as per POP (4 splits)	12.44^{e}	21.42^{gh}	49.56^{e}
T_{11}	FYM (2 splits)	12.74^{e}	22.41^{fg}	47.98^{e}
T_{12}	Absolute control	7.88^{f}	11.38^{i}	20.23^{f}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4.22. Effect of customized fertilizer and nutrient scheduling on magnesium uptake of okra at different growth stages

Treatment No.	Treatments	Mg uptake (kg ha^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	5.17^{c}	8.65^{d}	17.23^{ef}
T_2	75% CF (4 splits)	5.48^{b}	8.82^{cd}	17.94^{de}
T_3	100% CF (2 splits)	5.20^{c}	9.21^{ab}	18.41^{cd}
T_4	100% CF (4 splits)	5.51^{b}	8.88^{bcd}	18.90^{abc}
T_5	125% CF (2 splits)	5.46^{b}	9.36^{a}	19.34^{ab}
T_6	125% CF (4 splits)	5.84^{a}	9.09^{abc}	19.53^{a}
T_7	Soil test based NPK (2 splits)	4.93^{d}	7.85^{fg}	16.92^{fg}
T_8	Soil test based NPK (4 splits)	4.54^{e}	7.46^{h}	18.50^{bcd}
T_9	NPK as per POP (2 splits)	5.56^{b}	8.20^{e}	18.48^{cd}
T_{10}	NPK as per POP (4 splits)	4.89^{d}	8.02^{ef}	17.14^{efg}
T_{11}	FYM (2 splits)	4.17^{f}	7.56^{gh}	16.37^{g}
T_{12}	Absolute control	3.11^{g}	4.15^{i}	7.76^{h}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4.23. Effect of customized fertilizer and nutrient scheduling on sulphur uptake of okra at different growth stages

Treatment No.	Treatments	S uptake (kg ha^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	2.30 ^{d}	4.41 ^{hi}	6.71 ^{ef}
T_2	75% CF (4 splits)	2.44 ^{cd}	6.89 ^{b}	6.98 ^{def}
T_3	100% CF (2 splits)	2.48 ^{c}	4.97 ^{fg}	7.87 ^{cde}
T_4	100% CF (4 splits)	2.95 ^{a}	4.73 ^{g}	7.59 ^{cde}
T_5	125% CF (2 splits)	2.35 ^{cd}	7.49 ^{a}	12.30 ^{a}
T_6	125% CF (4 splits)	2.98^{a}	6.22 ^{c}	12.96 ^{a}
T_7	Soil test based NPK (2 splits)	2.72 ^{b}	5.80 ^{d}	5.88 ^{f}
T_8	Soil test based NPK (4 splits)	1.79 ^{e}	4.66 ^{gh}	8.02 ^{cd}
T_9	NPK as per POP (2 splits)	1.83 ^{e}	5.25 ^{ef}	8.78 ^{bc}
T_{10}	NPK as per POP (4 splits)	1.78 ^{e}	4.22 ^{i}	9.54 ^{b}
T_{11}	FYM (2 splits)	2.45 ^{cd}	5.45 ^{e}	8.44 ^{bc}
T_{12}	Absolute control	1.03 ^{f}	2.16^{j}	1.89 ^{g}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

splits (12.30%) at 90 DAS. The lowest S uptake was recorded in untreated control in all the crop stages.

4.3.7. Zinc uptake

Customized fertilizers at higher doses showed significant effect on Zn uptake by okra (Table 4.24). The Zn uptake by the okra was significantly higher when 125% CF applied as four splits at 30 DAS (52 g ha^{-1}) and 60 DAS (70 g ha^{-1}). At 90 DAS, the highest Zn uptake was recorded in 100% CF applied both as two splits (132 g ha^{-1}) and four splits (131 g ha^{-1}). The least uptake of Zn was obtained in control plots for all the crop stages. The pattern of Zn uptake showed an increasing trend.

4.3.8. Manganese uptake

The treatments receiving customized fertilizers and other nutrient management showed significant increase in uptake of Mn (Table 4.25). The highest uptake was noticed in 125% CF applied both as two splits(220 g ha^{-1}) and four splits (220 g ha^{-1}) at 30 DAS. Significantly higher Mn uptake was observed at 60 DAS in 100% CF (340g ha^{-1}) applied as four splits and followed by 125% CF as two splits (330g ha^{-1}) and 75% CF given as two splits (320g ha^{-1}). The Mn uptake was recorded highest in treatments applied with 125% CF applied as four splits (610g ha^{-1}) at 90 DAS. The least Mn uptake was recorded in control plot. Mn uptake increased as the crop matured.

4.3.9. Iron uptake

Different treatments of customized fertilizer showed a significant effect on Fe uptake (Table 4.26.). The Fe uptake was significantly higher at 125% CF applied both in four splits (137 g ha^{-1}) and two splits (136 g ha^{-1}) at 30 DAS. The treatments with 125% CF applied as two splits (189 g ha^{-1}) and 100% CF as four splits (185 g ha^{-1}) showed significantly higher Fe uptake at 60 DAS and uptake of

Table 4.24. Effect of customized fertilizer and nutrient scheduling on zinc uptake of okra at different growth stages

Treatment No.	Treatments	Zn uptake (g ha^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	29 ^{fg}	46 ^{cd}	102de
T_2	75% CF (4 splits)	36 ^{d}	58 ^{b}	112 ^{bcd}
T_3	100% CF (2 splits)	41 ^{c}	63 ^{b}	132 ^{a}
T_4	100% CF (4 splits)	48 ^{b}	58 ^{b}	131 ^{a}
T_5	125% CF (2 splits)	49 ^{b}	61 ^{b}	118 ^{abc}
T_6	125% CF (4 splits)	52 ^{a}	70 ^{a}	124^{ab}
T_7	Soil test based NPK (2 splits)	31 ^{ef}	49 ^{c}	119 ^{abc}
T_8	Soil test based NPK (4 splits)	28 ^{g}	42 ^{d}	128 ^{ab}
T_9	NPK as per POP (2 splits)	33 ^{de}	49 ^{c}	108 ^{cde}
T_{10}	NPK as per POP (4 splits)	29 ^{fg}	47 ^{cd}	94 ^{e}
T_{11}	FYM (2 splits)	24 ^{h}	42 ^{d}	101de
T_{12}	Absolute control	17 ^{i}	22 ^{e}	41 ^{f}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4. 25. Effect of customized fertilizer and nutrient scheduling on manganese uptake of okra at different growth stages

Treatment No.	Treatments	Mn uptake ($g\ ha^{-1}$)		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	180^{bc}	320^{ab}	490^{f}
T_2	75% CF (4 splits)	180^{b}	320^{abc}	520^{de}
T_3	100% CF (2 splits)	159^{d}	280^{cd}	560^{bc}
T_4	100% CF (4 splits)	180^{b}	340^{a}	570^{b}
T_5	125% CF (2 splits)	220^{a}	330^{ab}	570^{b}
T_6	125% CF (4 splits)	220^{a}	280^{cd}	610^{a}
T_7	Soil test based NPK (2 splits)	160^{cd}	260^{de}	520^{d}
T_8	Soil test based NPK (4 splits)	160^{cd}	240^{e}	550^{c}
T_9	NPK as per POP (2 splits)	189^{b}	290^{bc}	560^{bc}
T_{10}	NPK as per POP (4 splits)	180^{bc}	250^{e}	510^{ef}
T_{11}	FYM (2 splits)	157^{d}	170^{f}	490^{f}
T_{12}	Absolute control	90^{e}	90^{g}	230^{g}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Fe was significantly higher with 125% CF applied as four splits (341g ha^{-1}) when compared with other nutrients applied at 90 DAS. The lowest Fe uptake was recorded in untreated control for all the stages of crop. Irrespective of the treatments applied, the uptake of Fe increased as the crop matured.

4.3.10. Copper uptake

The customized fertilizer and nutrient scheduling had no significant influence on Cu uptake at 30 DAS (Table 4.27). However, customized fertilizer application at 75% CF as four splits (42 g ha^{-1}) showed significantly higher Cu uptake followed by 100% CF applied as two splits (37 g ha^{-1}) at 60 DAS. At 90 DAS, the highest Cu uptake was recorded in 100% CF given as four splits (61 g ha^{-1}). The least Cu uptake was recorded in control plots. This result showed that nutrient application had significant effect on Cu uptake as compared to control.

4.3.11. Boron uptake

The results showed that higher doses of customized fertilizer caused in higher uptake of B in okra (Table 4.28). There was significant increase in B uptake in 125% CF applied as four splits (34 g ha^{-1}) at 30 DAS and as two splits (54 g ha^{-1}) at 60 DAS and at 90 DAS (76 g ha^{-1}). Customized fertilizers at higher doses showed significant influence on B uptake when compared with other treatments without boron. The least B uptake was recorded in untreated control without boron source. Increase in B uptake was observed as the crop matured.

4.4. Soil Analysis

4.4.1. pH

The levels of customized fertilizer, other nutrient management and nutrient scheduling showed no significant influence on pH content of the soil after the experiment (Table 4.29).

Table 4. 26. Effect of customized fertilizer and nutrient scheduling on iron uptake of okra at different growth stages

Treatment No.	Treatments	Fe uptake (g ha^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	114^{cd}	159^{bc}	291^{ef}
T_2	75% CF (4 splits)	110^{de}	142^{cd}	291^{ef}
T_3	100% CF (2 splits)	102^{e}	162^{b}	320^{bc}
T_4	100% CF (4 splits)	129^{ab}	185^{a}	335^{ab}
T_5	125% CF (2 splits)	136^{a}	189^{a}	330^{abc}
T_6	125% CF (4 splits)	137^{a}	161^{bc}	341^{a}
T_7	Soil test based NPK (2 splits)	115^{cd}	138^{d}	275^{f}
T_8	Soil test based NPK (4 splits)	119^{bcd}	129^{de}	314^{cd}
T_9	NPK as per POP (2 splits)	122^{bc}	161^{bc}	324^{abc}
T_{10}	NPK as per POP (4 splits)	117^{cd}	160^{bc}	296^{de}
T_{11}	FYM (2 splits)	100^{e}	114^{e}	287^{ef}
T_{12}	Absolute control	65^{f}	63^{f}	131^{g}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4.27. Effect of customized fertilizer and nutrient scheduling on copper uptake of okra at different growth stages

Treatment No.	Treatments	Cu uptake (g ha^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	23^{a}	34^{abc}	35^{bcd}
T_2	75% CF (4 splits)	17^{a}	42^{a}	49^{ab}
T_3	100% CF (2 splits)	20^{a}	37^{ab}	45^{bc}
T_4	100% CF (4 splits)	21^{a}	29^{abc}	61^{a}
T_5	125% CF (2 splits)	24^{a}	24^{bcd}	33^{cd}
T_6	125% CF (4 splits)	25^{a}	30^{abc}	33^{cd}
T_7	Soil test based NPK (2 splits)	22^{a}	31^{abc}	35^{bcd}
T_8	Soil test based NPK (4 splits)	19^{a}	29^{abcd}	36^{bcd}
T_9	NPK as per POP (2 splits)	23^{a}	37^{ab}	38^{bcd}
T_{10}	NPK as per POP (4 splits)	23^{a}	25^{bcd}	30^{d}
T_{11}	FYM (2 splits)	22^{a}	21^{cd}	32^{cd}
T_{12}	Absolute control	12^{a}	15^{d}	14^{e}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4.28. Effect of customized fertilizer and nutrient scheduling on boron uptake of okra at different growth stages

Treatment No.	Treatments	B uptake (g ha^{-1})		
		30 DAS	60 DAS	90 DAS
T_1	75% CF (2 splits)	29 ^{e}	48 ^{abc}	56 ^{c}
T_2	75% CF (4 splits)	30 ^{de}	50 ^{ab}	59 ^{c}
T_3	100% CF (2 splits)	30 ^{cd}	53 ^{a}	68 ^{b}
T_4	100% CF (4 splits)	31 ^{c}	55 ^{a}	67 ^{b}
T_5	125% CF (2 splits)	32 ^{b}	54 ^{a}	76 ^{a}
T_6	125% CF (4 splits)	34 ^{a}	53 ^{a}	74 ^{ab}
T_7	Soil test based NPK (2 splits)	26 ^{g}	39 ^{cd}	44 ^{d}
T_8	Soil test based NPK (4 splits)	24 ^{h}	36 ^{d}	52 ^{c}
T_9	NPK as per POP (2 splits)	30 ^{cd}	40 ^{bcd}	57 ^{c}
T_{10}	NPK as per POP (4 splits)	28 ^{f}	29 ^{d}	54 ^{c}
T_{11}	FYM (2 splits)	24 ^{h}	39 ^{bcd}	56 ^{c}
T_{12}	Absolute control	16 ^{i}	17 ^{e}	19 ^{e}

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

4.4.2. Organic carbon

The treatments with customized fertilizers and nutrients added in different splits showed significant influence on the organic carbon of the soil (Table 4.29). Organic carbon was significantly higher in treatments receiving different levels of CF compared to other treatments, even with treatments receiving FYM alone. The highest organic carbon was noticed in 125% CF applied as two splits (1.12%). The lowest organic carbon content was noticed in treatments receiving no nutrients (0.95%).

4.4.3. Available nitrogen

The data pertaining to available N status of soil after the harvest of crop was given in Table 4.30. Application of recommended dose of NPK and soil test based NPK either as two splits or four splits recorded significantly higher available N content in the soil compared to different doses of customized fertilizer application. The least content of available N was noticed in control (88.20 kg ha^{-1}).

4.4.4. Available phosphorus

Application of 125% CF as four splits (85.03kg ha^{-1}) followed by 100% CF as four splits (79.37 kg ha^{-1}) and 75% CF applied as four splits (77.77kg ha^{-1}) recorded higher available P in the soil, and was followed by customized fertilizer applied as two splits (Table 4.30). The least P content in soil was observed in control plot (44.0 kg ha^{-1}).

4.4.5. Available potassium

The available K content in the soil was significantly affected by the treatments (Table 4.30). The highest available K was noticed in 125% CF (149.71 kg ha^{-1}) followed by 100% CF (148.21 kg ha^{-1}) applied in two splits. From the results, it was observed that the available K in the soil was lesser compared to the initial K status. The least content of available K was observed in control (109.76 kg ha^{-1}).

Table 4.29. Effect of customized fertilizer and nutrient scheduling for okra on pH and organic carbon content in soil

Treatment No.	Treatments	pH	OC (%)
T_1	75% CF (2 splits)	5.36 [a]	1.08 [ab]
T_2	75% CF (4 splits)	5.33 [a]	1.05 [bcd]
T_3	100% CF (2 splits)	5.33 [a]	1.07 [abc]
T_4	100% CF (4 splits)	5.33 [a]	1.00 [def]
T_5	125% CF (2 splits)	5.30 [a]	1.12 [a]
T_6	125% CF (4 splits)	5.23 [a]	1.02 [cde]
T_7	Soil test based NPK(2 splits)	5.26 [a]	0.98 [ef]
T_8	Soil test based NPK(4 splits)	5.30 [a]	0.99 [ef]
T_9	NPK as per POP (2 splits)	5.26 [a]	0.98 [ef]
T_{10}	NPK as per POP (4 splits)	5.23 [a]	1.01 [de]
T_{11}	FYM (2 splits)	5.26 [a]	0.99 [def]
T_{12}	Absolute control	5.23 [a]	0.95 [f]
	Pre-analysis of soil	5.3	1.13

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table. 4.30. Effect of customized fertilizer and nutrient scheduling for okra on available N, P and K in soil

Treatment No.	Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1	75% CF (2 splits)	105.00^{bc}	72.37^{bc}	141.49^{abc}
T_2	75% CF (4 splits)	109.20^{b}	77.77^{ab}	120.96^{ef}
T_3	100% CF (2 splits)	109.20^{b}	72.60^{bc}	148.21^{a}
T_4	100% CF (4 splits)	113.40^{b}	79.37^{ab}	137.39^{abcd}
T_5	125% CF (2 splits)	113.40^{b}	72.25^{bc}	149.71^{a}
T_6	125% CF (4 splits)	109.20^{b}	85.00^{a}	126.56^{de}
T_7	Soil test based NPK(2 splits)	134.33^{a}	48.24^{d}	140.37^{abcd}
T_8	Soil test based NPK(4 splits)	138.60^{a}	68.00^{c}	133.65^{bcde}
T_9	NPK as per POP (2 splits)	142.80^{a}	52.49^{d}	143.36^{ab}
T_{10}	NPK as per POP (4 splits)	134.40^{a}	49.17^{d}	128.43^{cde}
T_{11}	FYM (2 splits)	109.20^{b}	72.82^{bc}	137.39^{abcd}
T_{12}	Absolute control	88.20^{c}	43.99^{d}	109.76^{f}
	Pre-analysis in soil	284.4	115.10	293.44

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

4.4.6. Secondary nutrients in soil

The treatments with customized fertilizers and nutrients added in different splits showed significant influence on Ca content of the soil (Table 4.31). The Ca content was significantly higher in 75% CF as four splits (84.50 mg kg^{-1}) and two splits (83.07 mg kg^{-1}). The least Ca content was recorded in untreated control (52.92 mg kg^{-1}).

Application of 125% CF applied as four splits (37.97 mg kg^{-1}) showed significantly higher Mg content in the soil. The Mg content was significantly higher in all the customized fertilizer applied treatments compared to other nutrients applied. The least Mg content in soil was recorded in untreated control (30.70 mg kg^{-1}).

The levels of customized fertilizers, other method of nutrient management and nutrient scheduling had no significant influence on S content of the soil after the experiment.

4.4.7. Micronutrients in soil

The treatments have significant influence on the Zn content of soil. The treatment applied with 75% CF as four splits showed higher Zn (1.17 mg kg^{-1}) when compared to other customized fertilizer doses. The lowest Zn content in soil was in untreated control (0.64 mg kg^{-1}).

The Mn content in the soil showed significant variation with 125% CF applied as two splits (31.63 mg kg^{-1}) followed by four splits (31.53 mg kg^{-1}). The lowest Mn content in soil was recorded in untreated control (21.74 mg kg^{-1}).

The Fe content of the soil was significantly higher in all customized fertilizer applied treatments compared to other nutrients. The Fe content was significantly higher in 100% CF applied as four splits (18.73mg kg^{-1}) and two splits 18.33 (mg kg^{-1}). The least Fe content was observed in absolute control (13.55 mg kg^{-1}).

Table. 4.31. Effect of customized fertilizer and nutrient scheduling for okra on available secondary nutrients in soil

Treatment No.	Treatments	Secondary nutrients (mg kg^{-1})		
		Ca	Mg	S
T_1	75% CF (2 splits)	83.07 ^{a}	37.20 ^{ab}	8.06^{a}
T_2	75% CF (4 splits)	84.50 ^{a}	35.47 ^{c}	8.17^{a}
T_3	100% CF (2 splits)	74.67 ^{abcd}	36.53 ^{bc}	8.36^{a}
T_4	100% CF (4 splits)	67.37 ^{bcde}	37.07 ^{ab}	9.58^{a}
T_5	125% CF (2 splits)	80.13 ^{ab}	37.57 ^{ab}	7.91^{a}
T_6	125% CF (4 splits)	76.60 ^{abc}	37.97^{a}	8.75^{a}
T_7	Soil test based NPK (2 splits)	75.58 ^{abcd}	31.92 ^{d}	8.08^{a}
T_8	Soil test based NPK (4 splits)	59.35 ^{e}	31.77 ^{de}	9.44^{a}
T_9	NPK as per POP (2 splits)	65.48 ^{bcde}	31.83 ^{de}	8.39^{a}
T_{10}	NPK as per POP (4 splits)	60.67 ^{de}	31.47 ^{de}	8.24^{a}
T_{11}	FYM (2 splits)	62.23 ^{cde}	32.35 ^{d}	8.32^{a}
T_{12}	Absolute control	52.92 ^{e}	30.70 ^{e}	7.61^{a}
	Pre-analysis of soil	330.50	41.25	5.47

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Table 4. 32. Effect of customized fertilizer and nutrient scheduling for okra on micronutrients in soil

Treat-ment No.	Treatments	Micronutrients in soil (mg kg^{-1})				
		Zn	Mn	Fe	Cu	B
T_1	75% CF (2 splits)	0.76^{def}	27.23^{bc}	16.90^{ab}	8.10^{a}	0.14^{b}
T_2	75% CF (4 splits)	1.17^{a}	27.70^{bc}	17.03^{ab}	7.50^{a}	0.12^{c}
T_3	100% CF (2 splits)	0.93^{bcd}	27.93^{abc}	18.33^{a}	8.60^{a}	0.16^{a}
T_4	100% CF (4 splits)	0.95^{bc}	30.07^{ab}	18.73^{a}	9.30^{a}	0.12^{cd}
T_5	125% CF (2 splits)	0.88^{bcde}	31.63^{a}	17.14^{ab}	9.80^{a}	0.18^{a}
T_6	125% CF (4 splits)	0.84^{bcde}	31.53^{a}	16.69^{ab}	10.03^{a}	0.16^{ab}
T_7	Soil test based NPK (2 splits)	0.72^{ef}	25.00^{cd}	12.80^{c}	9.30^{a}	0.11^{cde}
T_8	Soil test based NPK (4 splits)	0.82^{bcde}	24.83^{cd}	13.60^{c}	9.23^{a}	0.10^{ef}
T_9	NPK as per POP (2 splits)	0.96^{b}	27.30^{bc}	14.00^{c}	8.70^{a}	0.10^{de}
T_{10}	NPK as per POP (4 splits)	0.78^{cdef}	28.53^{abc}	14.00^{c}	8.30^{a}	0.11^{cde}
T_{11}	FYM (2 splits)	0.99^{b}	28.33^{abc}	15.07^{bc}	8.83^{a}	0.09^{ef}
T_{12}	Absolute control	0.64^{f}	21.74^{d}	13.55^{c}	7.10^{a}	0.08^{f}
	Pre-analysis of soil	1.22	35.56	40.88	3.73	0.17

*In a column, means followed by common letters do not differ significantly at 5% level in DMRT

Various nutrient applications did not show any significant influence on the Cu content in the soil.

The customized fertilizer doses in different splits have significant influence on B content in soil (Table 4.32). Significantly higher B content was noticed in these treatments compared to other nutrients and control. Higher B content was recorded in 125% CF (0.18 mg kg^{-1}) in two splits followed by 125% CF (0.16 mg kg^{-1}) applied in four splits and 100% CF (0.16 mg kg^{-1}) as two splits. The lowest B content was recorded in untreated control (0.08 mg kg^{-1}).

4. 5. Economics

4.5.1. Gross Return

Gross returns from various treatments are presented in Table 4.33. Application of 125% CF applied as two splits (Rs.2,89,267 ha^{-1}) and four splits (Rs. 2,73,963 ha^{-1}) registered the highest gross return compared to lower doses of CF and other nutrients. Gross return of treatments receiving lower doses of CF and soil test based application and recommended doses of NPK were on par. However, these treatments showed significantly higher gross return compared to application of FYM alone. The untreated control without any nutrients recorded the least gross return (Rs. 1,13,452 ha^{-1}).

4.5.2. Net Return

The net return from the treatments supplied with125% CF applied as two splits (Rs. 1,86,709 ha^{-1}) was the highest followed by 125% CF as four splits (Rs. 1,64,906 ha^{-1}) but were statistically on par (Table 4.33). The net return obtained with application of soil test based application either as two or four splits and recommended dose of NPK as two splits were comparable to customized fertilizers when applied as 100% CF and 75% CF. The least net return was recorded in untreated control (Rs. 46,177 ha^{-1}).

4.5.3. Benefit: Cost Ratio

Benefit cost ratio was significantly affected by nutrient doses and their split application applied to okra (Table 4.33). The B: C ratio was significantly higher in 125% CF applied as two splits (2.82) compared to 125% CF applied as four splits and lower doses of CF applied either as two or four splits. Soil test based NPK application either as two or four splits and recommended doses of NPK as two splits recorded comparable BC ratio as that of 125% CF applied as two splits. The untreated control without any nutrients resulted in least B: C ratio (1.68).

Table. 4. 33. Economics of customized fertilizer and nutrient scheduling for okra

Treatments		Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	BC Ratio
T_1	75% CF (2 splits)	91043	207326	116283	2.28
T_2	75% CF (4 splits)	97543	213000	115457	2.18
T_3	100% CF (2 splits)	96800	224429	127629	2.32
T_4	100% CF (4 splits)	103300	230481	127181	2.23
T_5	125% CF (2 splits)	102557	289267	186709	2.82
T_6	125% CF (4 splits)	109057	273963	164906	2.51
T_7	Soil test based NPK(2 splits)	76081	206518	130437	2.71
T_8	Soil test based NPK(4 splits)	82581	219400	136819	2.66
T_9	NPK as per POP (2 splits)	79124	216867	137743	2.74
T_{10}	NPK as per POP (4 splits)	85624	199667	114043	2.33
T_{11}	FYM (2 splits)	83775	187748	103973	2.24
T_{12}	Absolute control	67275	113452	46177	1.68

DISCUSSION

5. DISCUSSION

An investigation entitled "customized fertilizer and nutrient scheduling for okra" was conducted to develop a customized fertilizer grade based on soil analysis and to study its influence on crop growth. The important results of the experiment are discussed in this chapter under the following major sections.

1. Development of customized fertilizer grade
2. Effect of customized fertilizer and other nutrients on the performance of okra
3. Effect of scheduling of different nutrients on the performance of okra
4. Effect of customized fertilizer and other nutrients on soil fertility
5. Economics

5. 1. Development of customized fertilizer grade

Customized fertilizers (CF) are multi-nutrient carriers that can maximize nutrient use efficiency and ensure soil fertility improvement. Pre-analysis of soil from the experimental site will determine the nutrient gap required to be supplemented with the customized fertilizer which will ensure the supply of both macronutrients and micronutrients to the plants.

The CF may include the combination of nutrients based on soil testing and crop requirement and the formulation may contain primary, secondary and micronutrients. The use of CF is not common in Kerala. Hence in this study an attempt was done to develop a customized grade suitable for okra based on the soil fertility rating and nutrient requirement of okra. For the development of CF, soil samples were collected from the field where crops were to be raised. The soil samples were then analysed for micronutrients and macronutrients. Based on the soil fertility rating for NPK, secondary nutrients and micronutrients of that particular soil, the actual nutrient requirement of okra for growing in that particular soil was worked out. The pre-analysis of soil indicated that the soil contained sufficient amounts of N, P, K, Ca, S, Cu, Fe, Zn and Mn. However, Mg and B content in the soil were deficient. Based on the soil fertility level and the prevailing nutrient recommendation for okra, actual nutrients needed for the particular soil was calculated. Accordingly the quantity of nutrients required for developing the CF fertilizer grade was worked out as 59 kg N, 9 kg P, 34 kg K, 16 kg Mg, 1 kg B for one hectare and this was taken as 100 per cent CF. Then the quantity of fertilizer (straight and water soluble fertilizer) to supply the above nutrients were worked out. The fertilizer used for the preparation of CF fertilizers to obtain the above nutrient are 47.36 kg of 19: 19: 19, 55.55 kg of KNO_3, 93.15 kg of urea, 66.67 of $MgCO_3$, 5.0 kg of Dilubor (to supply boron), and these fertilizer were mixed together to get the CF grade. The total quantities of fertilizer required for 100% CF was found to be 267.73 kg ha^{-1}. From this, CF grade 22.01 N: 3.35 P: 12.68 K: 5.97 Mg: 0.37 B was developed.

5. 2. Effect of customized fertilizer and other nutrients on the performance of okra

The result of the study revealed that application of nutrients had significant influence on the yield of okra. Application of customized fertilizer at 125% level recorded significantly higher yield compared to the lower dose of CF and other nutrient rates such as soil test based and application of nutrients as per recommended dose (Fig. 4). Application of 125% CF gave a yield increase of 32.11 per cent, 35.16 per cent and 49.84 per cent respectively compared to soil test based, application of nutrients at recommended dose and FYM alone.

Application of 125% CF at two splits recorded the highest yield which was on par with 125% CF applied in four splits. Yield increase in these treatments may be attributed to the higher growth parameters of these treatments. Significantly higher fruit yield per plant was recorded in treatments applied with 125% CF applied as two splits (Table 4.5). Application of 125% CF recorded significantly higher plant height at different growth stages compared to other nutrient management followed (Table 4.1). The increase in plant height with increased doses of CF was observed in all the stages of the crop up to 125% customized fertilizer dose. The increase in plant height may be due to the enhanced plant nutrient uptake with proper nourishment of the crop. Mudalagiriyappa *et al.* (2015) reported increased plant height in finger millet up to 102.5 cm on application of 150% customized fertilizer dose along with increased tiller production which they attributed to the extra dose of customized fertilizer. The higher plant height in wheat on the application of customized fertilizers over the standard recommended fertilizer doses was also reported by Sekhon *et al.* (2012). The improvement in growth characters resulted in higher sink for better yield. As (Black, 1968) pointed out, plant uptake may increase by improving the metabolic processes and increased activity of meristematic cells and cell elongation on providing all the essential nutrients by the plant. Lower values of plant height and number of branches were recorded in the absolute control plot indicating a deficient supply of macronutrients and micronutrients. In untreated control, there were no additional nutrients supplied for normal growth processes to take place apart from the residual nutrients in the soil. This resulted in lower performance leading to more competition of resources by the crop and weeds (Dada and Fayiminnu, 2010). A good response to the added fertilizers with higher nutrient uptake and accumulation in plants was noticed. Similarly Jana *et al.* (2010) reported a higher uptake with the production of green quality pods in Arka Anamika on comparison with different okra varieties on supplementation on nutrients in higher levels.

The lowest fruit yield was recorded from absolute control plots indicating deficient in supply of nutrients essential for plant growth. As discussed earlier, the favourable effects on growth parameters may have had their effects on translocation of photosynthates from vegetative to reproductive parts resulting in better yield. Amjad *et al.* (2001) reported that on application of NPK fertilizers, the yield was enhanced by 67 per cent over the control.

Application of 100% CF was superior in yield over the treatments soil test based, recommended dose of NPK and FYM alone and the yield increase was in the order of 6.76 per cent, 9.22 per cent and 21.09 per cent (Fig. 4). Compared to the nutrients applied in these treatments, the application of CF facilitated balanced application of all the nutrients and thereby increasing the growth and yield parameters. Similar findings were reported by Dwivedi *et al.* (2014) on the response to customized fertilizer by wheat. Application of 75% CF was equally effective to soil test based application and recommended dose of NPK. These results emphasised the need for balanced application of all primary, secondary and micro nutrients for the growth and development of okra.

Better development of growth parameters such as increased plant height and number of branches resulted in increased dry matter production in CF applied treatments. The dry matter production of the plant was significantly higher in 100% customized fertilizer applied treatments and was proportional to the higher uptake of nitrogen by okra in this particular treatment (Fig. 5). The higher dry matter production could be attributed to higher accumulation of nitrogen in plants which indicates higher photosynthetic rate especially at the maturity stage. Similarly, Mudalagiriyappa *et al.* (2015) obtained higher dry matter production in finger millet on increasing the customized fertilizer levels to 150 per cent (100.41 g $hill^{-1}$) over the control plot (32.56 g $hill^{-1}$). In the present study, the addition of nutrients in 100% CF, 125% CF, soil test based NPK, recommended dose of fertilizers, application of FYM alone and 75% CF resulted in 143.83 per cent, 134.63 per cent, 131 per cent, 126 per cent, 115.30 per cent and 114 per cent increased dry matter production respectively when compared to control. Similar findings were advanced by Mohammad *et al.* (2002) in rice and Nakano and Morita (2009) in forage rice. High nitrogen uptake in all the treatments during different growth stages reflected in higher dry matter accumulation. The cumulative effect of growth and yield attributes resulted in the higher dry matter production (Fig. 6). Mohapatra *et al.* (2001) reported that on increasing the levels of nutrients, simultaneous increase in growth rate and yield traits were observed in okra (cv. Utkal Gaurav). Gowda *et al.* (2002) reported that the biological yield was proportional to the increased rate of nutrients advocated in okra. The total dry matter production might have been due to the better yield attributing characters. In rice, Kaleeswari (2013) reported increase in yield of 17.70 per cent with the application of conventional recommended dose of fertilizers.

The highest uptake of N, P and K were observed in customized fertilizer applied plots when compared to the recommended doses of fertilizers and soil test based NPK application (Table 4.18 ; Table 4.19 ; Table 4.20). Dwivedi *et al.* (2014) reported highest uptake of N, P, K, S and Zn in wheat under 150 per cent customized fertilizer dose. In finger millet, Goud *et al.* (2013) obtained higher uptake of N (95.8 kg ha^{-1}) on application of 150% CF dose which enhanced the availability of nutrients due to the role of nitrogen in improving the root proliferation and hence providing more absorptive area for uptake of other essential nutrients.

The nitrogen uptake was higher in customized fertilizer applied plots when applied with 100% CF and 125% CF respectively (Fig. 7). A similar trend in uptake of potassium was observed for these treatments (Fig. 9). This could be attributed to the application of CF that included all the nutrients in a balanced proportion required for the crop allowing utilization of all the nutrients ultimately leading to higher uptake and better growth and yield attributes. The addition of nitrogen stimulates better growth , crop canopy expansion and interception of solar radiation as it is an essential component of bio-molecules such as amino acids, proteins, nucleic acids, phytohormones and enzymes (Milford *et al.*, 2000; Eckert, 2010). The efficiency of the plant for proper utilization of nitrogen depends on the application of potassium (Al-Abdulsalam and Hamaiel, 2004). Odeleye *et al.* (2005) reported an increase in plant height in okra on addition of potassium showing its major role in growth and development of plant by proper utilization of nutrients from potassium source. The phosphorus uptake by okra was found to be higher at 125% CF at vegetative stage (Fig. 8).

The P uptake as the nutrient level increases could be attributed to higher concentration of CF containing P source which increased the P content in rhizosphere region thereby improving the plant systems with higher uptake. In wheat, Dewal and Pareek (2004) reported similar findings. As the crop matured, the uptake of P was recorded higher in application of FYM alone at 60 DAS and soil test based recommendation at 90 DAS. The higher uptake of P from FYM alone applied plots might be due to active decomposition of organic matter added that would produce various organic acids and anions which in turns compete with the adsorption sites of H_2PO_4 thereby reducing the fixation of P in soil. Violante and Huang (1989) reported that the humic substances produced had greater affinity towards Al oxides than in PO_4. The higher uptake of P on application of soil test based recommendation at harvesting stage might be due to the combined application of the inorganic fertilizers with FYM for balanced fertilization of both macronutrients and micronutrients. Hua *et al.* (2008) and Reddy *et al.* (2003) reported that the bioavailability of P fertilizers increased in acidic soils with the production of humic substances.

Uptake of secondary nutrients was significantly higher in treatments applied with 125% CF either as two or four splits at all the growth stages. The higher uptake of magnesium can be attributed to higher levels of application of CF containing Mg (Fig. 10). The increased nutrient levels of CF source that included magnesium and boron enhanced the uptake of nutrients by okra simultaneously. This might be due to improving the fertilizer supplying potential to the plants by incorporating the deficient nutrients in balanced form. Reddy *et al.* (2009) and Mandal *et al.* (2004) reported that application of combined sources of nutrients with N, P, K, Zn and FYM was superior to the recommended dose of fertilizers. The application of major nutrients along with micronutrients showed superiority over sole application of these nutrients by regulating the uptake of nutrients, as the excessive application of nitrogen solely might result in lodging and disease incidence thereby lowering the quality of yield (Beuerlein *et al.*, 1992). Abulesha (1992) and Singhal and Aggarwal (2005) reported that the uptake of both nitrogen and phosphorus was significantly higher when organic and inorganic sources of nutrients were combined in okra along with higher protein content due to its combined effect.

The uptake of magnesium was higher at higher level of customized fertilizer and it regulated the uptake of macronutrients such as nitrogen and phosphorus. Magnesium plays an important role in translocation of carbohydrates and proteins. Higher uptake of Zn observed in higher dose of CF applied. Increased yield might be due to the favourable effects of zinc by functioning as an activator of several enzymes required for metabolic activities which in turn affected the synthesis of proteins and carbohydrates directly or indirectly. Similar results have been reported by Indulkar and Malewar (1994).

The boron content and uptake increased as the levels of customized fertilizers increased (Fig. 11). Boron being essential for reproductive phase in plants plays a pivotal role in development and differentiation of tissues. It also promotes Ca and K metabolism and in synthesis of pectin, ATP, DNA and RNA. Ghimire *et al.* (2008) reported sufficient production of pods per plant in okra when borax was applied to the soil. The addition of micronutrients not only enriched the micronutrients in soil but also act as catalyst in the uptake and replenishment of certain macronutrients (Phillips, 2004). The uptake of micronutrients such as Fe, Zn, Cu, Mn and B were significantly higher in customized fertilizer plots, mainly in 100% CF and 125% CF applied plots. The increased uptake of micronutrients due to the application of CF along with FYM could be attributed to marked improvement in availability of nutrients enhancing better root growth thereby allowing more absorption of nutrients by the plants (Sharma and Grewal, 1991). Chattopadhyay *et al.* (2003) reported that on application of NPK (150-75-100 kg) along with B (1.12 kg) and Zn (2.5 kg) the crop growth rate was higher in okra. Khokhar (2003) reported that with the application of different concentration of NPK, Zn and B resulted in marked improvement of physiological traits in okra.

In all the treatments, including different levels of CF, soil test based recommendation and recommended dose of fertilizers as per POP, FYM was applied as basal dose and different combinations of chemical fertilizers were applied as split doses. The results of the study revealed that integrated application of organic manure and chemical fertilizers was essential for good production in okra. Application of FYM alone was inferior compared to the integrated nutrient management. However, application of organic manure application alone treatment recorded significantly higher yield compared to the control treatment without addition of FYM and chemical fertilizers. The balanced supplementation of essential nutrients containing both macronutrients and micronutrients along with FYM will improve plant cell expansion and water intake into the cells thereby improving photosynthetic efficiency and consequently yield parameters in rice-wheat cropping system (Singh *et al.*, 2008).

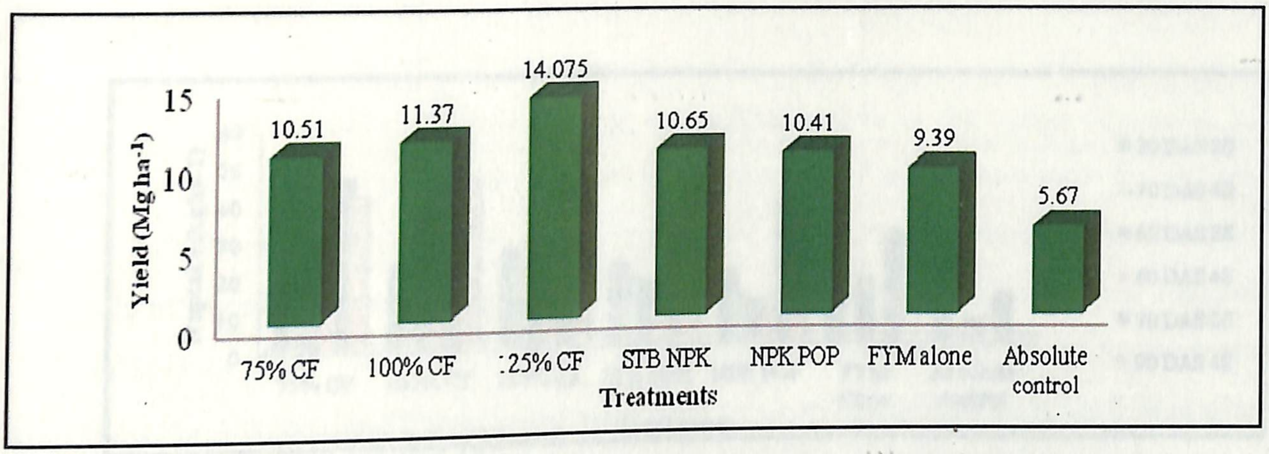

Fig. 4. Effect of different nutrient sources on yield of okra

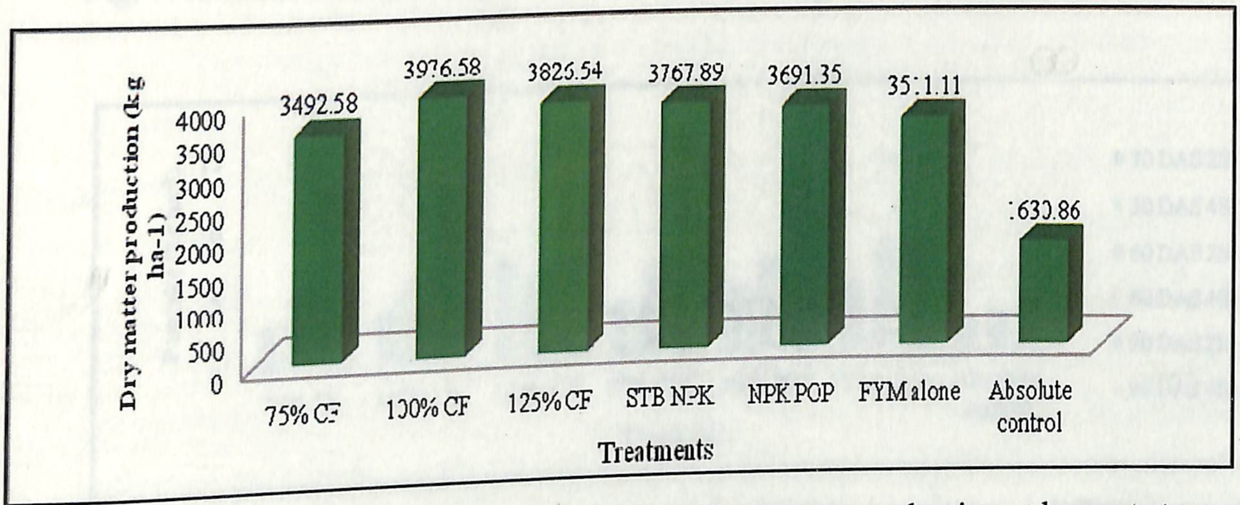

Fig. 5. Influence of different nutrient sources on dry matter production at harvest stage

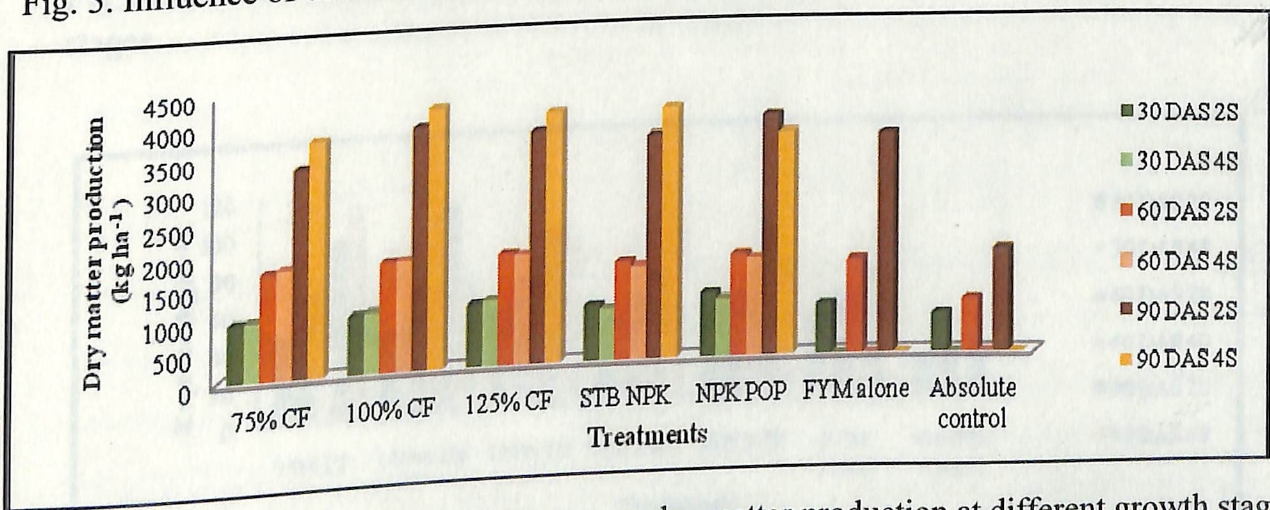

Fig. 6. Influence of different nutrient sources on dry matter production at different growth stages

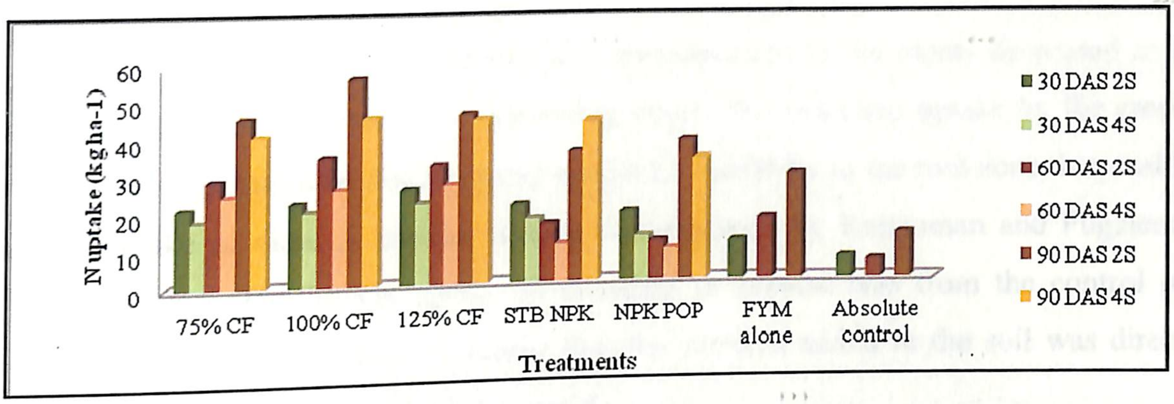

Fig. 7. Influence of different nutrient sources on nitrogen uptake at different growth stages

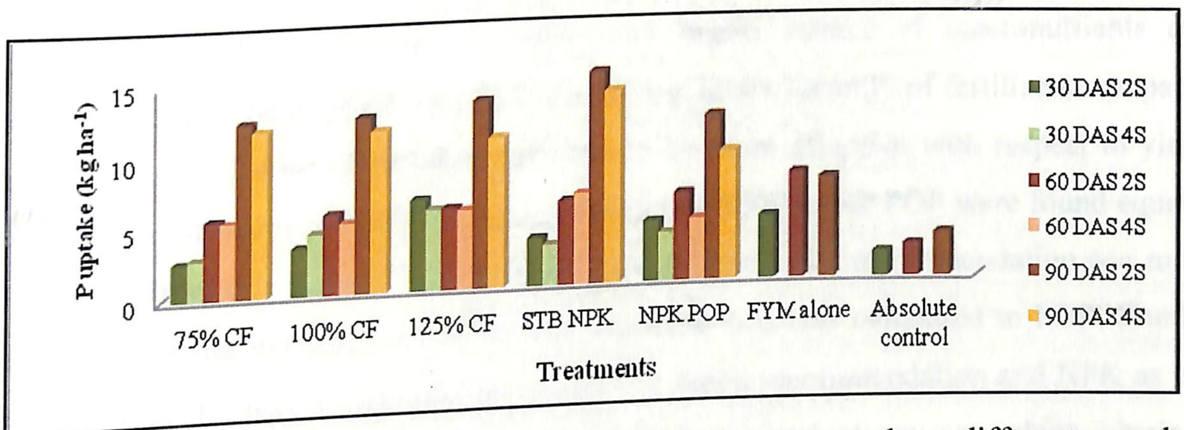

Fig. 8. Influence of different nutrient sources on phosphorus uptake at different growth stages

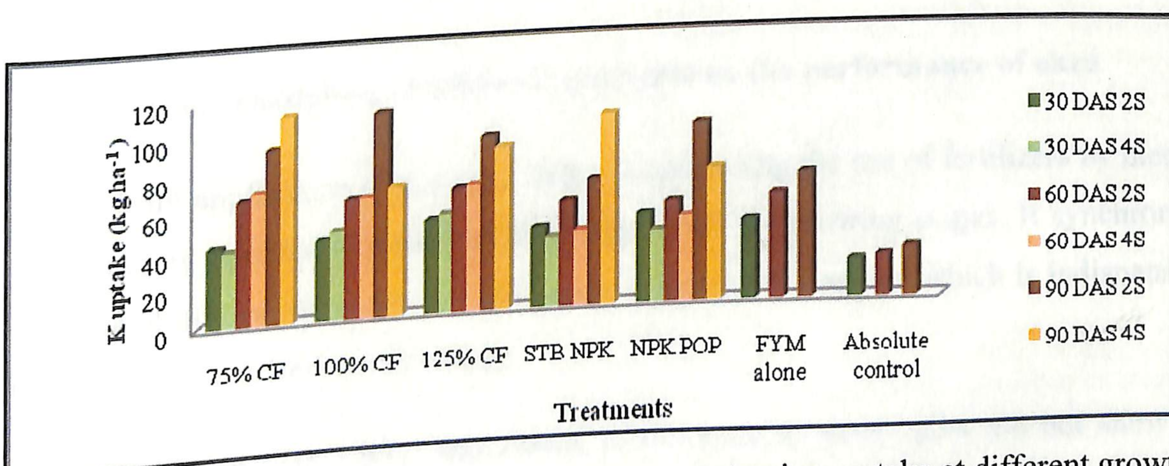

Fig. 9. Influence of different nutrient sources on potassium uptake at different growth stages

The contents of macronutrient and micronutrient in the plants decreased as the crop matured from vegetative to harvesting stage. The effective uptake by the crop at vegetative stage might be due to higher nutrient availability in the root zone that enabled higher uptake in okra. A similar finding was reported by Rajaraman and Pugalendhi (2013) in okra. The lowest uptake of nutrients at harvest was from the control plot without any fertilizers which indicates that the nutrient added in the soil was directly proportional to its uptake with higher yield.

The higher yield obtained due to higher levels of CF could be attributed to better growth and yield attributing characters and higher uptake of macronutrients and micronutrients. The application of CF containing lesser quantity of fertilizers compared to recommended dose of fertilizers proved to be more effective with respect to yield. Application of soil test based recommendation and NPK as per POP were found equally effective. From this it could be concluded that soil test based recommendation was more beneficial as the nutrient applied in this treatment was less compared to POP. Similar performance in yield on application of soil test based recommendation and NPK as per POP might be due to the application of primary nutrient sources which obtained similarity in the production of growth parameters, dry matter production and uptake of nutrients.

5.3. Effect of scheduling of different nutrients on the performance of okra

Split application of nutrients helps in optimizing the use of fertilizers by meeting the changing nutrient demands of the crops in all the growing stages. It synchronized with the ability of the plants for utilization of nutrients supplied which is indispensable for proper growth and development.

In the present study, application of nutrients in more splits did not show any significant variation in the growth and yield of okra (Fig. 12 ; Fig. 13). Split application of different levels of CF, soil test based recommendation and recommended dose of NPK did not show any significant variation. Application of CF either as two splits or four splits produced similar yield (Fig. 12). The yield parameters of okra were also similar when the nutrients were applied in two or four splits (Fig. 14). The lower response of okra to split application of higher levels of fertilizers as per POP in two and four splits on yield might be due to nutrient imbalances in soil on application of primary nutrient sources alone. This was in accordance with the findings of Uwah *et al.* (2010) in okra.

The dry matter production at harvest did not show any significant effects with split application (Fig 15). The dry matter production increased to 12.79 per cent, 7.5 per cent, 8.5 per cent and 12.46 per cent in 75% CF, 100% CF, 125% CF and soil test based recommendation in four splits compared to two splits of these treatments. However, the increase in dry matter production was not positively reflected in the development of yield contributing characters and yield. The dry matter production at harvest was higher for split application. This indicated that whatever may be the nutrient doses, application of nutrients as more splits did not result in yield increase. From this, it was deduced that by applying fertilizers in more splits, the total biological yield developed failed to contribute towards economic yield. The higher mobilization of nutrients due to enhanced enzyme activities resulted in higher biological yield when applied in splits. In rice, Devasenapathy (1997) reported similar result.

The uptake of NPK was also not significantly influenced by split application of nutrients (Fig. 16 ; Fig. 17 ; Fig. 18). The application of nutrients either as two or four splits showed similar trend in nutrient uptake by okra. This might be due to higher nutrient use efficiency by minimizing the potential loss from the soil by contributing directly from the available nutrient pool. A similar trend of macronutrient and micronutrient uptake on split application was noticed. Similar result was reported by Kamalakumari and Singaram (1996). The uptake of Mg and B was not significantly influenced by split application of nutrients (Fig 19 ; Fig 20). Similar result was reported by Bard and Wolstenholme (1999) that on split application of boron in more than two splits showed no significant effect in yield.

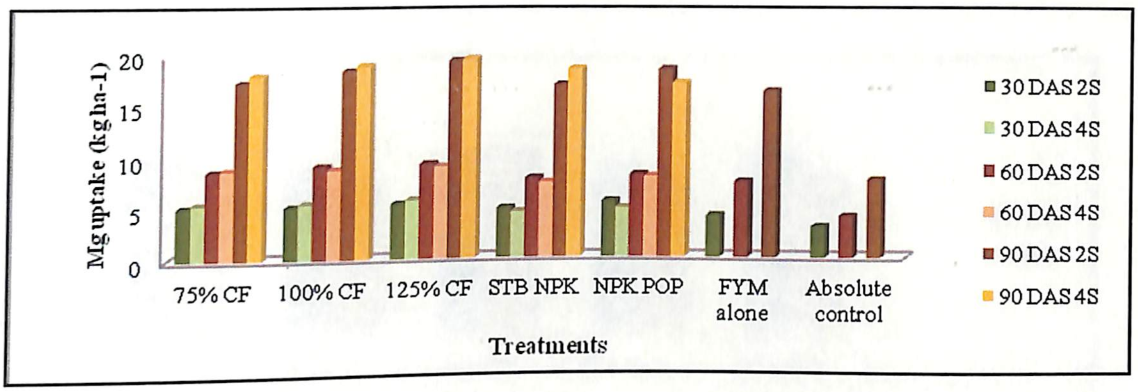

Fig. 10. Influence of different nutrient sources on magnesium uptake at different growth stages

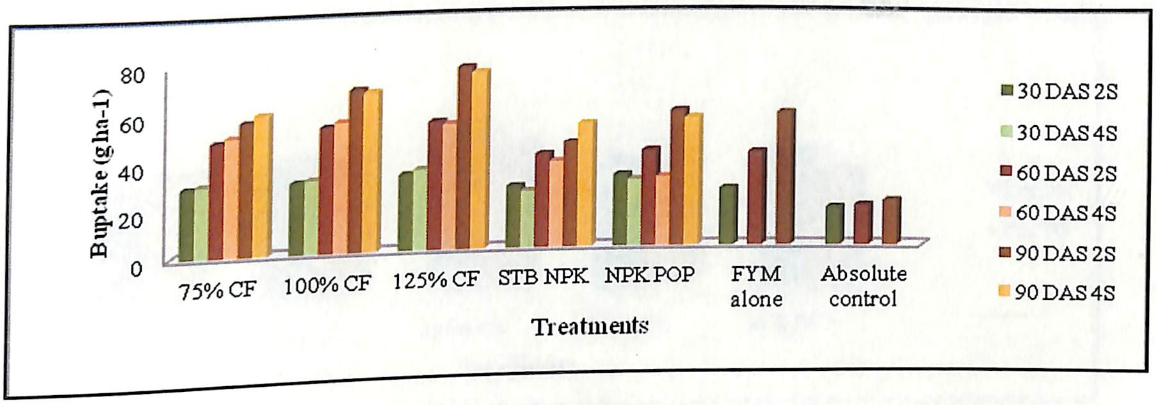

Fig. 11. Influence of different nutrient sources on boron uptake at different growth stages

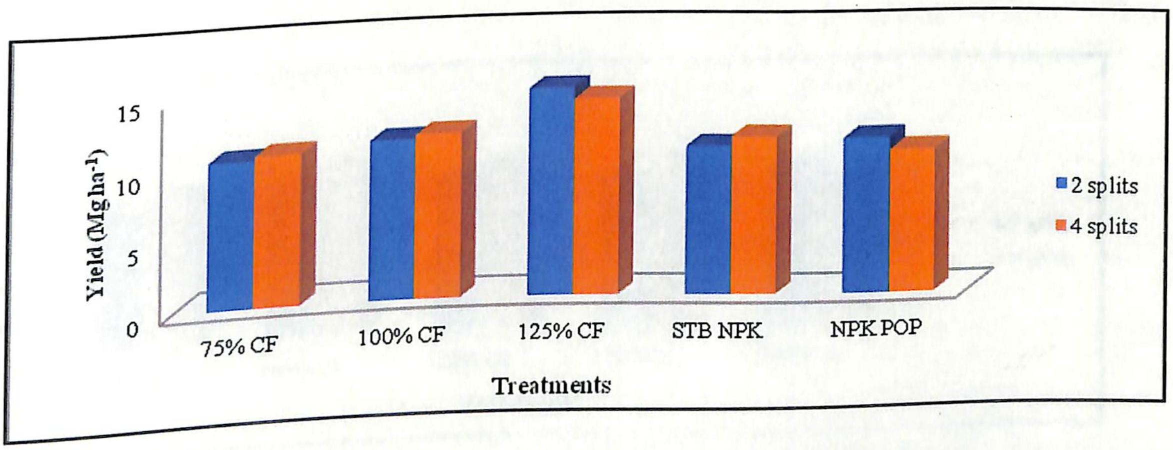

Fig. 12. Effect of split application of nutrients on the yield of okra

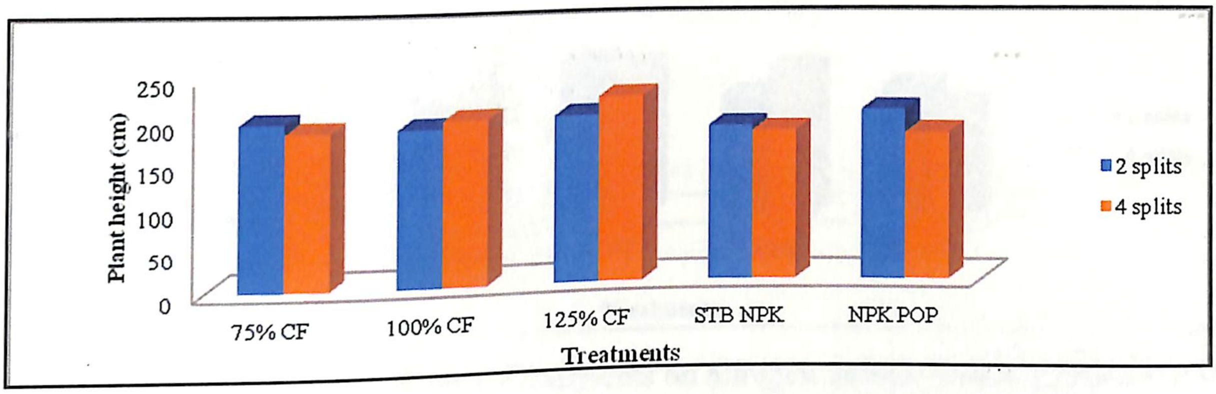

Fig. 13. Effect of split application of nutrients on the plant height of okra at harvest

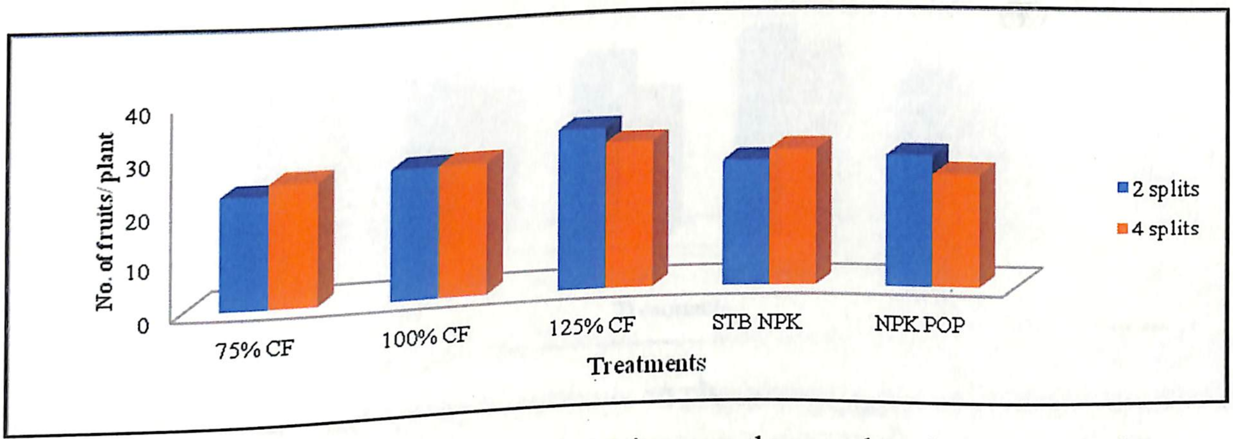

Fig. 14. Effect of split application of nutrients on the per plant fruit yield of okra

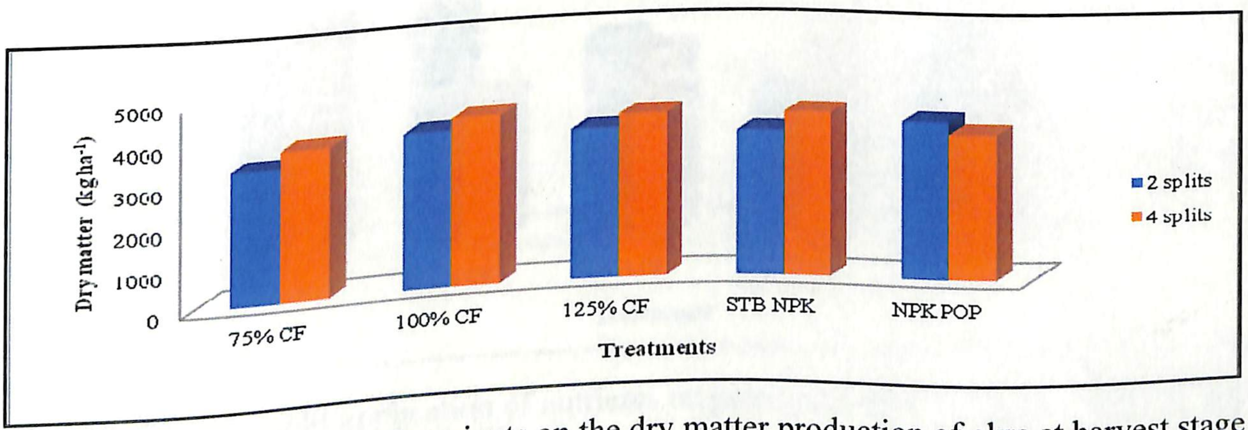

Fig. 15. Split application of nutrients on the dry matter production of okra at harvest stage

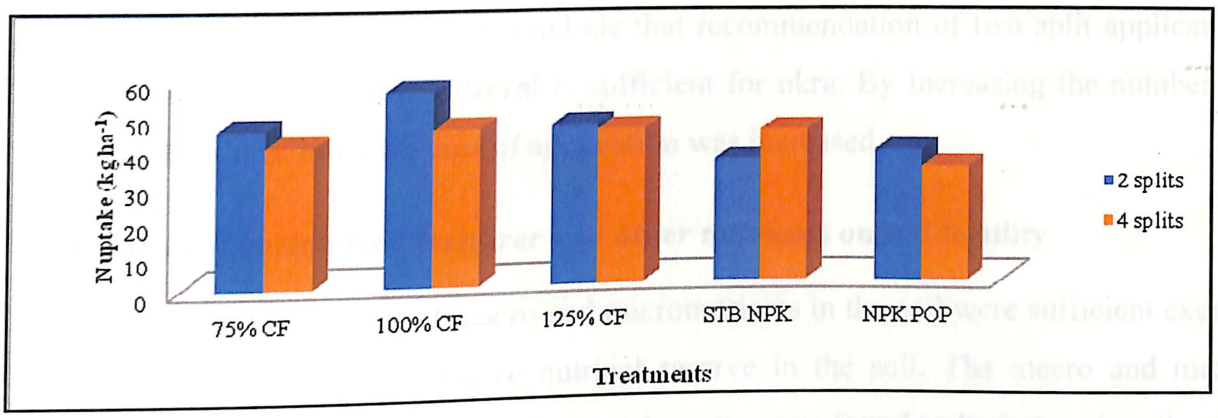

Fig. 16. Effect of split application of nutrients on nitrogen uptake of okra at harvest stage

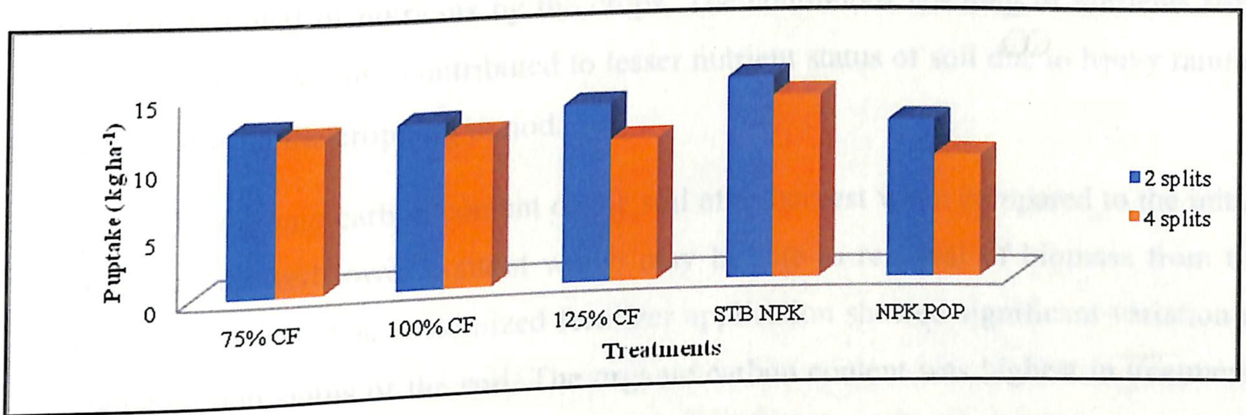

Fig. 17. Effect of split application of nutrients on phosphorus uptake of okra at harvest stage

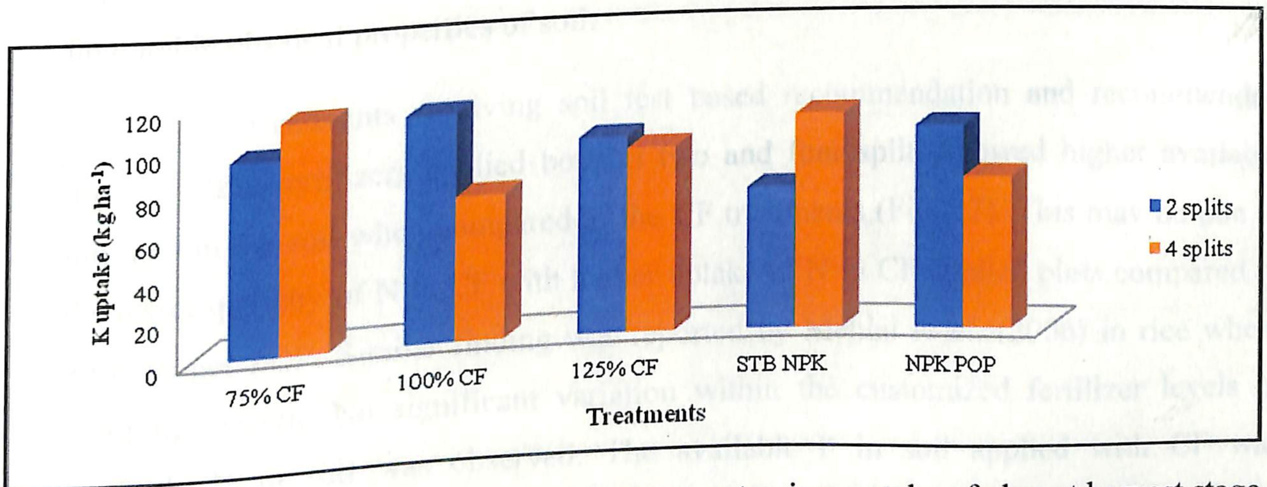

Fig. 18. Effect of split application of nutrients on potassium uptake of okra at harvest stage

From this study we can conclude that recommendation of two split application of nutrients *i.e.* at 30 days interval is sufficient for okra. By increasing the number of split applications, however cost of application was increased.

5.4. Effect of customized fertilizer and other nutrients on soil fertility

The initial content of macro and micronutrients in the soil were sufficient except for Mg and B because of native nutrient reserve in the soil. The macro and micro nutrient status of the soil after the harvest however was found to be lesser than the pre experimental nutrient status. This may be attributed to the efficient uptake by the crops and also removal of nutrients by the crops. The continuous leaching of nutrients from the soil might have also contributed to lesser nutrient status of soil due to heavy rainfall received during the cropping period.

The organic carbon content of the soil after harvest when compared to the initial soil status showed lower content which may be due to removal of biomass from the field after harvest. The customized fertilizer application showed significant variation in organic carbon status of the soil. The organic carbon content was highest in treatments applied with 125% in two splits (Fig. 21). Sadatulla and Shyla (2013) reported that application of 150% nutrients through customized fertilizer showed higher OC due to favourable physical properties of soil.

The treatments receiving soil test based recommendation and recommended dose of NPK fertilizers applied both as two and four splits showed higher available nitrogen in the soil when compared to the CF treatments (Fig. 22). This may be due to the lesser quantity of N in CF with higher uptake of N in CF applied plots compared to NPK as per POP. Similar finding was reported by Mehlal *et al.* (2006) in rice wheat cropping system. No significant variation within the customized fertilizer levels in available N in soil was observed. The available P in soil applied with CF was significantly higher compared to soil test based application and recommended dose of NPK but was on par with application of FYM alone (Fig. 23). This might be due to continuous split application of soluble form of P in CF treatments while in soil test based and recommended dose of NPK, P was applied as basal alone.

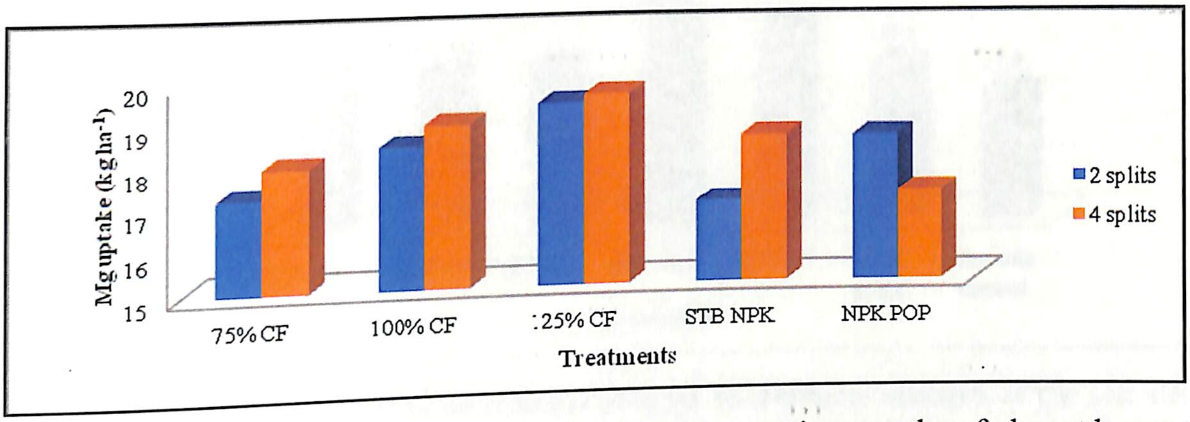

Fig. 19. Effect of split application of nutrients on magnesium uptake of okra at harvest stage

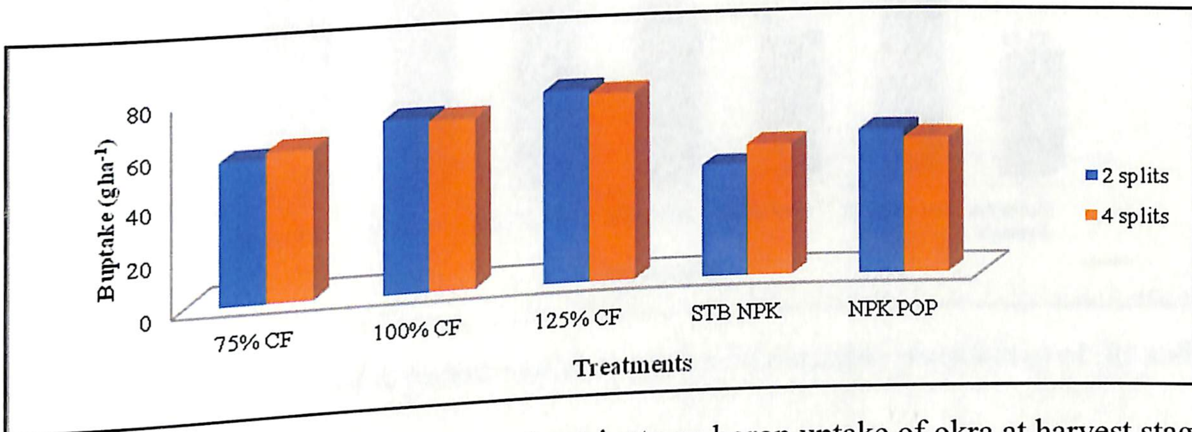

Fig. 20. Effect of split application of nutrients on boron uptake of okra at harvest stage

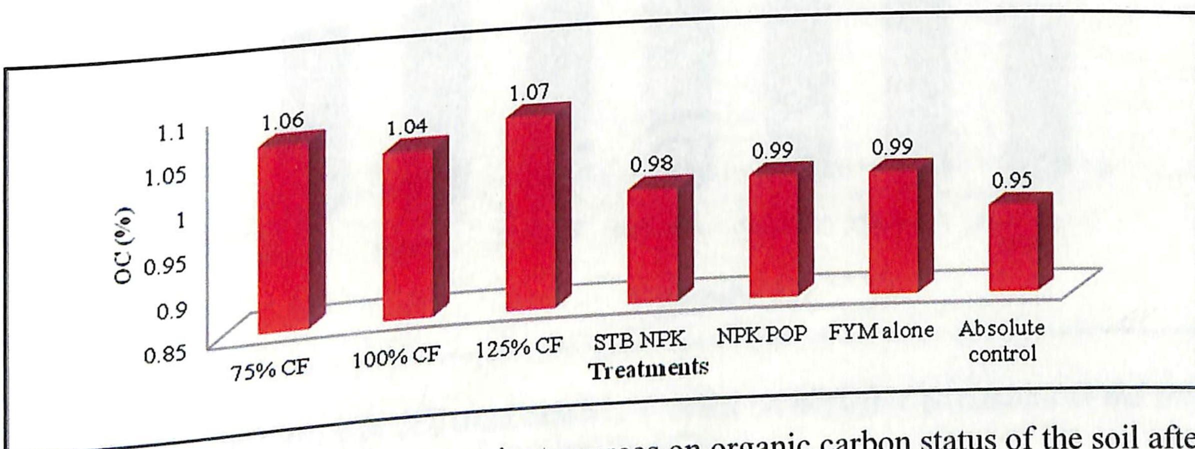

Fig. 21. Influence of different nutrient sources on organic carbon status of the soil after harvest

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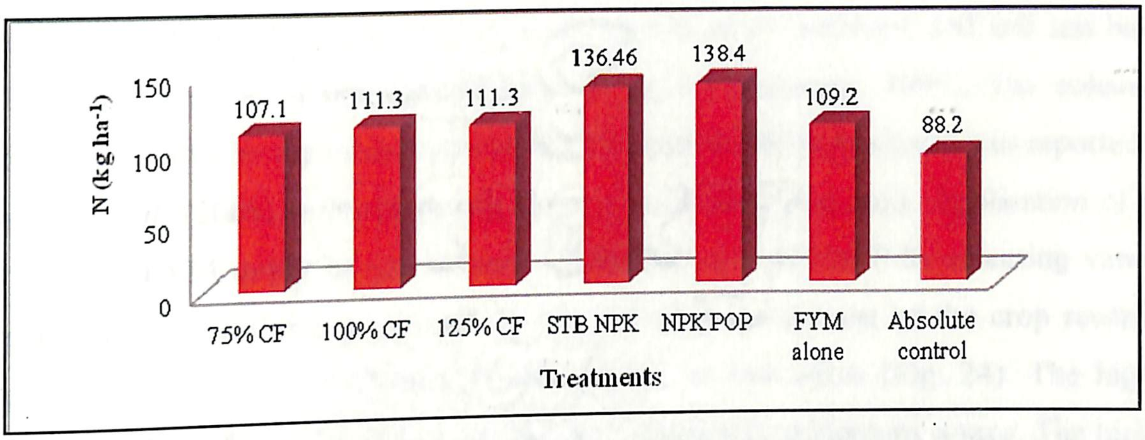

Fig. 22. Influence of different nutrient sources on available nitrogen of the soil after harvest

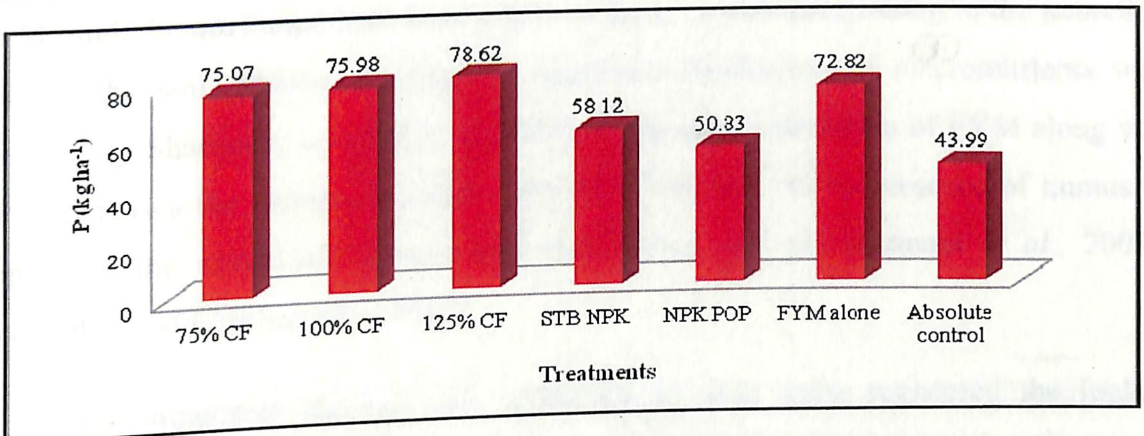

Fig. 23. Influence of different nutrient sources on available phosphorus of the soil after harvest

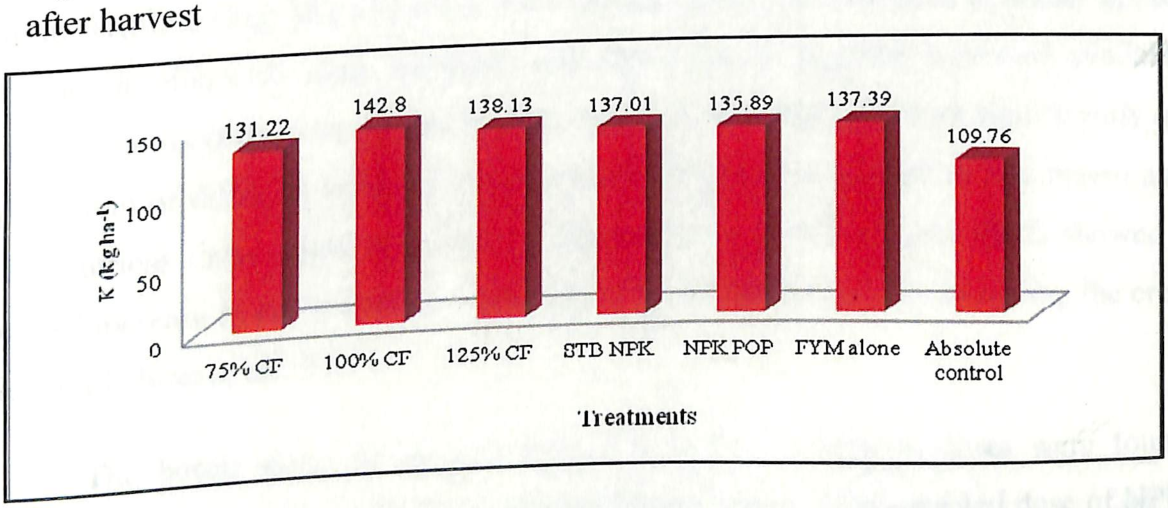

Fig. 24. Influence of different nutrient sources on available potassium of the soil after harvest

The lesser available P in soil with recommended dose of fertilizers and soil test based NPK might be due to one-time application of P (Venkatesh, 1999). The enhanced available P status by the integrated use of FYM and chemical fertilizers was reported by Sharma *et al.* (2005) in broccoli and Sharma *et al.* (2009) in okra. Application of CF along with FYM might have enhanced solubilisation of native P by releasing various organic acids. Available potassium in the soil after the harvest of the crop recorded higher in 100% CF and 125% CF both applied as two splits (Fig. 24). The higher presence of K in the soil could be attributed to addition of potassium source. The higher available potassium noted in plots with customized fertilizers in two splits along with FYM might be attributed beneficial effect of direct potassium addition to the potassium pool in the soil. Similar findings on combined application of macronutrients were reported by Sharma *et al.* (2003). In addition, the supplementation of FYM along with NPK increases the cation exchange capacity of the soil due to presence of humus by improving the microbial biomass and maintaining soil pH (Kumara *et al.*, 2007 ; Hemalatha and Chellamuthu, 2013).

The treatment applied with 125% CF as four splits registered the highest exchangeable Mg in soil when compared to other nutrients added due to the presence of Mg in fertilizer (Fig. 25). Higher content of this nutrient also resulted in higher uptake of macronutrients by okra. Sadatulla and Shyla (2013) reported increased available macronutrients and exchangeable Ca, Mg and S in soil which differed significantly on application of different levels of customized fertilizers. The increase in soil macro and micronutrient status could be related to adequate supply of fertilizers which showed a marked increase in concentration of nutrients in plant tissues thereby increasing the crop yield (Adediran *et al.*, 2005).

The boron status of the soil treated with CF at different doses were found significantly higher compared to soil test based application, recommended dose of NPK and application of FYM alone. This might be due to the presence of boron in the CF grade. The boron availability depends on the pH of the soil, and the uptake of this element correlates with extractable boron. Similar finding was reported by Ambare *et al.* (2005) in okra. The Fe, Mn and Zn content of the soil was significantly higher in treatment applied with different levels of CF in all the growth stages when compared to other treatments without CF. Similarly, Kaleeswari (2013) reported the improvement in soil nutrient status on application of customized fertilizers supplemented with micronutrient mixture on lowland rice. There was no significant variation on application of CF in two or four splits on the micronutrient status of the soil. The Zn content in the soil was significantly higher in lower doses of CF (75%) when compared to higher levels of CF while the available P was higher in higher levels of CF which may be due to antagonistic effect of P and Zn. Similar trend was also observed on the uptake of P and Zn. The increased in content of P might interfere with the metabolic activities of Zn.

Split application of different nutrients showed no significant variation in available nitrogen of the soil after harvest (Fig.27). The available phosphorus in the soil increased on application of nutrients with four splits except on recommended dose of NPK (Fig. 28). Singh *et al.* (1988) reported that the application of P in more than two splits increased the fertility level of soil by increasing the available P. The available potassium in the soil showed significant increase when applied as two splits (Fig. 29). Split application had no significant influence on exchangeable Mg content of the soil (Fig. 30). The boron content was also higher for application in two splits (Fig. 31). Except for P, all the other nutrients in the soil were higher when the nutrients were applied as two splits.

Application of CF at different levels resulted in higher contents of organic carbon, macro and micronutrient in the soil when compared to the application of soil test based recommendation and recommended dose of NPK.

5. 5. Economics

Customized fertilizers applied as 125% CF in two splits produced the highest BC ratio (2.82) indicating the effect of higher yield. Though no significant variation in the yield in treatments applied with 125% CF either as two or four splits, higher BCR was obtained due to lesser labour cost when applied in lesser splits. Significant higher

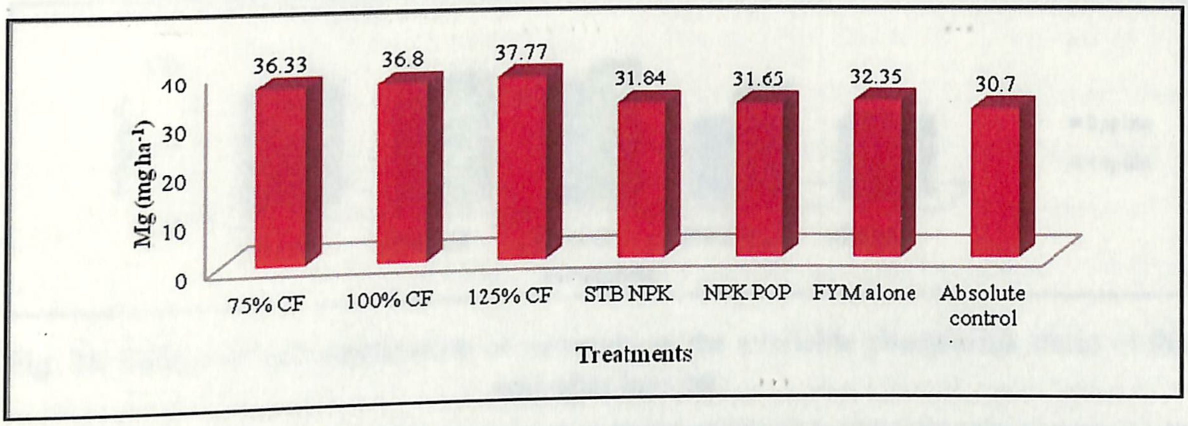

Fig. 25. Influence of different nutrient sources on exchangeable magnesium of the soil after harvest

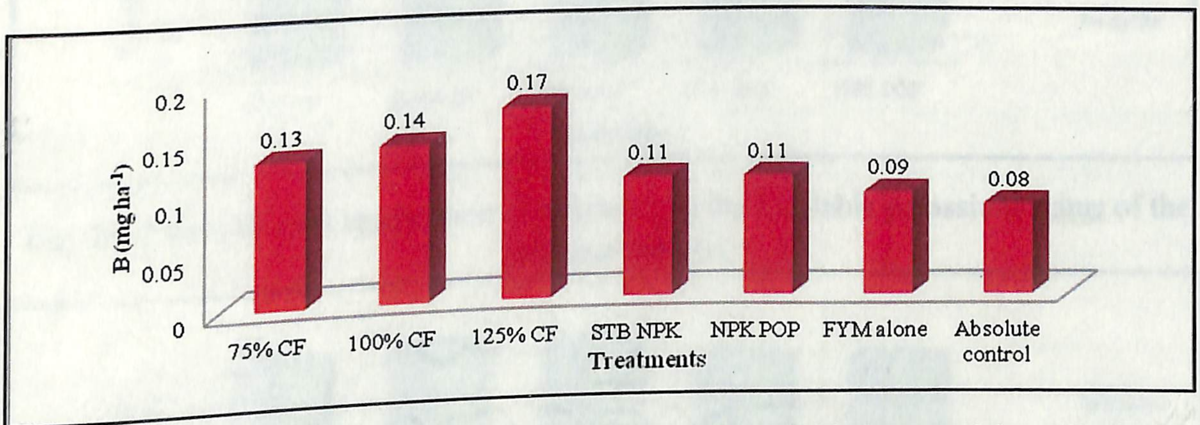

Fig. 26. Influence of different nutrient sources on available boron of the soil after harvest

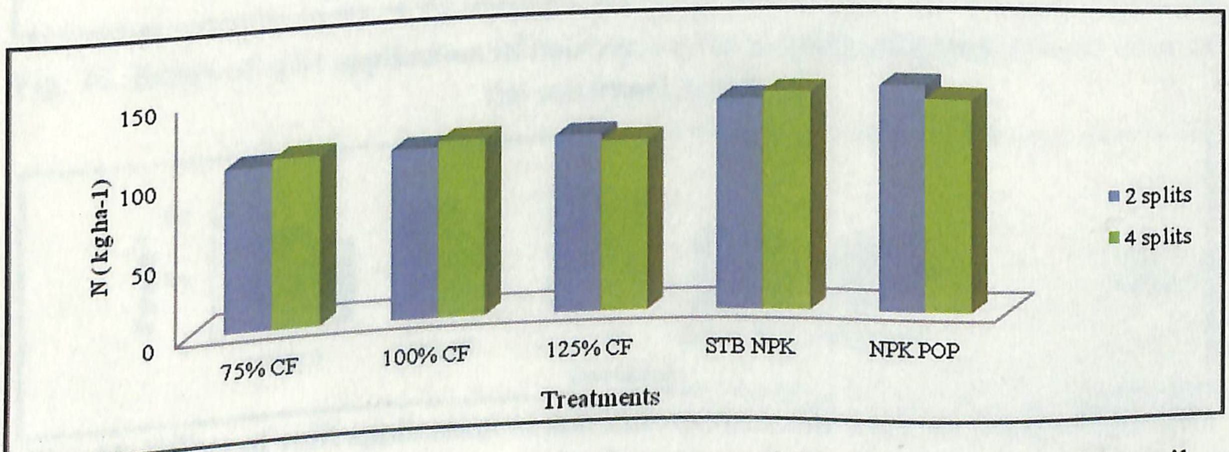

Fig. 27. Effect of split application of nutrients on available nitrogen status of the soil after harvest

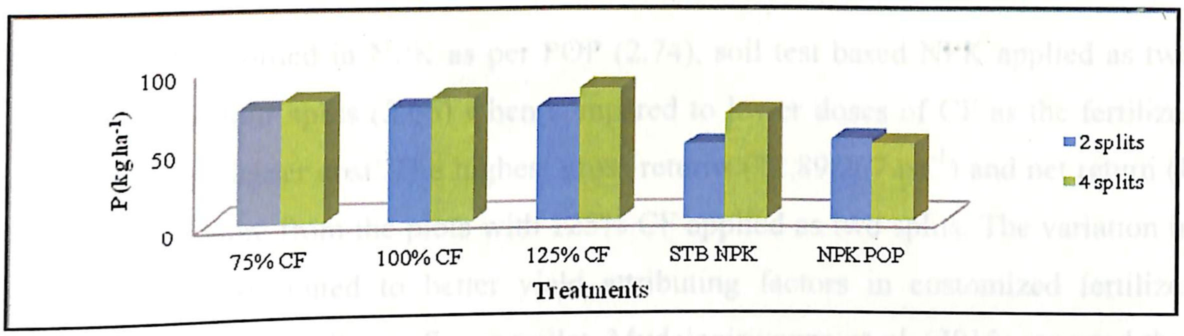

Fig. 28. Effect of split application of nutrients on the available phosphorus status of the soil after harvest

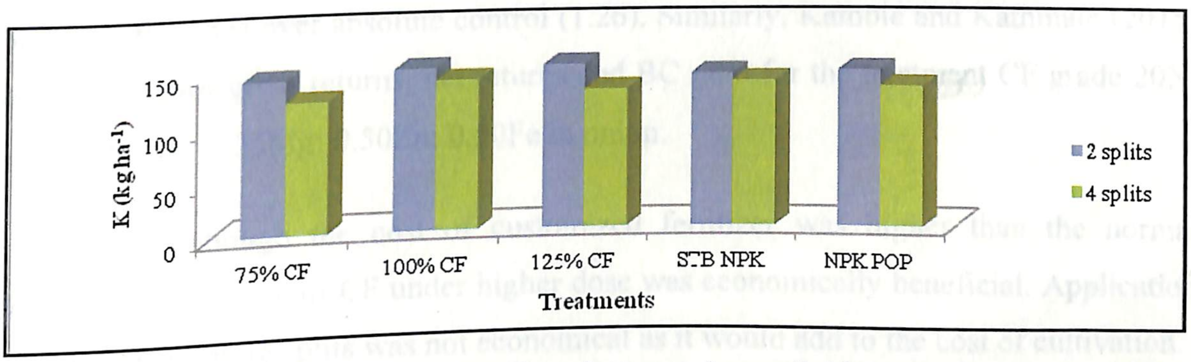

Fig. 29. Effect of split application of nutrients on the available potassium status of the soil after harvest

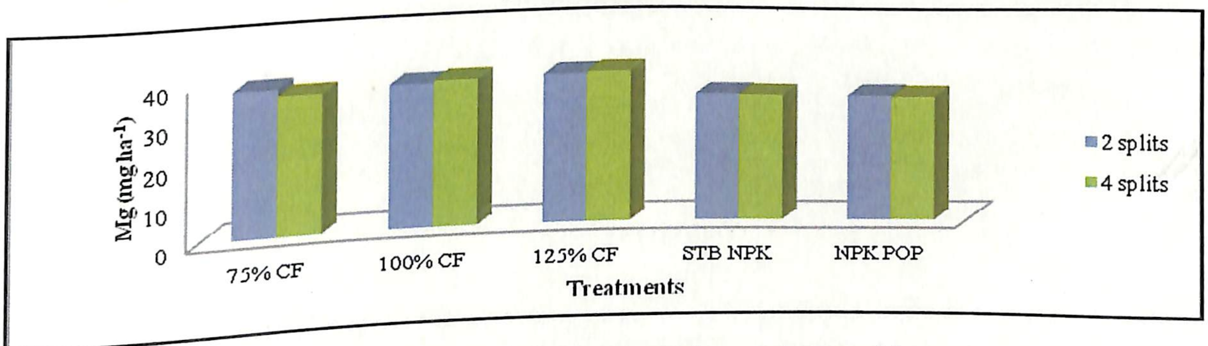

Fig. 30. Effect of split application of nutrients on the exchangeable magnesium status of the soil after harvest

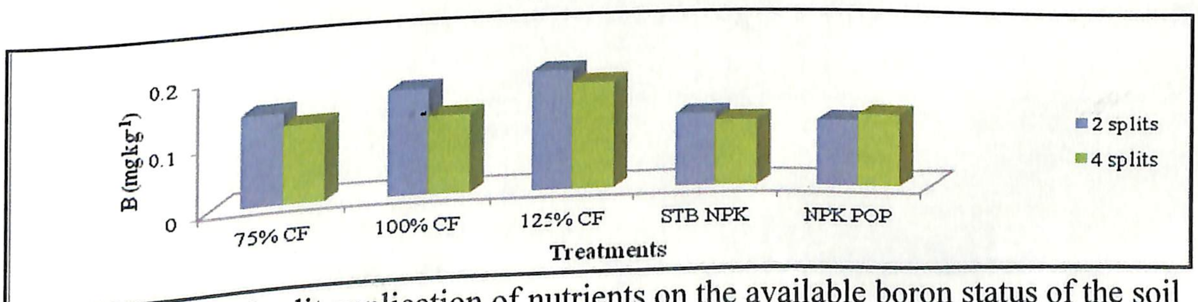

Fig. 31. Effect of split application of nutrients on the available boron status of the soil after harvest

BC ratio was recorded in NPK as per POP (2.74), soil test based NPK applied as two splits (2.71) or four splits (2.66) when compared to lower doses of CF as the fertilizer input added has lesser cost. The highest gross returns (₹2,89,267 ha^{-1}) and net return (₹ 1,86,600 ha^{-1}) were from the plots with 125% CF applied as two splits. The variation in yield could be attributed to better yield attributing factors in customized fertilizer applied plots. From studies in finger millet, Mudalagiriyappa *et al.* (2015) reported that application of 125 per cent of CF grade 20N: $17P_2O_5$: 11 K_2O: 3S: 0.4Zn gave higher mean BCR (2.53) over absolute control (1.26). Similarly, Kamble and Kathmale (2015) reported higher gross returns, net returns and BC ratio for the treatment CF grade 20N: 12P: 10K: 4S: 0.25Mg: 0.50Zn: 0.50Fe in onion.

Even though the cost of customized fertilizer was higher than the normal fertilizer, application of CF under higher dose was economically beneficial. Application of nutrients in more splits was not economical as it would add to the cost of cultivation.

SUMMARY

6. SUMMARY

The present investigation entitled "customized fertilizer and nutrient scheduling for okra" was carried out to develop customized fertilizer grade and to study the effect of different customized fertilizer doses on growth and productivity of okra as well as its techno- economic feasibility. The cropping period was from May to September 2015.

The experiment was conducted at the Water Management and Research Unit, Vellanikkara, Thrissur. The pre-analysis of the soil sample was evaluated to develop a customized fertilizer grade. The CF grade 22.01 N: 3.35 P: 12.68 K: 5.97 Mg: 0.37 B was obtained and treatments were allotted accordingly. There were twelve treatments for the experiment *viz.*, 75% CF as two splits, 75% as four splits, 100% CF as two splits, 100% CF as four splits, 125% CF as two splits, 125% CF as four splits, soil test based NPK as two splits, soil test based NPK as four splits, NPK as per POP as two splits, NPK as per POP as four splits, FYM alone and untreated control. Biometric and yield observations, plant analysis, soil analysis and economics of cost of customized fertilizer and nutrient scheduling were worked out. The results of the study are summarized and listed herewith:

1. The yield performance was best in 125% CF. The application of CF in two splits and four splits produced no significant variation in yield.

2. The lower doses of CF *i. e.*, 75 per cent CF, performed equally effective with respect to yield as soil test based NPK which indicated that lesser quantity of fertilizers in balanced fraction of the required nutrients are sufficient to meet the requirement of the crop.

3. The application of CF is more effective than soil test based and NPK as per POP since lesser quantity of NPK was applied in balanced proportion.

4. The quantity of NPK required as CF was much lower than the POP recommendations, and so fertilizer doses can be reduced greatly.

5. The combined application of fertilizers along with FYM gave better yield than application of FYM alone as a source of nutrients. Faster delivery of nutrients could be achieved through fertilizers since FYM alone could not meet the enormous requirement of nutrients by okra.

6. The growth and yield attributing characters in okra were found to be superior in customized fertilizer applied plots when compared to other treatments. This will directly reflected on the yield of the crop.

7. Though the application of CF in four splits showed higher dry matter production than in two splits, application in more splits did not cause any significant variation in yield.

8. The fertility status of the soil except for N showed a positive effect in CF applied plots. The improvement in nutrient status can be attributed to application of optimum dose of CF to maintain adequate supply of nutrients.

9. The application of higher levels of CF was cost effective due to higher yield despite increased cost of cultivation due to higher cost of inputs.

10. Application of customized fertilizer and other nutrients in more splits did not increase the yield. Less number of splits resulted in better soil nutrient availability and was also cost effective.

11. Yield, nutrient status, nutrient uptake and economics were superior for application of nutrients in two splits and so application at 30 days interval is appropriate.

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*Originals not seen

APPENDIX

APPENDIX-I

Meteorological data for the experimental period

(From 29-05-2015 to 22 -09-2015)

Standard week	Date and month	Temperature (^{0}C)		Mean relative humidity (%)	Total rainfall (mm)	No. of rainy days
		Max. ^{0}C	Min.^{0}C			
22	28/05 – 03/06	32.7	25.1	78	14.8	1
23	04/06 – 10/06	31.9	24.2	82	44.5	4
24	11/06 – 17/06	30.4	23.3	85	160.6	6
25	18/06 – 24/06	30.4	24.9	89	196.8	7
26	25/06 – 01/07	30.5	23.9	86	228.6	7
27	02/06 – 08/06	31.5	23.9	94	57.9	7
28	09/06– 15/06	30.6	23.8	94	101.4	5
29	16/06 – 22/06	27.9	23.3	91	257.2	7
30	23/06– 29/06	30.3	23.2	82	85.9	4
31	30/07– 05/08	30.9	24.8	81	22.0	2
32	06/08– 12/08	30.0	24.4	87	128.2	7
33	13/08– 19/08	31.6	23.9	80	114.9	4
34	20/08 – 26/08	31.8	23.5	82	41.0	1
35	27/08 – 02/09	31.9	23.9	79	16.6	2
36	03/09 – 09/09	31.5	23.5	84	88.6	6
37	10/09 – 16/09	31.8	23.6	80	47.2	4
38	17/09 – 23/09	31.7	23.9	82	37.6	1

APPENDIX-II

Cost of cultivation of customized fertilizer and nutrient scheduling for okra

Items	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
Materials												
Okra seed (7 kg ha-1)	9800	9800	9800	9800	9800	9800	9800	9800	9800	9800	9800	9800
FYM (12 tons ha^{-1})	12000	12000	12000	12000	12000	12000	12000	12000	12000	12000	22000	12000
Lime (350 kg ha-1)	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
Application cost (FYM)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Application cost (Lime)	500	500	500	500	500	500	500	500	500	500	500	500
Fertilizers												
CF -75%	17268	17268										
CF -100%			23025	23025								
CF-125%					28782	28782						
Urea							904	904	1674	1674		
Raj phos							394	394	1575	1575		
Muriate of potash							1008	1008	2100	2100		
Fertilizer application												
Women	2500	5000	2500	5000	2500	5000	2500	5000	2500	5000	2500	
PP chemicals												
PP chemicals	825	825	825	825	825	825	825	825	825	825	825	825
Application cost	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Land preparation												
Tractor	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050
Men	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Women	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Sowing												
Men	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400
Women	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250
Earthing up/ Weeding												
Women	4000	8000	4000	8000	4000	8000	4000	8000	4000	8000	4000	
Harvesting												
Women	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000
Men	700	700	700	700	700	700	700	700	700	700	700	700
Total cost	**91043**	**97543**	**96800**	**103300**	**102557**	**109057**	**76081**	**82581**	**79124**	**85624**	**83775**	**67275**

Cost of inputs		Fertilizers						Pesticides		Labour cost		Price of produce	
Okra seeds	Rs. 1400 kg-1	Urea	Rs. 7 kg-1	19:19:19	Rs. 140 kg-1	KNO3	Rs. 160 kg-1	Chlorpyriphos 20 EC	Rs. 390 l^{-}	Men	Rs.350 day-1	Okra	Rs. 20 kg-1
FYM	Rs. 1.0 kg-1	Raj phos	Rs. 9 kg-1	MgCO3	Rs. 70 kg-1			Ekalux 25 EC	Rs. 435 l^{-}	Women	Rs.250 day-1		
Lime	Rs. 10 kg-1	MOP	Rs. 18 kg-1	Dilubor	Rs. 440 kg-1					Tractor	Rs. 350 h-1		

CUSTOMIZED FERTILIZER AND NUTRIENT SCHEDULING FOR OKRA (*Abelmoschus esculentus* (L.) Moench)

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Multinutrient deficiencies in soil are common nowadays due to imbalanced use and extensive mining of nutrients, which have also led to the decline of soil and crop productivity over time. Customized fertilizers (CF), which are multinutrient carriers facilitating the supply of complete range of nutrients in right proportion for the crop grown in a particular soil, have come up as an alternative to tide over these problems. Scheduling of nutrients by split application promotes efficient utilization of nutrients in a need based manner and helps to reduce nutrient losses from the soil.

An investigation entitled "customized fertilizer and nutrient scheduling for okra (*Abelmoschus esculentus* (L.) Moench)" was carried out at the Water Management Research Unit, Vellanikkara, Thrissur from May to September, 2015 with the objective of developing a customized fertilizer and studying its techno- economic feasibility and nutrient scheduling in okra. The investigation consisted of 12 treatments *viz*., FYM + 75% CF (2 splits at 30 days interval), FYM + 75% CF (4 splits at 15 days interval), FYM + 100% CF (2 splits at 30 days interval), FYM + 100% CF (4 splits at 15 days interval), FYM + 125% CF (2 splits at 30 days interval), FYM + 125% CF (4 splits at 15 days interval), FYM + soil test based NPK application (N & K as 2 splits at 30 days interval), FYM + soil test based NPK application (N & K as 4 splits at 15 days interval), FYM + NPK as per POP (N & K as 2 splits at 30 days interval), FYM + NPK as per POP (N & K as 4 splits at 15 days interval), FYM alone based on N recommendation of POP (2 splits at 30 days interval) and absolute control. Biometric observations were recorded and nutrient contents and uptake were estimated at 30 DAS, 60 DAS and 90 DAS.

A customized fertilizer grade was developed based on the initial analysis of macro and micronutrient contents of soil and nutrient requirement of okra. Water soluble fertilizers and straight fertilizers were used for the preparation of CF. Based on the soil fertility rating and nutrient recommendation for okra, the actual nutrients needed for the experimental site was worked out in kg ha^{-1} as 59N: 9P: 34K: 16Mg: 1B. Based on this, CF grade 22.01N: 3.35 P: 12.68K: 5.97Mg: 0.37B was developed.

The study revealed that application of 125 per cent CF either as two or four splits was equally effective and recorded the highest yield compared to lower doses of CF and other nutrient management practices. Application of 125 per cent CF resulted in a yield increase of 32.11 per cent, 35.16 per cent and 49.84 per cent compared to soil test based application, application of nutrients at recommended dose and application of FYM alone respectively. Application of 100 per cent CF recorded higher yield compared to nutrient application based on soil test based NPK and NPK as per POP. The yield increase in 125 per cent CF was due to the better development of growth and yield parameters and higher nutrient uptake including that of Mg and B in customized fertilizer doses. The lower doses of CF (75%) performed equally well as soil test based NPK and NPK as per POP with respect to yield. The combined application of fertilizers along with FYM gave better yield than application of FYM alone as a source of nutrients. Faster delivery of nutrients could be achieved through fertilizers since FYM alone could not meet the huge requirement of nutrients by okra.

In this study, application of CF and other fertilizers in more splits did not show significant increase in yield of okra. Application of CF showed a positive effect on the soil fertility status except for nitrogen. The improvement in nutrient status could be attributed to application of optimum dose of CF along with FYM to maintain adequate supply of nutrients. The application of higher levels of CF was cost effective and economically beneficial due to higher yield despite increased cost of cultivation owing to higher cost of inputs. Nutrient application in lower splits was more economical due to reduced labour.

The study indicated that application of multinutrient carriers such as customized fertilizers are a technologically and economically viable practice for increasing soil and crop productivity. The quantities of NPK required as CF are much lower than the POP recommendations, and therefore fertilizer doses can be reduced substantially.