AGRO TECHNIQUES FOR BUSH TYPE VEGETABLE COWPEA (*Vigna unguiculata* (L.) Walp.) UNDER OPEN PRECISION FARMING

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by

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THESIS

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DEPARTMENT OF AGRONOMY
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KERALA, INDIA

2020

DECLARATION

I, hereby declare that this thesis entitled **"AGRO TECHNIQUES FOR BUSH TYPE VEGETABLE COWPEA (*Vigna unguiculata* (L.) Walp.) UNDER OPEN PRECISION FARMING"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"AGRO TECHNIQUES FOR BUSH TYPE VEGETABLE COWPEA (*Vigna unguiculata* (L.) Walp.) UNDER OPEN PRECISION FARMING"** is a record of research work done independently by Ms. Chijina K. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

B : C	Benefit Cost ratio
Ca	Calcium
CD	Critical Difference
CF	Conventional fertilizers
cfu	colony forming unit
cm	centimetre
DAP	Diammonium Phosphate
EC	Electrical Conductivity
et al.	co –workers/co-authors
Fig.	Figure
FYM	Farmyard manure
g	gram
ha	hectare
i.e.	That is
K	Potassium
KAU	Kerala Agricultural University
kg /ha.mm	kilogram per hectare millimetre
kg/ha	kilogram per hectare
kg	kilogram
L	Litre
LAI	Leaf Area Index
m	metre
m^2	square metre
Mg	Megnesium
MOP	Muriate of potash
N	Nitrogen
NS	Non Significant

NUE	Nutient Use Efficiency
P	Phosphorus
POP	Package of Practices
/plant	per plant
Rs./ha	Rupees per hectare
RDF	Recommended Dose of Fertilizers
RH	Relative Humidity
SEm	Standard Error of mean
S	Sulphur
t/ha	tonnes per hectare
TSS	Total Soluble Solids
viz.	Namely
WP	Water productivity
WSF	Water soluble fertilizers

LIST OF SYMBOLS

@	at the rate of
^{o}C	degree Celsius
%	per cent

INTRODUCTION

1. INTRODUCTION

Vegetables are important constituents of Indian agriculture and it plays a vital role in nutritional security due to their short duration, high yield, nutrient richness, economic viability and to generate on- farm and off-farm employment. India, being the second largest producer of vegetables, contributes about 13.30 per cent of the total world vegetable production. Vegetables are grown in an area of 9.5 million hectares with a production of 167.03 million tonnes (Anno.2019). India’s population is expected to touch 20 billion by 2050 and the vegetable requirement for the year 2050 will be 360 million tonnes with anticipated growth rate of 10 per cent. Considering the minimum recommended dietary requirement of 400 g per capita, the demand for fruits and vegetables would be around 450 million tonnes including post-harvest losses. The export” requirements would also pick up and may reach 10 per cent of production. In order to meet the requirements, the demand would be to the tune of around 540 million tonnes. Hence, challenge is to more than double the present production of 243.5” million tonnes to around 540 million tonnes. In order to bridge the wide gap between demand and supply there is need to improve the productivity of the existing system of vegetable cultivation.

Cowpea (*Vigna unguiculata* L.Walp.) is an important legume vegetable crop belongs to family Leguminaceae with subfamily Papilionaceae. High protein (24.8 %) and carbohydrate (63.6 %) contents with a relatively low fat content (1.9 %) and a complementary amino acid pattern to that of cereal grains make cowpea an important nutritional food in the human diet (Shaw, 2007). The average productivity of cowpea over India is 607 kg/ha (ICAR, 2020) which is considered to be low. The low productivity of cowpea is due to its cultivation in marginal and sub-marginal lands with poor management practices, resource poor farmers and low adoption of modern technologies.

Plant geometry plays an important role in the dominance and suppression during the process of competition. Ideal plant geometry is a plant growth component for better and efficient utilization of available plant growth resources in order to get maximum productivity in crops.

Fertilization and irrigation are two of the most important factors in crop production, as they strongly affect the yield and quality of the cultivated crops and precision farming offers tremendous advantages in efficient and rational use of fertilizers and water for enhancing NUE.

Fertigation is well recognized as the most effective and convenient means of maintaining optimum fertility level and water supply according to the specific requirements of the crop and soil, resulting into higher yields and better quality. The fertilizers applied through micro irrigation (MI) system is available in the root zone at field capacity (FC) state and gets easily absorbed by the plant. Fertigation also caused a great effect on fertilizer saving. Research has revealed that more than 40 per cent saving of fertilizer can be achieved through fertigation with a substantial increase in the yield. Water is also saved ranging from 39 to 62 per cent along with an increase in production. The irrigation efficiency of micro irrigation system has been reported to the tune of 90 to 95 per cent. In contrast, the irrigation efficiency of the traditional method is hardly 60 to 70 per cent because of the greater loss due to percolation, seepage and surface run off

Integration of microbial consortia and foliar feeding of nutrients under open precision farming will help to enhance the performance and yield of crop. Foliar nutrition which is a widely accepted ecofriendly practice enable application of nutrient supplements directly to the crop canopy in limited amounts for rapid and efficient crop use. Foliar application of nitrogen at particular stages may solve slow growth, nodule senescence and low seed yield in pulses without involving root absorption at critical stage (Pandrangi *et al*., 1991, Latha and Nadanasabababy, 2003). Bio inoculants have specific role in plant metabolism for enhanced productivity with improved water and fertilizer use efficiency. The enzyme system of bacteria supplies constant source of reduced nitrogen to the host plant and the plant in turn provides nutrients and energy for the activities of the bacteria (Singh *et al.*, 2008). The advanced technologies not only create avenues at higher level but also keep the growers with smaller holding at higher productivity and retain economic relevance to agriculture.

Application of these modern technologies under open precision farming will enhance the productivity of the vegetable cowpea. However, information on standardised agro-technique and the effect of integration of low cost technologies under open precision farming for bush type vegetable cowpea is meagre, an attempt has been made in this investigation to standardise the management practices for vegetable cowpea under open precision farming. The objectives were

Objective

- To standardize optimum spacing and irrigation requirement of bush type vegetable cowpea for enhanced growth and yield under open precision farming.
- To develop a fertigation schedule and response of biofertilisers for bush type vegetable cowpea

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In this chapter, information pertaining to "Agro techniques for bush type vegetable cowpea (*Vigna unguiculata* (L.) Walp.) under open precision farming" and related other vegetable and crops as influenced by different management practices has been reviewed.

Agro-technique

Agro-techniques are the technology followed in crop growing systems with the main objective to assure high crop yield with minimal investment of labour and capital per unit of product produced. These objectives can be accomplished by the introduction of advanced scientific management practices along with high yielding genotype and hybrids.

2.1 Spacing

Crop spacing is one of the most important factors which decides the number of crops planted in a unit area. It has a direct influence on the yield, quality and quite often on the earliness of the respective cultivar. Consequently, the number of plants per unit area has an indirect effect on the production costs and profitablity in general. Spacing has a very important role in vegetable production under open precision farming, due to the high production cost and amortization deductions (Borka,1971).

2.1.1 Effect of spacing on growth parameters

Close spacing of *Sesamum indicum* var. Dulce S-49 (7.5 x 60 cm and 15.0 x 60 cm) increased the leaf area index, crop growth rate and shoot dry matter production as compared to wider spacing (OseiBonsu, 1977).

A field experiment was conducted by Patil *et al.* (1991) to study the effect of spacing on the growth and the yield of cowpea and the result revealed that significantly higher growth attributes like plant height, number of leaves and branches per plant were recorded at wider spacing 45 x 15 cm as compared to narrow spacing 30 x 10 cm.

An agronomic investigation was conducted by Lone *et al*. (2009) for two consecutive years to study the effect of seed rate, row spacing and fertility levels on growth and nutrient uptake by soybean. Result revealed that spacing had significant influence on growth characters. At 90 days after sowing higher plant height (127.08 cm) and leaf area index (6.96) was recorded at 60 cm spacing and lower plant height (117.47 cm) and leaf area index (5.85) at 30 cm row spacing.

Leaf area index of vegetable cowpea was significantly influenced by spacing. At 12 weeks after planting the highest leaf area index (1.31) was observed at narrow row spacing as compared wider row spacing (0.95) (Muoneke *et al.*, 2013).

Tipodia and Nabam (2013) reported that at harvest, significantly higher leaf area index of (2.26) was recorded at 30 cm row spacing compared to 45 cm (1.93) row spacing in cowpea.

Among different spacings (30 x 30 cm , 25 x25 cm**,** and 30 x 15 cm), significantly higher dry matter production was recorded when green gram was sown at wider spacing (30 × 30 cm) (Keerthi, 2015).

Joshi and Rahevar (2015) reported that significantly higher plant height (149.6 cm) was recorded when the plants were planted at 30 cm apart as compared to 60 cm apart (130. 42 cm).

A field experiment was conducted by Satodiya *et al.* (2015) for three consecutive years to study the effect of spacing on growth and yield of vegetable cowpea. Result revealed that among the three different spacings (60 x 45, 60 x 30 and 45 x 45 cm) significantly higher plant height of 48. 76 cm was recorded when vegetable cowpea was planted at wider spacing.

Galwab and Kamau (2017) reported that significantly higher plant height (161.78 cm) and number of leaves per plant (137. 58) of cowpea were recorded when they were planted at a spacing of 60 x 20 cm compared to 45 x 20 cm.

In an agronomic evaluation, Lum *et al.* (2018) reported that among three row spacings (45 x 25, 75 x 25 and 90 x 25 cm) significantly higher plant height (126 cm) and number of leaves per plant (94.3) were recorded when plants were planted at 75 x 25 cm spacing in vegetable cowpea.

2.1.2 Effect of spacing on yield and yield attributes

Jakusko *et al*. (2013) conducted an field experiment to study the effect of inter row spacing on yield of some selected cowpea genotype. Among different spacings (45 ×25, 60 × 25, 75 × 25 cm) significantly higher pod length of 15.74 cm and number of pods per plant of 15.73 were recorded at wider spacing (75 × 25 cm).

The highest number of pods per plant (24) and pod weight (66 g/per plant) were recorded when vegetable cowpea was planted at a spacing of 50 x 20 cm compared to 50 x 10 cm (Muoneke *et al*. 2013).

In cowpea significantly lower seed yield (847 kg/ha) and halum yield (4,088 kg /ha) were recorded with row spacing of 45 cm compared to 30 cm due to significantly lower growth and yield components (Taipodia and Nabam ,2013).

Among different spacings (30 x 30 cm, 25 x 25 cm, and 30 x 15 cm), significantly higher yield attributes were recorded when green gram was sown at wider spacing (30 × 30 cm) (Keerthi, 2015).

Among different row spacings (30, 40 and 60 cm) significantly higher dry matter production per plant (38.8g), number of pods per plant (27.1) and pod length (4.5 cm) were recorded when Indian Bean seeds were planted at 60 cm apart compared to narrow spacing of 30 cm (Joshi and Rahevar, 2015).

The number of days taken to 50 per cent flowering and pod length of vegetable cowpea were not significantly influenced by spacing (Satodiya, 2015).

In cowpea number of days to fifty per cent flowering was not significantly influenced by the spacing (60 × 20 and 45 x 20 cm) (Galwab and Kamau, 2017).

Significantly higher number of pods per plant (37) was recorded when cowpea was planted at inter row spacing of 60 cm apart compared to 45 cm apart (Galwab and Kamau, 2017)

Wider spacing of 45 x 10 cm recorded significantly higher seed yield (1,143 kg/ha) and straw yield (2,733 kg/ha) of cowpea as compared to narrow spacing of 30 x 15 cm (Jagdale *et al.*, 2017).

In vegetable cowpea number of days taken to 50 per cent flowering and days to first harvest were not significantly influenced by spacing (Lum *et al.*, 2018).

2.1.3 Effect of spacing on quality parameters

In an agronomic investigation conducted by Lone *et al*. (2009) for two consecutive years it was found that protein content of soybean was not significantly influenced by spacing.

Taipodia and Nabam (2013) concluded that protein content of vegetable cowpea was not significantly influenced by row spacing.

Spacing had significantly influenced the crude protein content of black gram. Among three different spacings (30 x 10, 45 x 10, 60 x 10 cm) significantly higher protein content (23.08%) was recorded at wider spacing 60 x 10 cm compared to 30 x 10 cm (22.40%) (Amruta *et al.* , 2015).

According to Joshi and Rahevar (2015) the crude protein content of cowpea was not significantly influenced by the row spacing (30, 40 and 60 cm).

The crude protein content of vegetable cowpea was not significantly influenced by the spacing. However, the wider spacing 45 x 15 cm recorded higher protein content (26.34%) than narrow spacing (Jagadale *et al*., 2017).

Cowpea sown at 45 cm apart recorded significantly higher crude protein content (18.93%) and lower crude fibre content (25.64 %) compared to 30 and 60 cm row spacings (Iqbal *et al.*, 2018).

2.1.4 Effect of spacing on cost of cultivation

In Dhaincha (*Sesbania aculeata* L.) maximum net return of Rs. 88,684 /- per hectare and BCR of 5.4 was recorded under 60 cm spacing over 45 cm, which recorded a net return of Rs. 79,811 /- per hectare with BC ratio of 4.7 due to higher yield of seed (Chaudhari *et al*., 2013).

Higher net return of Rs. 12,936 /- per hectare with BC ratio 4.79 was recorded when Indian bean was sown at row spacing of 45 cm followed by 60 cm row spacing , which earned a net return of Rs.12,457 /- per hectare with BC ratio 4.68 (Joshi and Rahevar, 2015).

In cowpea wider spacing of 45 x 10 cm gave higher gross monetary returns (Rs.69, 912 /ha), net monetary returns (Rs. 47,123/ha) and high benefit: cost ratio (2.9). The lowest B: C ratio was recorded by narrow spacing 30 x 15 cm

(2.6). This may be due to higher economic yield produced by the wider row spacing (Jagadale *et al*., 2017).

2.2 Nutrient management under precision farming

The crop cowpea - has the ability to fix atmospheric nitrogen with the help of *Rhizobia,* because of this ability, application of inorganic fertilizers is considered not much important. Regardless of this N fixing ability, a positive response of cowpea to the application of organic and inorganic fertilizer has been reported by several authors from various cowpea grown areas (Madukwe *et al*., 2008; Singh *et al.*, 2011) especially to the application nitrogen (Amujoyegbe & Alofe, 2003; Singh *et al.*, 2007; Daramy *et al.*, 2016) and phosphorus (Owolade *et al.*, 2006; Singh *et al.*, 2011; Nkaa *et al.*, 2014). So there is a need of trials to understand the response of cowpea to the application of nitrogen, phosphorus and potassium fertilizers.

2.2.1 Nutrient levels on growth parameters under precision farming

Field trial was conducted by Abayomi, *et al.* (2008) to study the growth and yield response of cowpea to NPK fertilizer application. The result revealed that higher plant height (39. 80 cm) and the number of leaves per plant (26.80) were record when 60: 30: 30 kg NPK per hectare was applied which was found on par with treatment when NPK fertilizers were applied at the rate of 30: 15: 15 kg NPK per hectare.

Game *et al.* (2014) conducted a nutrient trial in cowpea to study the effect of growth and yield of cowpea as influenced by different levels of NPK(100%, 75%, 50% and 25% of the recommended dose of fertilizer) fertilizer application. The recommended dose of fertilizer for cowpea was 25: 50: 30 kg NPK /ha . Result revealed that different levels of fertilizer significantly influenced the growth characters. Higher plant height (18.63 cm) and number leaves per plant

(11.31) and dry matter (7.72 g/plant) were recorded when 100 per cent of recommended dose of fertilizers was applied as compared to other treatments.

An experiment conducted by Daramy *et al.* (2016) to study the effect of Nitrogen and Phosphorus fertilizer application on growth and yield performance of cowpea in Ghana. Results revealed that growth characters of cowpea was not significantly influenced by the different levels of nitrogen (10: 20: 30: 40 kg/ha) and phosphorus (15:30:45 kg/ha) fertilizer application.

2.2.2 Nutrient levels on yield and quality

Abayomi *et al.* (2008) reported that in cowpea, application of NPK fertilizer at the rate 30:15:15 kg per hectare recorded higher grain yield of (1.2 t/ha) which was found on par with fertilizer application at the rate 60: 30: 30 kg of NPK per hectare.

An experiment conducted by Daramy *et al*. (2016) to study the effect of Nitrogen and Phosphorus fertilizer application on growth and yield performance of cowpea in Ghana. Results revealed that yield and yield attributes of cowpea was not significantly influenced by the different level of nitrogen (10, 20, 30 and 40 kg/ha) and phosphorus (15, 30 and 45 kg/ha) fertilizer application.

Among different fertilizer level (100%, 75%, 50% and 25% of recommended dose of fertilizer), significantly higher number of pods per plant (11.2), pod length (11.91 cm) and grain yield (12.6 q/ha) were recorded when 100 per cent recommended dose of fertilizer (25: 50: 0 NPK kg /ha) was applied as compared to rest of the treatments (Game *et al*., 2014).

The experimental study revealed that among different levels of nitrogen (30, 60 kg N per ha) the cowpea quality parameters and nutritional value were higher with application of nitrogen at 30 kg/ha as compared to control of the treatment (Daramy *et al*., 2016).

Significantly higher total nutrient uptake (301 kg/ha) was reported with drip fertigation + 125 per cent recommended dose of fertilizers NPK as compared to drip irrigation + 100 per cent recommended dose of NPK and soil application of NPK fertilizers (Kakade *et al*., 2017).

2.3 Sources of nutrient under precision farming

Fertigation - a modern agro-technique provides an excellent opportunity to maximize yield and minimize environmental pollution (Hagin *et al*., 2002) by increasing the efficiency, minimizing fertilizer application and increasing return on the fertilizer invested. Farmers use water soluble fertilizers like potassium nitrate (KNO_3), mono potassium phosphate, calcium nitrate and sulphate of potash for fertigation. But the cost of these water soluble fertilizers (potassium nitrate (KNO_3), mono ammonium phosphate, calcium nitrate and sulphate of potash) are very high compared to conventional fertilizers like urea, diammonium phosphate, Muriate of potash. As the purchasing power of the farmer is very low there is burning need for scientific studies to be conducted to analyse the effect of water soluble and conventional fertilizer application in fertigation (through drip system) on growth, yield and benefit cost ratio of cowpea cultivation.

2.3.1 Source of nutrients on growth parameters under open precision farming

An experiment was conducted by Mohammadi (2008) in tomato and reported that significantly higher plant height (71.08 cm) and number of branches per plant (8.06) were recorded when fertigation was done through water soluble fertilizers (18: 18: 18) compared to conventional fertilizers (urea, single super phosphate, potassium chloride) and minimum plant height (65.85 cm) was recorded with soil application. However, the days to 50 per cent flowering and maturity were not significantly influenced by sources fertilizers and the levels of fertilizers.

The growth parameters were significantly influenced by source of fertilizers and level of fertigation in chilli. Significantly higher plant height (80 cm), number of branches (18) and number of leaves per plant (131) were recorded with 100 per cent recommended dose of fertilizer through water soluble fertilizers compared to application of 25 per cent recommended dose of fertilizer through water soluble fertilizer + 75 per cent through conventional fertilizers (Krishnamoorthy *et al.*, 2014). While, in tomato the days taken to 50 per cent flowering and 50 per cent pod initiation was not significantly influenced by different source of fertilizers (Rajan *et al*., 2014).

In Chilli, significantly higher plant height (104.87 cm) and number of branches per plants (15.71) were recorded in the treatment of fertigation with water soluble fertilizers (19:19:19 and KNO_3 at the rate of 100 per cent recommended dose of fertilizers and polyethylene mulching) which was found on par with fertigation with conventional fertilizers (Urea, DAP and MOP) at the rate of 100 per cent recommended dose of fertilizers and polyethylene mulching. Minimum plant height (85.83 cm) and branches per plant (11.35) were recorded in control– drip irrigation, non mulched and soil application of NPK fertilizers (Urea, SSP and MOP) at the rate of 100 per cent recommended dose of fertilizers (Reddy *et al.*, 2016).

Kakade *et al*. (2017) conducted a field experiment to study the effect of Bt cotton growth, uptake of nutrient and seed cotton yield as influenced by split application of nutrients. Results revealed that significantly higher plant height (148.15 cm), dry matter production (285.61 g) and sympodial branches per plant (35. 26) were recorded with drip fertigation + 125 per cent recommended dose of fertilizers NK as compared to drip irrigation + 100 per cent recommended dose of NPK and soil application of NPK fertilizers.

Significantly higher plant height (44 cm) and number of leaves (23.70) in cauliflower (*Brassica oleracea* var. botrytis L.) were recorded when fertigation was done with urea phosphate, urea and Muriate of potash which was found on par with fertigation with monoammonium phosphate, urea and muriate of potash at harvest. Significantly lower plant height (40 cm) and the number of leaves (19.8) were recorded when fertigation was done with diammonium phosphate, urea, Muriate of potash (Khodidan, 2017).

In chilli significantly higher LAI per plant (1,228) was recorded with 100 per cent recommended dose of fertilizer through water soluble fertilizers compared to 25 per cent recommended dose of fertilizer through water soluble fertilizer + 75 per cent conventional fertilizers (Krishnamoorthy *et al.*, 2014).

Reddy *et al*. (2016) reported that source of fertilizers and the level of fertilizers had significantly influenced the leaf area index and leaf area of chilli. Higher LAI and leaf area were recorded with fertigation using water soluble fertilizers like 19:19:19 and KNO_3 at the rate of 100 per cent recommended dose of fertilizers and polyethylene mulching which was found on par with fertigation with conventional fertilizers like Urea, DAP and MOP at 100 per cent recommended dose of fertilizers and polyethylene mulching. Minimum leaf area index and leaf area were recorded in control– drip irrigation, non mulched and soil application of NPK fertilizers (Urea, SSP and MOP) at 100 per cent recommended dose of fertilizers.

2.3.2 Effect of source of fertilizers on yield attributes and yield under open precision farming

Yield per plant and yield per hectare of tomato was significantly influenced by sources of fertilizers. Higher yield per plant (2.45 kg) and yield (97.64 t/ha) were recorded when drip fertigation was done with 19:19:19 and minimum yield per plant (1.99 kg) and yield (74.39 t/ha) were recorded when conventional NPK fertilizer (urea, single super phosphate and Muriate of potash) was applied to the soil **(**Mohammadi, 2008**).**

Krishnamoorthy *et al*. (2014) reported that significantly higher yield parameters such as number of fruits per plant (110), fruit length (11.5 cm) fruit weight (8.75 g), yield per plant (960 g) and yield (26.4 10 t/ha) were recorded with 100 per cent recommended dose of fertilizer through water soluble fertilizers compared to 25 per cent recommended dose of fertilizer through water soluble fertilizer + 75 per cent conventional fertilizers in chilli.

A field experiment was conducted by Rajan *et al*. (2014) to study the efficiency of conventional solid soluble fertilizer and liquid fertilizer applied through drip fertigation in tomato and results revealed that yield of tomato was not significantly influenced by different sources of fertigation.

Highest curd yield (21.75 t/ha) of cauliflower was recorded when 100 per cent recommended dose of fertilizers was given using urea + Muriate of potash + urea phosphate which was found on par with 60 per cent recommended dose of fertilizers with application monoammonium phosphate + urea + Muriate of potash. (Khodidan, 2017).

In cotton significantly higher boll weight (55.43 g), yield per plant (266.31 g) and seed cotton yield (3,503 kg/ha) were reported with drip fertigation + 125 per cent recommended dose of NPK fertilizers as compared to drip irrigation +

100 per cent recommended dose of NPK and soil application of NPK fertilizers (Kakade *et al*., 2017).

Reddy *et al*. (2018) conducted an experiment at Bangalore to study the impact of mulching and sources of fertilizers on yield and nutrient uptake of red chilli (*Capsicum annum*) under drip irrigation. Results revealed that the yield attributes were significantly influenced by source of fertilizers. Significantly higher number of fruits per plant, fruit length, fruit girth and fruit yield (5.03 t/ha) were recorded with 100 per cent recommended dose of fertilizer through water soluble fertilizers and which was on par with fertigation with conventional fertilizers urea, diammonium phosphate and Muriate of potash at 100 per cent recommended dose of fertilizer.

2.3.3 Effect of source of nutrients on nutrient uptake under open precision farming

A field experiment was conducted by Rajan *et al*. (2014) to study the efficiency of conventional solid soluble fertilizers and liquid fertilizers applied through drip in tomato. Results revealed that yield of tomato were not significantly influenced by different sources of fertigation.

Reddy *et al*. (2018) reported that significantly higher nitrogen (148.01kg /ha) phosphorus (23.80 kg/ha) and potassium (290.05 kg/ha) uptake was recorded with hundred per cent recommended dose of fertilizer through water soluble fertilizers which was found on par with fertigation with conventional fertilizers urea, diammonium phosphate at hundred per cent recommended dose of fertilizer in chilli.

2.3.4 Source of nutrients on quality under open precision farming

Mohammadi (2008) reported that the total soluble solid content and shelf life of tomato were significantly influenced by the source of nutrients. Higher total soluble salt (3.89 %) and enhanced shelf life (20 days) were recorded when fertigation was done with water soluble fertilizers 18:18:18 followed by fertigation with conventional NPK fertilizers 46:16:80 and the minimum total soluble solids (3.44%) and shelf-life (19.78 days) was recorded when conventional NPK fertilizers 46: 16: 60 was applied to the soil.

In Chilli higher pungency and total carotenoid were recorded with hundred per cent recommended dose of fertilizer through water soluble fertilizers. Soil application of hundred per cent recommended dose of fertilizer recorded significantly lower pungency and carotenoid content (Reddy *et al.*, 2016).

2.3.5 Effect of levels and sources of nutrients on cost of cultivation under open precision farming

Under open precision farming higher net return (Rs. 1, 57,610 /-) and BC ratio (1.42) were recorded with fertigation using 18: 18: 18 and followed by fertigation with conventional NPK fertilizers (urea, single super phosphate and Muriate of potash (Mohammadi, 2008).

Higher net return of Rs. 1,83,196 and BC ratio of 3.27 were recorded with hundred per cent recommended dose of fertilizer through water soluble fertilizers compared to twenty five per cent recommended dose of fertilizer through water soluble fertilizer + seventy five per cent conventional fertilizers (Krishnamoorthy *et al*., 2014).

BC ratio was significantly influenced by source of NPK fertilizer applied in tomato. Significantly higher BC ratio 1.96 was recorded when conventional fertilizers were applied through drip as compared to water soluble solid and liquid fertilizers (Rajan *et al*., 2014).

2.4 Effect of bio fertilizers on growth and yield of crops under open precision farming

Among different *Rhizobium* inoculated and non inoculated treatments, significantly higher plant height, number of pods per plant, pod weight, pod length, yield and seed index were recorded in treated vegetable cowpea plants than untreated plants (Singh *et al.* 2007)..

Artificial inoculation of *Rhizobium* had recorded significantly higher plant height, number of leaves, pod length and pod weight in *Vigna mungo* (Ravikumar, 2012).

Soumaya *et al.* (2016) reported that *Rhizobium* inoculation had significantly increased the plant height in *Hedysarum coronarium* as compared to uninoculated plants.

Inoculation of cowpea seeds with the biofertilizers recorded significant higher number of pods, pod weight and pod yield compared to without inoculation (Chatterjee and Bandyopadhyay, 2017).

Significantly higher number of pods per plant, pod length and seed weight was recorded when seeds of *Vigna mungo* and *Vigna radiata* were artificially inoculated with *Rhizobium japonicum* (Ravikumar, 2012).

Significantly higher dry matter at the time of harvest was recorded when duel inoculation of *Bacillus stubilis* and *Braddyrhizobium* was done compared to control (without inoculation) (Petkar *et al*., 2018). The mean leaf area of sulla (*Hedysarum coronarium)* was significantly lower for nitrogen fertilized plant at

154 and 174 days after sowing compared to *Rhizobium* treated plants (Soumaya *et al.* 2016).

2.4.1 Effect of *Rhizobium* on nodule parameters under open precision farming

Inoculation of cowpea seeds with *Rhizobium* resulted significantly higher number of nodules at 30 and 60 days after sowing compared to non inoculated seeds (Singh *et al.* 2007).

Highest number of nodules in *Vigna mungo* and *Vigna radiata* was recorded when *Rhizobium* was artificially inoculated than not treated control (Ravikumar, 2012).

Solomon *et al.* (2012) reported that *Bradyrhizobium* strain TAL 379 produced significantly higher number of root nodules than TAL 378 and the uninoculated control.

Rhizobium inoculated plants set a high mean nodule number and nodule weight per plant (Soumaya *et al.* 2016).

2.4.2 Effect of *Rhizobium* on nutrient uptake under open precision farming

A field experiment was conducted by Massawe *et al.* (2017) to study the effect of nutrient uptake by common bean and lab-lab bean. Results revealed that *Rhizobium* inoculation had increased the uptake of nitrogen, phosphorus, potassium, calcium and magnesium by the plant.

2.5 Water saving irrigation

Furrow method of irrigation the traditional method of irrigation practiced by the farmers which requires higher quantity of water for irrigation with lower water use efficiency. As the quantity of water available for irrigation in agriculture is decreasing, there is a burning need for the adoption of irrigation method with maximum water use efficiency. This can be achieved by adopting technologies like drip irrigation and deficit irrigation. Drip irrigation is the most efficient method for the water and nutrient delivery system for growing crops. It delivers water and nutrients directly to the crop root zone, in the right amounts, at the right time, so that each plant gets exactly what it needs, for its optimal growth. Water saving irrigation maximizes irrigation water productivity, which is the main limiting factor (English, 1990). In other words, water saving irrigation aims at stabilizing yields and at obtaining maximum crop water productivity rather than maximum yields (Zhang and Oweis, 1999).

2.5.1 Effect of drip of irrigation levels on growth parameters under open precision farming

A field experiment was conducted by Reddy *et al.* (2011) to study the influence of drip irrigation method on growth and yield of onion at Raichur region. Results revealed that there was a significant difference in the growth attributes at 90 days after transplanting. Plants supplied with water at 80 per cent ET recorded higher plant height (68.16 cm) and number of leaves per plant (12.70) which was on par with 100 per cent ET and minimum height was recorded in furrow irrigated method.

Gupta *et al.* (2015) reported that significantly higher dry matter content of tomato was recorded with 80 per cent ET through drip irrigation compared to drip irrigation at 100 per cent ET and surface irrigation method.

A field experiment was conducted by Ayyadurai *et al*. (2017) in blackgram (*Vigna mungo* L.) at Coimbatore and results showed that significantly higher plant height (44.4 cm) and dry matter production were recorded with drip fertigation + hundred per cent recommend dose of fertilizer with urea, SSP and

MOP + foliar application of one per cent urea phosphate which was found on par with drip fertigation with seventy five per cent recommend dose of fertilizers of NPK with foliar spray one per cent urea phosphate.

In cowpea significantly higher plant height (95.8 cm) and number of leaves per plant (20) were recorded in 100 per cent water applied treatments compared to 60 and 80 per cent water applied treatments (Nouralinezhad *et al.*, 2018).

2.5.2 Effect of drip irrigation levels on yield attributes and yield under open precision farming

In an agronomic investigation conducted for two consecutive years to study the yield and economic return of drip irrigated green beans production in Turkey, found that the mean marketable yield of green beans showed no significant difference between 80 per cent and 100 per cent Pan evaporation treatments (Kuscu *et al*., 2009).

The total marketable yield per hectare of onion was significantly influenced by different levels and methods of irrigation. Significantly higher yield (28.76 t/ha) was recorded in the treatment of 80 per cent ET using drip irrigation than other treatments and the lowest yield was recorded in furrow irrigated treatments (14.8 t/ha) (Reddy *et al*., 2011).

Nagaz *et al*. (2012) conducted a field experiment to study the yield response of drip irrigated onion under varying drip irrigation levels. Significantly higher fresh bulb yield was recorded under drip irrigation of hundred per cent treatment which was statistically comparable with drip irrigation at eighty per cent. However, a significant reduction in yield was recorded with drip irrigation at 60 per cent and furrow method.

An experiment conducted at KCAET Thavanur, Kerala Agricultural University to study the effect of different fertigation levels on cowpea (NS 621) inside polyhouse. Results revealed that among different treatments significantly higher yield (3,263 kg/ha) was recorded in treatment which irrigated daily and fertigation done once in four days. The minimum yield (1,942 kg/ha) was observed in the case of treatment having alternate day irrigation and alternate day fertigation (Varughese *et al*., 2014).

In blackgram (*Vigna mungo* L.) yield components such as number of pods per plant and number of seeds per pod and grain yield were significantly influenced by irrigation levels. Significantly higher number of pods per plant (34.5), number of seeds per pod (7.7) and grain yield (926 kg /ha) were recorded with drip fertigation at hundred per cent recommended dose of fertilizers. Significantly lower number of pods per plant (19.3) number of seeds per pod (6.1) and grain yield for (469 kg/ha) was recorded with surface irrigation and soil application of hundred per cent recommend dose of fertilizers (Ayyadurai *et al*., 2017).

Significantly higher sunflower yield of 2.6 t/ha was recorded with drip irrigation at hundred per cent irrigation whereas lowest yield of 2.01 t/ha was recorded in with furrow method of irrigation (Mila *et al*., 2017).

Among drip irrigation levels (100, 80, 60 and 40% ET) significantly higher cowpea grain yield of 1.06 t/ha was recorded with drip irrigation at hundred per cent ET followed by eighty and sisxty per cent ET and lower grain yield was recorded with drip irrigation at forty per cent ET (Faloye and and Alatise, 2016).

In an agronomic investigation conducted by Melo *et al*. (2018) in cowpea, reported that among four drip irrigation levels (40,60,80 and 100% ETc), drip irrigation with hundred per cent of ET recorded higher pod length, pod weight and pod yield and found on par with drip irrigation with eighty per cent of ET. Minimum pod length, pod weight and pod yield were recorded at forty per cent ET.

A field experiment was conducted for two consecutive year to study the effect of drip irrigation and nitrogen fertilization on yield and water productivity in common Bean (*Phaseolus vulgaris*) and cowpea (*Vigna ungiculata*) in Northern Iran. Result revealed that among drip irrigation levels, the highest water productivity and seed yield in 2016 and 2017 of common bean and cowpea was recorded with drip irrigation at hundred per cent ET than compared to drip irrigation at forty per cent ET (Nouralinezhad *et al*., 2018).

A field experiment was conducted by Reddy *et al*. (2018) to compare surface and subsurface drip irrigation on quality, yield and water use efficiency of watermelon (*Citrullus lanatus* L.). Drip irrigation at 80 per cent ET gave maximum watermelon yield (57.50 t/ha) followed by 100 per cent (55.38 t/ha).The lowest fruit yield (51.14t/ha) was record in furrow irrigated treatments.

Drip irrigation levels had a significant influence on fresh pod yield of cowpea. Higher fresh pod yield (7.33 t/ha) was recorded with drip irrigation at 120 per cent ET and lowest fresh pod yield (4.78 t/ha) was recorded with drip irrigation at 60 per cent ET (Salim *et al*., 2018).

2.5.3 Effect of drip irrigation levels on quality under open precision farming

A field experiment was conducted by Reddy *et al*. (2011) to study the influence of drip irrigation methods on growth, yield and quality of onion at Raichur Region. Result revealed that drip irrigation at one twenty per cent ET recorded maximum total soluble solid (13.50°Brix) found on par with drip irrigation at hundred per cent ET. The minimum total soluble solid (12.25°brix) was recorded with drip irrigation at 60 per cent ET.

Among various drip irrigation levels, higher fruit length of tomato (4.35 cm), total soluble solid (4.92°Brix) Vitamin C content (7.8 mg/ 100 g) and total sugar (3.77 %) was recorded with drip irrigation at 80 per cent ET than compared to drip irrigation at 60 per cent ET and furrow method of irrigation (Gupta *et al*., 2015).

Fruit quality of banana was significantly influenced by different drip irrigation levels. Drip irrigation at 70 per cent cumulative pan evaporation record significantly higher total soluble solid, reducing sugar, total sugar and less acidity in fruit than conventional furrow method. (Pramanik and Patra, 2016).

Rao *et al*. (2017) reported that in guava fruit quality character such as total soluble solid and ascorbic acid content was not significantly influenced by different irrigation levels.

2.5.4 Water productivity and water use efficiency under open precision farming

A field experiment was conducted by Reddy *et al*. (2011) to study the influence of drip irrigation methods on growth, yield and quality of onion at Raichur Region. Among different drip fertigation treatments, total irrigation water used was lowest in 60 per cent ET (948.88 m^3/ha) followed by 80 and 100 per cent ET and higher quantity of water was applied in furrow irrigation method. Highest water saving was recorded in 60 per cent ET (65.73%) followed by 80 per cent ET (55.18 %) and100 per cent (44.6 %) (Reddy *et al*.,2011).

Drip irrigation in onion had a significant and favourable effect on water use efficiency. Among different irrigation treatments higher irrigation water use efficiency (7.91 kg/m^3) was recorded with drip irrigation at 60 per cent EP followed by drip irrigation at 80 per cent EP (6.24 kg/m^3). Lower irrigation water use efficiency was recorded with furrow irrigation method (Nagaz *et al*., 2012).

Drip irrigation in tomato had a significant and favourable effect on water use efficiency. Irrigation water use efficiency at 60 and 80 per cent ET were on par and was significantly superior to drip irrigation at 100 per cent ET and surface irrigation method (Gupta *et al*., 2015).

In banana, conventional surface water irrigation recorded higher irrigation water use and the lower irrigation water use efficiency compared to drip irrigation. Among different drip irrigation treatments drip irrigation at 60 per cent CPE saved the considerable amount of water and recorded higher irrigation water use efficiency of 1289 kg/ha cm followed by drip irrigation at 50 per cent CPE (Pramanik and Patra, 2016).

A field experiment was conducted by Mila *et al.* (2017) to study the effects of deficit irrigation on yield, water productivity and economic return of sunflower. Among different drip irrigation levels highest water productivity (2.53 kg / m^3) was found with drip irrigation at forty per cent Ep compared to drip irrigation at hundred and eighty per cent Ep.

Salim *et al*., (2018) in cowpea reported that higher crop water productivity was recorded with drip irrigation at 120 per cent ET (2.14 kg/ m^3) followed drip irrigation at 100 per cent ET lower crop water productivity (1.43 kg / m^3) was recorded with drip irrigation at 0.6 per cent ET.

2.5.5 Drip irrigation levels on cost of cultivation under open precision farming

A field experiment was conducted by Mila *et al*. (2017) to study the effects of deficit irrigation on yield, water productivity and economic return of sunflower. Among different drip irrigation levels higher net return Rs. 5,338 per hectare was recorded with drip irrigation 60 per cent irrigation at vegetative and pre flowering stage) as compared to drip irrigation (100 % irrigation at vegetative and pre flowering and pod formation.

2.6 Foliar nutrition under open precision farming

Foliar applications of fertilizers are the one of the promising method which ensure high use efficiency of applied nutrients. Foliar spray enables plants to absorb the applied nutrients from the solution through their leaf surface and thus, may result in the economic use of fertilizer (Manasa *et al*., 2015). The high effectiveness, rapid plant responses, convenience and elimination or reduction of toxicity symptoms brought by excessive soil accumulation of given element due to foliar nutrition makes it more reliable (Jules, 1984). Recently speciality fertilizers with different ratios of N, P and K having high solubility had been introduced and is highly amenable for foliar nutrition (Jeyabal *et al*., 1998). The importance of foliar feeding of water soluble fertilizers in horticultural crops is immensely felt among the scientists and farmers, since macro and micro nutritional deficiencies in Indian soils have been on the increase due to adoption of high input agriculture (Garhwal *et al*., 2007).

2.6.1 Effect of foliar nutrition on growth parameters under open precision farming

Among the different source of water soluble fertilizers the maximum plant height, number of branches, fruit length, fruit diameter and the number of fruits of tomato were recorded in the treatment with foliar application of water soluble fertilizer NPK 19:0:19 followed by 19:19:19 than multi K (Chaurasia *et al.*, 2005).

Growth parameters of hybrid tomato differed significantly with the foliar application of water soluble fertilizers. Among different foliar treatments significantly higher plant height and number of branches per plant were recorded when five spray of 2 per cent NPK 19: 19:19 was applied as foliar as compared to without foliar application (Premsekhar and Rajashree, 2009).

An experiment was conducted by Narayan *et al.* (2011) to study the effect of foliar application of water soluble fertilizers on flowering, yield and quality of tomato. Result revealed that significantly higher plant height (122 cm),number of primary and secondary branches per plant were recorded when 80 per cent recommended dose of fertilizers + foliar spray of water soluble fertilizers than compared to 100 per cent recommended dose of fertilizers only. He also concluded that application of water soluble fertilizer delayed the days taken to attain 50 per cent flowering and fruiting.

In vegetable cowpea foliar application of water soluble fertilizer failed to give any significant effect on the days to 50 per cent flowering and pod formation. At harvest number of leaves per plant and plant height of vegetable cowpea were significantly influenced by foliar application of nutrients and the parameters were maximum with foliar application of water soluble fertilizer (Singhal *et al*., 2015).

Among different concentration of foliar nutrients applied, one per cent foliar spray with water soluble fertilizer recorded significantly higher growth attributes in chilli as compared to water spray and foliar spray of water soluble fertilizers at 0.5 per cent concentration (Devi *et al*., 2016).

Foliar application of 2 per cent diammonium phosphate at flowering and pod filling stages in cowpea recorded highest value of growth characters such as plant height and number of branches per plant and leaf are index compared to other treatments (Maheswari and Kartika, 2017).

In pigeonpea significantly higher plant height (58.3 cm), number of branches per plant (67), number of nodules per plant (15.6) and dry weight of nodule (18.5 mg/ plant) were recorded with foliar application of diammonium phosphate 2 per cent spray at flowering and 15 days later compared to control of water spray (Sivakumar and Pandiyan, 2020).

Thakur *et al.* (2017) conducted an experiment in blackgram and results revealed that significant higher leaf area index of 0.95 was recorded with foliar application of magnesium sulphate @ 0.3 per cent compared to absolute control.

2.6.2 Effect of foliar nutrition on yield attributes and yield under precision farming

Chaurasia *et al.* (2005) reported that significantly higher tomato fruit length and yield were recorded with five foliar sprays of ten per cent water soluble liquid fertilizers (19:09:19 and 19:19:19). The minimum values in all the parameters were recorded in the control (Water spray).

An experiment conducted by Das and Jana (2015) to study the effect of foliar spray of water soluble fertilizers at flowering stage on yield of pulses. In black gram it was found that foliar application of 3 per cent NPK (19:19:19) fertilizer spray with no basal dose of fertilizer application recorded highest seed yield.

2.6.3 Effect of foliar nutrition on NPK uptake under open precision farming

A field experiment was conducted by Yadav and Chaudhary (2012) in cowpea to study the effect of fertility levels and foliar nutrition on profitability, nutrient content and uptake of cowpea (*Vigna unguiculata* L. Walp). Total NPK uptake of cowpea was significantly influenced by the foliar application. Results indicated that foliar sprays of two per cent DAP; two per cent urea and two per cent KCl remained on par with respect to total uptake of nitrogen, phosphorus and potassium over water sprayed control.

NPK uptake of chilli was significantly influenced by foliar application of water soluble fertilizers. Foliar application of 19:19:19 at two per cent concentration recorded higher nutrient uptake as compared to water spray (Devi and Shanthi, 2013).

Pigeonpea (*Cajanus cajan* L. Mill) foliar application of 19:19:19 at 0.4 per cent concentration recorded significantly higher NPK uptake 126.6, 28.79, 407.02 kg /ha respectively compared to no foliar applied treatments (Gowda *et al*., 2015).

2.6.4 Effect of foliar nutrition on quality

Valsalan and Kumaresan (2006) found that in chilli the soil application of 50 per cent NPK along with the foliar spray of water soluble fertilizer has been significantly increased the quality parameters such as capsaicin, ascorbic acid, total soluble salt, crude protein and crude fibre content as compared to control.

Among different foliar nutrition treatment significantly higher protein content (20.60%) in cowpea was recorded when 2 per cent diammonium phosphate spray was applied as compared to water spray (Yadav and Chaudhary, 2012).

2.6.5 Effect of foliar spray on cost of cultivation under open precision farming

Significantly highest BC ratio 1: 4.12 was recorded in tomato when water soluble fertilizers were applied as foliar compared to without foliar application (1: 2.83) (Chaurasia *et al*., 2005).

Valavan and Kumaresan (2006) reported that soil application of 50 per cent NPK along with foliar application of water soluble fertilizers had recorded significantly higher BC ratio of 1:3.1 as compared to control without foliar (1: 2.23)

In tomato highest benefit cost ratio of 1: 2.73 was recorded with 87.5 per cent recommended dose of fertilizer as water soluble fertilizers (19:19:19) while lowest BC ratio of 1: 1. 59 in control (without foliar) (Narayan *et al.*, 2011).

Yadav and Chaudhary (2012) compared the net returns by cowpea from the foliar sprays with water, 2 per cent urea, 2 per cent Diammonium phosphate and 2 per cent KCl at branching and flowering. The net return (Rs. 24,039) was higher from the plot with foliar spray of Diammonium phosphate was given at the concentration of 2 per cent as compared to control.

Significantly higher B:C ratio of 2.43 was recorded when green gram was planted at wider spacing along with the foliar spray of 1 per cent potassium nitrate at 50 per cent flowering (Keerthi, 2015).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Three field experiments were conducted over a period of two years during 2017 –2018 and 2018 - 2019 at Agricultural Research Station, Mannuthy of Kerala Agricultural University, Vellanikkara. The programme aimed to study the performance of genotype and to standardize optimum spacing and irrigation requirement of bush type vegetable cowpea for enhanced growth and yield under open precision farming. It also aims to develop a fertigation schedule and to study the response of biofertilisers for bush type vegetable cowpea. The details of the materials used and the experimental techniques adopted during the course of investigation are presented in this chapter. The three experiments were conducted under this study. Experiment I : Evaluation of genotypes and optimization of spacing for enhanced growth and yield of bush type vegetable cowpea under open precision farming; Experiment II: Standardization of source of nutrients and levels of fertigation in bush type vegetable cowpea under open precision farming and Experiment III : Standardization of irrigation schedule and response of bio-fertilisers for bush type vegetable cowpea under open precision farming.

3.1. GENERAL DETAILS

3.1.1 Location

The field experiments were conducted at Agricultural Research Station, Mannuthy of Kerala Agricultural University with latitude of 10^{0}31'12.9" N, longtitude of 76^{o}13'14.4" E and at an altitude of 40.29 m above the mean sea level.

3.1.2 Season and weather condition

The experimental site enjoys typical humid tropical climate and the mean monthly meteorological data on rainfall, maximum and minimum temperature and relative humidity during the period of experimentation (August 2017 - March 2019) are presented in Table 1.

3.1.3 Soil characteristics

The soil texture of the experimental site is sandy clay loam and belongs to the taxonomical order Oxisol. The soil is acidic with pH of 5.5. The basic physicochemical properties of the soil are presented in Table 2.

3.1.4 Field operations

The experimental area was ploughed, stubbles removed, levelled and laid out into plots as per the lay out (Fig. 1, Fig. 2, and Fig. 3) after receipt of SW monsoon showers. The first two experiments were carried out continuously from August 2017 to June 2018 and field was kept fallow for the rest of the season (July 2018 to November 2018). The third experiment was conducted during November 2018 to February 2019 .The beds of 15 cm height were taken in plot and lay out of drip and mulching were done (Plate 1).

3.1.5 Drip irrigation and mulching

In a bed, two drip laterals were laid at 30 cm apart and online emitters were placed at a spacing of 45 cm. Irrigation was given at alternate days and irrigation requirement was worked out from daily evaporation data collected from US Class A open Pan Evaporimeter. Mulching was done with 30 μ silver black polythene sheet.

3.1.6 After cultivation

Gap filling was done on 7th day after sowing to maintain the plant population. Three hand weedings were done at 20 and 40 DAS and at harvest.

Table 1. Mean monthly meteorological data during the period of experimentation (2017 to 2019) at Agricultural research station, Mannuthy of Kerala Agricultural University.

Month	Rainfall (mm)			Evaporation (mm)			Mean temperature (^{o} C)					
	2017	2018	2019	2017	2018	2019	Maximum			Minimum		
							2017	2018	2019	2017	2018	2019
January	0	0	0	4.7	4.4	4.7	34.1	33.5	32.9	22.9	20.9	20.4
February	0	5.2	0	5.7	5.6	5.1	36.0	35.7	35.3	23.2	22.5	23.4
March	13.2	33.2	0	4.5	5	4.8	36.1	36.7	36.8	24.7	24.0	24.8
April	19.1	28.9	76.4	4.0	4.3	4.7	35.7	36.1	36.1	26.0	24.8	25.5
May	167.5	483.6	48.8	3.6	3.3	4.0	34.6	33.2	34.6	24.9	22.6	
June	630.2	730	324.4	2.5	2.2		30.4	29.8		23.5	23.2	
July	385.5	793.2	654.4	2.7	2.6		30.8	29.6		22.8	22.5	
August	478.0	928.0	977.5	2.6	2.3		30.1	29.2		23.3	22.2	
September	413.9	290.0	419.0	2.8	3.3		31.5	32.2		22.9	22.5	
October	183.4	393.0	418.4	2.3	3.0		31.7	32.8		22.3	22.9	
November	58.3	66.6	0	3.0	3.4		33.0	32.7		21.8	23.3	
December	11.5	0	0	3.9	3.5		32.4	33.0		21.1	22.5	

3.1.7 Plant protection

Aphid and pod borer attack were noticed in all the three experiment which were controlled by spraying Confidor @ 0.5 ml/ L and Ekalux @ 3 ml/ L respectively in the cropped area before reaching economic threshold levels

3.1.8 Harvesting

Vegetable pods were harvested by picking as and when they mature

3.2. EXPERIMENT DETAILS

The details of the experiments with regard to treatments, design of layout, plot size *etc.* are given below.

3.2.1 Experiment 1: Evaluation of genotypes and optimization of spacing for enhanced growth and yield of bush type vegetable cowpea under open precision farming

The experiment was laid out in Factorial Randomized Complete Block Design with three levels of spacing and six genotype. The experiment consisted of 18 treatment combinations with three replications and the plot size of the experiment was 3.6 x 3.6 m (12.96 m^2). The treatment details are given below and the general view of the experiment is shown in Plate 2.

Table 2. Physical and chemical properties of the experimental site

Sl. No.	Particulars	Values	Method
I.	**Physical properties**		
1.	Particle size analysis		
a.	Coarse sand (%)	15.93	International Pipette method(Piper, 1966)
b.	Fine sand (%)	31.01	
c.	Silt (%)	26.00	
d.	Clay (%)	27.01	
2.	Textural class	Sandy clay loam	
3.	Bulk density (g/cc)	1.33	Keen and Racksowski (1921)
4.	Field capacity (%)	20.56	Pressure plate apparatus method, Richard and Milton (1943)
5.	Permanent wilting point (%)	8.23	
II.	**Chemical properties**		
1.	pH (1: 2.5 soil : water extract)	5.4	Soil water suspension of 1: 2.5 and read in pH meter (Jackson, 1958)
2.	Electrical conductivity (dS/m) (1: 2.5 soil : water extract)	0.11	Soil water suspension of 1: 2.5 and read in EC meter (Jackson, 1958)
3.	Organic carbon (%)	0.90	Walkley and Black method (Walkley and Black, 1934)
4.	Available nitrogen (kg/ha)	123.46	Alkaline permanganate method (Subbiah and Asija, 1956)
5.	Available P_2O_5 (kg /ha)	36.52	Ascorbic Acid Reduce Molybdophosphoric blue colour method (Bray and Kurtz, 1945)
6.	Available K_2O (kg/ha)	766.19	Neutral normal ammonium acetate extract using flame Photometer (Jackson, 1958)
7.	Available Calcium content (mg/kg)	600.25	Nitric – perchloric acid (9:4) digestion (Hesse, 1971) and estimation using ICP – OES (model : optima 8x00 series)
8.	Available Magnesium content (mg/kg)	92.63	
9.	Available Sulphur content (mg/kg)	9.38	$CaCl_2$ Extract – Turbidimetry method (Chesnin and Yien, 1951)
10.	Copper (mg/kg)	2.79	Nitric – perchloric acid (9:4) digestion (Hesse, 1971) and estimation using ICP – OES (model : optima 8x00 series)
11.	Iron (mg/kg)	27.19	
12.	Zinc (mg/kg)	1.88	
13.	Manganese (mg/kg)	56.85	
14.	Boron (mg/kg)	0.34	Hot water extract and Azomethine–H Method using spectrophotometer(Berger and Truog, 1945; Gupta, 1967)

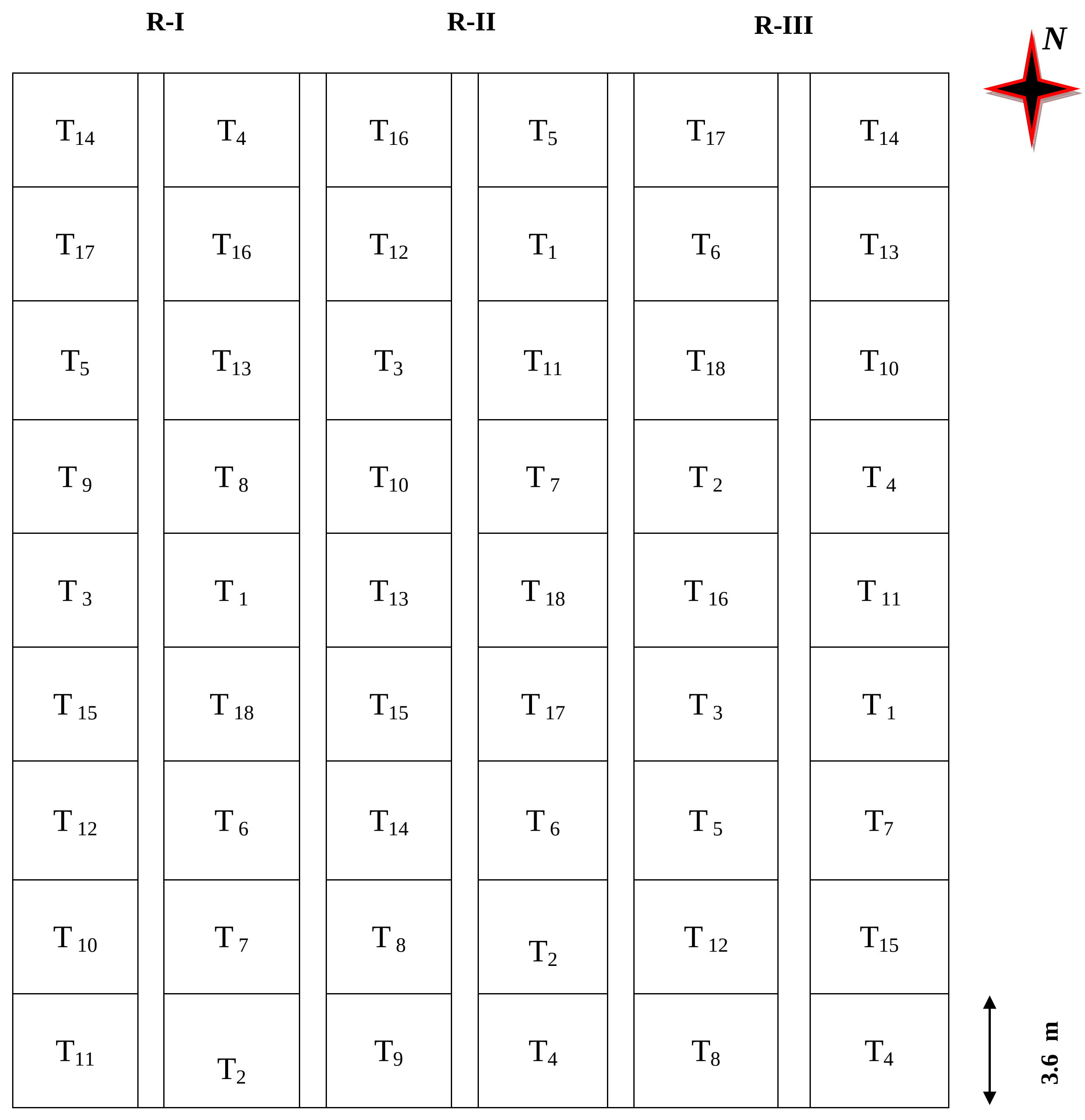


Fig. 1. Layout of experiment I

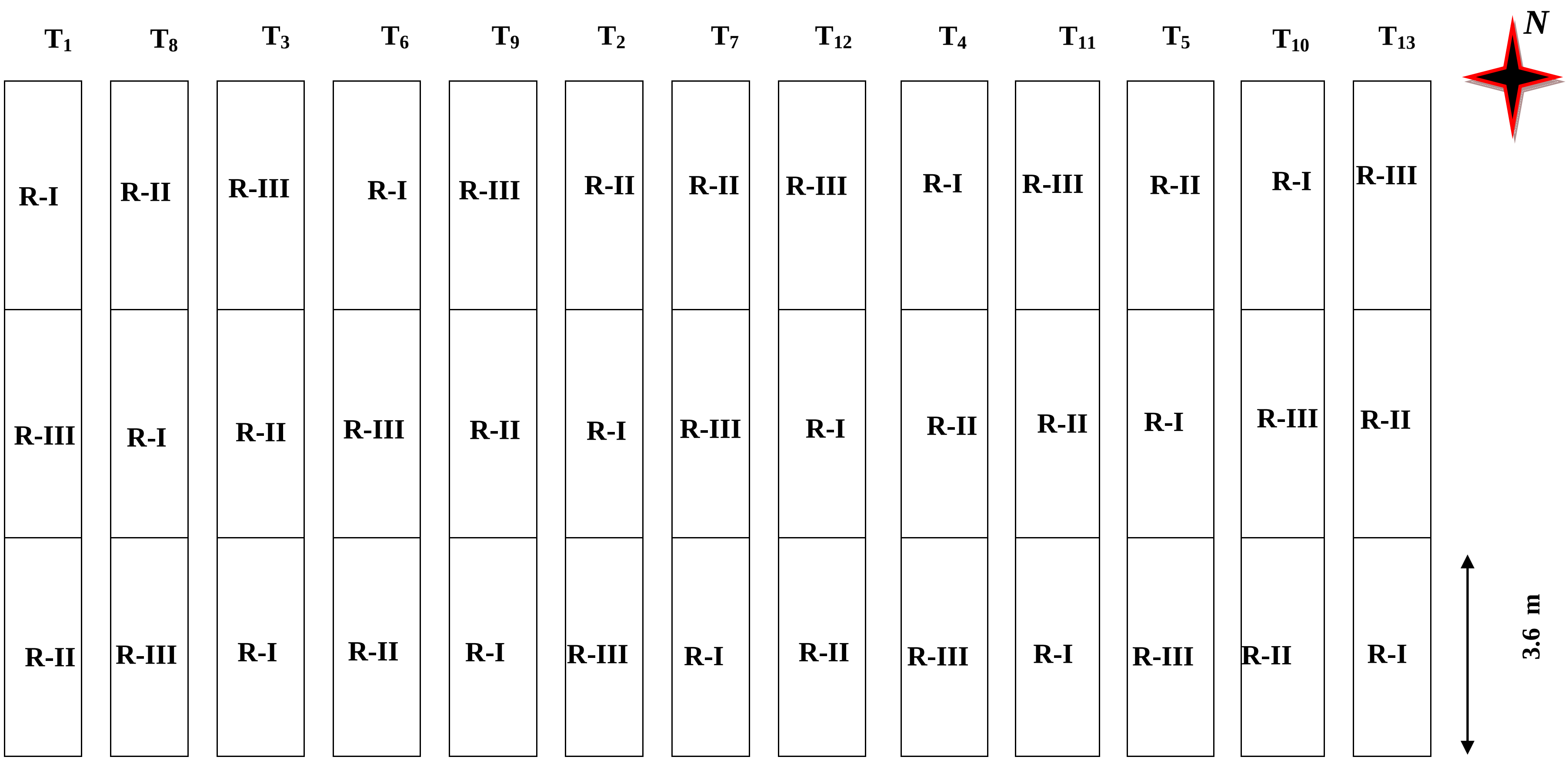


Fig. 2. Layout of experiment II

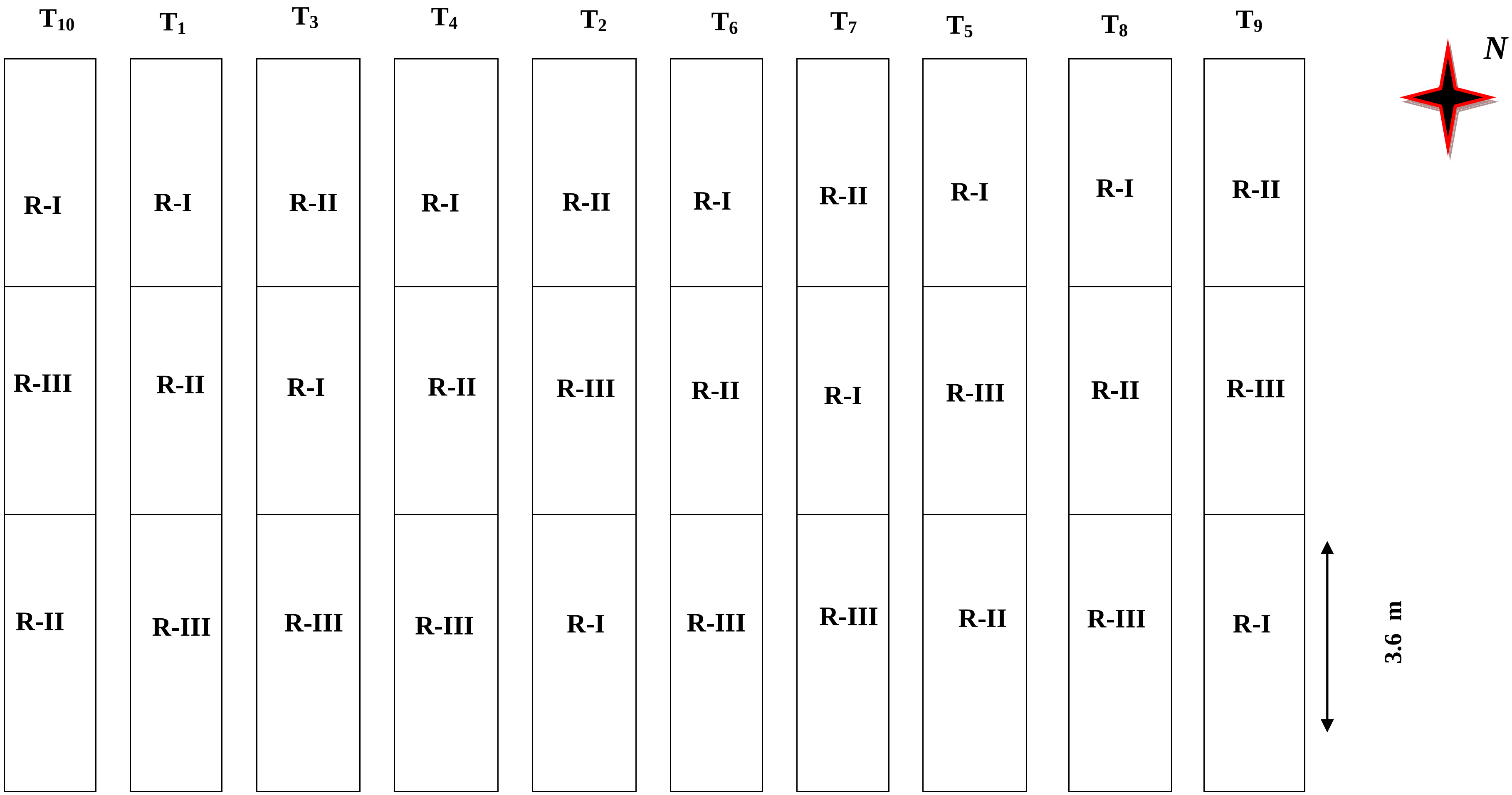


Fig. 3. Layout of experiment III

Land preparation

Layout of drip

Laying of mulching sheet

Sowing

Plate 1. Field operations

20 DAS

40 DAS

Plate 2. General view of field

3.2.1.1 Treatment details

I. Spacing (S)

S_1 - 60 cm x 30 cm

S_2 - 45 cm x 30 cm

S_3 - 30 cm x 15 cm (POP)

II. Genotype (V)

V_1 - Lalita

V_2 - UV-5

V_3 - Bhagyalakshmi

V_4 - Kashi Kanchan

V_5 - Pusa Komal

V_6 - Anaswara

Treatment combinations	
T_1	Lalita + 60 X 30 cm
T_2	VU – 5 + 60 X 30 cm
T_3	Bhagyalakshmi + 60 X 30 cm
T_4	Kashi Kanchan + 60 X 30 cm
T_5	Pusa Komal + 60 X 30 cm
T_6	Anaswara+ 60 X 30 cm
T_7	Lalitha + 45 X 30 cm
T_8	VU – 5 + 45 X 30 cm
T_9	Bhagyalakshmi + 45 X 30 cm
T_{10}	Kashi Kanchan + 45 X 30 cm
T_{11}	Pusa Komal + 45 X 30 cm
T_{12}	Anaswara+ 45 X 30 cm
T_{13}	Lalitha + 30 X 15 cm
T_{14}	VU – 5 + 30 X 15 cm
T_{15}	Bhagyalakshmi + 30 X 15 cm
T_{16}	Kashi Kanchan + 30 X 15 cm
T_{17}	Pusa Komal + 30 X 15 cm
T_{18}	Anaswara+ 30 X 15 cm

3.2.1.2 CROP HUSBANDARY

3.2.1.2.1 Planting

Seeds of different cowpea genotype were sown at spacing as per treatment on raised beds of 15 cm height.

3.2.1.2.2 Manures and fertilizers

Lime was applied at the time of first ploughing at rate of 250 kg /ha. Before sowing farm yard manure at the rate of 25 t/ha was applied uniformly and incorporated. Fertigation was given as per nutrient uptake by the crop (185: 50: 170 kg N: P_2O_5: K_2O /ha) under open precision farming. Half of phosphorus was applied basally in all the treatments through Rajphos, and remaining half P_2O_5 and full dose of K_2O were applied as NPK complex (19:19:19), Potassium nitrate (13: 0 : 45) and Urea (46 % N). Potassium nitrate and Urea were applied in 20 equal splits and NPK complex in 14 equal splits. Fertigation was given at three days interval starting from two leaf stage. The fertigation schedule followed in the experiment is given in Table 3. Initial soil test results showed that the soil was deficient in magnesium and boron and the deficiencies were corrected by applying magnesium sulphate and solubor at the rate of 80 kg and 5kg per hectare respectively.

3.2.2 Experiment 2: Standardization of source of nutrients and levels of fertigation for bush type vegetable cowpea under open precision farming

The experiment was laid out in Factorial Randomized Complete Block Design with four levels of fertilizers, three sources of fertilizers and one control (POP recommendation). The experiment consisted of 13 treatment combinations which were replicated thrice. The plot size was 3.9 x 3.9 m (12.96 m^2).

Lalita

Pusa Komal

Bhagyalakshmi

VU-5

Kashi Kanchan

Anaswara

Plate 3. Genotypes of cowpea

The treatment details are given below and the general view of the experiment is shown in Plate 4.

Table 3. Fertigtaion schedule for Experiment 1

Stage of crop	Fertilizer	Quantity of fertilizer applied (kg /ha)
Establishment (3 equal splits)	19:19:19	28.17
	KNO_3	48.33
	Urea	38.40
Vegetative (11equal splits)	19:19:19	103.29
	KNO_3	177 .21
	Urea	140.8
Fruiting (6 equal splits)	KNO_3	56.34
	Urea	76.80

3.2.2.1 Treatment details

I. Levels of fertilizers (F)

F_1 - 50 % uptake - 93:25:85 kg N: P_2O_5: K_2O /ha

F_2 - 75 % uptake - 139:37: 127 kg N: P_2O_5: K_2O /ha

F_3 - 100 % uptake - 185: 50: 170 kg N: P_2O_5: K_2O /ha

F_4 - 125 % uptake - 231: 63: 212 kg N: P_2O_5: K_2O /ha

F_0 (Control) - POP recommendation through conventional fertilizers – 20: 30: 10 kg N: P_2O_5: K_2O /ha

Instead of soil application, POP recommendation as conventional fertilizers were applied through drip irrigation to study the response of vegetable cowpea under open precision farming

II. Sources of fertilizers (S)

S_1 - 100 % uptake with conventional fertilizers

S_2- 50 % uptake through conventional fertilizers as basal dose + 50 % through water soluble fertilizers

S_3 - 100 % uptake through water soluble fertilizers

Treatment combinations	
T_1	93:25:85 kg N: P_2O_5: K_2O /ha + 100 % CF
T_2	93:25:85 kg N: P_2O_5: K_2O /ha + 50 % as CF- basal + 50% WSF
T_3	93:25:85 kg N: P_2O_5: K_2O /ha + 100 % WSF
T_4	139:37: 127 kg N: P_2O_5: K_2O /ha + 100 % CF
T_5	139:37: 127 kg N: P_2O_5: K_2O /ha + 50 % as CF- basal + 50% WSF
T_6	139:37: 127 kg N: P_2O_5: K_2O /ha + 100 % WSF
T_7	185: 50: 170 kg N: P_2O_5: K_2O /ha + 100 % CF
T_8	185: 50: 170 kg N: P_2O_5: K_2O /ha + 50 % as CF- basal + 50% WSF
T_9	185: 50: 170 kg N: P_2O_5: K_2O /ha + 100 % WSF
T_{10}	231: 63: 212 kg N: P_2O_5: K_2O /ha + 100 % CF
T_{11}	231: 63: 212 kg N: P_2O_5: K_2O /ha + 50 % as CF- basal + 50% WSF
T_{12}	231: 63: 212 kg N: P_2O_5: K_2O /ha + 100 % WSF
T_{13}	POP (Control) + 100 % CF

CF- Conventional fertilizers, WSF - Water soluble fertilizers

Table 4. Details of quantity of fertilizer applied

	Dose	Quantity
F_1	50 % uptake	93: 13: 88 kg N: P_2O_5: K_2O /ha
F_2	75 % uptake	139: 19: 132 kg N: P_2O_5: K_2O /ha
F_3	100 % uptake	185: 25: 170 kg N: P_2O_5: K_2O /ha
F_4	125 % uptake	231: 31: 219 kg N: P_2O_5: K_2O /ha
F_0	POP (Control)	20: 30: 10 kg N: P_2O_5: K_2O /ha

The details of quantity of fertilizer applied and source of fertilizers as per treatment are given in Table 5, 6, 7 and 8

Plate 4. General view of field – Experiment II

Table 5. Fertigation schedule - 100 % through conventional fertilizers

Stage of crop	**Fertilizers**	**Quantity of fertilizers applied (kg /ha)**			
		F_1	**F_2**	**F_3**	**F_4**
Establishment(3 equal split doses)	Urea	29.34	44.04	58.71	73.41
	Diammonim phosphate	2.91	4.35	5.82	7.35
	Muriate of potash	21.81	32.79	43.74	54.66
Vegetative (11 equal split doses)	Urea	107.58	161.48	215.27	269.17
	Diammonim phosphate	10.67	15.95	21.34	26.95
	Muriate of potash	79.97	120.23	160.38	200.42
Fruiting (6 equal split doses)	Urea	5.82	8.70	11.64	14.70
	Muriate of potash	43.62	65.58	87.48	109.32

Table 6. Fertigation schedule - 50 % through conventional fertilizers as basal and 50 % through water soluble fertilizers

50 % through conventional fertilizers as basal					
Fertilizers		**Quantity of fertilizers applied (kg /ha)**			
		F_1	**F_2**	**F_3**	**F_4**
Urea		100	150.8	201.08	182.29
Diammonim phosphate		34.72	52.05	69.44	86.77
Muriate of potash		72.91	109.36	145.83	251.34
50 % through water soluble fertilizers					
Stage of crop	**Fertilizers**	**Quantity of fertilizers applied (kg /ha)**			
		F_1	**F_2**	**F_3**	**F_4**
Establishment (3 equal split doses)	19:19:19	7.048	10.566	14.09	17.616
	KNO_3	0.036	0.054	0.073	0.091
	Urea	0.038	0.057	0.076	0.095
Vegetative (11 equal split doses)	19:19:19	25.842	38.744	51.68	64.594
	KNO_3	0.132	0.198	0.267	0.33
	Urea	0.138	0.209	0.278	0.347
Fruiting (6 equal split doses)	KNO_3	0.072	0.11	0.14	0.18
	Urea	0.075	0.114	0.152	0.189

Table 7. Fertigation schedule - 100 % through water soluble fertilizers

Stage of crop	**Fertilizers**	**Quantity of fertilizers applied (kg /ha)**			
		F_1 50 %	**F_2 75 %**	**F_3 100%**	**F_4 125%**
Establishment (3 equal split doses)	19:19:19	7.02	10.56	14.07	17.46
	KNO_3	0.078	0.11	0.16	0.20
	Urea	0.081	0.12	0.16	0.20
Vegetative (11 equal split doses)	19:19:19	25.74	38.72	51.59	64.02
	KNO_3	0.286	0.43	0.57	0.72
	Urea	0.297	0.44	0.59	0.75
Fruiting (6 equal split doses)	KNO_3	0.15	0.23	28.14	34.92
	Urea	0.16	0.24	0.32	0.41

Table 8. Fertigation schedule - POP through conventional fertilizers (F_0 - control)

Number of fertigation at 3 days intervals	**Fertilizers**	**Quantity of fertilizers applied (kg /ha)**
Establishment (3 equal split doses)	Urea	4.60
	Diammonim phosphate	6.9
	Muriate of potash	2.5
Vegetative (11 equal split doses)	Urea	16.89
	Diammonim phosphate	25.62
	Muriate of potash	9.16
Fruiting (6 equal split doses)	Urea	9.22
	Muriate of potash	5.0

3.2.2.2 Planting

The best treatment based on growth and yield from experiment I was carried forward for the experiment II. The seeds of cowpea variety Lalita (best genotype from experiment I) were sown at a spacing of 60 x 30 cm (best spacing from experiment I) on raised beds of 15 cm height under open precision farming.

3.2.2.3 Manures and fertilizers

Lime was applied at the time of first ploughing at rate of 250 kg /ha . Farm yard manure at the rate of 25 t/ha was applied uniformly and incorporated before sowing. Half of phosphorus was applied basally in all the treatments through Rajphos and full nitrogen, remaining half P_2O_5 and full dose of K_2O were applied as conventional fertilizers or water soluble fertilizers as per treatment through fertigation. All the fertigation treatment doses were applied in twenty equal splits with three splits at establishment stage, eleven at vegetative stage and six at fruiting stage. Potassium nitrate (13:0:45), monoammonium phosphate (12:61:00) and NPK complex 19:19:19 were used as source of nutrients for water soluble fertilizers in all the experiments and urea, diammonium phosphate and Muriate of potash as source for conventional fertilizers. Fertigation was started ten days after sowing and applied at three days interval. Fertigation schedule for experiment II is given in Table 5,6,7 and 8. Initial soil test results showed that the soil was deficient in magnesium and boron and the deficiencies were corrected by applying magnesium sulphate and solubor at the rate of 80 kg and 5 kg per hectare respectively.

3.3 Experiment 3: Standardization of irrigation schedule and response of bio-fertilisers for bush type vegetable cowpea under open precision farming

The experiment was laid out in Randomized Complete Block Design with three factors (irrigation, foliar nutrition and *Rhizobium*) each at 2 levels along with two controls. The experiment consisted of 10 treatment combinations with three replications. The plot size was 3.6 x 3.6 m (12.96 m^2). The treatment details are given below and the general view of the experiment is shown in Plate 5.

3.3.1 Treatment details

I. Irrigation (I)

I_1 - 60% Ep

I_2 - 80% Ep

II. *Rhizobium* (B)

B_1 - With *Rhizobium*

B_2 - Without *Rhizobium*

III. Foliar nutrition (F)

F_1 - With foliar nutrition

F_2 - Without foliar nutrition

Treatment combinations	
T_1	Irrigation @ 60% Ep + *Rhizobium* + foliar nutrition
T_2	Irrigation @ 60% Ep + *Rhizobium* + no foliar nutrition
T_3	Irrigation @ 60% Ep + no *Rhizobium* + foliar nutrition
T_4	Irrigation @ 60% Ep + no *Rhizobium* + no foliar nutrition
T_5	Irrigation @ 80% Ep + *Rhizobium* + foliar nutrition
T_6	Irrigation @ 80% Ep + *Rhizobium* + no foliar nutrition
T_7	Irrigation @ 80% Ep + no *Rhizobium* + foliar nutrition
T_8	Irrigation @ 80% Ep + no *Rhizobium* + no foliar nutrition
Control 1	Irrigation at 100% Ep + without *Rhizobium* + without foliar nutrition
Control 2	Conventional channel irrigation once in 2 days + without *Rhizobium* + POP level of fertilizer application + without foliar nutrition

3.3.2 Planting

The best treatment based on growth and yield from experiment I was carried forward for the experiment III. The seeds of cowpea variety Lalita (best genotype from experiment I) were sown at a spacing of 60 x 30 cm (best spacing from experiment I) on raised beds of 15 cm height under open precision farming

3.3.3 Manures and fertilizers

The best treatment of fertigation based on growth and yield from experiment II was carried forward for the experiment III. Lime was applied at the time of first ploughing at rate of 250 kg /ha. Farm yard manure at the rate of 20 t/ha was applied uniformly and incorporated before sowing. Urea (46 % N), Rajphos (18% P_2O_5) and Muriate of potash (60 % K_2O) were applied as source of nutrients for the nutrient requirement as 20:30:10 kg N: P_2O_5 and K_2O per hectare (best treatments from experiment II)

Half quantity of nitrogen, potassium and whole phosphorus were applied at the time of first ploughing. The remaining nitrogen and potassium were given at 15 DAS through fertigation. Based on the uptake soil test results, boron deficiency was corrected by applying solubor at the rate of 5 kg/ha.

3.3.4 Drip irrigation

Irrigation was given on daily basis as per treatment based on the pan evaporation data collected from US Class A Pan Evaporimeter. Quantity of water was applied based on the daily pan evaporation data and discharge rate of the emitters. Total quanity of water applied in each treatment is given below.

100 % Ep - 1,33,330 L/ha

80 % Ep - 1,06,664 L/ha

60 % Ep – 79,998 L/ha

Furrow irrigation - 3,630,000 L/ha

Plate 5. General view of field – Experiment III

3.3.5 Foliar application of nutrients

In foliar treatments, 40% of the nutrient requirement (20:30:10 kg N, P_2O_5, K_2O) was applied through foliar as 19:19:19 complex in 4 splits at 10, 20, 30 and 40 days after planting. In the first and 4th foliar spray, 19:19:19 complex was given at 1 per cent concentration and in second and third the rate of 2 per cent.

3.3.6 Seed treatment with *Rhizobium*

Weighed quantity of 0.25 kg of seed was mixed 25 g of *Rhizobium* culture from Tamil Nadu Agricultural University, Coimbatore. Seeds were moistened by sprinkling rice – gruel water as cohesive prior to mixing. Moistened seeds were well mixed with culture and shade dried for 30 minutes and sown within 24 hours as per POP of KAU (Crops, 2016).

3.4 Collection of experimental data

3.4.1 Physical properties of soil

Before the experiment composite soil samples were collected from experimental area. The samples were air dried, powdered and passed through 2 mm sieve. A representative sample of sieved soil was used for analysing physical characteristics of the soil. Various methods used for analysis of soil are given in Table 9.

Table 9. Physical properties of the soil

No.	Properties	Method
1	Bulk density	Keen and Racksowski (1921)
2	Permanent wilting point	Pressure plate apparatus method, Richard and Milton (1943)
3	Field capacity	

3.4.2 Chemical properties of soil

Soil samples were collected from experimental site at 0 – 15 cm depth, dried under shade, powdered and passed through 0.2 mm sieve for organic carbon and 2 mm sieve for macro and micro nutrients before and after the experiments. The soil samples were analysed for pH, EC, available N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B. The methods followed were given in the Table 10.

3.4.3 Microbiological studies

Total population of microflora was enumerated by serial dilution and plate count technique (Wollum, 1982). Population of total bacteria, fungi, actinomycetes and *Rhizobium* of the soil were counted at flowering and at harvest. Microbial biomass carbon was analysed by fumigation and extraction method (Jenkinson and Powlson, 1976). The soil samples were collected from crop root zone of each treatment and the details of the media used for the enumeration is presented in Table 11.

3.4.4 Growth parameters

Five plants were randomly selected from each plot and observations on growth were recorded. The following observations were recorded at different growth stages of the crop.

3.4.4.1 Plant height

The height of five plants was measured in centimetres from the base of the plant to the fully opened youngest leaf and the average height of the plant in centimetres was calculated at 20, 40 DAS and at harvest.

Table 10. Methods for chemical analysis of soil

No.	Particulars	Method
1	Ph	Soil water suspension of 1: 2.5 and read in pH meter (Jackson, 1958)
2	Electrical conductivity	Soil water suspension of 1: 2.5 and read in EC meter (Jackson, 1958)
3	Organic carbon	Walkley and Black method (Walkley and Black, 1934)
4	Available N	Alkaline permanganate method (Subbiah and Asija, 1956)
5	Available P	Ascorbic Acid Reduce Molybdophosphoric blue colour method (Bray and Kurtz, 1945)
6	Available K	Neutral normal ammonium acetate extract using flame Photometer (Jackson, 1958)
7	Available Ca & Mg	Nitric – perchloric acid (9:4) digestion (Hesse, 1971) and estimation using ICP – OES (model : optima 8x00 series)
8	Available S	$CaCl_2$ Extract – Turbidimetry method (Chesnin and Yien, 1951)
9	Available Fe, Mn, Cu and Zn	Nitric – perchloric acid (9:4) digestion (Hesse, 1971) and estimation using ICP – OES (model : optima 8x00 series)
10	Available B	Hot water extract and Azomethine – H Method using spectrophotometer (Berger and Truog, 1945; Gupta, 1967)

Table 11. Details of the media used for the enumeration

No.	Microbes	Medium	Reference
1	Bacteria	Nutrient agar	Agarwal and Hasija, 1986
2	Fungi	Martin's rose bengal agar	
3	Actinomycetes	Kenknight's agar	
4	*Rhizobium*	Yeast extract mannitol agar media	Thompson and Vincent, 1967

3.4.4.2 Number of leaves per plant

Total numbers of fully opened green leaves produced were counted from five plants and their average was taken as number of leaves per plant at 20, 40 DAS and harvest.

3.4.5 Yield attributes and yield (at harvest)

3.4.5.1 Dry matter production per plant (g)

Five plants were uprooted, cleaned and oven dried at 70^0 C and dry weight was recorded and expressed as g/ plant at harvest.

3.4.5.2 Days to 50 % flowering

Number of days taken for attaing 50 per cent flowering in each plot was recorded.

3.4.5.3 Days to first harvest

The number of days taken for first harvest was recorded.

3.4.5.4 Pod length

Matured pods from observation plants were picked, length of pod was measured and mean was expressed in cm.

3.4.5.5 Number of pods per plant

Number of matured pods from observation plants were recorded and mean value was given.

3.4.5.6 Yield per plant (g / plant)

Matured pods from the observation plants were picked, weighed immediately after picking and mean green pod yield was expressed in g/ plant

3.4.5.7 Yield per plot (kg/plot)

Matured pods from the net plot area were picked, weighed immediately after picking and the total yield of green pods from each net plot was expressed in kg/ plot.

3.4.5.8 Yield per hectare (kg /ha)

On the basis of green pod yield per plot, green pod yield in kilogram per ha was calculated.

3.4.5.9 Duration of crop

Number of days from sowing to last harvest in each plot was recorded.

3.4.6 Physiological parameters

3.4.6.1 Crop growth rate (CGR)

It represent the dry weight gained by a unit area of crop in unit time expressed as g/ day /m^2. It is given as

$$CGR = \frac{\text{Final dry weight } (W_2) - \text{ Initial dry weight } (W_1)}{\text{Time of final observation } (t_2) - \text{Time of initial observation } (t_1)}$$

3.4.6.2 Relative crop growth rate (RGR)

RGR indicates the increase in dry weight per unit of original dry weight over any specific time interval (Fischer, 1921). This was calculated using the formula

$$RGR = \frac{L_n W_2 - L_n W_1}{t_2 - t_1}$$

L_n – logarithm at base e (natural logarithm)

W_2 - final dry weight

W_1 - initial dry weight

t_2 – Time of final observation

t_1 – Time of initial observation

RGR was expressed as g/g/day

3.4.6.3 Net assimilation rate (NAR)

NAR indicates increase in dry weight of plant per unit time. NAR is calculated from the following equation

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{L_n L_2 - L_n L_1}{L_2 - L_1}$$

L_2 and L_1 Total leaf area at time t_1 and t_2

W_2 and W_1 - total dry weight at time t_1 and t_2

3.4.6.4 Leaf area index (LAI)

Leaf area index is the ratio of leaf area of plant to land area (Watson, 1947). The leaf area of randomly selected plants were measured at 20, 40 DAS and harvest. Leaf area index was calculated using the formula

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

3.4.6.5 Leaf area duration (LAD)

It is a measure of the ability of the plant to produce and maintain leaf area and is obtained by integrating the leaf – area index over crop growth period. It is usually expressed in days or weeks

LAD = Mean leaf area index (LAI) x Number of days in the crop growth period

3.4.7 Quality analysis

3.4.7.1 Crude fibre content (%)

Crude fibre (CF) content in cowpea was estimated by acid-alkali digestion method. The CF was calculated by using the formula given by Mahadevan (1965) and expressed in per cent.

$$CF\ (\%) = \frac{\text{Weight before ashing} - \text{Weight after ashing}}{\text{Weight of the sample taken}} \times 100$$

3.4.7.2 Crude protein content (%)

The crude protein (CP) content was calculated by using the following formula given by Doubetz and Wells (1968) and expressed in per cent.

$$CP (\%) = \% N \times 6.25$$

Per cent nitrogen (N) was analyzed by modified Kjeldahl's method (Jackson, 1973).

3.4.8 Plant analysis

Five plants were collected from each plot, oven dried and powdered. The nutrient content of the plant sample was determined by standard procedures. Details of methods used for chemical analysis are given in the Table 12.

Table 12. Methods used for chemical analysis of plants

No.	Nutrient	Method
1	N	Micro kjeldahl digestion and distillation (Jackson, 1958)
2	P	Diacid digestion of sample followed by filtration. Vandadomolybdate phosphoric yellow colour in nitric acid system (Piper, 1966)
3	K	Diacid extract using flame photometer (Piper, 1966)
4	Ca & Mg	Nitric – perchloric acid (9:4) digestion (Hesse, 1971) and estimation using ICP – OES (model : optima 8x00 series)
5	Fe, Mn, Cu & Zn	Nitric – perchloric acid (9:4) digestion (Hesse, 1971) and estimation using ICP – OES (model : optima 8x00 series)
6	B	By dry ashing (Gaines and Mitchell, 1979) and Azomethine H method (Bingham, 1982)

3.4.9 Nutrient uptake

Total uptake was calculated for each treatment by following formula and expressed in kg /ha.

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{\% Nutrient concentration x Dry matter production (kg/ha)}}{100}$$

3.4.10 Nutrient use efficiency

Nutrient use efficiency is the ratio of yield in the fertilized plot to quantity of fertilizer applied

$$\text{Nutrient use efficiency} = \frac{\text{Yield in fertilized plot}}{\text{Quantity of fertilizer applied}}$$

3.4.11 Nutrient budgeting

Balance sheet for nitrogen, phosphorous and potassium were prepared separately and nutrient balance is calculated by using the formula

Apparent loss (kg/ha) = Expected balance in soil (kg/ha) – Actual soil fertility status (kg/ha)

3.4.12 Number of effective nodules per plant

The number of effective nodule per plant was determined at flowering stage. The selected plants were irrigated upto saturation point and the plants were uprooted. The pink coloured effective nodules were separated from the roots of the selected plants, counted and expressed as number of effective nodules per plant.

3.4.13 Water **productivity**

Water productivity of each treatment was calculated by using the formula

$$\text{Water productivity} = \frac{\text{Total biomass(kg/ha)}}{\text{Quantity of water applied(mm)}}$$

3.4.14 Economic analysis

Cost of production of bush type vegetable cowpea under open precision farming was calculated based on the labour charge of the locality and cost of inputs. The net return per hectare and B: C ratio was calculated from the cost of production and prevailing market price of the produce.

3.4.15 Statistical analysis

Data generated on various parameters were analysed using statistical package MSTAT (Freed, 1986) for analysis of variance. Multiple comparisons among the treatment means were done using critical difference at 5% level probability.

RESULTS

4. RESULTS

The results of field experiments conducted with the project entitled "Agro techniques for bush type vegetable cowpea (*Vigna unguiculata* (L.) Walp.) under open precision farming" during 2017 - 19 at Agricultural Research Station, Kerala Agricultural University, Thrissur, Kerala are presented in this chapter. Three experiments were laid out in factorial randomized block design. Experiment I dealt with evaluation of genotypes and optimization of spacing for enhanced growth and yield of bush type vegetable cowpea under open precision farming with 18 treatments and three replications. Experiment II was conducted to standardize the source of nutrients and levels of fertigation in bush type vegetable cowpea under open precision farming with 13 treatments and three replications. Experiment III was dealt with standardization of irrigation scheduling and response of bio-fertilisers for bush type vegetable cowpea under open precision farming with 10 treatments and three replications. The best treatment from each experiment was carried forward for the next subsequent experiments. The results of the experiments are presented below.

Experiment 1: Evaluation of genotypes and optimization of spacing for enhanced growth and yield of bush type vegetable cowpea under open precision farming

4.1. Effect of spacing on growth and yield of cowpea genotypes

The experiment was conducted to evaluate the performance of vegetable cowpea (*Vigna unguiculata* (L.) Walp.) genotypes and to optimize the spacing under open precision farming.

4.1.1. Growth characters

4.1.1.1. Plant height

Plant height of cowpea genotypes differed significantly at 20, 40 DAS and at harvest (Table 13). Taller plants were produced by genotype Lalita (18.02 cm) and VU -5 (17.31 cm) which were on par at 20 DAS. While at 40 DAS and at harvest the tallest plants were produced by genotype VU – 5 followed by Anaswara and the same trend followed at harvest also. The plants were shorter in genotypes Bhagyalakshmi and Lalita at 40 DAS and at harvest respectively.

The plant height did not show significant difference between spacing at 20 DAS. However, considerable variation was noticed due to spacing at 40 DAS and at harvest. At 40 DAS and harvest the tallest plants were observed at wider spacing (60 x 30 cm) followed by 45 x 30 cm. The shorter plants were observed at narrow row spacing.

4.1.1.2 Number of leaves per plant

The data on number of leaves per plant are given in Table 14. Number of leaves per plant of cowpea genotypes differed significantly at all stages of growth. The number of leaves per plant followed almost similar trend at fortnightly interval. Genotype Anaswara exhibited highest number of leaves per plant (5.62, 20.97 and 32.00) followed by Pusa Komal (5.26, 16.97 and 27.22) at 20, 40 DAS and at harvest. Number of leaves per plant of cowpea genotypes varied significantly with spacing also at 40 DAS and at harvest. While, at 20 DAS, number of leaves per plant of cowpea was statistically comparable with respect to spacing. At 40 DAS wider spacing (60 x 30 cm) produced highest number of leaves per plant (17.68), followed by 45 x 30 cm row spacing (15.12) and continued to be the same trend and at harvest.

Table 13. Plant height (cm) of cowpea genotypes influenced by spacing (at 20, 40 DAS and at harvest)

Spacings / Genotype	**Plant height**											
	20 DAS				**40 DAS**				**Harvest**			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	18.5	16.59	18.92	18.02	50.55	46.70	44.75	47.33	59.70	54.63	51.84	55.39
VU-5	17.65	17.08	17.22	17.31	93.40	87.19	86.24	88.94	169.13	120.80	109.60	133.17
Bhagyalakshmi	10.84	12.65	11.71	11.73	35.53	30.66	28.77	31.65	59.77	54.71	52.36	55.61
Kashi Kanchan	11.53	11.51	13.16	12.06	38.02	32.14	29.40	33.19	73.68	63.39	56.17	64.41
Pusa Komal	13.13	14.27	16.61	14.67	62.73	60.10	47.67	56.83	133.50	90.75	83.22	102.49
Anaswara	16.4	14.93	14.38	15.24	90.16	82.78	75.17	82.70	146.79	134.60	112.82	131.40
Mean	14.68	14.50	15.33		61.73	56.60	52.00		107.09	86.48	77.67	

Factors	**20 DAS C.D**	**20 DAS SE (±m)**	**40 DAS C.D**	**40 DAS SE (±m)**	**Harvest C.D**	**Harvest SE (±m)**
Spacing	NS	0.70	3.69	1.28	8.54	2.959
Genotype	2.86	0.99	5.22	1.81	12.07	4.184
Spacing x Genotype	NS	1.72	NS	3.13	20.91	7.248

Table 14. Number of leaves per plant of cowpea genotypes influenced by spacing (at 20 DAS, 40 DAS and at harvest)

Spacing / Genotype	Number of leaves per plant											
	20 DAS				**40 DAS**				**Harvest**			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	5.06	5.53	5.66	5.42	13.60	11.93	9.20	11.57	16.33	11.33	11.00	12.88
VU-5	5.06	5.33	4.20	4.86	12.66	11.13	10.26	11.35	27.33	27.00	23.66	26.00
Bhagyalakshmi	3.33	5.66	4.33	4.44	19.60	18.00	11.40	16.33	29.33	28.33	24.00	27.22
Kashi Kanchan	5.40	5.53	5.73	5.55	12.93	11.13	8.80	10.95	25.33	18.33	18.33	20.66
Pusa Komal	5.26	5.33	5.20	5.26	23.20	15.13	12.60	16.97	33.66	27.66	20.33	27.22
Anaswara	5.66	5.33	5.86	5.62	24.13	23.40	15.40	20.97	41.66	35.33	19.00	32.00
Mean	4.96	5.45	5.16		17.68	15.12	11.27		28.94	24.66	19.38	

Factors	**20 DAS C.D.**	**20 DAS SE (±m)**	**40 DAS C.D.**	**40 DAS SE (±m)**	**Harvest C.D.**	**Harvest SE (±m)**
Spacing	NS	0.55	1.60	0.55	1.45	0.50
Genotype	2.26	1.10	2.26	0.78	2.06	0.71
Spacing x Genotype	NS	1.91	3.92	1.35	3.56	1.23

Least number of leaves per plant (11.27 and 19.38) was exhibited by narrow row spacing (30 x 15 cm) at 40 DAS and at harvest.

Spacing x genotype interaction effect was also found to be significant. At 40 DAS, Anaswara at 60 x 30 cm (24.13) produced the highest number of leaves followed by Anaswara at 45 x 30 cm (23.40) and continued to be the same trend at harvest.

4.1.2. Yield attributes

4.1.2.1 Dry matter production per plant

Dry matter production per plant differed significantly with respect to cowpea genotypes. From the Table 15, it is clear that genotype Anaswara recorded maximum dry matter production (75.18 g/plant) followed by Bhagyalakshmi (68.78 g/plant) at harvest. Least dry matter production was from genotype VU-5 (49.16 g/plant). Dry matter production differed significantly among different spacings. Wider row spacing (60 x 30 cm) recorded the highest dry matter production (79.59 g/plant) followed by 45 x 30 cm row spacing (63.67 g/plant) and least dry matter production was from narrow row spacing (46.55 g/plant).

Spacing x genotype interaction did not show significant variation respect to dry matter production. However, highest dry matter was exhibited by the treatment combination of Anaswara at 60 x 30 cm spacing with a dry matter production of 89.52 g/plant.

4.1.2.2 Days to fifty per cent flowering

The days taken to complete 50 per cent flowering is given Table 15. Genotypes showed variation with respect to days to 50 per cent flowering.

Table 15. Yield attributes of cowpea genotypes influenced by spacing

Spacing / Genotype	Dry matter production (g/plant)				Days to 50 % flowering (days)				Days to first harvest (days)			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	82.11	61.87	39.82	61.27	32.00	33.00	33.00	33.00	42.00	42.00	42.00	42.00
VU-5	61.60	47.21	38.68	49.16	43.00	43.00	44.00	43.00	51.00	51.00	51.00	51.00
Bhagyalakshmi	86.46	70.54	49.34	68.78	44.00	44.00	44.00	44.00	49.66	50.66	51.00	50.44
Kashi Kanchan	76.83	61.87	44.48	61.06	44.00	44.00	44.00	44.00	49.00	51.00	50.66	50.22
Pusa Komal	81.03	64.34	47.16	64.17	44.00	44.00	44.00	44.00	50.66	52.00	51.00	51.22
Anaswara	89.52	76.19	59.82	75.18	44.00	46.00	47.00	47.00	51.66	50.66	53.33	51.88
Mean	79.59	63.67	46.55		42.00	42.00	42.55		49.00	49.55	49.83	
Factors	**C.D.**		**SE (±m)**		**C.D.**		**SE (±m)**		**C.D.**		**SE (±m)**	
Spacing	3.11		1.08		NS		0.32		NS		0.47	
Genotype	4.40		1.52		0.93		0.45		1.38		0.67	
Spacing x Genotype	NS		2.64		NS		0.79		NS		1.17	

Genotype Lalita attained fifty per cent flowering earlier (33.00 days) than the other genotypes. All the spacing treatments were statistically comparable with respect to days to fifty per cent flowering. However, 60 x 30 cm spacing completed fifty per cent flowering earlier (42.00 days) than 45 x 30 cm (42.00 days) and 30 x 15 cm (42.55 days) spacing.

The spacing x genotype interaction was also on par. However, genotype Lalita at 60 x 30 cm spacing completed fifty per cent flowering earlier (32.00 days) than all other treatment combinations.

4.1.2.3 Days to first harvest

The days taken to first harvest is given Table 15. Genotypes showed variation with respect to days to to first harvest. Genotype Lalita harvested earlier (42.00 days) than the other genotypes. All the spacing treatments were statistically comparable with respect to first harvest. The spacing x genotype interaction was also on par.

4.1.2.4 Pod length

The length of pods differed significantly among different genotypes. Longest pods were produced by genotype Lalita (27.53 cm) followed by Kashi Kanchan (25.38 cm) and shortest pods by Bhagyalakshmi (16.10 cm) (Table 16). The plants at all spacing produced longer pods which were on par. However, wider row spacing (60 x 30 cm) produced longer pods (22.68 cm). Though spacing x genotype interaction was non-significant, longest pods were present in the treatment combination of genotype Lalita at 60 x 30 cm spacing (27.79 cm).

Table 16. Yield attributes of cowpea genotypes influenced by spacing (at harvest)

Spacing / Genotype	Pod length (cm)				Number of pods per plant			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	27.79	27.47	27.35	27.53	17.54	14.47	7.77	13.26
VU-5	25.18	24.17	24.33	24.56	7.37	6.84	3.80	6.00
Bhagyalakshmi	16.29	16.27	15.75	16.10	21.11	15.61	13.97	16.90
Kashi Kanchan	25.32	25.32	25.51	25.38	11.97	8.44	7.44	9.28
Pusa Komal	16.59	16.48	16.28	16.45	16.60	14.86	9.04	13.50
Anaswara	24.92	24.92	24.01	24.61	14.01	7.71	2.71	8.14
Mean	22.68	22.43	22.20		14.76	11.32	7.45	
Factors	**C.D.**		**SE (±m)**		**C.D.**		**SE (±m)**	
Spacing	NS		0.28		2.99		1.03	
Genotype	1.17		0.40		4.23		1.46	
Spacing x Genotype	NS		0.70		NS		2.53	

4.1.2.5 Number of pods per plant

Total number of pods produced per plant is depicted in Table 16. Number of pods per plant of bush type vegetable cowpea differed significantly among different genotypes. Higher number of pods per plant was recorded by genotype. Bhagyalakshmi (16.90) which was found on par with Pusa Komal (13.50) and Lalita (13.26). Lowest number of pods per plant (6.00) was obtained from VU-5. Number of pods per plant differed significantly among different spacings. Wider row spacing (60 x 30 cm) gave maximum number of pods (14.76) and minimum (7.45) from narrow row spacing of 30 x 15 cm. Highest number of pods were present in treatment combination of genotype Bhagyalakshmi at 60 x 30 cm (21.11) followed by Lalita at 60 x 30 cm (17.54) which was on par with other combinations.

4.1.2.6 Yield per plant

The data regarding the yield per plant is depicted in Table 17. Yield per plant of bush type vegetable cowpea differed significantly among different genotypes. The genotype Lalita recorded highest yield per plant (119.02 g) followed by Kashi Kanchan (76.60 g). Lowest yield per plant was recorded by the genotype VU-5 (49.71 g).

Yield per plant of cowpea genotype varied significantly. With wider spacing (60 x 30 cm) vegetable cowpea recorded the highest per plant yield of 112.05 g. Lowest per plant yield (28.44 g) was obtained from narrow row spacing (30 x 15 cm).

The spacing x genotype interaction was also found to be significant. Higher yield per plant was obtained from the treatment combination of Lalita at 60 x 30 cm (186.66 g).

Table 17.Yield attributes of cowpea genotypes influenced by spacing (at harvest)

Spacing / Genotype	**Yield per plant (g/plant)**				**Yield per plot (kg/plot)**			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	186.66	121.90	48.50	119.02	13.43	13.16	13.97	13.52
VU-5	77.83	51.70	19.60	49.71	5.60	5.58	5.65	5.61
Bhagyalakshmi	84.13	56.26	21.26	53.88	6.05	6.08	6.13	6.08
Kashi Kanchan	120.46	79.33	30.00	76.60	8.67	8.57	8.64	8.62
Pusa Komal	98.10	65.40	24.56	62.68	7.06	7.06	7.07	7.06
Anaswara	105.13	69.80	26.73	67.22	7.57	7.53	7.7	7.60
Mean	112.05	74.06	28.44		8.06	8.00	8.19	
Factors	**C.D.**		**SE (±m)**		**C.D.**		**SE (±m)**	
Spacing	2.66		0.92		NS		0.07	
Genotype	3.76		1.30		0.28		0.09	
Spacing x Genotype	6.51		2.25		NS		0.17	

4.1.2.7 Yield per plot

From Table 17, It is clear that, the yield per plot was maximum with genotype Lalita (13.52 kg/ plot) followed by Kashi Kanchan (8.62 kg/plot). Lowest yield per plot was recorded with genotype VU-5 (5.61 kg/plot). Yield per plot was not significantly differed among spacing. However, higher yield per plot was recorded from narrow row spacing 30 x 15 cm (8.19 kg/plot). The interaction effect was also on par. Even so, higher yield per plot was recorded in the treatment combination of Lalita at 30 x 15 cm (13.97 kg/plot).

4.1.2.8 Yield

The data pertaining to the effect of treatments on fresh pod yield of cowpea genotypes is given in Table 18. Among different genotypes highest yield of 13.91 t/ha was exhibited by genotype Lalita followed by Kashi Kanchan (8.87 t/ha). Lowest fresh pod yield (5.77 t/ha) was exhibited by UV-5. All spacings were statistically comparable with respect to yield. However, narrow row spacing (30 x 15 cm) recorded higher pod yield (8.42 t/ha).

Genotype x spacing interaction was on par with respect to yield per hectare. However, highest yield was recorded by the treatment combination of Lalita at 30 x 15 cm (14.37 t/ha).

4.1.2.9 Duration of crop

Duration of bush type vegetable cowpea differed significantly with respect to genotypes (Table 18). It was observed that genotype VU – 5 attained final maturity earlier (69 days) than other genotypes. Anaswara attained final maturity lately (88 days). All the spacing treatments were statistically comparable with respect to duration of crop. Genotypes x spacing interaction were also on par.

Table 18. Yield and duration of cowpea genotypes influenced by spacing (at harvest)

Genotype \ Spacing	**Yield (t/ha)**				**Duration of crop (Days)**			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	13.82	13.54	14.37	13.91	76.00	75.00	75.00	75.00
VU-5	5.76	5.74	5.81	5.77	69.00	69.00	68.00	69.00
Bhagyalakshmi	6.23	6.25	6.30	6.26	75.00	74.00	76.00	75.00
Kashi Kanchan	8.92	8.82	8.89	8.87	76.00	75.00	75.00	75.00
Pusa Komal	7.26	7.27	7.27	7.27	77.00	77.00	77.00	77.00
Anaswara	7.79	7.75	7.92	7.82	89.00	87.00	88.00	88.00
Mean	8.30	8.23	8.42		77.00	76.00	77.00	
Factors	**C.D.**		**SE (±m)**		**C.D.**		**SE (±m)**	
Spacing	NS		0.07		NS		0.53	
Genotype	0.29		0.10		2.181		0.75	
Spacing x genotype	NS		0.17		NS		1.30	

4.1.3 Incidence of pest and diseases

The major disease observed in the field was blackeye cowpea mosaic virus disease. As per the data presented in Table 19, the per cent incidence of blackeye cowpea mosaic virus in genotype varied significantly. Higher incidence was recorded with genotype Anaswara followed by Pusa Komal. Lower incidence was recorded with genotype Lalita.

Spacing had a significant influence on the incidence of blackeye cowpea mosaic virus. Higher incidence was recorded with narrow row spacing and lower incidence with wider row spacing. Interaction effect was on par with respect to incidence of blackeye cowpea mosaic virus disease.

Mean population of pod borer per plant did not differ significantly among the genotypes. Spacing had significant influence on the pod borer incidence. Narrow row spacing recorded higher pod borer incidence as compared to wider row spacing. Interaction effect was on par with respect to the incidence of pod borer. Almost similar trend followed in case of aphids incidence.

4.1.4 Physiological parameters

4.1.4.1 Crop Growth Rate (CGR)

Crop growth rate (CGR) varied significantly among genotypes during 0 - 20, 20 - 40 DAS and 40 DAS - harvest (Table 20). During 0 - 20 DAS higher CGR was recorded by genotype Anaswara (0.27 g/day/m^2) followed by Bhagyalakshmi (0.25 g/day/m^2). The lower CGR was recorded by genotype Lalita (0.17 g/day/m^2) and the trend continued to be same at 20 - 40 DAS. While, 40 DAS - harvest VU-5 recorded lower CGR (1.15 g/day/m^2).

Table 19. Incidence of Blackeye cowpea mosaic virus (%), mean population per plant of Pod borer and Aphids in cowpea genotypes influenced by spacing

Spacing / Genotype	**Blackeye cowpea mosaic virus (%)**				**Pod borer per plant**				**Aphids per plant**			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	3.33	10.00	16.67	10.00	1.33	1.66	2.33	1.77	10.00	20.00	26.67	18.89
VU-5	10.00	13.33	20.00	14.44	1.00	1.66	1.66	1.44	6.67	16.67	16.67	13.33
Bhagyalakshmi	6.67	10.00	16.67	11.11	0.66	1.33	1.33	1.11	3.33	13.33	16.67	11.11
Kashi Kanchan	3.33	13.33	16.67	11.11	0.66	1.66	2.00	1.44	10.00	13.33	23.33	15.56
Pusa Komal	10.00	16.67	20.00	15.56	1.00	2.00	2.00	1.66	6.67	20.00	23.33	16.67
Anaswara	13.33	23.33	26.67	21.11	1.33	2.33	2.00	1.88	13.33	23.33	23.33	20.00
Mean	7.78	14.44	19.44		1.00	1.77	1.88		8.33	17.78	21.67	

Factors	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**
Spacing	3.66	1.27	0.56	0.19	4.88	1.69
Genotype	5.18	1.79	NS	0.27	NS	2.39
Spacing x Genotype	NS	3.11	NS	0.47	NS	4.14

Crop growth rate of vegetable cowpea genotype differed significantly among different spacings. Maximum CGR (0.23 g/day/m^2) was recorded at wider row spacing (60 x 30 cm) and found on par with 45 x 30 cm spacing (0.22 g/day/m^2). Minimum CGR (0.21 g/day/m^2) was recorded at narrow row spacing (30 x 15 cm) at 0– 20 DAS and the trend continued to be same during 20 - 40 DAS and at 40 DAS - harvest.

Genotype x spacing interaction was on par. However, Anaswara at 60 x 30 cm recorded higher CGR and continued to be the same at 40 DAS - harvest.

4.1.4.2 Relative growth rate (RGR)

The data pertaining to the relative growth rate (RGR) at 0- 20 DAS, 20 – 40 DAS and at 40 DAS to harvest are presented in the Table 21. Higher RGR of 0.085 g/g/day was recorded with genotype Anaswara followed by Bhagyalakshmi with RGR of 0.080 g/g/day at 0 to 20 DAS. Lower RGR of 0.062 g/g/day was recorded with Lalita. RGR value did not differ significantly among genotypes at 20 – 40 DAS. Even so, higher RGR of 1.95 g/g/day was recorded by genotype Lalita. Significantly different values of RGR were recorded among genotypes at 40 DAS to harvest. RGR was highest in genotype Lalita, Kashi Kanchan and Pusa Komal (0.04 g/g/day).

In the case of spacing treatments, highest RGR was recorded with 60 x 30 cm spacing (0.076 g/g/day) which was statistically comparable with 45 x 30 cm spacing with an RGR of 0.074 g/g/day during 0 - 20 DAS and at 40 DAS to harvest. The lowest RGR was recorded with 30 x 15 cm spacing (0.073 g/g/day). The values of RGR did not differ significantly among spacing at 20 – 40 DAS. Even so, higher value of RGR was recorded with 60 x 30 cm row spacing. The genotype x spacing interaction was on par at all the stages of crop growth.

Table 20. Crop growth rate (g/day/m^2) of cowpea genotypes influenced by spacing

Spacing / Genotype	**Crop growth rate**											
	0 – 20 DAS				**20 - 40 DAS**				**40 DAS – harvest**			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	0.18	0.17	0.16	0.17	1.09	1.07	1.01	1.06	2.80	1.84	0.82	1.82
VU-5	0.21	0.20	0.21	0.21	1.26	1.00	1.02	1.09	1.60	1.16	0.70	1.15
Bhagyalakshmi	0.26	0.26	0.24	0.25	1.54	1.41	1.14	1.36	2.52	1.85	1.08	1.81
Kashi Kanchan	0.22	0.21	0.21	0.21	1.14	1.03	1.10	1.09	2.47	1.84	0.91	1.74
Pusa Komal	0.22	0.21	0.21	0.21	1.44	1.15	0.98	1.19	2.38	1.84	1.15	1.79
Anaswara	0.28	0.26	0.26	0.27	1.78	1.67	1.44	1.63	2.40	1.87	2.87	1.85
Mean	0.23	0.22	0.21		1.37	1.22	1.11		2.36	1.73	0.99	

Factors	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**
Spacing	0.012	0.004	0.14	0.050	0.238	0.083
Genotype	0.016	0.006	0.205	0.071	0.337	0.117
Spacing x Genotype	NS	0.010	NS	0.123	NS	0.202

Table 21. Relative crop growth rate (g/g/ day) of cowpea genotypes influenced by spacing

Spacing / Genotype	Relative crop growth rate											
	0 – 20 DAS				**20 - 40 DAS**				**40 DAS – harvest**			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	0.066	0.062	0.058	0.062	1.920	1.970	1.987	1.959	0.059	0.046	0.027	0.044
VU-5	0.073	0.069	0.071	0.071	1.893	1.780	1.777	1.817	0.038	0.034	0.023	0.032
Bhagyalakshmi	0.084	0.082	0.080	0.080	2.013	1.847	1.707	1.856	0.044	0.037	0.030	0.037
Kashi Kanchan	0.074	0.073	0.072	0.073	1.807	1.753	1.823	1.794	0.053	0.046	0.026	0.042
Pusa Komal	0.074	0.073	0.073	0.073	1.903	1.860	1.713	1.826	0.045	0.043	0.034	0.040
Anaswara	0.087	0.084	0.083	0.085	1.977	1.963	1.873	1.938	0.039	0.304	0.028	0.034
Mean	0.076	0.074	0.073		1.919	1.862	1.813		0.046	0.040	0.02	

Factors	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**
Spacing	0.003	0.001	NS	0.042	0.006	0.002
Genotype	0.004	0.001	NS	0.060	0.008	0.003
Spacing x Genotype	NS	0.002	NS	0.104	NS	0.005

4.1.4.3 Net assimilation rate (NAR)

The data regarding the net assimilation rate (NAR) of cowpea genotypes during 0 – 20 DAS, 20 – 40 DAS and during 40 DAS to harvest are depicted in Table 22. NAR of vegetable cowpea genotypes did not differed significantly among genotypes during 0 - 20 DAS. Even so, higher assimilation rate was recorded VU – 5 (0.031 g/ cm^2/day.). During 20 – 40 DAS and 40 DAS – harvest, NAR differed significantly among genotypes and highest NAR of 0.109 g/ cm^2/day was recorded by in genotype Bhagyalakshmi which was found on par with Anaswara (0.094 g/ cm^2/day). While, at harvest significantly higher NAR was recorded with genotype Lalita.

NAR was varied significantly among spacings during 0 -20 DAS and during 40 DAS - harvest. Higher NAR of 0.031 g/ cm^2/day was recorded from narrow row spacing (30 x 15 cm) followed by 45 x 30 cm (0.024 g/ cm^2/day). Lower NAR of 0.022 g/ cm^2/day was recorded from wider row spacing (60 x 30 cm). While, during 40 DAS-harvest higher NAR was recorded with Genotype Lalita. All the spacing treatments were statistically comparable with respect to NAR during 20 -40 DAS. Interaction effect was also on par at all the stages of crop growth.

Table 22. Net assimilation rate (g/ cm^2/day) of cowpea genotypes influenced by spacing

Spacing / Genotype	Net assimilation rate											
	0 - 20 DAS				20 - 40 DAS				40 DAS – Harvest			
	60 x 30 cm	45 x 30 cm	30 x 15 cm	Mean	60 x 30 cm	45 x 30 cm	30 x 15 cm	Mean	60 x 30 cm	45 x 30 cm	30 x 15 cm	Mean
Lalita	0.019	0.022	0.029	0.023	0.053	0.048	0.056	0.052	0.018	0.017	0.010	0.015
VU-5	0.025	0.028	0.040	0.031	0.060	0.058	0.092	0.070	0.010	0.010	0.007	0.009
Bhagyalakshmi	0.024	0.024	0.030	0.026	0.012	0.088	0.112	0.109	0.010	0.009	0.007	0.009
Kashi Kanchan	0.019	0.022	0.032	0.024	0.055	0.078	0.070	0.068	0.012	0.011	0.008	0.010
Pusa Komal	0.023	0.024	0.029	0.025	0.073	0.073	0.082	0.076	0.010	0.009	0.009	0.009
Anaswara	0.022	0.023	0.029	0.025	0.088	0.086	0.108	0.094	0.007	0.007	0.009	0.008
Mean	0.022	0.024	0.031		0.076	0.072	0.087		0.011	0.011	0.008	

Factors	C.D.	SE (±m)	C.D.	SE (±m)	C.D.	SE (±m)
Spacing	0.005	0.002	NS	0.005	0.002	0.001
Genotype	NS	0.003	0.020	0.007	0.002	0.001
Spacing xGenotype	NS	0.005	NS	0.012	NS	0.001

4.1.4.4 Leaf area index

The data pertaining to the leaf area index (LAI) are presented in the Table 23. Leaf area index differed significantly among genotypes at 20, 40 DAS and at harvest. The genotype Anaswara exhibited significantly higher leaf area index (0.22) and found on par with Lalita (0.19) and Kashi Kanchan (0.19) at 20 DAS. Lower leaf area index (0.12) was exhibited by Pusa Komal. The genotype Anaswara exhibited significantly higher leaf area index (1.65) followed by Bhagyalakshmi (1.43) at 40 DAS. The lower leaf area index (0.76) was exhibited by genotype VU- 5. The genotype Anaswara recorded significantly higher leaf area index of 3.02 which was found on par with Bhagyalakshmi (2.83) at harvest. The lower leaf area index was exhibited genotype Lalita (1.41).

The effect of spacings on leaf area index of cowpea genotypes followed similar trend at all the stages of growth. Higher leaf area index (0.29, 1.81 and 3.77) was recorded at narrow row spacing (30 x 15 cm) followed by 45 x 30 cm (0.12,0.92 and 1.83) and minimum (0.09, 0.88 and 1.71) was recorded at wider row spacing (60 x 30 cm) at 20, 40 DAS and at harvest.

Genotype x spacing interaction was on par with respect to leaf area index at 20 and 40 DAS. However, Anaswara at 30 x 15 cm recorded higher leaf area index 0.40 and 2.50 at 20 and 40 DAS respectively. Genotype x spacing interaction was found significant at harvest. Higher leaf area index 4.92 was recorded when genotype Bhagyalakshmi was planted at 30 x 15 cm spacing followed by Kashi Kanchan (4.16) at 30 x 15 cm and minimum leaf area index (0.90) was recorded when Lalita was planted at 45 x 30 cm spacing.

4.1.4.5 Leaf area duration (LAD)

The data regarding the leaf area duration are presented in Table 24. Leaf area duration (LAD) of vegetable cowpea genotypes differed significantly at all the stages of growth. Highest LAD was recorded in Anaswara (2.23 days) which was found on par with Kashi Kanchan (1.98 days), Lalita (1.93 days) and VU -5 (1.65 days) at 20 DAS. Lower LAD was recorded in genotype Pusa Komal (1.28 days). At 40 DAS, highest LAD was recorded in genotype Anaswara (18.79 days) followed by Bhagyalakshmi (15.73 days). The lower leaf area duration was recorded in genotype VU – 5 (9.24 days). Highest LAD continued to be the same trend at harvest also. However, genotype Lalita recorded the minimum LAD at harvest (24.18 days).

Effect of spacing on LAD followed the similar trend at all stages of growth. Highest LAD was recorded in 30 x 15 cm spacing (2.96 days) followed by 45 x 30 cm (1.25 days) at 20 DAS. Lowest LAD was recorded in wider row spacing 60 x 30 cm (0.98 days) and continued to be the same trend at 40 DAS and at harvest.

Interaction effect of genotype x spacing, was found on par at 20 DAS. However, higher LAD was obtained from the treatment combinations of Anaswara at 30 x 15 cm spacing (4.00 days) and continued to be the same trend at 40 DAS. Interaction effect of genotype x spacing, differed significantly at harvest. Higher LAD was obtained from the treatment combinations of Bhagyalakshmi at 30 x 15 cm spacing (69.79 days) followed by Anaswara at 30 x 15 cm (62.62 days). Lower LAD was obtained from treatment combination of Lalita at 45 x 30 cm (16.46 days).

Table 23. Leaf area index of cowpea genotypes influenced by spacing

Spacing / Genotype	Leaf area index											
	20 DAS				**40 DAS**				**At harvest**			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	0.10	0.14	0.33	0.19	0.74	0.73	1.52	1.00	1.07	0.90	2.27	1.41
VU-5	0.10	0.13	0.25	0.16	0.56	0.47	1.24	0.76	1.39	1.48	3.53	2.13
Bhagyalakshmi	0.06	0.10	0.22	0.13	1.12	1.14	2.05	1.43	1.63	1.94	4.92	2.83
Kashi Kanchan	0.12	0.13	0.34	0.19	0.74	0.87	1.50	1.04	1.70	1.87	4.16	2.58
Pusa Komal	0.07	0.09	0.22	0.12	1.00	1.00	2.05	1.35	1.81	2.11	3.96	2.63
Anaswara	0.12	0.14	0.40	0.22	1.12	1.34	2.50	1.65	2.65	2.66	3.75	3.02
Mean	0.09	0.12	0.29		0.88	0.92	1.81		1.71	1.83	3.77	

Factors	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**
Spacing	0.04	0.01	0.14	0.04	0.23	0.08
Genotype	0.06	0.02	0.20	0.06	0.32	0.16
Spacing x Genotype	NS	0.03	NS	0.12	0.57	0.28

Table 24. Leaf area duration (days) of cowpea genotypes influenced by spacing

Spacing / Genotype	Leaf area duration											
	20 DAS				**40 DAS**				**At harvest**			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	1.03	1.39	3.36	1.93	8.44	8.78	18.56	11.93	18.09	16.46	37.99	24.18
VU-5	1.06	1.32	2.56	1.65	6.73	6.04	14.96	9.24	19.56	19.55	47.72	28.94
Bhagyalakshmi	0.62	1.10	2.29	1.33	11.90	12.50	22.81	15.73	27.67	30.86	69.79	42.77
Kashi Kanchan	1.20	1.34	3.39	1.98	8.62	10.06	18.45	12.37	24.50	27.41	56.75	36.22
Pusa Komal	0.71	0.92	2.20	1.28	10.77	10.98	22.71	14.82	28.15	31.19	60.15	39.83
Anaswara	1.26	1.44	4.00	2.23	12.50	14.84	29.05	18.79	37.80	39.98	62.62	46.80
Mean	0.98	1.25	2.96		9.82	10.53	21.09		25.96	27.57	55.84	

Factors	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**
Spacing	0.45	0.15	1.57	0.54	2.92	1.01
Genotype	0.63	0.22	2.23	0.77	4.13	1.43
Spacing x Genotype	NS	0.38	NS	1.34	7.15	2.48

4.1.5 Quality parameters

4.1.5.1 Crude fibre

From the Table 25 it is clear that crude fibre content of vegetable cowpea genotypes differed significantly. Significantly higher crude fibre content (17.42 %) was produced by genotype by Bhagyalakshmi followed by Pusa Komal (16.17 %). Lower crude fibre content was recorded by genotype Kashi Kanchan (12.47 %) followed by VU–5 (12.98 %). All spacings were statistically comparable with respect crude fibre content. The spacing x genotype interaction was also on par.

4.1.5.2 Crude protein

The data on the crude protein content in pod is depicted in Table 25. The content of crude protein differed significantly among genotypes. The highest content of crude protein was recorded from genotypes Lalita (20.41 %) which was found on par with Kashi Kanchan (20.03 %). Lowest content of crude protein was recorded from genotype Anaswara (19.36 %). All the spacing treatments were statistically comparable with respect to crude protein content. However, wider spacing (60 x 30 cm) recoded higher crude protein content (19.75 %). The spacing x genotype interaction was also on par. However, genotype Lalita at 60 x 30 cm recoded higher protein content (20.49 %).

4.1.6 Plant analysis

4.1.6.1.1 Content of nitrogen in plant

The data pertaining to the content of nitrogen in plant are presented Table 26. Among the genotypes, genotype Lalita (1.56 %) recorded the highest content of nitrogen followed by Kashi Kanchan. Minimum content of nitrogen (1.24 %)

Table 25. Quality parameters of cowpea genotypes influenced by spacing

Spacing / Genotype	Crude fibre (%)				Crude protein (%)			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	13.36	13.12	13.49	13.32	20.49	20.33	20.41	20.41
VU-5	12.66	13.30	13.00	12.98	19.56	19.41	19.49	19.49
Bhagyalakshmi	17.59	17.40	17.27	17.42	19.66	19.42	19.53	19.54
Kashi Kanchan	12.57	12.24	12.60	12.47	20.04	20.03	20.01	20.03
Pusa Komal	16.09	16.36	16.08	16.17	19.41	19.33	19.59	19.44
Anaswara	13.36	13.43	13.74	13.51	19.33	19.56	19.18	19.36
Mean	14.27	14.31	14.36		19.75	19.68	19.70	

Factors	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**
Spacing	NS	0.165	NS	0.076
Genotype	0.672	0.233	0.311	0.108
Spacing xGenotype	NS	0.403	NS	0.187

Table 26. Plant nutrient content (%) of cowpea genotypes influenced by spacing

Spacing / Genotype	N content (%)				P content (%)				K content (%)			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	1.59	1.54	1.56	1.56	0.17	0.16	0.16	0.16	3.21	3.09	3.09	3.13
VU-5	1.30	1.26	1.28	1.28	0.36	0.36	0.36	0.36	2.99	2.79	2.78	2.85
Bhagyalakshmi	1.33	1.26	1.29	1.29	0.38	0.34	0.34	0.35	2.28	2.16	2.16	2.20
Kashi Kanchan	1.45	1.44	1.44	1.44	0.18	0.18	0.17	0.18	2.86	2.75	2.73	2.78
Pusa Komal	1.26	1.23	1.31	1.27	0.28	0.27	0.27	0.27	3.09	2.99	3.00	3.03
Anaswara	1.24	1.30	1.19	1.24	0.23	0.22	0.22	0.23	3.13	3.06	3.02	3.07
Mean	1.36	1.34	1.34		0.27	0.26	0.25		2.92	2.80	2.80	

Factors	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**
Spacing	NS	0.01	NS	0.006	NS	0.06
Genotype	0.04	0.01	0.02	0.008	0.25	0.08
Spacing x Genotype	NS	0.02	NS	0.015	NS	0.15

was recorded in genotype Anaswara. All the spacing treatments were statistically comparable with respect to content of nitrogen. The spacing x genotype interaction was also on par. Even so, higher content of nitrogen in plant was recorded in the treatment combination Lalita at 60 x 30 cm.

4.1.6.1.2 Content of phosphorus in plant

The data pertaining to the content of phosphorus in plants are presented are represented in Table 26. Among different genotypes highest content of phosphorus (0.36 %) was recorded in genotype VU-5 and it was on par with Bhagyalakshmi (0.35 %).The lowest plant phosphorus content (0.16%) was recorded by genotype Lalita. The content of phosphorus among different spacings did not differ significantly. The interaction effect was also on par.

4.1.6.1.3 Content of potassium in plants

The data related to the content of potassium in plant at harvest is depicted in Table 26. The content of potassium differs significantly among genotypes. The highest content was recorded in the genotype Lalita (3.13%) found on par with Anaswara (3.07 %) and Pusa Komal (3.03 %).The lowest content was recorded in the genotype Bhagyalakshmi (2.20 %).Among the spacings, the content of potassium in plant exhibited statistically comparable values. The interaction effect was also on par.

4.1.6.1.4 Content of nitrogen in pod

The data related to the content of nitrogen in pod is depicted in Table 27. The content of nitrogen differed significantly among different genotypes. The highest content was recorded by genotype Lalita (3.26 %) followed by Kashi Kanchan (3.20 %). Among different spacings, the content of nitrogen in pods exhibited statically comparable value. The interaction effect was also on par.

4.1.6.1.5 Content of phosphorus in pod

The data pertaining to the content of phosphorus in pod are presented Table 27. Among different genotypes, highest content of phosphorus in pod (0.56 %) was recorded in genotype VU-5 and found on par with Lalita (0.55 %) and Kashi Kanchan (0.54 %). The lowest content of phosphorus was recorded (0.38 %) in genotype Pusa Komal. Among the spacings, the content of phosphorus in pods exhibited statistically comparable values. Genotype x spacing interaction was also on par with respect to content of phosphorus in pods.

4.1.6.1.6 Content of potassium in pod

The data related to the content of potassium in pod are depicted in the Table 27. The content of potassium differed significantly among genotypes. The highest content was recorded in genotype Lalita (4.41 %) followed by Bhagyalakshmi (4.25 %). The lowest potassium content (4.01 %) was recorded by genotype Pusa Komal.

The content of potassium among spacing treatments did not differ significantly. The interaction effect was also on par.

4.1.7. Nutrient uptake by plant

4.1.7.1 Uptake of nitrogen by plant

The data pertaining to the uptake of nitrogen by plants are presented in Table 28. Highest uptake of nitrogen was by genotype Lalita (165.43 kg/ha) followed by Kashi Kanchan (137.29 kg/ha). The lowest nitrogen uptake was recorded by genotype VU-5 (94.38 kg/ha).

Uptake of nitrogen differed significantly with respect to spacing treatments. Highest nitrogen uptake (185.69 kg/ha) was recorded at narrow row spacing (30 x 15 cm) followed by 60 x 30 cm. Lowest nitrogen uptake was

Table 27. Nutrient content (%) of pod as influenced by spacing

Spacing / Genotype	N content				P content				K content			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	3.28	3.25	3.27	3.26	0.56	0.56	0.52	0.55	4.43	4.40	4.40	4.41
VU-5	3.13	3.11	3.12	3.12	0.60	0.54	0.54	0.56	4.09	4.05	4.07	4.07
Bhagyalakshmi	3.15	3.11	3.13	3.12	0.52	0.50	0.51	0.51	4.27	4.27	4.22	4.25
Kashi Kanchan	3.21	3.21	3.20	3.20	0.55	0.52	0.54	0.54	4.02	4.02	4.01	4.02
Pusa Komal	3.11	3.09	3.14	3.11	0.39	0.38	0.37	0.38	4.03	4.02	3.98	4.01
Anaswara	3.09	3.13	3.07	3.09	0.54	0.49	0.49	0.51	4.11	4.07	4.09	4.09
Mean	3.16	3.15	3.15		0.53	0.50	0.50		4.16	4.14	4.13	

Factors	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**
Spacing	NS	0.01	NS	0.01	NS	0.02
Genotype	0.04	0.01	0.04	0.01	0.09	0.03
Spacing x Genotype	NS	0.02	NS	0.02	NS	0.05

Table 28. Uptake of nutrients (kg/ha) by cowpea genotypes as influenced spacing

Spacing / Genotype	Total nitrogen uptake				Total phosphorous uptake				Total potassium uptake			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	141.44	142.69	212.17	165.43	22.40	22.39	28.19	24.32	212.06	216.83	343.75	257.55
VU-5	74.49	66.14	142.52	94.38	17.04	17.04	34.80	22.96	127.32	127.64	266.10	173.68
Bhagyalakshmi	96.16	84.84	176.34	119.11	21.85	22.27	41.63	28.58	147.83	155.27	278.36	193.82
Kashi Kanchan	107.27	97.74	206.85	137.29	16.92	16.86	26.32	20.03	161.45	171.84	311.36	214.88
Pusa Komal	94.33	83.32	167.96	115.20	15.98	16.42	31.96	21.45	168.36	176.74	342.47	229.19
Anaswara	101.97	93.45	208.29	134.57	18.80	19.26	35.97	24.68	188.46	212.18	435.20	278.61
Mean	102.61	94.70	185.69		18.83	19.04	33.14		167.58	176.75	329.54	

Factors	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**	**C.D.**	**SE (±m)**
Spacing	10.65	3.69	1.73	0.60	14.31	4.95
Genotype	15.06	5.21	2.45	0.85	20.24	7.01
Spacing x Genotype	NS	9.03	4.24	1.47	35.061	12.14

recorded at 45 x30 spacing (94.70 kg/ha). Genotype x spacing interaction was on par with respect to uptake of nitrogen by plants. Even so, highest uptake of nitrogen was recorded by treatment combination of Lalita at 30 x 15 cm (212.17 kg/ha)

4.1.7.2 Uptake of phosphorous by plant

The uptake of phosphorus by plants differed significantly among genotypes at harvest (Table 28). Genotype Bhagyalakshmi recorded the highest phosphorus uptake of 28.58 kg /ha followed by Anaswara (24.68 kg/ha). The lowest phosphorus uptake was recorded by genotype Kashi Kanchan (20.03 kg/ha).

Among different spacings narrow row spacing (30 x 15 cm) recorded the highest uptake (33.14 kg/ha) of phosphorus by plant followed by 45 x 30 cm spacing (19.04 kg/ha). Lowest uptake (18.83 kg/ha) of phosphorus was recorded at wider row spacing (60 x 30 cm).

Genotype x spacing interaction was also differed significantly with respect to the uptake of phosphorus by plant. Bhagyalakshmi at 30 x 15 cm was highest with uptake of 41.63 kg/ha followed by Anaswara at 30 x 15 cm with uptake of 35.97 kg/ha. The lowest phosphorous uptake was recorded from the treatment combination of Pusa Komal at 60 x 30 cm with uptake of 15.98 kg/ha .

4.1.7.3 Uptake of potassium by plant

The data related to the uptake of potassium by plants are depicted in Table 28. Uptake of potassium differed significantly among genotypes. Higher uptake of potassium by plant was

recorded by genotype Anaswara with an uptake of 278.61 kg/ha followed by Lalita with an uptake of 257.55 kg/ha. Lowest uptake of phosphorus was recorded by genotype VU – 5 with an uptake of 173.68 kg/ha. Among different spacings, higher nutrient uptake of 329.54 kg/ha was recorded by 30 x 15 cm spacing followed by 45 x 30 cm (176.75 kg /ha). The lowest potassium uptake (167.58 kg/ha) was recorded in wider row spacing (60 x 30 cm).

Genotype x spacing interaction was also differed significantly with respect to the uptake of potassium by plant. Anaswara at 30 x 15 cm was highest with uptake of 435.20 by kg /ha followed by Lalita at 30 x 15 cm with uptake of 343.75 kg/ha . The lowest potassium uptake was recorded from the treatment combination of VU - 5 at 60 x 30 cm with uptake of 127.32 kg/ha.

4.1.8 Nutrient content of soil

4.1.8.1 EC of the soil

The data pertaining to electrical conductivity of soil are presented in Table 29. The electrical conductivity of the soil did not differ significantly among genotypes. They were on par among spacing also. The interaction effect was also on par.

4.1.8.2 Soil pH

The pH of the soil did not differ significantly among genotypes (Table 29). They were on par among spacing also. The interaction effect was also on par.

4.1.8.3 Organic carbon content of soil

From the data presented in Table 30, it is clear that organic carbon content of the soil recorded a high value of 0.84 per cent by genotype UV- 5 and Kashi Kanchan and the lowest value of 0.79 per cent by genotype Lalita and Anaswara. Organic carbon of soil differed significantly among spacings. Higher organic carbon content of 0.86 per cent recorded by spacing of 45 x 30 cm and minimum

Table 29. Electrical conductivity (dS/m) and pH of cowpea genotypes influenced by spacing

Spacings / Genotype	EC				pH			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	0.09	0.09	0.09	0.09	5.75	5.74	5.81	5.76
VU-5	0.09	0.10	0.10	0.10	5.65	5.76	5.69	5.70
Bhagyalakshmi	0.09	0.11	0.10	0.10	5.65	5.79	5.71	5.71
Kashi Kanchan	0.09	0.10	0.10	0.10	5.82	5.72	5.78	5.77
Pusa Komal	0.11	0.13	0.10	0.11	5.66	5.67	5.77	5.70
Anaswara	0.10	0.10	0.10	0.10	5.67	5.72	5.78	5.72
Mean	0.09	0.10	0.10		5.70	5.73	5.75	
Factors	**C.D**		**SE (±m)**		**C.D**		**SE (±m)**	
Spacing	NS		0.005		NS		0.032	
Genotype	NS		0.007		NS		0.046	
Spacing x Genotype	NS		0.012		NS		0.079	

Table 30. Organic carbon content (%) and available soil nitrogen content (kg/ha) of cowpea genotypes influenced by spacing

Genotype \ Spacings	Organic carbon				Nitrogen			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x15 cm**	**Mean**
Lalita	0.78	0.83	0.77	0.79	131.08	142.31	128.28	133.89
VU-5	0.82	0.89	0.80	0.84	134.86	136.15	133.05	134.68
Bhagyalakshmi	0.81	0.88	0.80	0.83	136.46	143.56	131.98	137.33
Kashi Kanchan	0.82	0.89	0.80	0.84	134.81	146.66	129.06	136.84
Pusa Komal	0.80	0.83	0.79	0.81	134.83	143.35	132.35	137.30
Anaswara	0.77	0.83	0.78	0.79	135.49	140.46	128.20	134.71
Mean	0.80	0.86	0.79		134.59	142.14	130.65	

Factors	**C.D**	**SE (±m)**	**C.D**	**SE (±m)**
Spacing	0.014	0.005	1.93	0.66
Genotype	0.020	0.007	2.73	0.94
Spacing x Genotype	NS	0.012	4.73	1.63

organic carbon content by 0.79 per cent by spacing of 30 x 15 cm. Genotype x spacing interaction was statistically comparable with respect to organic carbon of soil.

4.1.8.4 Available nitrogen content of soil

Significantly varying available nitrogen content was observed among genotypes (Table 30). The available nitrogen content was highest (137.33 kg/ha) in genotype Bhagyalakshmi and it was on par with Pusa Komal, Kashi Kanchan and Anaswara. The lowest value of available nitrogen content of 133.89 kg/ha was recorded by genotype Lalita. Among spacings, higher value of available nitrogen content of 142.14 kg/ha by spacing 45 x 30 cm and lower value of available nitrogen content of 130.65 kg/ha by spacing of 30x 15 cm. Interaction was also significantly varied. The higher available nitrogen content (146.66 kg/ha) was from treatment combination Kashi Kanchan at 45 x 30 cm. The lower available nitrogen content (128.20 kg/ha) was from treatment combination of Anaswara at 30 x 15 cm found on par with Lalita at 30 x 15 cm.

4.1.8.5 Available phosphorus content of soil

Significantly different available phosphorus content was observed among genotypes (Table 31). The available phosphorus content was highest (36.79 kg/ha) in genotype VU-5 and it was on par with Kashi Kanchan, Pusa Komal and Bhagyalakshmi. The lowest value of available phosphorus content of 33.51 kg/ha by genotype Anaswara was found on par with Lalita. Among spacings, higher value of available phosphorus content of 36.82 kg/ha by spacing 45 x 30 cm and lower value of available phosphorus content 33.85 kg/ha by spacing 30 x 15 cm were observed. Interaction effect was statistically comparable with respect to available phosphorous content of soil.

Table 31. Available soil phosphorus and potassium (kg/ha) content of cowpea genotypes influenced by spacing

Spacings / Genotype	Phosphorus				Potassium			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	34.64	35.48	34.13	34.75	423.30	424.02	406.05	417.79
VU-5	37.24	38.41	34.71	36.79	424.58	449.12	416.37	430.02
Bhagyalakshmi	35.94	36.69	33.72	35.45	422.45	431.93	418.86	424.41
Kashi Kanchan	35.49	38.44	34.25	36.06	423.63	433.63	417.61	424.96
Pusa Komal	35.24	37.22	34.14	35.53	419.18	434.27	416.82	423.42
Anaswara	33.68	34.69	32.15	33.51	415.32	420.33	410.29	415.31
Mean	35.37	36.82	33.85		421.41	432.22	414.33	

Factors	**C.D**	**SE (±m)**	**C.D**	**SE (±m)**
Spacing	1.02	0.50	5.28	1.83
Genotype	1.44	0.70	7.47	2.59
Spacing x Genotype	NS	1.22	12.95	4.48

4.1.8.6 Available potassium content of soil

The effect of genotype on available potassium content of soil differed significantly among genotypes (Table 31). The available potassium content was highest (430.02 kg/ha) in genotype VU-5 and it was on par with Kashi Kanchan, Bhagyalakshmi and Pusa Komal. The lowest value of available potassium content of 415.31 kg/ha by genotype Anaswara was found on par with Lalita. Among spacings, higher value of available potassium content 432.22 kg/ha by spacing 45 x 30 cm and lower value of available potassium content 414.33 kg/ha by spacing 30 x 15 cm. Interaction was also significantly different. The higher available potassium content (449.12 kg/ha) was from treatment combination of UV - 5 at 45 x 30 cm and the lower content (406.05 kg/ha) was from treatment combination of Lalita at 30 x 15 cm found on par with Anaswara at 30 x 15 cm.

4.1.8.7 Available calcium content of soil

The available calcium content of soil had significant difference among genotypes (Table 32). Higher available calcium content (552.03 mg/kg) was recorded with genotype VU-5 and it was on par with Bhagyalakshmi, Pusa Komal and Kashi Kanchan. The lowest value of available calcium content of 521.29 mg/kg by genotype Anaswara. Among spacings, higher value of available calcium content of 555.97 mg/kg by spacing of 45 x 30 cm and lower value of available calcium content of 528.33 mg/ kg by spacing of 30 x 15 cm. Interaction was also significantly different. The higher available calcium content (574.74 mg/kg) was from the treatment combination of Bhagyalakshmi at 45 x 30 cm and found on par with Kashi Kanchan at 45 x 30 cm.

4.1.8.8 Available magnesium content of soil

The effect of genotype on available magnesium content of soil differed significantly among genotypes (Table 32). The available magnesium content was

Table 32. Available soil calcium and magnesium (mg/kg) content of cowpea genotypes influenced by spacing

Spacings / Genotype	Calcium				Magnesium			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	516.28	539.03	523.35	526.22	80.98	83.04	81.94	81.99
VU 5	552.59	569.58	533.92	552.03	81.77	85.85	80.95	82.86
Bhagyalakshmi	542.97	574.74	532.77	550.16	80.98	86.55	79.42	82.32
Kashi Kanchan	544.49	570.51	527.77	547.59	81.28	85.14	81.06	82.49
Pusa Komal	554.46	558.37	534.68	549.17	81.15	84.72	80.50	82.12
Anaswara	522.84	523.56	517.49	521.29	79.28	82.74	78.78	80.27
Mean	538.94	555.97	528.33		80.91	84.67	80.44	
Factors	**C.D**		**SE (±m)**		**C.D**		**SE (±m)**	
Spacing	7.70		2.67		1.08		0.37	
Genotype	10.89		3.77		1.53		0.53	
Spacing x Genotype	18.87		6.54		NS		0.92	

highest (82.86 mg/ kg) in genotype VU-5 and it was on par with Kashi Kanchan, Bhagyalakshmi, Pusa Komal and Lalita. The lowest value of available magnesium content of 80.27 mg/kg by genotype Anaswara. Among spacings, higher available magnesium content of 84.67 mg/kg by spacing 45 x 30 cm and lower available magnesium content of 80.44 mg/kg by spacing 30 x 15 cm were noticed. Interaction effect was statistically comparable with respect to available magnesium content of soil.

4.1.8.9 Available sulphur content of soil

The data pertaining to available sulphur content of soil are presented in Table 33. Genotype UV - 5 recorded significantly higher available sulphur content of 8.76 mg/kg and found on par with genotype Bhagyalakshmi, Pusa Komal and Kashi Kanchan. The lowest value of available sulphur of content 8.17 mg/kg by genotype Anaswara. Among spacings, higher available sulphur content of 9.33 mg/kg by spacing 45 x 30 cm and lower available sulphur content of 8.08 mg/ha by spacing 30 x 15 cm were observed. Interaction effect was statistically comparable with respect to available sulphur content of soil.

4.1.8.10 Available iron content of soil

The data pertaining to available iron content of soil are presented in Table 33. Genotype Pusa Komal recorded significantly higher available iron content of 19.71 mg/kg and found on par with genotype Bhagyalakshmi, UV - 5 and Kashi Kanchan. The lowest value of available iron content of 17.75 mg/kg by genotype Anaswara and Lalita. The available iron content of soil was statistically comparable with respect to spacing. Genotype x spacing interaction was also on par with respect to iron content of soil.

Table 33. Available soil Sulphur and Iron (mg/kg) content of cowpea genotypes influenced by spacing

Spacing / Genotype	Sulphur				Iron			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	8.10	8.86	7.91	8.29	17.38	18.54	17.33	17.75
VU-5	8.25	9.68	8.36	8.76	16.60	20.42	19.45	18.82
Bhagyalakshmi	8.40	9.48	8.22	8.70	19.11	19.98	18.97	19.35
Kashi Kanchan	8.26	9.49	8.14	8.63	18.50	19.34	17.99	18.61
Pusa Komal	8.39	9.41	8.17	8.65	19.11	21.12	18.90	19.71
Anaswara	7.77	9.05	7.68	8.17	18.28	18.46	16.51	17.75
Mean	8.19	9.33	8.08		18.16	19.64	18.19	

Factors	**C.D** (Sulphur)	**SE (±m)** (Sulphur)	**C.D** (Iron)	**SE (±m)** (Iron)
Spacing	0.31	0.10	NS	0.32
Genotype	0.44	0.15	1.33	0.46
Spacing x Genotype	NS	0.26	NS	0.80

4.1.8.11 Available zinc content of soil

The data pertaining to available zinc content of soil are presented in Table 34. The available zinc content of the soil was statistically comparable with respect to genotypes and spacing. Interaction effect was found significant with respect to the available zinc content of soil. The higher available zinc content (4.69 mg/kg) was from treatment combination of Bhagyalakshmi at 45 x 30 cm and lower zinc content (4.31 mg/kg) was from treatment combination of genotypes Lalita and Anaswara at 30 x 15 cm.

4.1.8.12 Available manganese content of soil

The data pertaining to available manganese content of soil are presented in Table 34. Manganese content of soil differed significantly with respect to genotypes. Significantly higher manganese content of soil was recorded with genotype VU-5. Manganese content of soil was statistically comparable with respect to spacing. Interaction was significantly different. The higher available manganese content (50.78 mg/kg) was from treatment combination of UV - 5 at 45 x 30 cm and lower manganese content (45.30 mg/kg) was from treatment combination of Pusa Komal at 30 x 15 cm.

4.1.8.13 Available copper content of soil

The content of copper differed significantly among genotypes (Table 35). Significantly higher available copper content (2.35 mg/kg) in genotype VU-5 and lower available copper content (2.24 mg/kg) in genotype Bhagyalakshmi were noticed. Available copper content of the soil was statistically comparable with respect to spacing treatment. Interaction was significantly different. The higher available copper content (2.46 mg/kg) was from treatment combination of Kashi Kanchan at 45 x 30 cm and lower copper content (2.15 mg/kg) from treatment combination of Bhagyalakshmi at 30 x 15 cm.

Table 34. Available soil Zinc and Manganese (mg/kg) content of cowpea genotypes influenced by spacing

Spacing / Genotype	Zinc				Manganese			
	60 x 30 cm	**60 x 30 cm**	**60 x 30 cm**	**60 x 30 cm**	**60 x 30 cm**	**45 x 30 cm**	**30 x15 cm**	**Mean**
Lalita	4.35	4.49	4.31	4.38	47.33	48.37	46.66	47.45
VU-5	4.51	4.63	4.37	4.50	48.62	50.78	46.95	48.78
Bhagyalakshmi	4.60	4.69	4.38	4.56	45.75	49.09	45.46	46.77
Kashi Kanchan	4.39	4.40	4.23	4.34	45.69	48.28	45.37	46.45
Pusa Komal	4.55	4.49	4.40	4.48	48.19	49.37	45.30	47.62
Anaswara	4.51	4.61	4.31	4.48	47.68	47.74	46.96	47.46
Mean	4.49	4.55	4.33		47.21	48.94	46.12	

Factors	C.D	SE (±m)	C.D	SE (±m)
Spacing	NS	0.049	NS	0.26
Genotype	NS	0.069	1.09	0.38
Spacing x Genotype	0.34	0.120	1.90	0.65

4.1.8.14 Available boron content of soil

The data pertaining to available boron content of soil are presented in Table 35. The available boron content of the soil was statistically comparable with respect to genotypes and spacing. Interaction effect was found non-significant with respect to the available boron content of soil.

4.1.9 Economics of cultivation

The data regarding net returns and B: C ratio is presented in Table 36. The net return differed significantly with genotypes. Genotype Lalita recorded the highest net return (Rs. 43,881) followed by genotype Kashi Kanchan. Among the spacing treatments also the net return varied significantly. Among spacings, wider spacing recorded the highest net return. The interaction effect was also differed significantly. Interaction effect of genotype x spacing differed significantly. Higher net return was obtained from the treatment combination of genotype Lalita at 60 x 30 cm Rs. 242,293. Lower net return was obtained from treatment combination of Pusa Komal at 30 x 15 cm (Rs. -86,335.48) and B:C ratio also followed the same trend.

Experiment II: Standardization of source of nutrients and levels of fertilizers in bush type vegetable cowpea under open precision farming

The experiment was conducted to study the effect of source of nutrients on the performance of vegetable cowpea *Vigna unguiculata* (L.) Walp.) and to standardize optimum level of fertilizers for maximum yield under open precision farming.

Table 35 . Available soil Copper and Boron (mg/kg) content of cowpea genotypes influenced by spacing

Spacings / Genotype	Copper				Boron			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	2.30	2.40	2.23	2.31	0.22	0.24	0.22	0.23
VU 5	2.35	2.41	2.28	2.35	0.23	0.22	0.24	0.23
Bhagyalakshmi	2.23	2.32	2.15	2.24	0.22	0.23	0.24	0.23
Kashi Kanchan	2.34	2.46	2.16	2.32	0.24	0.23	0.22	0.23
Pusa Komal	2.29	2.32	2.25	2.29	0.22	0.23	0.23	0.23
Anaswara	2.29	2.33	2.20	2.27	0.20	0.23	0.21	0.21
Mean	2.30	2.38	2.21		0.22	0.23	0.23	

Factors	**C.D** (Copper)	**SE (±m)** (Copper)	**C.D** (Boron)	**SE (±m)** (Boron)
Spacing	NS	0.02	NS	0.003
Genotype	0.08	0.02	NS	0.005
Spacing x Genotype	0.14	0.04	NS	0.008

Table 36. Net return (Rs. /ha) and B: C ratio of cowpea genotypes influenced by spacing

Spacing / Genotype	Net return				B:C Ratio			
	60 x 30 cm	**45 x 30 cm**	**30 x 15 cm**	**Mean**	**60 x 30 cm**	**45 x 30 cm**	**30 x 15 cm**	**Mean**
Lalita	242,293	-126,223	15572	43,881	1.67	1.62	1.03	1.44
VU-5	110,311	126,233	-165,756	-134,097	0.69	0.68	0.62	0.66
Bhagyalakshmi	-89,871	-101,321	-141,708	-110,967	0.75	0.75	0.68	0.72
Kashi Kanchan	-27,855	-19596	-16,140	-21,197	1.08	0.95	0.96	0.99
Pusa Komal	-88,326	-87,316	-94,476	-90,039	0.78	0.78	0.79	0.78
Anaswara	-64,632	14,518	-115,502	-55,205	1.04	0.83	0.86	0.91
Mean	-23,117	-74,360	-86,335		0.97	0.96	0.82	
Factors	**C.D.**		**SE (±m)**		**C.D.**		**SE (±m)**	
Spacing	16,580		5,744		0.029		0.010	
Genotype	23,447		8,123		0.041		0.014	
Spacing x Genotype	40,612		14,070		0.070		0.024	

4.2.1. Growth characters

4.2.1.1. Plant height

The height of plants did not differ significantly among levels of fertilizers at 20, 40 DAS and at harvest (Table 37). However, tallest plants were recorded from the treatment, application of fertilizers @ 139:37: 127 kg N: P_2O_5: K_2O /ha at 20 and 40 DAS. While at harvest tallest plants were recorded when fertilizers were applied @ 185: 50: 170 kg N: P_2O_5: K_2O /ha. The height of plants did not differ significantly among source of nutrients. Even so, tallest plants were recorded from the treatment with fifty per cent of the fertilizer application was given through conventional sources as basal and remaining fifty per cent through fertigation as water soluble fertilizers at 20 DAS.While fertigation with conventional fertilizer recorded the tallest plant at 40 DAS and at harvest. Interaction effect of fertilizer levels and sources of nutrients was statistically comparable with respect to height of plant at all the stages of crop growth.

4.2.1.2 Number of leaves per plant

The data on number of leaves per plant are given in Table 38. Number of leaves per plant of vegetable cowpea did not differ significantly among levels of fertilizers at all stages of growth. Even so, higher number of leaves per plant (4.84) was recorded with application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha through fertigation at 20 DAS. While at 40 DAS and at harvest higher number of leaves per plant 13.53 and 16.80 was recorded with application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha through fertigation.

Number of leaves per plant was statistically comparable with respect to sources of nutrients at all the stages of crop. Even so, higher number of leaves per plant was recorded in fertigation treatment with water soluble fertilizers at 20

Table 37. Plant height (cm) of cowpea as influenced by levels and sources fertilizers

Treatments	20 DAS	40 DAS	At harvest
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	19.69	45.67	54.18
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	20.09	46.24	54.53
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	19.11	43.96	55.93
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	19.99	44.49	55.38
Control (F_0)	20.06	44.29	53.84
SE (±m)	0.678	1.037	1.103
C.D. at 5 %	NS	NS	NS
Sources of fertilizers (S)			
S_1 - 100 % - CF	20.03	45.75	56.73
S_2 - 50 % CF as basal dose + 50 % WSF	20.09	45.44	55.28
S_3 - 100 % - WSF	19.56	44.76	54.15
SE (±m)	0.587	0.898	0.955
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	20.94	46.44	53.84
F_1S_2	18.68	44.78	54.50
F_1S_3	19.45	45.78	54.20
F_2S_1	19.91	46.11	58.80
F_2S_2	21.33	47.84	52.47
F_2S_3	19.00	44.76	52.33
F_3S_1	19.76	44.18	56.20
F_3S_2	20.05	43.82	55.33
F_3S_3	17.51	43.87	56.27
F_4S_1	19.50	46.27	58.07
F_4S_2	20.53	44.07	53.07
F_4S_3	19.94	43.13	55.00
SE (±m)	1.17	1.796	1.910
C.D. at 5 %	NS	NS	NS

Table 38. Number of leaves per plant of cowpea as influenced by levels and sources fertilizers

Treatments	20 DAS	40 DAS	At harvest
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	4.84	12.22	15.84
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	4.56	12.56	16.00
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	4.47	13.53	16.80
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	4.44	12.56	16.27
Control (F_0)	4.47	11.53	15.13
SE (±m)	0.119	0.391	0.438
C.D. at 5 %	NS	NS	NS
Sources of fertilizers (S)			
S_1 - 100 % - CF	4.42	12.70	16.05
S_2 - 50 % CF as basal dose + 50 % WSF	4.51	12.98	16.34
S_3 - 100 % - WSF	4.66	12.73	16.32
SE (±m)	0.103	0.338	0.379
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	4.80	11.73	15.00
F_1S_2	4.80	12.53	16.20
F_1S_3	4.93	12.40	16.33
F_2S_1	4.00	12.27	15.93
F_2S_2	4.87	13.67	17.07
F_2S_3	4.80	11.73	15.00
F_3S_1	4.67	13.93	16.93
F_3S_2	4.27	13.93	16.93
F_3S_3	4.47	12.73	16.53
F_4S_1	4.20	12.87	16.33
F_4S_2	4.47	12.87	16.33
F_4S_3	4.67	11.93	16.13
SE (±m)	0.207	0.677	0.759
C.D. at 5 %	NS	NS	NS

DAS. While at 40 DAS and at harvest application of fifty per cent of fertilizer dose as conventional sources as basal and remaining fifty per cent through fertigation as water soluble fertilizers recorded higher number of leaves per plant (12.98 and 16.34). Interaction effect was also on par.

4.2.2. Yield attributes and yield

4.2.2.1 Dry matter production per plant

Dry matter production per plant did not differ significantly with respect to levels of fertilizers (Table 39). However, higher dry matter production per plant (70.87 g) was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation.

The source of nutrients was statistically comparable with respect to dry matter production at harvest. However, higher dry matter was produced with fertigation through 100 per cent water soluble fertilizers (68.74 g). Interaction effect was also on par.

4.2.2.2 Days to fifty per cent flowering

The days taken to complete fifty per cent flowering is arranged in Table 39. Days to fifty per cent flowering differed significantly among levels of fertilizers. Application of package of practice recommendation (control) attained fifty per cent flowering earlier (32.33 days) as compared to other treatments. Days to fifty per cent flowering were statistically comparable with respect to sources of nutrients. Level of fertilizers x sources of nutrients interaction was also on par.

4.2.2.3 Days to first harvest

The days taken to first harvest is arranged in Table 39. Days to first harvest differed significantly among levels of fertilizers. Early harvest (41.33

Table 39. Yield attributes of cowpea as influenced by levels and sources fertilizers

Treatments	Dry matter production per plant (g)	Days to 50 per cent flowering (days)	Days to first harvest (days)
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	67.01	32.44	41.44
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	64.74	32.44	42.56
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	66.15	32.44	42.67
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	70.87	33.33	42.78
Control (F_0)	63.45	32.33	41.33
SE (±m)	2.372	0.192	0.26
C.D. at 5 %	NS	0.564	0.77
Sources of fertilizers (S)			
S_1 - 100 % - CF	64.10	32.58	42.50
S_2 - 50 % CF as basal dose + 50 % WSF	65.09	32.67	42.46
S_{3} - 100 % - WSF	68.74	32.71	42.29
SE (±m)	2.504	0.167	0.23
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	61.15	32.33	41.33
F_1S_2	66.50	32.33	41.00
F_1S_3	73.37	32.67	42.00
F_2S_1	63.64	32.33	42.67
F_2S_2	68.35	33.00	43.33
F_2S_3	62.23	32.00	41.67
F_3S_1	63.70	32.33	42.67
F_3S_2	62.13	32.67	43.00
F_3S_3	72.61	32.33	42.33
F_4S_1	67.90	33.33	43.33
F_4S_2	67.30	33.00	42.33
F_4S_3	77.42	33.67	42.67
SE (±m)	5.009	0.333	0.45
C.D. at 5 %	NS	NS	NS

days) was recorded with application of package of practice recommendation (control). Days to first harvest were statistically comparable with respect to sources of nutrients. Level of fertilizers x sources of nutrients interaction was also on par.

4.2.2.4 Pod length

All fertilizer levels exhibited statistically comparable values for the length of pods (Table 40). Even so, application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha through fertigation produced longer pods (26.84 cm). They were also on par with respect to sources of nutrients and produced longer pods with fertigation with conventional fertilizers (26.94 cm). Interaction effect, levels of fertilizers x sources of nutrients were on par with respect to pod length of vegetable cowpea at harvest. The longer pods (27.63 cm) were produced in the treatment combination of application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha with conventional sources of fertilizers (F_3S_1) under open precision farming.

4.2.2.5 Number of pods per plant

Total number of pods produced per plant is depicted in Table 40. Number of pods per plant of bush type vegetable cowpea was statistically comparable with levels of fertilizers. Even so, higher number of pods per plant (11.65) was recorded by the application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation. Number of pods produced per plant had no significant difference among source of nutrients. However, higher number of pods per plant was recorded with fertigation through water soluble fertilizers (11.43). Interaction effect was statistically comparable with respect to number of pods per plant. However, higher number of pods per plant was recorded in the treatment combination of application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha

Table 40. Yield attributes of cowpea as influenced by levels and sources fertilizers

Treatments	Pod length (cm)	Number of pod per plant	Yield per plant (g)
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	26.84	11.43	101.58
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	26.83	11.33	104.01
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	26.83	11.01	99.55
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	26.83	11.65	103.31
Control (F_0)	26.61	11.54	102.89
SE (±m)	0.400	0.643	16.349
C.D. at 5 %	NS	NS	NS
Sources of fertilizers (S)			
S_1 - 100 % - CF	26.94	11.22	96.50
S_2 - 50 % CF as basal dose + 50 % WSF	26.81	11.34	99.26
S_3 - 100 % - WSF	26.78	11.43	104.92
SE (±m)	0.346	0.556	4.827
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	27.61	11.87	90.14
F_1S_2	26.35	11.80	104.90
F_1S_3	26.56	11.23	109.71
F_2S_1	26.51	12.07	101.68
F_2S_2	27.09	10.80	110.31
F_2S_3	26.89	11.13	100.05
F_3S_1	27.63	10.07	92.14
F_3S_2	26.06	12.07	95.85
F_3S_3	26.82	10.91	110.67
F_4S_1	26.04	10.87	102.05
F_4S_2	27.17	11.18	96.99
F_4S_3	27.27	12.32	110.90
SE (±m)	0.693	1.113	9.655
C.D. at 5 %	NS	NS	NS

with water soluble fertilizers through fertigation (F_4S_3) under open precision farming.

4.2.2.6 Yield per plant

The data regarding the yield per plant is depicted in Table 40. Yield per plant of bush type vegetable cowpea did not differ significantly among levels of fertilizers. Even so, Drip fertigation @ 139:37: 127 kg N: P_2O_5: K_2O /ha recorded higher yield per plant (104.01 g). Yield per plant had no significant difference among sources of nutrients. Interaction effect, levels of fertilizers x sources of nutrients was statistically comparable with respect to yield per plant at harvest. Even so, higher yield per plant (110.90 g) were recorded in treatment combination of application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha with water soluble fertilizers through fertigation (F_4S_3).

4.2.2.7 Yield per plot

From Table 41, It is clear that, the yield per plot was the maximum with drip fertigation @ 139:37: 127 kg N: P_2O_5: K_2O /ha (5.39 kg) which was statistically comparable with other treatments. Sources of nutrients were statistically comparable with respect to yield per plot. Even so, fertigation with water soluble fertilizers produced higher yield per plot (5.30 kg) compared to other treatments. Interaction effect was also on par. Even so, higher yield per plot (5.90 kg) was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation as 100 per cent water soluble fertilizers (F_4S_3).

4.2.2.8 Yield per hectare

The data pertaining to the effect of treatments on yield of vegetable cowpea under open precision farming is given in Table 41. Among different

Table 41. Yield attributes of cowpea as influenced by levels and sources fertilizers

Treatments	Yield per plot (kg)	Yield per ha (t/ha)	Duration of crop (days)
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	5.17	7.46	74.56
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	5.39	7.70	75.33
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	4.84	7.39	75.00
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	5.19	7.71	76.89
Control (F_0)	4.66	7.84	74.33
SE (±m)	0.242	0.40	0.506
C.D. at 5 %	NS	NS	1.483
Sources of fertilizers (S)			
S_1 - 100 % - CF	4.85	7.15	75.58
S_2 - 50 % CF as basal dose + 50 % WSF	5.06	7.35	75.33
$S_{3 -}$ 100 % - WSF	5.30	7.78	75.38
SE (±m)	0.209	0.346	0.438
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	4.54	6.68	75.67
F_1S_2	5.78	7.77	74.00
F_1S_3	5.18	7.94	74.00
F_2S_1	5.05	7.53	75.00
F_2S_2	5.72	8.17	75.33
F_2S_3	5.42	7.41	75.67
F_3S_1	4.73	6.83	75.00
F_3S_2	5.01	7.10	74.67
F_3S_3	4.76	8.25	75.33
F_4S_1	5.07	7.56	76.67
F_4S_2	4.61	7.18	76.33
F_4S_3	5.90	8.39	77.67
SE (±m)	0.419	6.68	0.876
C.D. at 5 %	NS	NS	NS

levels of fertilizers higher yield of 7.84 t/ha was exhibited by with application of POP recommendation which was statistically comparable with other treatments.Yield of vegetable cowpea among sources of nutrients did not differ significantly. Interaction effect of fertilizer levels x sources of nutrients was statistically comparable with respect to yield per hectare at harvest.

4.2.2.9 Duration of crop

Duration of bush type vegetable cowpea differed significantly with respect to levels of fertilizers (Table 41). It was observed that control plot attained final maturity earlier (74.33 days) than other treatments. Application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation attained final maturity lately (76.89 days). Duration of crop was on par among sources of nutrients. Interaction effect, levels of fertilizers x sources of nutrients were on par with respect to duration of vegetable cowpea under open precision farming. .

4.2.3 Physiological parameters

4.2.3.1 Crop growth rate (CGR)

The data pertaining to the effect of treatments on Crop growth rate (CGR) of vegetable cowpea under open precision farming is given in Table 42. Crop growth rate (CGR) did not varied significantly among levels of fertilizers at 0 – 20 DAS and at 40 DAS to harvest. While during 20 - 40 DAS, CGR varied

Table 42. Crop growth rate ($g/day/cm^2$) of cowpea as influenced levels and sources fertilizers

Treatments	Crop growth rate		
	0 - 20 DAS	20 – 40 DAS	40 DAS – Harvest
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	0.073	0.841	1.16
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	0.066	0.942	0.93
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	0.065	0.929	1.07
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	0.071	0.894	1.27
Control (F_0)	0.072	0.90	0.99
SE (±m)	0.002	0.019	0.12
C.D. at 5 %	NS	0.057	NS
Sources of fertilizers (S)			
S_1 - 100 % - CF	0.069	0.872	1.06
S_2 - 50 % CF as basal dose + 50 % WSF	0.070	0.891	1.05
$S_{3\,-}$ 100 % - WSF	0.069	0.916	1.13
SE (±m)	0.002	0.017	0.10
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	0.068	0.807	1.06
F_1S_2	0.077	0.866	1.07
F_1S_3	0.073	0.849	1.35
F_2S_1	0.071	0.859	0.98
F_2S_2	0.069	0.983	0.99
F_2S_3	0.059	0.984	0.82
F_3S_1	0.069	0.938	1.03
F_3S_2	0.063	0.900	0.95
F_3S_3	0.064	0.947	1.23
F_4S_1	0.069	0.884	1.17
F_4S_2	0.071	0.889	1.19
F_4S_3	0.073	0.909	1.46
SE (±m)	0.004	0.034	0.20
C.D. at 5 %	NS	NS	NS

significantly among levels of fertilizers. Maximum CGR was recorded with drip fertigation @ 139:37: 127 kg N: P_2O_5: K_2O /ha (0.94 g/day/cm^2) which were found on par with drip fertigation @ 185: 50: 170 kg N: P_2O_5: K_2O /ha and control treatment. Minimum CGR (0.84 g/day/cm^2) was recorded with drip fertigation @ 93:25:85 kg N: P_2O_5: K_2O /ha. CGR did not vary significantly among sources of nutrients at all the stages of crop growth. Even so, Higher CGR (0.07 g/day/cm^2) was recorded with application of fifty per cent of fertilizer dose through conventional sources as basal and remaining fifty per cent through fertigation as water soluble fertilizers during 0 - 20 DAS. While, higher CGR 0.91 and 1.13 g/day/cm^2 recorded with drip fertigation with water soluble fertilizers during 20 – 40 DAS and at 40 DAS to harvest respectively. Interaction effect of fertilizer levels x source of nutrients were on par with respect to CGR at all the stages of crop growth.

4.2.3. 2 Relative growth rate (RGR)

The data pertaining to the Relative Growth Rate (RGR) during 0-20 DAS, 20 – 40 DAS and during 40 DAS to harvest are presented in the Table 43. RGR did not vary significantly among drip fertigation levels at all the stages of crop growth. RGR did not vary significantly among sources of nutrients at all the stages of crop growth. Interaction effect of fertilizer levels of fertilizers x sources of nutrients was also on par with respect to RGR at all the stages of crop growth.

4.2.3.3 Net assimilation rate (NAR)

The data regarding the Net Assimilation Rate (NAR) of vegetable cowpea at 0 – 20 DAS, 20–40 DAS and at 40 DAS to harvest are depicted in Table 44. NAR of vegetable cowpea did not differ significantly among levels and sources of

Table 43. Relative crop growth rate (g/g/cm^2) of cowpea as influenced by levels and sources fertilizers

Treatments	Relative crop growth rate		
	0-20 DAS	20-40 DAS	40 DAS – Harvest
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	0.018	0.127	0.041
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	0.013	0.137	0.032
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	0.013	0.136	0.036
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	0.018	0.130	0.041
Control (F_0)	0.016	0.132	0.035
SE (±m)	0.002	0.002	0.003
C.D. at 5 %	NS	NS	NS
Sources of fertilizers (S)			
S_1 - 100 % - CF	0.016	0.131	0.037
S_2 - 50 % CF as basal dose + 50 % WSF	0.016	0.131	0.037
$S_{3\ -}$ 100 % - WSF	0.015	0.134	0.038
SE (±m)	0.002	0.002	0.002
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	0.015	0.128	0.039
F_1S_2	0.021	0.126	0.038
F_1S_3	0.018	0.127	0.045
F_2S_1	0.017	0.129	0.035
F_2S_2	0.016	0.136	0.033
F_2S_3	0.007	0.144	0.029
F_3S_1	0.016	0.135	0.035
F_3S_2	0.011	0.136	0.033
F_3S_3	0.012	0.138	0.039
F_4S_1	0.016	0.131	0.040
F_4S_2	0.018	0.130	0.039
F_4S_3	0.019	0.130	0.045
SE (±m)	0.003	0.003	0.005
C.D. at 5 %	NS	NS	NS

Table 44. Net assimilation rate ($g/cm^2/day$) of cowpea as influenced by levels and sources fertilizers

Treatments	Net assimilation rate		
	0- 20 DAS	**20-40 DAS**	**40 DAS-Harvest**
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	0.006	0.008	0.002
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	0.004	0.009	0.002
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	0.004	0.008	0.002
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	0.005	0.008	0.003
Control (F_0)	0.004	0.007	0.003
SE (±m)	0.001	0.002	0.000
C.D. at 5 %	NS	NS	NS
Sources of fertilizers (S)			
S_1 - 100 % - CF	0.004	0.0084	0.002
S_2 - 50 % CF as basal dose + 50 % WSF	0.004	0.0085	0.002
S_3 - 100 % - WSF	0.004	0.0088	0.002
SE (±m)	0.005	0.002	0.002
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	0.005	0.008	0.002
F_1S_2	0.007	0.008	0.003
F_1S_3	0.005	0.008	0.002
F_2S_1	0.005	0.008	0.002
F_2S_2	0.005	0.009	0.002
F_2S_3	0.002	0.009	0.002
F_3S_1	0.004	0.009	0.002
F_3S_2	0.003	0.009	0.002
F_3S_3	0.004	0.009	0.003
F_4S_1	0.005	0.008	0.003
F_4S_2	0.005	0.008	0.003
F_4S_3	0.005	0.009	0.003
SE (±m)	0.001	0.002	0.002
C.D. at 5 %	NS	NS	NS

fertilizers. Interaction effect of fertilizer levels x source of nutrients were on par with respect to NAR at all the stages of crop growth.

4.2.3.4 Leaf area index

The data pertaining to the leaf area index (LAI) are presented in the Table 45. Leaf area index did not differ significantly among levels of fertilizers during 0-20 and during 20-40 DAS. While at harvest, significantly higher LAI 1.51 was recorded with application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha which was statistically comparable with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha . LAI did not vary significantly among sources of nutrients at all the stages of growth.

Levels of fertilizers x sources of nutrients interaction differed significantly among LAI at 20 DAS. Higher LAI 0.26 was recorded in the treatment combination, application of fertilizers @ 139:37: 127 kg N: P_2O_5: K_2O /ha as water soluble fertilizers. While, at 40 DAS and at harvest interaction effect was statistically comparable with respect to LAI.

4.2.3.5 Leaf area duration (LAD)

The data regarding the leaf area duration are presented in Table 46. Leaf area duration (LAD) did not differ significantly among levels of fertilizers at 20 and 40 DAS. While, levels of drip fertigation had a significant influence on LAD at harvest and higher LAD was recorded with application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha. LAD of vegetable cowpea was also statistically comparable with respect to sources of nutrients at all the stages of crop growth.

Levels of fertilizers x sources of nutrients interaction differed significantly among LAD at 20 DAS. Higher LAD 2.56 days was recorded in the treatment

Table 45. Leaf area Index of cowpea as influenced by levels and sources fertilizers

Treatments	**Leaf area Index**		
	20 DAS	**40 DAS**	**At harvest**
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	0.24	0.80	1.36
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	0.24	0.81	1.40
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	0.23	0.88	1.51
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	0.24	0.83	1.48
Control (F_0)	0.25	0.79	1.31
SE (±m)	0.01	0.028	0.038
C.D. at 5 %	NS	NS	0.11
Sources of fertilizers (S)			
S_1 - 100 % - CF	0.23	0.82	1.39
S_2 - 50 % CF as basal dose + 50 % WSF	0.23	0.85	1.44
$S_{3\,-}$ 100 % - WSF	0.24	0.83	1.46
SE (±m)	0.01	0.024	0.033
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	0.24	0.75	1.24
F_1S_2	0.23	0.84	1.41
F_1S_3	0.24	0.79	1.43
F_2S_1	0.20	0.78	1.33
F_2S_2	0.25	0.90	1.54
F_2S_3	0.26	0.76	1.32
F_3S_1	0.25	0.92	1.52
F_3S_2	0.22	0.91	1.55
F_3S_3	0.23	0.81	1.44
F_4S_1	0.22	0.84	1.47
F_4S_2	0.24	0.86	1.49
F_4S_3	0.25	0.79	1.48
SE (±m)	0.01	0.049	0.065
C.D. at 5 %	0.0312	NS	NS

Table 46. Leaf area duration (days) of cowpea as influenced by levels and sources fertilizers

Treatments	Leaf area duration		
	20 DAS	**40 DAS**	**At harvest**
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	2.37	10.32	21.56
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	2.37	10.51	22.11
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	2.30	11.13	23.88
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	2.36	10.66	23.07
Control (F_0)	2.53	10.40	20.93
SE (±m)	0.061	0.264	0.541
C.D. at 5 %	NS	NS	1.587
Sources of fertilizers (S)			
S_1 - 100 % - CF	2.26	10.49	22.12
S_2 - 50 % CF as basal dose + 50 % WSF	2.31	10.81	22.94
S_{3} - 100 % - WSF	2.40	10.74	22.93
SE (±m)	0.053	0.229	0.468
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	2.39	9.89	19.90
F_1S_2	2.29	10.72	22.57
F_1S_3	2.42	10.35	22.22
F_2S_1	2.03	9.83	21.13
F_2S_2	2.53	11.49	24.36
F_2S_3	2.56	10.20	20.86
F_3S_1	2.45	11.68	24.44
F_3S_2	2.18	11.30	24.64
F_3S_3	2.28	10.41	22.57
F_4S_1	2.18	10.54	23.02
F_4S_2	2.43	11.01	23.44
F_4S_3	2.48	10.42	22.76
SE (±m)	0.106	0.458	0.937
C.D. at 5 %	0.312	NS	NS

combination, application of fertilizers @ 139:37:127 kg N: P_2O_5: K_2O /ha through fertigation as water soluble fertilizers. While, at 40 DAS and at harvest interaction effect was statistically comparable with respect to LAD.

4.2.4 Quality parameters

4.2.4.1 Crude fibre

From the Table 47, it is clear that crude fibre content of vegetable cowpea pod differed significantly among levels of fertilizers. Significantly higher crude fibre content (12.91 %) was recorded with control followed by application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha through fertigation. Lower crude fibre (11.90 %) with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation. Sources of nutrients were statistically comparable with respect to crude fibre content. Level of fertilizers and sources of nutrients interaction effect was also statistically comparable with respect to crude fibre content.

4.2.4.2 Crude protein

The data on the crude protein content in pod is depicted in Table 47. The content of crude protein differed significantly levels of fertilizers. The highest content of crude protein (20.81 %) was recorded with application of fertilizers @ 185:50:170 kg N: P_2O_5: K_2O/ha which was statistically comparable with application of application of fertilizers @ 139:37:127 kg N: P_2O_5: K_2O/ha (20.33 %). Minimum content of crude protein (18.48 %) was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O/ha. Sources of nutrients were statistically comparable with respect to crude protein content.

Table 47. Quality parameters of cowpea as influenced by levels and sources fertilizers

Treatments	Crude fibre (%)	Crude protein (%)
Levels of fertilizers (F)		
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	12.39	20.18
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	12.23	20.33
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	12.14	20.81
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	11.90	18.48
Control (F_0)	12.91	20.20
SE (±m)	0.11	0.348
C.D. at 5 %	0.33	1.019
Sources of fertilizers (S)		
S_1 - 100 % - CF	12.24	19.71
S_2 - 50 % CF as basal dose + 50 % WSF	12.22	19.68
S_3 - 100 % - WSF	12.13	20.07
SE (±m)	0.10	0.301
C.D. at 5 %	NS	NS
Interaction		
F_1S_1	12.38	20.00
F_1S_2	12.39	19.83
F_1S_3	12.38	20.71
F_2S_1	12.46	20.06
F_2S_2	12.25	20.11
F_2S_3	11.98	20.83
F_3S_1	12.19	20.56
F_3S_2	12.21	20.71
F_3S_3	12.02	21.17
F_4S_1	11.93	18.21
F_4S_2	11.93	17.98
F_4S_3	11.86	19.25
SE (±m)	0.20	0.602
C.D. at 5 %	NS	NS

Interaction effect was also statistically comparable with respect to crude protein content of vegetable cowpea pod under open precision farming.

4.2.5 Plant analysis

4.2.5.1.1 Content of nitrogen in plant

The data on content of nitrogen in plant given in Table 48. Content of nitrogen in plant of vegetable cowpea did not differ significantly among levels of fertilizers at 20 DAS and 40 DAS. While, at harvest higher content of nitrogen in plant 1.29 per cent was recorded with application of fertilizer @ 185: 50: 170 kg N: P_2O_5: K_2O /ha through fertigation followed by application of fertilizers @ 139:37:127 kg N: P_2O_5: K_2O /ha (1.21 %). Minimum content of nitrogen (1.16 %) was with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha. The content of plant nitrogen among different sources of nutrients did not differ significantly at all the stages of crop growth.

Levels of fertilizers x sources of nutrients interaction did not had a significant effect on plant nitrogen content at 20 DAS and at 40 DAS. While, at harvest interaction was found significant. Among levels of fertilizers x sources of nutrients interaction, higher plant nitrogen content (1.38 %) was recorded in the treatment combination of drip fertigation @ 185: 50: 170 kg N: P_2O_5: K_2O /ha through water soluble fertilizers (F_3S_3).

4.2.5.1.2 Content of phosphorus in plant

The data on content of phosphorus in plants given in Table 49. Content of phosphorus in plant differed significantly among levels of fertilizers at 20 DAS. Higher content of phosphorus in plant (0.17%) was recorded with application of

Table 48. Plant nitrogen content (%) of cowpea as influenced by levels and sources fertilizers

Treatments	Plant nitrogen content		
	20 DAS	**40 DAS**	**At harvest**
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	0.86	1.18	1.18
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	0.82	1.20	1.21
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	0.80	1.14	1.29
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	0.93	1.12	1.16
Control (F_0)	0.93	1.20	1.17
SE (±m)	0.02	0.02	0.02
C.D. at 5 %	NS	NS	0.07
Sources of fertilizers (S)			
S_1 - 100 % - CF	0.85	1.13	1.18
S_2 - 50 % CF as basal dose + 50 % WSF	0.83	1.15	1.20
S_3 - 100 % - WSF	0.86	1.17	1.22
SE (±m)	0.03	0.02	0.02
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	0.92	1.14	1.22
F_1S_2	0.72	1.15	1.25
F_1S_3	0.93	1.13	1.16
F_2S_1	0.79	1.15	1.26
F_2S_2	0.81	1.13	1.29
F_2S_3	0.86	1.22	1.18
F_3S_1	0.77	1.07	1.36
F_3S_2	0.79	1.15	1.17
F_3S_3	0.86	1.19	1.38
F_4S_1	0.90	1.00	1.07
F_4S_2	0.92	1.18	1.26
F_4S_3	0.96	1.11	1.23
SE (±m)	0.06	0.04	0.04
C.D. at 5 %	NS	NS	0.12

Table 49. Plant phosphorus content (%) of cowpea as influenced by levels and sources fertilizers

Treatments	Plant Phosphorus content		
	20 DAS	**40 DAS**	**At harvest**
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	0.16	0.17	0.24
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	0.17	0.18	0.24
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	0.16	0.16	0.16
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	0.14	0.16	0.10
Control (F_0)	0.16	0.17	0.23
SE (±m)	0.01	0.05	0.06
C.D. at 5 %	0.02	NS	NS
Sources of fertilizers (S)			
S_1 - 100 % - CF	0.16	0.17	0.21
S_2 - 50 % CF as basal dose + 50 % WSF	0.15	0.16	0.21
S_3 - 100 % - WSF	0.16	0.17	0.19
SE (±m)	0.01	0.04	0.06
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	0.15	0.17	0.24
F_1S_2	0.17	0.15	0.30
F_1S_3	0.16	0.20	0.18
F_2S_1	0.18	0.17	0.27
F_2S_2	0.15	0.16	0.25
F_2S_3	0.18	0.20	0.21
F_3S_1	0.17	0.17	0.18
F_3S_2	0.13	0.15	0.16
F_3S_3	0.17	0.16	0.13
F_4S_1	0.13	0.17	0.14
F_4S_2	0.14	0.17	0.15
F_4S_3	0.15	0.16	0.13
SE (±m)	0.01	0.09	0.12
C.D. at 5 %	NS	NS	NS

fertilizers @ 139:37: 127 kg N: P_2O_5: K_2O /ha through fertigation. Minimum content of phosphorus (0.14 %) was with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O/ha. While at 40 DAS and at harvest the content of plant phosphorus was found on par with respect to levels of fertilizers. The content of plant phosphorus among different sources of nutrients did not differ significantly at all the stages of crop growth.

4.2.5.1.3 Content of potassium in plants

The data related to the content of potassium in plant at 20 DAS, 40 DAS and at harvest is depicted in Table 50. The content of potassium did not differ significantly among fertilizer levels at all the stages of crop growth. However, higher plant potassium content (1.74 and 1.76 %) was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation at 40 DAS and at harvest. Among the sources of nutrients, the content of potassium in plant exhibited statistically comparable values. Levels of fertilizers x sources of nutrients interaction was statistically comparable with respect to content of potassium in plant.

4.2.5.1.4 Content of calcium in plant

The data pertaining to the content of calcium in plant are presented Table 51. At 20 DAS, the calcium content of plant differed significantly among the fertigation levels. Higher plant calcium content (12.36 mg/kg) was recorded with application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha through fertigation and it was on par with application of fertilizers @ 139:37: 127 kg N: P_2O_5: K_2O /ha through fertigation. Minimum content of calcium 11.20 mg/kg was recorded with application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha through fertigation, and continued the same trend during 40 DAS and at harvest. Plant

Table 50. Plant potassium content (%) of cowpea as influenced by levels and sources fertilizers

Treatments	Plant Potassium content		
	20 DAS	40 DAS	At harvest
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	1.34	1.55	1.75
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	1.39	1.55	1.74
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	1.30	1.67	1.75
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	1.32	1.74	1.76
Control (F_0)	1.24	1.51	1.73
SE (±m)	0.03	0.07	0.010
C.D. at 5 %	NS	NS	NS
Sources of fertilizers (S)			
S_1 - 100 % - CF	1.29	1.68	1.75
S_2 - 50 % CF as basal dose + 50 % WSF	1.33	1.63	1.75
S_3 - 100 % - WSF	1.36	1.60	1.75
SE (±m)	0.03	0.06	0.008
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	1.35	1.62	1.76
F_1S_2	1.35	1.41	1.75
F_1S_3	1.33	1.62	1.72
F_2S_1	1.39	1.66	1.74
F_2S_2	1.40	1.64	1.73
F_2S_3	1.40	1.34	1.74
F_3S_1	1.16	1.67	1.76
F_3S_2	1.34	1.53	1.77
F_3S_3	1.40	1.82	1.73
F_4S_1	1.28	1.78	1.75
F_4S_2	1.26	1.77	1.76
F_4S_3	1.41	1.68	1.79
SE (±m)	0.05	0.11	0.017
C.D. at 5 %	NS	NS	NS

Table 51. Calcium (mg/kg) content of cowpea as influenced by levels and sources fertilizers

Treatments	**Calcium**		
	20 DAS	**40 DAS**	**At harvest**
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	11.20	20.61	23.64
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	12.27	21.09	24.20
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	12.36	22.98	25.16
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	11.24	20.55	24.93
Control (F_0)	11.30	21.17	24.07
SE (±m)	0.26	0.22	0.37
C.D. at 5 %	0.75	0.63	1.09
Sources of fertilizers (S)			
S_1 - 100 % - CF	12.36	21.59	24.71
S_2 - 50 % CF as basal dose + 50 % WSF	11.90	21.46	24.64
S_{3} - 100 % - WSF	11.47	21.16	24.37
SE (±m)	0.22	0.19	0.32
C.D. at 5 %	0.65	NS	NS
Interaction			
F_1S_1	12.24	20.54	24.80
F_1S_2	11.11	20.32	21.99
F_1S_3	10.25	20.97	24.13
F_2S_1	12.78	20.57	21.28
F_2S_2	11.69	21.28	26.38
F_2S_3	12.34	21.41	24.95
F_3S_1	12.33	24.43	26.90
F_3S_2	11.92	23.56	24.30
F_3S_3	12.83	20.96	24.29
F_4S_1	12.10	20.83	25.87
F_4S_2	11.05	20.13	25.63
F_4S_3	10.55	20.67	23.30
SE (±m)	0.44	0.37	0.64
C.D. at 5 %	NS	1.10	1.88

calcium content differed significantly among sources of nutrients at 20 DAS. Higher content of plant calcium was recorded with fertigation through conventional fertilizers. While at 40 DAS and at harvest content of plant calcium did not differ significantly. Interaction effect of fertilizer levels and sources of nutrients was statistically comparable with respect to plant calcium content at 20 DAS. Significantly higher plant calcium content 24.43 mg/kg was recorded in the treatment combination, application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha through fertigation as conventional sources (F_3S_1) at 40 DAS and followed almost similar trend at harvest.

4.2.5.1.5 Content of magnesium in plant

The magnesium content of plants differed significantly among levels of fertilizers at 20, 40 DAS and at harvest (Table 52). Higher plant magnesium content (24.37 mg/kg) was recorded with application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha through fertigation at 20 DAS. Lower plant magnesium content (20.52 mg/kg) was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation and continued the same trend at 40 DAS and at harvest. Among the sources of nutrients, the content of magnesium in plant exhibited statistically comparable values at all the stages of crop growth.

Interaction effect of fertilizer levels and sources of nutrients was found significant at 20 DAS and at harvest. Higher content of magnesium in plant was recorded in the treatment combination of application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha with conventional fertilizers through fertigation (F_3S_1). Significantly lower content of magnesium (20.32 g/kg) in plant was recorded in the treatment combination of application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha with fifty per cent of fertilizer dose through conventional sources as

Table 52. Magnesium (mg/kg) content of cowpea as influenced by levels and sources fertilizers

Treatments	Magnesium		
	20 DAS	**40 DAS**	**At harvest**
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	20.59	21.88	23.65
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	21.15	22.78	23.72
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	24.37	24.97	25.81
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	20.52	21.15	21.88
Control (F_0)	20.77	21.95	23.63
SE (±m)	0.24	0.41	0.25
C.D. at 5 %	0.71	1.22	0.73
Sources of fertilizers (S)			
S_1 - 100 % - CF	21.72	23.01	23.69
S_2 - 50 % CF as basal dose + 50 % WSF	21.61	22.70	23.86
S_{3-} 100 % - WSF	21.63	22.53	23.80
SE (±m)	0.21	0.36	0.21
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	20.78	23.72	24.61
F_1S_2	20.41	20.68	24.67
F_1S_3	20.58	21.23	21.67
F_2S_1	20.61	22.18	22.91
F_2S_2	20.34	23.25	24.32
F_2S_3	22.50	22.90	23.93
F_3S_1	24.90	24.91	25.53
F_3S_2	24.89	25.32	25.25
F_3S_3	23.32	24.69	26.63
F_4S_1	20.60	21.23	21.70
F_4S_2	20.32	20.30	21.87
F_4S_3	20.65	21.92	22.07
SE (±m)	0.42	0.72	0.43
C.D. at 5 %	1.24	NS	1.26

basal and remaining fifty per cent through fertigation as water soluble fertilizers (F_4S_2). Followed almost similar trend at harvest also. While at 40 DAS interaction effect was statistically comparable with respect to content of magnesium in plant.

4.2.5.1.6 Content of sulphur in plant

The data regarding to the content of sulphur in plant are given in Table 53. Plant sulphur content of vegetable cowpea did not differ significantly among levels of fertilizers at 20 DAS and at harvest. While, at 40 DAS significantly higher content of sulphur 1.61 mg/kg was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation and the lowest content of sulphur 1.33 mg/kg was recorded with application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha and in control treatment. Among the sources of nutrients, the content of sulphur in plant exhibited statistically comparable values at 20 DAS. While, sources of nutrients had a significant influence on the plant sulphur content at 40 DAS and at harvest. Significantly higher content of sulphur 1.50 mg/kg was recorded with conventional fertilizers at 40 DAS and followed the same trend at harvest.

Interaction effect of fertilizer levels and sources of nutrients was statistically comparable with respect to the content of plant sulphur at 20 DAS. At 40 DAS significantly higher content of sulphur (1.92 mg/kg) in plant was recorded in the treatment combination of application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through water soluble fertilizers (F_4S_3). Significantly lower content of sulphur (1.32 mg/kg) was recorded in the treatment combination of application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha with fifty per cent of

Table 53. Plant sulphur (mg/kg) content of cowpea as influenced by levels and sources fertilizers

Treatments	Sulphur		
	20 DAS	**40 DAS**	**At harvest**
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	1.07	1.33	1.79
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	1.07	1.45	1.88
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	1.25	1.56	1.85
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	1.37	1.61	1.85
Control (F_0)	1.16	1.33	1.80
SE (±m)	0.14	0.02	0.02
C.D. at 5 %	NS	0.07	NS
Sources of fertilizers (S)			
S_1 - 100 % - CF	1.12	1.50	1.88
S_2 - 50 % CF as basal dose + 50 % WSF	1.07	1.45	1.81
S_3 - 100 % - WSF	1.22	1.48	1.82
SE (±m)	0.12	0.02	0.02
C.D. at 5 %	NS	0.06	0.06
Interaction			
F_1S_1	0.96	1.34	1.79
F_1S_2	1.01	1.32	1.67
F_1S_3	1.23	1.33	1.88
F_2S_1	1.01	1.44	1.94
F_2S_2	1.16	1.44	1.85
F_2S_3	1.04	1.46	1.85
F_3S_1	1.17	1.62	1.91
F_3S_2	1.02	1.50	1.69
F_3S_3	1.56	1.55	1.95
F_4S_1	1.33	1.61	1.87
F_4S_2	0.87	1.82	1.73
F_4S_3	1.90	1.92	1.96
SE (±m)	0.23	0.04	0.04
C.D. at 5 %	NS	0.13	0.13

fertilizer dose was given through conventional sources as basal and remaining fifty per cent through fertigation as water soluble fertilizers (F_1S_2) followed almost similar trend at harvest also.

4.2.5.1.7 Content of iron in plant

The data regarding to the content of iron in plant are given in Table 54. Plant iron content of vegetable cowpea did not differ significantly among levels of fertilizers at 20 DAS. Even so, higher the content of iron (267.83 mg/kg) was recorded with application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha through fertigation at 20 DAS. While at 40 DAS and at harvest significantly higher content of iron 306.25 mg/kg and 911.97 mg/kg was recorded with application of fertilizer @ 185: 50: 170 kg N: P_2O_5: K_2O /ha through fertigation and the lowest content of iron 269.81 and 752.03 mg/kg was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha at 40 DAS and at harvest.

Sources of nutrients had a significant influence on the plant iron content at all the stages of crop growth. At 20 DAS higher content of iron 253.79 mg/kg was recorded with fertigation through water soluble fertilizers followed by fertigation through conventional fertilizers (252.92 mg/kg). Lowest content of iron 246.39 mg/kg was recorded with fifty per cent of fertilizer dose was given through conventional sources as basal and remaining fifty per cent through fertigation as water soluble fertilizers. While at 40 DAS higher content of iron 313.21mg/kg was recorded with fertigation through conventional fertilizers and lower content of iron was recoded with application water soluble fertilizers (274.20 mg/kg). At harvest higher content of iron 921.90 mg/kg was recorded followed by application

Table 54. Plant iron (mg/kg) content of cowpea as influenced by levels and sources fertilizers

Treatments	Iron		
	20 DAS	**40 DAS**	**At harvest**
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	267.83	277.19	902.36
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	265.72	295.56	903.11
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	262.89	306.25	911.97
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	217.56	269.81	752.03
Control (F_0)	244.4	304.33	906.7
SE (±m)	15.28	7.49	1.09
C.D. at 5 %	NS	21.96	3.20
Sources of fertilizers (S)			
S_1 - 100 % - CF	252.92	313.21	891.35
S_2 - 50 % CF as basal dose + 50 % WSF	246.39	296.50	921.90
S_3 - 100 % - WSF	253.79	274.20	855.38
SE (±m)	13.24	6.48	0.94
C.D. at 5 %	38.82	19.01	2.77
Interaction			
F_1S_1	264.92	305.92	917.25
F_1S_2	275.00	286.00	1070.08
F_1S_3	263.58	289.67	719.75
F_2S_1	286.58	294.42	819.42
F_2S_2	245.67	283.83	1032.75
F_2S_3	264.92	308.42	857.17
F_3S_1	268.75	349.92	1070.33
F_3S_2	229.67	323.00	962.67
F_3S_3	276.92	320.28	702.92
F_4S_1	191.42	302.58	758.42
F_4S_2	209.10	276.33	744.25
F_4S_3	252.17	263.83	753.42
SE (±m)	26.36	9.65	1.89
C.D. at 5 %	NS	28.30	5.54

of 50 per cent of fertilizer dose was given through conventional sources as basal and remaining fifty per cent through fertigation as water soluble fertilizers followed by 100 per cent conventional fertilizers (891.35mg/kg)**.** Lowest content of iron was recoded with application of water soluble fertilizers (855.38 mg/kg).

Interaction effect of fertilizer levels and sources of nutrients was statistically comparable with respect to the content of plant iorn at 20 DAS. At 40 DAS significantly higher content of iron 349.92 mg/kg in plant was recorded in the treatment combination of application of content of iron (263.83 mg/kg) in plant was recorded in the treatment combination of application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha as water soluble fertilizers (F_4S_3). Followed almost similar trend at harvest also.

4.2.5.1.8 Content of zinc in plant

The data regarding to the content of zinc in plant are given in Table 55. Plant zinc content of vegetable cowpea differed significantly among levels of fertilizers at 20 DAS. Higher the content of zinc (50.44 mg/kg) was recorded with application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha through fertigation at 20 DAS. Lowest content of zinc 44.34 mg/kg was recorded with application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha and continued the same trend at 40 DAS and at harvest.

Content of zinc was statistically comparable with respect to sources of nutrients at 20 DAS. While, content of zinc in plant differed significantly at 40 DAS and at harvest. Higher plant zinc content 57.91 mg/kg was recorded with fertigation through water soluble fertilizers at 40 DAS. The lowest plant zinc content 55.98 mg/kg was recorded with fertigation through conventional fertilizers and continued the same trend at harvest also.

Table 55. Plant zinc (mg/kg) content of cowpea as influenced by levels and sources fertilizers

Treatments	**Zinc**		
	20 DAS	**40 DAS**	**At harvest**
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	44.34	55.75	62.92
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	47.13	58.36	67.22
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	50.44	59.22	67.56
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	46.64	55.72	65.75
Control (F_0)	47.67	57.50	62.75
SE (±m)	1.35	0.70	0.74
C.D. at 5 %	3.97	2.04	2.17
Sources of fertilizers (S)			
S_1 - 100 % - CF	47.25	55.98	64.31
S_2 - 50 % CF as basal dose + 50 % WSF	47.46	56.07	65.39
S_3 - 100 % - WSF	47.08	57.91	66.64
SE (±m)	1.17	0.60	0.64
C.D. at 5 %	NS	1.77	1.88
Interaction			
F_1S_1	43.83	55.67	57.50
F_1S_2	46.00	53.83	65.33
F_1S_3	43.19	57.75	65.92
F_2S_1	44.83	60.25	66.00
F_2S_2	48.47	56.17	66.50
F_2S_3	48.08	58.67	69.17
F_3S_1	52.50	55.17	67.83
F_3S_2	50.25	58.75	67.17
F_3S_3	48.58	63.75	67.67
F_4S_1	47.83	52.83	65.92
F_4S_2	46.00	55.92	66.83
F_4S_3	46.08	58.42	64.50
SE (±m)	2.34	1.21	1.28
C.D. at 5 %	NS	3.54	3.76

Interaction effect was statistically comparable with respect to zinc content in plant at 20 DAS. While at 40 DAS interaction effect of fertilizer levels and sources of nutrients had significant influence on plant zinc content. Higher zinc content (63.75 mg/kg) was reordered in the treatment combination of application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha as water soluble fertilizers through fertigation (F_3S_3) under open precision farming and continued the same trend at harvest also.

4.2.5.1.9 Content of manganese in plant

The data regarding to the content of manganese in plant are given in Table 56. Plant manganese content of vegetable cowpea differed significantly among levels of fertilizers at all the stages of crop growth. Higher content of manganese (159.11 mg/kg) was recorded with application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha through fertigation at 20 DAS. Lowest content of manganese (116.25 mg/kg) was recorded with application of fertilizers @ 20: 30: 10 kg N: P_2O_5: K_2O /ha (control) and continued the same trend at 40 DAS and at harvest. Content of manganese in plant was differed significantly among the sources of nutrients. Higher content of manganese (142.29 mg/kg) was recorded with fertigation through water soluble fertilizers. Lowest plant manganese content 155.18 mg/kg was recorded with fertigation through conventional fertilizers and continued the same trend at harvest also. While at 40 DAS, plant manganese content was statistically comparable with respect to sources of fertilizers.

Interaction effect of fertilizer levels and sources of nutrients had significant influence on plant manganese content at 20 DAS and at harvest. Higher plant manganese content 168.50 mg/kg was recorded in the treatment combination of application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha as

Table 56. Plant manganese (mg/kg) content of cowpea as influenced by levels and sources fertilizers

Treatments	Manganese		
	20 DAS	40 DAS	At harvest
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	133.89	144.27	372.250
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	126.83	151.85	372.861
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	159.11	164.85	432.417
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	147.67	165.50	385.139
Control (F_0)	116.25	137.08	364.167
SE (±m)	0.58	8.63	2.095
C.D. at 5 %	1.70	25.30	6.145
Sources of fertilizers (S)			
S_1 - 100 % - CF	140.86	155.18	361.063
S_2 - 50 % CF as basal dose + 50 % WSF	141.04	155.28	365.688
$S_{3\,-}$ 100 % - WSF	142.29	156.99	405.469
SE (±m)	0.50	7.47	1.814
C.D. at 5 %	1.48	NS	5.322
Interaction			
F_1S_1	131.67	143.83	307.250
F_1S_2	131.08	144.46	420.333
F_1S_3	138.92	144.51	389.167
F_2S_1	133.00	154.81	337.333
F_2S_2	120.25	144.08	262.583
F_2S_3	127.25	156.67	418.667
F_3S_1	156.58	160.50	372.583
F_3S_2	152.25	164.10	442.500
F_3S_3	168.50	169.95	482.167
F_4S_1	142.92	164.34	427.083
F_4S_2	159.17	166.16	355.833
F_4S_3	140.92	166.00	372.500
SE (±m)	1.01	14.94	3.629
C.D. at 5 %	2.95	NS	10.643

water soluble fertilizers through fertigation (F_3S_3). Lower plant manganese content 120.25 mg/kg was recorded the treatment combination of application of fertilizers @ 139:37: 127 kg N: P_2O_5: K_2O /ha with application of 50 per cent of fertilizer dose through conventional sources as basal and remaining fifty per cent through fertigation as water soluble fertilizers (F_2S_2) and the same trend continued at harvest also. Interaction effect was on par with respect to manganese content in plant at harvest.

4.2.5.1.10 Content of copper in plant

The data regarding to the content of copper in plant are given in Table 57. Plant copper content of vegetable cowpea differed significantly among levels of fertilizers at all the stages of crop growth. At 20 DAS, higher content of manganese (17.14 mg/kg) was recorded with application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha through fertigation. Lowest content of copper (16.25 mg/kg) was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha. While at 40 DAS, higher copper content (18.88 mg/kg) was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha. Lower content of copper (16.77 mg/kg) was recorded with application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha and followed the same trend at harvest.

Content of copper in plant was differed significantly among the sources of nutrients at 20 DAS. Higher content of copper (16.65 mg/kg) was recorded with fertigation through water soluble fertilizers followed similar trend at harvest. Lowest plant copper content 16.35 mg/kg was recorded with fertigation through conventional fertilizers and continued the same trend at harvest also. While at 40 DAS, plant copper content was statistically comparable with respect to sources of fertilizers.

Table 57. Plant copper (mg/kg) content of cowpea as influenced by levels and sources fertilizers

Treatments	Copper		
	20 DAS	**40 DAS**	**At harvest**
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	16.42	16.77	21.11
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	16.39	17.48	22.08
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	17.14	18.44	22.74
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	16.25	18.88	23.17
Control (F_0)	16.33	17.00	21.92
SE (±m)	0.16	0.40	0.40
C.D. at 5 %	0.47	1.17	1.18
Sources of fertilizers (S)			
S_1 - 100 % - CF	16.35	17.33	21.42
S_2 - 50 % CF as basal dose + 50 % WSF	16.61	17.68	21.94
S_{3} - 100 % - WSF	16.65	18.18	22.70
SE (±m)	0.14	0.35	0.35
C.D. at 5 %	0.41	NS	1.02
Interaction			
F_1S_1	16.42	16.75	17.25
F_1S_2	16.42	16.22	22.33
F_1S_3	16.42	17.34	23.75
F_2S_1	16.42	17.17	22.25
F_2S_2	16.42	18.11	23.33
F_2S_3	16.33	17.17	20.67
F_3S_1	16.25	16.25	23.67
F_3S_2	18.50	17.00	21.33
F_3S_3	16.67	22.06	23.22
F_4S_1	16.33	19.14	22.50
F_4S_2	16.17	20.83	22.83
F_4S_3	16.25	16.67	24.17
SE (±m)	0.28	0.69	0.69
C.D. at 5 %	0.82	2.03	2.04

Interaction effect of fertilizer levels and sources of nutrients had significant influence on plant copper content at all the stages of crop growth. Higher plant copper content 18.50 mg/kg was recorded in the treatment combination of fertilizer application @ 185: 50: 170 kg N: P_2O_5: K_2O /ha with application of fifty per cent of fertilizer dose through conventional sources as basal and remaining fifty per cent through fertigation as water soluble fertilizers (F_3S_2) at 20 DAS. Lower plant copper content 16.17 mg/kg was recorded with the treatment combination of application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha in which 50 per cent of the fertilizer dose through conventional sources as basal and remaining fifty per cent through fertigation as water soluble fertilizers (F_4S_2). At 40 DAS higher plant copper content 22.06 mg/kg was recorded in the treatment combination of application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha through fertigation as water soluble fertilizers (F_3S_3). Lower plant copper content 16.22 mg/kg was recorded in the treatment combination of application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha through fifty per cent of fertilizer dose through conventional sources as basal and remaining fifty per cent through fertigation as water soluble fertilizers (F_1S_2). While at harvest higher plant copper content 24.17 mg/kg was recorded in the treatment combination of application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through water soluble fertilizers (F_4S_3). Lower plant copper content 17.25 mg/kg was recorded in the treatment combination of application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha through conventional sources (F_1S_1).

4.2.5.1.11 Content of boron in plant

The boron content of plants differed significantly among levels of fertilizers at 20 and 40 DAS and at harvest (Table 58). Higher plant boron content

Table 58. Plant boron (mg/kg) content of cowpea as influenced by levels and sources fertilizers

Treatments	Boron		
	20 DAS	**40 DAS**	**At harvest**
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	24.86	27.23	34.65
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	27.66	28.47	36.77
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	31.80	32.22	37.38
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	20.90	24.02	35.06
Control (F_0)	24.37	25.89	31.64
SE (±m)	0.58	0.34	.6.78
C.D. at 5 %	1.71	1.00	1.98
Sources of fertilizers (S)			
S_1 - 100 % - CF	26.86	28.38	35.85
S_2 - 50 % CF as basal dose + 50 % WSF	26.21	28.04	35.87
S_{3-} 100 % - WSF	26.03	27.79	36.02
SE (±m)	0.50	0.29	0.58
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	26.66	27.29	32.50
F_1S_2	21.18	27.08	35.00
F_1S_3	26.75	27.33	36.45
F_2S_1	28.64	28.75	37.29
F_2S_2	28.43	28.75	35.83
F_2S_3	25.89	27.91	37.18
F_3S_1	31.50	32.08	38.41
F_3S_2	32.04	31.87	38.54
F_3S_3	31.87	32.70	35.20
F_4S_1	20.62	25.41	35.20
F_4S_2	20.62	23.12	34.16
F_4S_3	21.45	23.54	35.83
SE (±m)	1.01	0.59	1.17
C.D. at 5 %	NS	NS	NS

(31.80 mg/kg) was recorded with application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O/ha through fertigation at 20 DAS and followed the same trend at fortnightly intervals. Lower plant boron content (20.90 mg/kg) was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation and continued the same trend at 40 DAS and at harvest. Among the sources of nutrients, the content of boron in plant exhibited statistically comparable values at all the stages of crop growth. Interaction effect of fertilizer levels and sources of nutrients was statistically comparable with respect to content of boron in plant at all the stages of crop growth.

4.2.5.2 Nutrient content of pod

4.2.5.2.1 Content of nitrogen in pod

The data related to the content of nitrogen in pod is depicted in Table 59. The content of nitrogen in pod differed significantly among fertigation levels. The highest content (3.33 %) was recorded application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O/ha which was statistically comparable with application of fertilizers @ 139:37: 127 kg N: P_2O_5: K_2O /ha. The lowest content (2.96 %) was recorded with application of application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha. Among the sources of nutrients, the content of nitrogen in pod exhibited statistically comparable values. Levels of fertilizers x sources of nutrients interaction was also on par with respect to content of nitrogen in pod.

4.2.5.2.2 Content of phosphorus in pod

The data pertaining to the content of phosphorus in pod are presented Table 59. The content phosphorous in pod was statistically comparable with respect to levels of fertilizers. Even so, higher content of phosphorus in pod

Table 59. Nutrient content (%) of cowpea pods as influenced by levels and sources fertilizers

Treatments	Nutrient content of pod		
	N	P	K
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	3.23	0.24	2.40
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	3.25	0.25	2.40
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	3.33	0.26	2.45
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	2.96	0.27	2.48
Control	3.23	0.26	2.46
SE (±m)	0.056	0.007	0.054
C.D. at 5 %	0.163	NS	NS
Sources of fertilizers (S)			
S_1 - 100 % - CF	3.15	0.25	2.44
S_2 - 50 % CF as basal dose + 50 % WSF	3.15	0.25	2.44
S_3 - 100 % - WSF	3.21	0.25	2.43
SE (±m)	0.048	0.006	0.047
C.D. at 5 %	NS	NS	NS
Interaction			
F_1S_1	3.20	0.23	2.31
F_1S_2	3.17	0.27	2.39
F_1S_3	3.31	0.23	2.50
F_2S_1	3.21	0.25	2.44
F_2S_2	3.22	0.25	2.34
F_2S_3	3.33	0.24	2.42
F_3S_1	3.29	0.26	2.54
F_3S_2	3.31	0.23	2.60
F_3S_3	3.39	0.27	2.20
F_4S_1	2.91	0.27	2.48
F_4S_2	2.88	0.25	2.40
F_4S_3	3.08	0.28	2.57
SE (±m)	0.096	0.012	0.093
C.D. at 5 %	NS	0.034	NS

(0.27 %) was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation. Among the sources of nutrients, the content of phosphorous in pod exhibited statistically comparable values. Levels of fertilizers x sources of nutrients interaction differed significantly among content of phosphorous in pod. Higher content of phosphorous (0.28 %) in pod was recorded in the treatment combination, application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha with water soluble fertilizers through fertigation (F_4S_3) under open precision farming.

4.2.5.2.3 Content of potassium in pod

The data related to the content of potassium in pod are depicted in the Table 59. The content of potassium did not differ significantly among fertigation levels. Even so, higher potassium content (2.48 %) was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha. Among the sources of nutrients, the content of potassium in pod exhibited statistically comparable values. Levels of fertilizers x sources of nutrients interaction was also on par with respect to the content of pottassium in pod.

4.2.6 Nutrient uptake

4.2.6.1 Uptake of nitrogen by plant

The data pertaining to the uptake of nitrogen by plant are presented Table 60. Among the fertigation levels, the nitrogen uptake by plant did not differ significantly. However, higher uptake of nitrogen was recorded with application of fertilizers @ 139:37: 127 kg N: P_2O_5: K_2O /ha through fertigation. Sources of nutrients had significant influence on the nitrogen uptake by plant. Higher uptake of nitrogen was recorded with fertigation through 100 per cent water soluble fertilizers (92.74 kg/ha) and lower uptake of nitrogen was recorded with fertigation through water soluble fertilizers. Interaction effect of fertilizer levels and sources of nutrients was on par with respect to uptake of nitrogen by vegetable cowpea under open precision farming.

4.2.6.2 Uptake of phosphorus by plant

The data related to the uptake of phosphorus by plant at harvest is depicted in Table 60 .Among the fertilizer levels, the phosphorous uptake by plant did not differ significantly. However, higher uptake of phosphorous was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation. Sources of nutrients had significant influence on the phosphorous uptake by plant. Higher uptake of phosphorus was recorded with fertigation with water soluble fertilizers (8.98 kg/ha). Interaction effect of fertilizer levels x sources of nutrients were on par with respect to uptake of phosphorous by vegetable cowpea under open precision farming.

4.2.6.3 Uptake of potassium by plant

The data related to the uptake of potassium by plant at harvest is depicted in Table 60. Among the fertilizer levels, the potassium uptake by plant did not differ significantly. However, higher uptake of potassium (92.05 kg/ha) was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation. Sources of nutrients had no significant influence on the potassium uptake by plant. Even so, higher uptake of potassium was recorded with fertigation with water soluble fertilizers (88.65 kg/ha). Interaction effect of fertilizer levels x sources of nutrients were on par with respect to uptake of potassium by vegetable cowpea under open precision farming.

Table 60. Nutrient uptake (kg/ha) of cowpea as influenced by levels and sources fertilizers

Treatments	Nutrient uptake		
	N	**P**	**K**
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	87.94	8.72	85.84
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	90.78	8.64	83.66
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	88.84	8.42	85.19
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	88.16	9.34	92.05
Control (F_0)	73.45	8.42	81.65
SE (±m)	2.931	0.30	4.112
C.D. at 5 %	NS	NS	NS
Sources of fertilizers (S)			
S_1 - 100 % - CF	81.31	8.38	82.76
S_2 - 50 % CF as basal dose + 50 % WSF	84.60	8.41	84.08
S_{3} - 100 % - WSF	92.74	8.98	88.65
SE (±m)	2.538	0.266	3.561
C.D. at 5 %	7.445	0.780	NS
Interaction			
F_1S_1	80.29	7.62	76.52
F_1S_2	83.50	8.79	85.85
F_1S_3	100.04	9.76	95.14
F_2S_1	84.45	8.49	82.91
F_2S_2	97.51	8.86	86.91
F_2S_3	90.37	8.58	81.17
F_3S_1	83.86	8.31	83.56
F_3S_2	83.14	7.46	83.60
F_3S_3	99.52	9.48	88.40
F_4S_1	76.63	9.10	88.05
F_4S_2	87.45	8.65	85.27
F_4S_3	100.39	10.28	102.83
SE (±m)	5.077	0.532	7.122
C.D. at 5 %	NS	NS	NS

4.2.7 Nutrient use efficiency

4.2.7.1 Nitrogen use efficiency

The data related to the nitrogen use efficiency are depicted in the Table 61. The nitrogen use efficiency differed significantly among fertigation levels. Higher nitrogen use efficiency was recorded with control (92.20). Minimum nitrogen use efficiency (8.65) was with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation. Among the sources of nutrients, the nitrogen use efficiency exhibited statistically comparable values. Levels of fertilizers x sources of nutrients interaction was also on par with respect to the nitrogen use efficiency.

4.2.7.2 Phosphorus use efficiency

The data related to the phosphorus use efficiency are depicted in the Table 61. The phosphorus use efficiency differed significantly among fertigation levels. Higher phosphorus use efficiency was recorded with application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha through fertigation (79.35). Minimum phosphorus use efficiency was with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation (31.70). Sources of nutrients had significant influence on phosphorus use efficiency. Higher phosphorus use efficiency was exhibited with water soluble fertilizers and lower phosphorus use efficiency was recorded by conventional fertilizers. Levels of fertilizers x sources of nutrients interaction was also found significant. Higher phosphorus use efficiency was recorded in the treatment combination, application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha as water soluble fertilizers (F_1S_3).

4.2.7.3 Potassium use efficiency

The data related to the potassium use efficiency are depicted in the Table 61. The potassium use efficiency differed significantly among fertilizer levels. Higher potassium use efficiency was recorded with control treatment (84.40) and lower potassium use efficiency was with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation (9.12). Sources of nutrients had significant influence on potassium use efficiency. Higher potassium use efficiency was exhibited with water soluble fertilizers. Levels of fertilizers x sources of nutrients interaction was also found significant. Higher potassium use efficiency was recorded in the treatment combination, application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha as water soluble fertilizers (F_1S_3).

4.2.8 Nutrient budgeting

The data related to the nutrient budgeting of nitrogen, phosphorus and potassium are depicted in the Table 62, 63 and 64. From the nitrogen balance sheet of cowpea, it is very clear that the initial nitrogen status of soil was high within the range of 111 to 186. 20 kg/ha and the nutrient uptake ranges from 72.04 to 91.01 kg. As the soil was rich in nitrogen and the crop requirement was low being a legume crop, the final nitrogen status of soil is rich and even the lowest nutrient level of the treatment had higher nutrient content in the soil after the experiment. The balance of nitrogen after the uptake by the crop was well above 50 kg N /ha. This indicated that the nitrogen requirement for cowpea was low being a legume crop and this resulted in non response for the levels of treatment. The package of practice recommendation with 20 kg N/ha was sufficient to produce a remarkable yield being the soil highly fertile and low requirement of nitrogen for cowpea. However, the uptake rate was found to be more or less the same in all the treatments as the nutrients were available in sufficient quantities in the stock pool of soil.

Similar trend was noticed in the case of phosphorus balance sheet of soil. The initial phosphorus status of soil was high to the range of 20 – 28 kg/ha and the uptake of phosphorus was only to the range of 7 – 10 kg/ha. So the balance of nutrients was high in the soil. Even the initials status of soil phosphorus might have been enough to produce a higher yield of cowpea. Being a short duration crop, the requirement for nutrients was very less with fertigation. The initial phosphorus status of control treatments was especially high compared to the other treatments and this resulted in non-significant effect between higher and lower levels of fertilizers.

In the case of potassium also the initial potassium status of soil was very high with potassium content ranged from 363 to 502 kg/ha. It is observed that the package of practice recommendation treatment with lowest nutrient dose had the highest initial potassium status of 502.80 kg/ha. At the same time the crop uptake was only to the range of 70-85 kg/ha. So the crop did not get the chance to utilize the applied nutrients fully as evidenced from the balance of nutrients. The final nutrient status of potassium in all the treatments was in the medium range of potassium as per soil fertility classification. This resulted in non-significant effect between levels of fertilizers.

Table 61. Nutrient use efficiency (%) of cowpea as influenced by levels and sources fertilizers

Treatments	Nutrient use efficiency		
	N	P	K
Levels of fertilizers (F)			
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	21.33	79.35	22.54
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	13.42	49.09	14.13
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	10.38	38.40	11.29
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	8.65	31.70	9.12
Control (F_0)	92.20	61.47	84.40
SE (±m)	0.74	2.74	0.78
C.D. at 5 %	2.17	8.05	2.30
Sources of fertilizers (S)			
S_1 - 100 % - CF	11.55	42.63	12.27
S_2 - 50 % CF as basal dose + 50 % WSF	12.55	46.34	13.33
S_3 - 100 % - WSF	14.39	53.14	15.27
SE (±m)	0.64	2.38	0.68
C.D. at 5 %	NS	6.97	1.99
Interaction			
F_1S_1	16.19	60.23	17.11
F_1S_2	21.31	79.27	22.52
F_1S_3	26.49	98.53	27.99
F_2S_1	11.51	42.09	12.12
F_2S_2	15.16	55.45	15.96
F_2S_3	13.59	49.71	14.31
F_3S_1	9.62	35.58	10.47
F_3S_2	10.15	37.55	11.04
F_3S_3	11.37	42.06	12.37
F_4S_1	8.89	32.61	9.38
F_4S_2	7.61	27.89	8.02
F_4S_3	9.44	34.61	9.96
SE (±m)	1.28	4.75	1.36
C.D. at 5 %	NS	13.94	3.98

Table 62. Nitrogen balance sheet of cowpea influenced by levels and sources fertilizers

Treatments	Initial nutrient status (kg/ha) (A)	Quantity of nutrient added (kg/ha) (B)	Nutrient uptake (kg/ha) (C)	Expected balance in soil (D) (kg/ha) {(A + B) -(C)}	Actual soil fertility status (kg/ha) (E)	Apparent loss(F) (kg/ha) D - E	Net loss (G) (kg/ha) A - E
T_1 - 93:25:85 kg N: P_2O_5: K_2O /ha + 100 % CF (F_1S_1)	178.80	93.00	72.04	199.76	125.33	74.43	104.37
T_2 - 93:25:85 kg N: P_2O_5: K_2O /ha + 50 % as CF as basal + 50% WSF (F_1S_2)	186.27	93.00	83.93	195.34	132.80	62.54	123.73
T_3 - 93:25:85 kg N: P_2O_5: K_2O /ha + 100 % WSF(F_1S_3)	175.07	93.00	83.60	184.47	137.33	47.13	127.93
T_4 - 139:37: 127 kg N: P_2O_5: K_2O /ha + 100 % CF (F_2S_1)	176.93	139.00	76.12	239.82	153.33	86.48	90.45
T_5 - 139:37: 127 kg N: P_2O_5: K_2O /ha + 50 % as CF- basal + 50% WSF (F_2S_2)	182.53	139.00	87.81	233.73	179.47	54.26	128.27
T_6 - 139:37: 127 kg N: P_2O_5: K_2O /ha + 100 % WSF(F_2S_3)	147.07	139.00	81.74	204.33	136.53	67.79	79.27
T_7 - 185: 50: 170 kg N: P_2O_5: K_2O /ha + 100 % CF (F_3S_1)	162.00	185.00	80.19	266.81	164.53	102.27	59.73
T_8 - 185: 50: 170 kg N: P_2O_5: K_2O /ha + 50 % as CF- basal + 50% WSF(F_3S_2)	169.47	185.00	77.08	277.39	136.53	140.85	28.61
T_9 - 185: 50: 170 kg N: P_2O_5: K_2O /ha + 100 % WSF(F_3S_3)	169.47	185.00	85.72	268.75	178.67	90.08	79.38
T_{10} - 231: 63: 212 kg N: P_2O_5: K_2O /ha + 100 % CF (F_4S_1)	111.60	231.00	70.43	272.17	164.53	107.64	3.96
T_{11} - 231: 63: 212 kg N: P_2O_5: K_2O /ha + 50 % as CF- basal + 50% WSF(F_4S_2)	173.20	231.00	73.34	330.86	200.00	130.86	42.34
T_{12} - 231: 63: 212 kg N: P_2O_5: K_2O /ha + 100 % WSF(F_4S_3)	160.13	231.00	91.01	300.12	142.13	157.99	2.15
T_{13} - POP (Control) + 100 % CF	134.00	20.00	73.45	80.55	133.60	53.05	187.05

Table 63. Phosphorus balance sheet of cowpea influenced by levels and sources fertilizers

Treatments	**Initial nutrient status (kg/ha) (A)**	**Quantity of nutrient added (kg/ha) (B)**	**Nutrient uptake (kg/ha) (C)**	**Expected balance in soil (D) (kg/ha) {(A + B) -(C)}**	**Actual soil fertility status (kg/ha) (E)**	**Apparent loss(F) (kg/ha) D - E**	**Net loss (G) (kg/ha) A - E**
T_1 - 93:25:85 kg N: P_2O_5: K_2O /ha + 100 % CF (F_1S_1)	23.27	25	7.12	41.15	39.66	1.49	5.85
T_2 - 93:25:85 kg N: P_2O_5: K_2O /ha + 50 % as CF as basal + 50% WSF (F_1S_2)	28.08	25	8.51	44.57	42.93	1.64	2.38
T_3 - 93:25:85 kg N: P_2O_5: K_2O /ha + 100 % WSF(F_1S_3)	25.86	25	8.82	42.04	35.79	6.25	3.08
T_4 - 139:37: 127 kg N: P_2O_5: K_2O /ha + 100 % CF (F_2S_1)	23.12	38	7.78	53.34	25.75	27.59	4.22
T_5 - 139:37: 127 kg N: P_2O_5: K_2O /ha + 50 % as CF- basal + 50% WSF (F_2S_2)	24.51	38	8.31	54.20	65.38	11.17	16.29
T_6 - 139:37: 127 kg N: P_2O_5: K_2O /ha + 100 % WSF(F_2S_3)	21.43	38	8.27	51.16	62.37	11.21	16.43
T_7 - 185: 50: 170 kg N: P_2O_5: K_2O /ha + 100 % CF (F_3S_1)	25.83	50	7.74	68.09	29.92	38.16	7.03
T_8 - 185: 50: 170 kg N: P_2O_5: K_2O /ha + 50 % as CF- basal + 50% WSF(F_3S_2)	17.56	50	7.05	60.51	44.55	15.96	16.97
T_9 - 185: 50: 170 kg N: P_2O_5: K_2O /ha + 100 % WSF(F_3S_3)	25.90	50	7.98	67.92	19.32	48.60	3.02
T_{10} - 231: 63: 212 kg N: P_2O_5: K_2O /ha + 100 % CF (F_4S_1)	21.20	63	8.30	75.90	33.31	42.59	14.13
T_{11} - 231: 63: 212 kg N: P_2O_5: K_2O /ha + 50 % as CF- basal + 50% WSF(F_4S_2)	25.45	63	7.81	80.64	23.53	57.11	9.42
T_{12} - 231: 63: 212 kg N: P_2O_5: K_2O /ha + 100 % WSF(F_4S_3)	28.95	63	9.58	82.37	49.66	32.71	15.17
T_{13} - POP (Control) + 100 % CF	29.85	30	7.59	52.26	24.70	27.56	5.05

Table 64. Potassium balance sheet of cowpea influenced by levels and sources fertilizers

Treatments	Initial nutrient status (kg/ha) (A)	Quantity of nutrient added (kg/ha) (B)	Nutrient uptake (kg/ha) (C)	Expected balance in soil (D) (kg/ha) {(A + B) - (C)}	Actual soil fertility status (kg/ha) (E)	Apparent loss(F) (kg/ha) D - E	Net loss (G) (kg/ha) A – E
T_1 - 93:25:85 kg N: P_2O_5: K_2O /ha + 100 % CF (F_1S_1)	394.53	88	76.52	406.01	290.37	115.64	104.16
T_2 - 93:25:85 kg N: P_2O_5: K_2O /ha + 50 % as CF as basal + 50% WSF (F_1S_2)	384.83	88	85.85	386.97	325.63	61.35	59.20
T_3 - 93:25:85 kg N: P_2O_5: K_2O /ha + 100 % WSF(F_1S_3)	400.88	88	95.14	393.74	297.09	96.64	103.79
T_4 - 139:37: 127 kg N: P_2O_5: K_2O /ha + 100 % CF (F_2S_1)	363.92	132	82.91	413.01	343.39	69.63	20.53
T_5 - 139:37: 127 kg N: P_2O_5: K_2O /ha + 50 % as CF- basal + 50% WSF (F_2S_2)	363.92	132	86.91	409.01	355.71	53.31	8.21
T_6 - 139:37: 127 kg N: P_2O_5: K_2O /ha + 100 % WSF(F_2S_3)	396.40	132	81.17	447.23	302.39	144.84	94.01
T_7 - 185: 50: 170 kg N: P_2O_5: K_2O /ha + 100 % CF (F_3S_1)	360.56	170	83.56	447.00	353.15	93.86	7.41
T_8 - 185: 50: 170 kg N: P_2O_5: K_2O /ha + 50 % as CF- basal + 50% WSF(F_3S_2)	419.17	170	83.60	505.58	387.12	118.46	32.05
T_9 - 185: 50: 170 kg N: P_2O_5: K_2O /ha + 100 % WSF(F_3S_3)	404.61	170	88.40	486.21	366.16	120.05	38.45
T_{10} - 231: 63: 212 kg N: P_2O_5: K_2O /ha + 100 % CF (F_4S_1)	428.51	219	88.05	559.46	386.11	173.35	42.40
T_{11} - 231: 63: 212 kg N: P_2O_5: K_2O /ha + 50 % as CF- basal + 50% WSF(F_4S_2)	425.89	219	85.27	559.62	389.28	170.34	36.61
T_{12} - 231: 63: 212 kg N: P_2O_5: K_2O /ha + 100 % WSF(F_4S_3)	368.03	219	102.82	484.20	392.71	91.50	24.68
T_{13} - POP (Control) + 100 % CF	502.80	10	81.65	431.15	297.69	133.46	205.11

4.2.9 Nutrient content of soil

4.2.9.1 EC of the soil

The data pertaining to electrical conductivity of soil are presented in Table 65. The electrical conductivity of the soil differed significantly among levels of fertilizers. Higher electrical conductivity (0.10 dS/m) was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation which was found on par with drip fertigation with application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha. Lower electrical conductivity (0.069 dS/m) was recorded with control treatment. Sources of nutrients had significant influence on the electrical conductivity of soil at harvest. Higher electrical conductivity was recorded with fertigation through water soluble fertilizers (0.096 dS/m) and lower electrical conductivity with fertigation through conventional fertilizers (0.090 dS/m). Interaction effect of fertilizer levels and sources of nutrients was on par with respect to electrical conductivity of soil.

4.2.9.2 Soil pH

The pH of the soil did not differ significantly with levels or sources of fertilizers (Table 65).

4.2.9.3 Organic carbon content of soil

The data pertaining to organic carbon content of soil are presented in Table 65. The organic carbon content of the soil was statistically comparable with respect to levels of fertilizers and sources of fertilizers. Interaction effect was found non-significant with respect to the organic carbon content of soil.

4.2.9.4 Available nitrogen content of soil

Significantly different available nitrogen content was observed among levels of fertilizers (Table 65). The available nitrogen content was highest (168.89 kg/ha) with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation and followed by application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha (159.91 kg/ha). Minimum content of available nitrogen of 125.60 kg/ha was recorded in control treatment. Among sources of nutrients higher available nitrogen content of 157.07 kg/ha was recorded with fifty per cent of fertilizer dose through conventional sources as basal and remaining fifty per cent through fertigation as water soluble fertilizers. Lower available nitrogen content of 151.93 kg/ha was recorded with conventional fertilizers. Level of fertilizers x sources of nutrients interaction was also on par.

4.2.9.5 Available phosphorus content of soil

Significantly different available phosphorus content of soil was observed among levels of fertilizers (Table 66). The available phosphorus content was highest (26.18 kg/ha) with the application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation. The lowest value of available phosphorus content of 20.85 kg/ha was recorded with control. Available phosphorus content did not show significant difference among source of nutrients. However, available phosphorus content was recorded with fertigation through water soluble fertilizers (25.09 kg/ha). Interaction effect of fertilizer levels x sources of nutrients was on par with respect to available soil phosphorus content.

Table 65. Electrical conductivity (dS/m), pH, Organic carbon content (%) and available soil Nitrogen content (kg/ha) of cowpea as influenced by levels of fertilizers and sources of fertilizers

Treatments	EC	pH	OC	N
Levels of fertilizers (F)				
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	0.07	6.28	0.71	131.82
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	0.09	6.21	0.74	156.44
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	0.10	6.38	0.72	159.91
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	0.10	6.33	0.72	168.89
Control (F_0)	0.069	6.20	0.71	125.60
SE (±m)	0.002	0.15	0.01	3.07
C.D. at 5 %	0.006	NS	NS	9.00
Sources of fertilizers (S)				
S_1 - 100 % - CF	0.090	6.32	0.72	151.93
S_2 - 50 % CF as basal dose + 50 % WSF	0.092	6.33	0.72	157.07
S_3 - 100 % - WSF	0.096	6.29	0.73	155.43
SE (±m)	0.002	0.04	0.01	2.66
C.D. at 5 %	0.006	NS	NS	7.79
Interaction				
F_1S_1	0.069	6.36	0.70	125.33
F_1S_2	0.073	6.26	0.70	132.80
F_1S_3	0.091	6.21	0.74	137.33
F_2S_1	0.090	6.24	0.73	153.33
F_2S_2	0.093	6.17	0.74	179.47
F_2S_3	0.092	6.22	0.76	136.53
F_3S_1	0.097	6.38	0.75	164.53
F_3S_2	0.104	6.47	0.70	136.53
F_3S_3	0.101	6.29	0.72	178.67
F_4S_1	0.103	6.28	0.70	164.53
F_4S_2	0.104	6.49	0.73	200.00
F_4S_3	0.110	6.22	0.71	142.13
SE (±m)	0.004	0.09	0.01	5.31
C.D. at 5 %	NS	NS	NS	NS

4.2.9.6 Available potassium content of soil

The effect of levels of fertilizers on available potassium content of soil differed significantly (Table 66). The available potassium content was highest (389.36 kg/ha) with the application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation. The lowest value of available potassium content of 297.69 kg/ha was recorded with control. Available potassium content had significant difference among source of nutrients. Higher available potassium content 353.84 kg/ha was recorded with fifty per cent of fertilizer dose through conventional sources as basal and remaining fifty per cent through fertigation as water soluble fertilizers. Interaction effect of fertilizer levels x sources of nutrients was also on par with respect to available soil potassium content.

4.2.9.7 Available calcium content of soil

The available calcium content of soil did not differed significantly among levels of fertilizers (Table 66). Available calcium content was statistically comparable with respect to sources of fertilizers. Interaction effect was also on par.

4.2.9.8 Available magnesium content of soil

The available magnesium content of soil had no significant difference among levels of fertilizers (Table 66). All sources of fertilizers exhibited statistically comparable value for available magnesium content of soil. Interaction effect of fertilizer levels x sources of nutrients was also on par with respect to available soil magnesium content.

Table 66. Available soil Phosphorus, Potassium (kg/ha), Calcium, Magnesium and Sulphur (mg/kg) content of cowpea as influenced by levels of fertilizers and sources of fertilizers

Treatments	P	K	Ca	Mg	S
Levels of fertilizers (F)					
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	23.46	304.36	537.99	82.51	9.03
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	24.43	333.83	536.90	82.99	9.09
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	25.20	368.81	532.54	81.85	9.02
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	26.18	389.36	540.32	81.48	8.83
Control (F_0)	20.85	290.69	530.36	84.76	8.98
SE (±m)	0.38	6.02	215.86	0.41	0.08
C.D. at 5 %	1.12	17.65	NS	NS	NS
Sources of fertilizers (S)					
S_1 - 100 % - CF	24.27	343.25	539.14	81.97	9.05
S_2 - 50 % CF as basal dose + 50 % WSF	24.67	353.84	537.22	82.10	9.02
S_3 - 100 % - WSF	25.09	352.01	535.84	82.33	8.97
SE (±m)	0.33	5.21	186.94	0.36	0.07
C.D. at 5 %	NS	15.28	NS	NS	NS
Interaction					
F_1S_1	22.79	290.37	540.25	81.79	8.95
F_1S_2	23.84	325.63	539.26	82.65	9.34
F_1S_3	23.76	297.09	534.45	83.08	8.82
F_2S_1	23.83	343.39	539.79	82.44	8.92
F_2S_2	24.22	355.71	535.79	82.67	9.05
F_2S_3	25.24	302.39	535.13	83.88	9.29
F_3S_1	24.54	353.15	539.13	81.88	9.13
F_3S_2	25.45	387.12	524.34	81.54	9.09
F_3S_3	25.61	366.16	534.15	82.12	8.83
F_4S_1	25.94	386.11	537.39	81.77	9.19
F_4S_2	26.75	389.28	541.81	82.11	8.50
F_4S_3	25.86	392.71	541.76	80.58	8.81
SE (±m)	0.66	10.42	373.88	0.72	0.15
C.D. at 5 %	NS	NS	NS	NS	NS

4.2.9.9 Available sulphur content of soil

The available sulphur content of soil also exhibited the same trend as that of magnesium (Table 66). All sources of fertilizers exhibited statistically comparable values for available sulphur content of soil. Interaction effect of fertilizer levels x sources of nutrients was also on par with respect to available soil sulphur content.

4.2.9.10 Available iron content of soil

The data pertaining to available iron content of soil are presented in Table 67. The available iron content of the soil was statistically comparable with respect to levels of fertilizers. It was also on par with sources of nutrients. Interaction effect was also found non-significant with respect to the available iron content of soil.

4.2.9.11 Available zinc content of soil

The available zinc content of soil had no significant difference among levels of fertilizers (Table 67). All sources of fertilizers exhibited statistically comparable value for available zinc content of soil. Interaction effect of fertilizer levels x sources of nutrients was also on par with respect to available soil zinc content.

4.2.9.12 Available manganese content of soil

The data pertaining to available manganese content of soil are presented in Table 67. The available manganese content of the soil was statistically comparable with respect to available soil manganese content. It was also on par with sources of nutrients. Interaction effect was also found non-significant with respect to the available manganese content of soil.

Table 67. Available soil Iron, Zinc, Manganese, Copper and Boron (mg/kg) of cowpea as influenced by levels of fertilizers and sources of fertilizers

Treatments	**Fe**	**Zn**	**Mn**	**Cu**	**B**
Levels of fertilizers (F)					
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	17.07	4.30	53.31	3.20	0.24
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	16.17	4.31	53.22	3.30	0.25
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	16.55	4.34	53.49	3.27	0.26
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	16.25	4.23	53.93	3.22	0.25
Control (F_0)	16.39	4.38	53.30	3.21	0.01
SE (±m)	0.33	0.03	0.48	0.03	0.02
C.D. at 5 %	NS	NS	NS	NS	NS
Sources of fertilizers (S)					
S_1 - 100 % - CF	16.70	4.30	54.14	3.30	0.26
S_2 - 50 % CF as basal dose + 50 % WSF	16.44	4.31	53.51	3.25	0.25
S_{3} - 100 % - WSF	16.41	4.30	53.16	3.22	0.25
SE (±m)	0.28	0.02	0.42	0.03	0.01
C.D. at 5 %	NS	NS	NS	NS	NS
Interaction					
F_1S_1	16.99	4.31	53.72	3.28	0.26
F_1S_2	16.88	4.32	54.24	3.17	0.23
F_1S_3	17.32	4.26	51.98	3.16	0.24
F_2S_1	16.59	4.33	53.08	3.33	0.26
F_2S_2	15.43	4.28	52.98	3.25	0.26
F_2S_3	16.48	4.33	53.59	3.31	0.25
F_3S_1	16.68	4.33	54.48	3.31	0.27
F_3S_2	16.44	4.40	52.92	3.19	0.25
F_3S_3	16.54	4.30	53.08	3.33	0.26
F_4S_1	16.54	4.22	55.29	3.28	0.26
F_4S_2	15.92	4.27	51.36	3.22	0.25
F_4S_3	16.30	4.21	55.13	3.16	0.24
SE (±m)	0.57	0.05	0.84	0.05	0.01
C.D. at 5 %	NS	NS	NS	NS	NS

4.2.9.13 Available copper content of soil

The available copper content of soil had no significant difference among levels of fertilizers (Table 67). All sources of fertilizers exhibited statistically comparable value for available copper content of soil. Interaction effect of fertilizer levels x sources of nutrients was also on par with respect to available soil copper content.

4.2.9.14 Available boron content of soil

The available boron content of soil had no significant difference among levels of fertilizers (Table 67). All sources of fertilizers exhibited statistically comparable value for available boron content of soil. Interaction effect of fertilizer levels x sources of nutrients was also on par with respect to available soil boron content.

4.2.10 Correlation studies

Data on macro and micro nutrient content of plants at 20 and 40 DAS and at harvest were subjected to the correlation analysis. Correlation coefficient between fertilizer levels, sources of nutrients and nutrient content of plant were estimated and presented in the Table 68. Correlation studies revealed that, nitrogen and potassium had a significant positive correlation with potassium, calcium, magnesium, sulphur, iron, zinc, manganese, copper and boron content in plant.

4.2.11 Economics of cultivation

The data regarding net return and B: C ratio is presented in Table 69. The net return did not differ significantly among fertigation levels. Among the sources of nutrients, the net return exhibited statistically comparable values.

Table 68. Correlation between levels of fertilizers, sources of nutrients on plant nutrient content

	K	Ca	Mg	S	Fe	Zn	Mn	Co	B
N	.557**	.768**	.286**	.494**	.570**	.632**	.527**	.535**	.414**
K	-	.755**	.344**	.512**	.583**	.623**	.575**	.616**	.479**
Ca		-	.478**	.644**	.702**	.806**	.664**	.650**	.645**
Mg			-	.383**	.472**	.481**	.439**	.371**	.610**
S				-	.614**	.621**	.624**	.574**	.506**
Fe					-	.757**	.886**	.768**	.755**
Zn						-	.746**	.730**	.637**
Mn							-	.783**	.743**
Co								-	.670**

Table 69. Net return (Rs./ha) and B: C ratio of cowpea as influenced by levels and sources fertilizers

Treatments	Net return	B: C ratio
Levels of fertilizers (F)		
F_1 - 93:25:85 kg N: P_2O_5: K_2O /ha	75873	1.33
F_2 - 139:37: 127 kg N: P_2O_5: K_2O /ha	83146	1.36
F_3 -185: 50: 170 kg N: P_2O_5: K_2O /ha	65311	1.29
F_4 - 231: 63: 212 kg N: P_2O_5: K_2O /ha	74023	1.32
Control (F_0)	98470	1.30
SE (±m)	52735	0.07
C.D. at 5 %	NS	NS
Sources of fertilizers (S)		
S_1 - 100 % - CF	63910	1.28
S_2 - 50 % CF as basal dose + 50 % WSF	69343	1.30
S_3 - 100 % - WSF	79928	1.35
SE (±m)	15571	0.06
C.D. at 5 %	NS	NS
Interaction		
F_1S_1	45293	1.21
F_1S_2	89395	1.38
F_1S_3	92932	1.41
F_2S_1	81627	1.35
F_2S_2	104143	1.42
F_2S_3	63668	1.31
F_3S_1	48381	1.22
F_3S_2	52543	1.22
F_3S_3	95009	1.44
F_4S_1	80338	1.35
F_4S_2	53023	1.23
F_4S_3	88708	1.37
SE (±m)	31143	0.12
C.D. at 5 %	NS	NS

Levels of fertilizers x sources of nutrients interaction was also on par with respect to the net return. B: C ratio also followed the same trend.

4.3. Experiment III: Standardization of irrigation schedule and response of bio-fertilisers for bush type vegetable cowpea under open precision farming

The experiment was conducted to study the effect of *Rhizobium* treatment and foliar nutrition on the performance of vegetable cowpea *Vigna unguiculata* (L.) Walp.) (var. Lalita) and to standardize optimum level of drip irrigation for maximum yield under open precision farming.

4.3.1. Growth characters

4.3.1.1. Plant height

The height of plants differed significantly among drip irrigation at 20 and 40 DAS and at harvest (Table 70). Tallest plants (23.17 cm) were produced by drip irrigation at 100 % Ep (control 1) followed by drip irrigation treatment of 80 per cent Ep (19.32 cm) at 20 DAS. The shorter plants (14.69 cm) were observed in control 2 (conventional channel irrigation once in 2 days). The drip irrigation of 100 per cent Ep produced the tallest plants at 40 DAS and at harvest. Plant height of cowpea varied significantly with *Rhizobium* seed treatment at 20 DAS. Taller plants were observed with seed treatment of *Rhizobium* as compared to without *Rhizobium*. While at 40 DAS and at harvest the height of plants were statistically comparable with respect to with and without *Rhizobium* seed treatment.

The effect of foliar nutrition of 19:19:19 on plant height followed similar trend at all the stages of growth. The tallest plants were present under foliar application along with fertigation treatments as compared to fertigation alone at 20 and 40 DAS and at harvest.

Interaction effect of drip irrigation x *Rhizobium* was non-significant comparable with respect to plant height at all stages of growth. Interaction effect drip irrigation x *Rhizobium*, *Rhizobium* x foliar nutrition and drip irrigation x *Rhizobium* x foliar nutrition were also non-significant at all the stages of crop growth.

4.3.1.2 Number of leaves per plant

The data on number of leaves per plant are given in Table 71. Number of leaves per plant of vegetable cowpea differed significantly among different irrigation treatments at all stages of growth. The drip irrigation treatment of 100 per cent Ep (control 1) produced higher number of leaves per plant (7.87, 15.00 and 21.11) which was on par with that of 80 per cent Ep (6.92, 16.02 and 19.87) at 20, 40 DAS and at harvest,. The minimum number of leaves per plant (4.60, 12.22 and 14.44) were recorded in conventional channel irrigation once in 2 days (control 2) at all the stages of growth. The seed treatment with *Rhizobium* had no significant effect with respect to number of leaves per plant at 20 and 40 DAS and at harvest. However, higher number of leaves per plant was produced with seed treatment (6.57, 15.25 and 17.63) at all the stages of crop growth.

Number of leaves per plant was differed significantly with respect to foliar nutrition at all the stages of crop growth. At 20 and 40 DAS and at harvest significantly higher number of leaves per plant (6.75, 15.48 and 17.98) was recorded with combined application of fertigation and foliar nutrition as compared to fertigation alone.

Table 70 . Plant height (cm) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	Plant height		
	20 DAS	40 DAS	At harvest
Irrigation (I)			
60 % Ep (I_1)	17.33	43.00	52.14
80 % Ep (I_2)	19.32	48.42	56.08
SE (±m)	0.46	0.805	0.83
C.D. at 5%	1.42	2.443	2.53
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	19.21	45.50	55.14
Without *Rhizobium* (B_2)	17.45	45.92	53.08
SE (±m)	0.46	0.805	0.83
C.D. at 5%	1.42	NS	NS
Foliar nutrition (F)			
With foliar nutrition (F_1)	19.28	47.58	55.42
Without foliar nutrition (F_2)	17.38	43.83	52.81
SE (±m)	0.46	0.805	0.83
C.D. at 5%	1.42	2.443	2.53
Interaction			
$I_1B_1F_1$	19.10	44.33	54.22
$I_1B_1F_2$	16.08	39.00	51.33
$I_1B_2F_1$	17.40	44.67	52.89
$I_1B_2F_2$	16.76	44.00	50.11
$I_2B_1F_1$	22.24	51.67	58.89
$I_2B_1F_2$	19.40	47.00	56.11
$I_2B_2F_1$	18.38	49.67	55.67
$I_2B_2F_2$	17.27	45.33	53.67
SE (±m)	0.93	1.611	1.66
C.D. at 5%	NS	NS	NS
Control			
Control 1	23.17	53.00	59.11
Control 2	14.69	42.33	47.78
SE (±m)	0.846	1.997	2.246
C.D. at 5%	2.51	5.93	6.67

Table 71. Number of leaves of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	Number of leaves per plant		
	20 DAS	40 DAS	Harvest
Irrigation (I)			
60 % Ep (I_1)	6.13	14.00	14.67
80 % Ep (I_2)	6.92	16.02	19.87
SE (±m)	0.19	0.253	0.336
C.D. at 5%	0.60	0.769	1.018
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	6.57	15.25	17.63
Without *Rhizobium* (B_2)	6.48	14.77	16.91
SE (±m)	0.19	0.253	0.336
C.D. at 5%	NS	NS	NS
Foliar nutrition (F)			
With foliar nutrition (F_1)	6.75	15.48	17.98
Without foliar nutrition (F_2)	6.30	14.54	16.56
SE (±m)	0.19	0.253	0.336
C.D. at 5%	NS	0.769	1.018
Interaction			
$I_1B_1F_1$	6.53	14.78	15.07
$I_1B_1F_2$	5.20	13.72	14.29
$I_1B_2F_1$	6.47	14.11	14.86
$I_1B_2F_2$	6.33	13.37	14.44
$I_2B_1F_1$	7.40	16.78	21.10
$I_2B_1F_2$	7.13	15.72	20.04
$I_2B_2F_1$	6.60	16.26	20.89
$I_2B_2F_2$	6.53	15.33	17.45
SE (±m)	0.39	0.507	0.671
C.D. at 5%	NS	NS	NS
Control			
Control 1	7.87	15.00	21.11
Control 2	4.60	12.22	14.44
SE (±m)	0.40	0.809	0.552
C.D. at 5%	1.18	2.403	1.641

4.3.2. Yield attributes and yield

4.3.2.1 Dry matter production per plant

Dry matter production per plant differed significantly with respect to irrigation levels (Table 72). Drip irrigation at 100 per cent Ep (control 1) recorded maximum dry matter production of 70.37 g which was on par with that at drip irrigation of 80 per cent Ep (74.56 g) at harvest. Least dry matter production was with drip irrigation at 60 per cent Ep (55.57 g). The seed treatment had no significant effect with respect to dry matter production at harvest. Supplementation of nutrients through foliar application also exhibited significant difference with respect to dry matter production per plant. Foliar application along with fertigation treatments produced higher dry matter (70.86 g) as compared to fertigation treatments (59.27 g).

4.3.2.2 Days to fifty per cent flowering

The number of days taken to complete fifty per cent flowering is arranged in Table 72. Days to fifty per cent flowering differed significantly among drip irrigation levels. Drip irrigation at 80 per cent Ep attained fifty per cent flowering earlier (32.83 days) which was found on par with drip irrigation at 100 per cent Ep (control 1). Conventional channel irrigation once in 2 days (control 2) took more days to attain fifty per cent flowering as compared to other treatments (34.67 days). Seed treatment did not produce variation in attainment of flowering.

Foliar nutrition varied significantly with respect to days to fifty per cent flowering. Earlier flowering was noticed with fertigation alone (32.92 days) as compared to with foliar application treatments (34.17 days).

Table 72.Yield attributes of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	**Dry matter production (g/ plant)**	**Days to 50% flowering (days)**	**Days to first harvest (days)**
Irrigation (I)			
60 % Ep (I_1)	55.57	34.25	43.58
80 % Ep (I_2)	74.56	32.83	42.50
SE (±m)	2.177	0.25	0.27
C.D. at 5%	6.602	0.77	0.84
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	65.13	33.58	43.08
Without *Rhizobium* (B_2)	65.00	33.50	43.00
SE (±m)	2.177	0.255	0.27
C.D. at 5%	NS	NS	NS
Foliar nutrition (F)			
With foliar nutrition (F_1)	70.86	34.17	43.67
Without foliar nutrition (F_2)	59.27	32.92	42.42
SE (±m)	2.177	0.255	0.27
C.D. at 5%	6.602	0.773	0.84
Interaction			
$I_1B_1F_1$	64.75	35.00	44.33
$I_1B_1F_2$	47.43	33.67	43.00
$I_1B_2F_1$	61.67	35.00	44.33
$I_1B_2F_2$	48.45	33.33	42.67
$I_2B_1F_1$	78.85	33.33	43.00
$I_2B_1F_2$	69.48	32.33	42.00
$I_2B_2F_1$	78.18	33.33	43.00
$I_2B_2F_2$	71.72	32.33	42.00
SE (±m)	4.353	0.510	0.55
C.D. at 5%	NS	NS	NS
Control			
Control 1	70.37	33.00	42.33
Control 2	62.38	34.67	44.67
SE (±m)	4.391	0.461	0.496
C.D. at 5%	13.046	1.369	1.473

4.3.2.3 Days to first harvest

The number of days taken first harvest is presented in Table 72. Days to first harvest differed significantly among drip irrigation levels. Drip irrigation at 100 per cent Ep (control 1) harvested earlier (42.33 days) which was found on par with drip irrigation at 80 per cent Ep. Conventional channel irrigation once in 2 days (control 2) took more days to first harvest as compared to other treatments (44.67 days). Seed treatment did not produce variation in attainment of flowering.

Foliar nutrition varied significantly with respect to days to first harvest. Earlier harvesting was noticed with fertigation alone (42.42 days) as compared to with foliar application treatments (43.67 days).

4.3.2.4 Pod length

Neither irrigation levels nor seed treatment exhibited produced variation for the length of pods (Table 73). Even so, drip irrigation at 100 per cent Ep (control 1) produced longer pods (28.08 cm) compared to other levels.

4.3.2.5 Number of pods per plant

Total number of pods produced per plant is depicted in Table 73. Number of pods per plant of bush type vegetable cowpea differed significantly among different drip irrigation levels. Higher number of pods per plant was recorded with drip irrigation at 80 per cent Ep (16.67) which was statistically comparable with drip irrigation at 100 per cent Ep (16.33). Lowest number of pods per plant (11.65) was obtained with drip irrigation at 60 per cent Ep. Number of pods produced per plant had no significant difference with seed treatment.

Foliar application had a significant effect on number of pods per plant. The highest number of pods per plant (14.87) was observed in foliar applied treatments and lowest was observed under fertigation treatment (13.45).

Table 73. Yield attributes of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	Pod length (cm)	Number of pods per plant	Yield per plant (g)
Irrigation (I)			
60 % Ep (I_1)	27.53	11.65	96.24
80 % Ep (I_2)	27.65	16.67	148.88
SE (±m)	0.407	0.363	8.874
C.D. at 5%	NS	1.100	26.91
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	27.68	14.70	121.28
Without *Rhizobium* (B_2)	27.50	13.63	124.84
SE (±m)	0.407	0.363	8.874
C.D. at 5%	NS	NS	NS
Foliar nutrition (F)			
With foliar nutrition (F_1)	27.51	14.87	140.45
Without foliar nutrition (F_2)	27.66	13.45	105.67
SE (±m)	0.407	0.363	8.874
C.D. at 5%	NS	1.100	26.916
Interaction			
$I_1B_1F_1$	27.83	12.37	121.13
$I_1B_1F_2$	27.28	12.13	69.67
$I_1B_2F_1$	26.87	12.78	116.22
$I_1B_2F_2$	28.16	9.33	77.93
$I_2B_1F_1$	27.94	17.73	159.80
$I_2B_1F_2$	27.65	16.55	134.53
$I_2B_2F_1$	27.42	16.62	164.67
$I_2B_2F_2$	27.57	15.77	140.53
SE (±m)	0.814	0.725	17.748
C.D. at 5%	NS	NS	NS
Control			
Control 1	28.08	16.33	145.33
Control 2	27.60	12.20	118.80
SE (±m)	0.998	0.651	17.367
C.D. at 5%	NS	1.933	51.600

4.3.2.6 Yield per plant

The data regarding the yield per plant is depicted in Table 73. Yield per plant of bush type vegetable cowpea differed significantly among drip irrigation levels. Drip irrigation at 80 per cent Ep recorded the highest yield per plant (148.88 g) which was on par with drip irrigation at 100 per cent Ep (control 1) (145.33 g). Lowest yield per plant was recorded with drip irrigation at 60 per cent Ep (96.24 g). *Rhizobium* seed treatment had no significant effect on yield per plant. Higher yield per plant (140.45 g) was recorded with foliar application along with fertigation treatments as compared to fertigation alone. Interaction effect drip irrigation x *Rhizobium*, *Rhizobium* x foliar nutrition and drip irrigation x *Rhizobium* x foliar nutrition was also on par.

4.3.2.7 Yield per plot

From Table 74. It is clear that, the yield per plot was maximum with drip irrigation at 100 per cent Ep (8.68 kg) which was statistically comparable with drip irrigation at 80 per cent Ep (8.51 kg). Lowest yield per plot (4.92 kg) was recorded with drip irrigation at 60 per cent Ep. Seed treatment with and without *Rhizobium* was statistically comparable with respect to yield per plot. Even so, seed treatment with *Rhizobium* produced higher yield per plot (7.06 kg) than seed treatment without *Rhizobium* (6.37 kg).

Yield per plot differed significantly among foliar nutrition treatments. Foliar application along with fertigation treatments has recorded higher yield per plot (7.18 kg) as compared to fertigation alone (6.26 kg).

Interaction effect (drip irrigation x *Rhizobium*, drip irrigation x foliar nutrition, *Rhizobium* x foliar nutrition and drip irrigation x Rhizobium x foliar nutrition) were on par with respect to yield per plot of vegetable cowpea at harvest under open precision farming.

4.3.2.8 Yield per hectare

The data pertaining to the effect of treatments on yield of vegetable cowpea under open precision farming is given in Table 74. Among different drip irrigation levels highest yield of 12.16 t/ha was exhibited with drip irrigation at 100 per cent Ep which was statistically comparable with that at 80 per cent Ep (11.24 t/ha). Lowest fresh pod yield (6.51 t/ha) was exhibited with drip irrigation at 60 per cent Ep. *Rhizobium* seed treatment did not produce signify difference on per ha yield. Foliar nutrition differed significantly with respect to yield of vegetable cowpea and higher yield 9.47 t/ha was recorded with foliar application along with fertigation as compared to fertigation alone (8.28 t/ha).

4.3.2.9 Duration of crop

Duration of bush type vegetable cowpea differed significantly with respect to drip irrigation levels (Table 74). It was observed that conventional channel irrigation once in 2 days (control 2) attained maturity earlier (70.00 days) than other treatments. Drip irrigation at 100 per cent Ep attained final maturity lately (78.00 days). Duration of crop was on par among *Rhizobium* seed treatment levels. Foliar application along with fertigation treatments has been recorded longer duration (75.25 days) as compared to fertigation alone treatments (74.08 days).Interaction effect (drip irrigation x *Rhizobium*, drip irrigation x foliar nutrition, *Rhizobium* x foliar nutrition and drip irrigation x *Rhizobium* x foliar nutrition) were on par with respect to duration of vegetable cowpea under open precision farming.

Table 74. Yield of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	**Yield per plot (kg)**	**Yield per ha (t/ha)**	**Duration of the crop (days)**
Irrigation (I)			
60 % Ep (I_1)	4.92	6.51	72.25
80 % Ep (I_2)	8.51	11.24	77.08
SE (±m)	0.296	0.392	0.354
C.D. at 5%	0.897	1.190	1.072
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	7.06	9.34	74.58
Without *Rhizobium* (B_2)	6.37	8.41	74.75
SE (±m)	0.29	0.39	0.354
C.D. at 5%	NS	NS	NS
Foliar nutrition (F)			
With foliar nutrition (F_1)	7.18	9.47	75.25
Without foliar nutrition (F_2)	6.26	8.28	74.08
SE (±m)	0.29	0.392	0.354
C.D. at 5%	0.89	1.190	1.072
Interaction			
$I_1B_1F_1$	6.16	8.15	73.33
$I_1B_1F_2$	4.82	6.38	71.00
$I_1B_2F_1$	5.13	6.79	73.00
$I_1B_2F_2$	3.58	4.74	71.67
$I_2B_1F_1$	8.49	11.14	77.33
$I_2B_1F_2$	8.32	11.01	76.67
$I_2B_2F_1$	8.94	11.82	77.33
$I_2B_2F_2$	8.30	10.98	77.00
SE (±m)	0.59	0.785	0.707
C.D. at 5%	NS	NS	NS
Control			
Control 1	8.68	12.16	78.00
Control 2	6.30	8.82	70.00
SE (±m)	0.652	0.883	0.668
C.D. at 5%	1.93	2.62	1.984

4.3.3 Physiological parameters

4.3.3.1 Crop growth rate (CGR)

The data pertaining to the effect of treatments on Crop Growth Rate (CGR) of vegetable cowpea under open precision farming is given in Table 75. CGR did not vary significantly among drip irrigation levels during 0 – 20 DAS and at 40 DAS to harvest. While during 20 - 40 DAS, CGR varied significantly among drip irrigation levels. Maximum CGR was recorded with drip irrigation treatment of 80 per cent Ep (1.2 g/day/m^2) which found on par with drip irrigation at 100 per cent Ep (control 1). Minimum CGR (0.87 g/day/m^2) was recorded in conventional channel irrigation once in 2 days (control 2). CGR varied significantly among seed treatment with and without *Rhizobium* at 20 DAS. Higher CGR (0.06 g/day/m^2) was recorded in seed treatment with *Rhizobium*. While, CGR did not varied significantly among *Rhizobium* seed treatment levels during 20 – 40 DAS and at 40 DAS to harvest.

Crop growth rate of vegetable cowpea did not differ significantly due to supplementation with foliar nutrition during 0 – 20 DAS and 40 - harvest. Higher CGR of 0.05 g/day/m^2 and 0.61 g/day/m^2 was recorded with supplementation through foliar during 0 – 20 DAS and 40 – harvest respectively. While, crop growth rate differed significantly due to foliar nutrition during 20 – 40 DAS. Maximum CGR of 1.13 g/day/m^2 was recorded with foliar nutrition as compared to fertigation alone (1.00 g/day/m^2).

4.3.3.2 Relative growth rate (RGR)

The data pertaining to the Relative Growth Rate (RGR) during 0- 20 DAS, 20 – 40 DAS and during 40 DAS to harvest are presented in the Table 76. RGR did not vary significantly among drip irrigation levels at all the stages of crop growth. But significant variation was noticed with seed treatment during 0 - 20

Table 75. Crop growth rate (g/day/m^2) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	**Crop growth rate**		
Irrigation (I)	**0-20 DAS**	**20-40 DAS**	**40 DAS-Harvest**
60 % Ep (I_1)	0.05	0.93	0.61
80 % Ep (I_2)	0.05	1.20	0.61
SE (±m)	0.006	0.039	0.059
C.D. at 5%	NS	0.118	NS
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	0.06	1.10	0.58
Without *Rhizobium* (B_2)	0.04	1.02	0.63
SE (±m)	0.006	0.039	0.059
C.D. at 5%	0.019	NS	NS
Foliar nutrition (F)			
With foliar nutrition (F_1)	0.05	1.13	0.61
Without foliar nutrition (F_2)	0.04	1.00	0.60
SE (±m)	0.006	0.039	0.059
C.D. at 5%	NS	0.118	NS
Interaction			
$I_1B_1F_1$	0.07	1.02	0.64
$I_1B_1F_2$	0.05	0.90	0.55
$I_1B_2F_1$	0.02	0.95	0.66
$I_1B_2F_2$	0.04	0.84	0.57
$I_2B_1F_1$	0.05	1.32	0.57
$I_2B_1F_2$	0.05	1.16	0.58
$I_2B_2F_1$	0.05	1.22	0.58
$I_2B_2F_2$	0.03	1.09	0.71
SE (±m)	0.013	0.078	0.119
C.D. at 5%	NS	NS	NS
Control			
Control 1	0.03	1.04	0.63
Control 2	0.02	0.87	0.74
SE (±m)	0.011	0.075	0.109
C.D. at 5%	NS	0.222	NS

Table 76. Relative crop growth rate (g/g/ day) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	Relative crop growth rate		
Irrigation (I)	**0-20 DAS**	**20-40 DAS**	**40 DAS-Harvest**
60 % Ep (I_1)	0.01	0.16	0.02
80 % Ep (I_2)	0.01	0.17	0.02
SE (±m)	0.007	0.008	0.002
C.D. at 5%	NS	NS	NS
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	0.02	0.18	0.02
Without *Rhizobium* (B_2)	0.001	0.15	0.02
SE (±m)	0.007	0.008	0.002
C.D. at 5%	0.022	0.023	NS
Foliar nutrition (F)			
With foliar nutrition (F_1)	0.01	0.17	0.02
Without foliar nutrition (F_2)	0.01	0.16	0.02
SE (±m)	0.007	0.008	0.002
C.D. at 5%	NS	NS	NS
Interaction			
$I_1B_1F_1$	0.01	0.14	0.02
$I_1B_1F_2$	0.00	0.15	0.02
$I_1B_2F_1$	0.04	0.19	0.03
$I_1B_2F_2$	0.02	0.16	0.03
$I_2B_1F_1$	0.00	0.16	0.02
$I_2B_1F_2$	0.00	0.16	0.02
$I_2B_2F_1$	0.00	0.17	0.02
$I_2B_2F_2$	0.03	0.18	0.02
SE (±m)	0.014	0.015	0.005
C.D. at 5%	NS	NS	NS
Control			
Control 1	0.02	0.17	0.02
Control 2	0.06	0.21	0.03
SE (±m)	0.014	0.015	0.04
C.D. at 5%	0.042	NS	NS

DAS and 20 - 40 DAS. Higher RGR of 0.02 g/g/ day and 0.18 g/g/ day were recorded with seed treatment compared to no *Rhizobium* during 0 - 20 DAS and 20 - 40 DAS respectively. While, RGR did not vary significantly with *Rhizobium* seed treatment during 40 DAS – harvest. In the case of foliar nutrition treatments, the values of RGR did not differ significantly at all the stages of crop growth.

4.3.3.3 Net assimilation rate (NAR)

The data regarding the Net Assimilation Rate (NAR) of vegetable cowpea during 0 – 20 DAS, 20 – 40 DAS and 40 DAS to harvest are depicted in Table 77. NAR of vegetable cowpea did not differ significantly with drip irrigation levels during 0 - 20 DAS. While, during 20 – 40 DAS and 40 DAS - harvest, NAR differed significantly. Among drip irrigation levels and highest NAR of 0.11 g/ mm^2/day was recorded with drip irrigation at 60 per cent Ep at the both stages.

NAR varied significantly with seed treatment during 0 - 20 DAS and 40 DAS – harvest. Higher NAR of 0.06 g/ mm^2/day and 0.09 g/ mm^2/day were recorded with seed treatment during 0 – 20 DAS and 40 – harvest. The values of NAR did not vary significantly due to foliar nutrition at all the stages of crop growth.

4.3.3.4 Leaf area index

The data pertaining to the leaf area index (LAI) are presented in the Table 78. Leaf area index differed significantly among drip irrigation levels at 20, 40 DAS and at harvest. Higher leaf area index of 0.15, 1.91 and 2.32 were recorded with drip irrigation of 80 per cent Ep at 20, 40 DAS and at harvest which was statistically comparable with drip irrigation treatments of 100 per cent Ep (control 1). Conventional channel irrigation once in 2 days (control 2) recorded significantly lower leaf area index of 0.05, 0.65 and 0.73 at 20, 40 DAS and at harvest respectively.

Table 77. Net assimilation rate (g/ mm^2/day) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	. Net assimilation rate		
Irrigation (I)	**0-20 DAS**	**20-40 DAS**	**40 DAS-Harvest**
60 % Ep (I_1)	0.05	0.11	0.11
80 % Ep (I_2)	0.04	0.06	0.06
SE (±m)	0.006	0.010	0.004
C.D. at 5%	NS	0.030	0.013
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	0.06	0.07	0.09
Without *Rhizobium* (B_2)	0.04	0.10	0.08
SE (±m)	0.006	0.010	0.004
C.D. at 5%	0.018	NS	0.013
Foliar nutrition (F)			
With foliar nutrition (F_1)	0.05	0.09	0.08
Without foliar nutrition (F_2)	0.05	0.08	0.09
SE (±m)	0.006	0.010	0.004
C.D. at 5%	NS	NS	NS
Interaction			
$I_1B_1F_1$	0.08	0.10	0.10
$I_1B_1F_2$	0.07	0.09	0.10
$I_1B_2F_1$	0.03	0.15	0.11
$I_1B_2F_2$	0.04	0.10	0.12
$I_2B_1F_1$	0.04	0.05	0.05
$I_2B_1F_2$	0.05	0.06	0.05
$I_2B_2F_1$	0.05	0.06	0.06
$I_2B_2F_2$	0.03	0.08	0.07
SE (±m)	0.012	0.020	0.008
C.D. at 5%	NS	NS	NS
Control			
Control 1	0.04	0.09	0.04
Control 2	0.03	0.10	0.09
SE (±m)	0.013	0.022	0.009
C.D. at 5%	NS	0.064	0.026

Table 78. Leaf area Index of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	LAI		
	20 DAS	40 DAS	Harvest
Irrigation (I)			
60 % Ep (I_1)	0.09	0.82	0.90
80 % Ep (I_2)	0.15	1.91	2.32
SE (±m)	0.006	0.056	0.055
C.D. at 5%	0.017	0.169	0.168
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	0.13	1.48	1.75
Without *Rhizobium* (B_2)	0.11	1.24	1.47
SE (±m)	0.006	0.056	0.055
C.D. at 5%	0.017	0.169	0.168
Foliar nutrition (F)			
With foliar nutrition (F_1)	0.13	1.49	1.84
Without foliar nutrition (F_2)	0.11	1.23	1.38
SE (±m)	0.006	0.056	0.055
C.D. at 5%	0.017	0.169	0.168
Interaction			
$I_1B_1F_1$	0.11	1.02	1.09
$I_1B_1F_2$	0.08	0.79	0.88
$I_1B_2F_1$	0.10	0.78	0.89
$I_1B_2F_2$	0.07	0.67	0.74
$I_2B_1F_1$	0.17	2.11	2.86
$I_2B_1F_2$	0.16	1.98	2.18
$I_2B_2F_1$	0.13	2.06	2.51
$I_2B_2F_2$	0.12	1.47	1.74
SE (±m)	0.011	0.111	0.111
C.D. at 5%	NS	NS	NS
Control			
Control 1	0.16	1.84	1.91
Control 2	0.05	0.65	0.73
SE (±m)	0.016	0.104	0.100
C.D. at 5%	0.048	0.310	0.299

The effect of *Rhizobium* seed treatment on leaf area index of cowpea followed similar trend at all the stages of growth. Higher leaf area index (0.13, 1.48 and 1.75) was recorded with seed treatment as compared to no *Rhizobium* treatment at 20 and 40 DAS and at harvest.

LAI was also differed significantly with respect to foliar nutrition at all the stages of crop growth. At 20 and 40 DAS and at harvest significantly higher LAI of 0.13, 1.49 and 1.84 respectively were recorded with supplementation of 19:19:19 as foliar as compared to fertigation alone.

Drip irrigation x foliar nutrition interaction was significant at 20 and 40 DAS and higher LAI of 2.18 was recorded with treatment combination of drip irrigation at 80 per cent Ep along with foliar nutrition.

4.3.3.5 Leaf area duration (LAD)

The data regarding the leaf area duration are presented in Table 79. Leaf Area Duration (LAD) differed significantly among drip irrigation levels at all the stages of growth. Higher LAD (1.45, 24.66 and 42.27 days) were recorded at drip irrigation treatments of 80 per cent Ep which was on par with that of 100 per cent Ep (control 1) at 20 and 40 DAS and at harvest. Lower LAD of 0.50, 7.81 and 13.76 days were observed in conventional channel irrigation once in 2 days (control 2) at 20 and 40 DAS and at harvest respectively. LAD varied significantly with *Rhizobium* seed treatment at 20 and 40 DAS and at harvest. Maximum LAD was observed with seed treatment of *Rhizobium* as compared to without *Rhizobium* seed treatment.

LAD differed significantly with respect to supplementation of nutrients through foliar at all the stages of crop growth. Maximum LAD (1.28, 19.66 and 33.32 days) was recorded with foliar application along with fertigation treatments at 20 and 40 DAS and at harvest as compared to fertigation alone.

Table 79. Leaf area duration (days) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	Leaf area duration		
	20 DAS	**40 DAS**	**Harvest**
Irrigation (I)			
60 % Ep (I_1)	0.91	9.91	17.16
80 % Ep (I_2)	1.45	24.66	42.27
SE (±m)	0.056	0.560	0.764
C.D. at 5%	0.171	1.699	2.318
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	1.29	18.80	32.27
Without *Rhizobium* (B_2)	1.07	15.77	27.15
SE (±m)	0.056	0.560	0.764
C.D. at 5%	0.171	1.699	2.318
Foliar nutrition (F)			
With foliar nutrition (F_1)	1.28	19.66	33.32
Without foliar nutrition (F_2)	1.08	14.92	26.10
SE (±m)	0.056	0.560	0.764
C.D. at 5%	0.171	1.699	2.318
Interaction			
$I_1B_1F_1$	1.09	11.95	21.07
$I_1B_1F_2$	0.78	9.57	16.71
$I_1B_2F_1$	1.02	9.97	16.77
$I_1B_2F_2$	0.73	8.15	14.08
$I_2B_1F_1$	1.69	30.32	49.77
$I_2B_1F_2$	1.60	23.36	41.54
$I_2B_2F_1$	1.31	26.38	45.67
$I_2B_2F_2$	1.22	18.59	32.08
SE (±m)	0.113	1.120	1.529
C.D. at 5%	NS	NS	NS
Control			
Control 1	1.57	20.67	37.45
Control 2	0.50	7.81	13.76
SE (±m)	0.161	1.034	1.403
C.D. at 5%	0.478	3.073	4.170

4.3.4 Quality parameters

4.3.4.1 Crude fibre

From the Table 80, it is clear that crude fibre content of vegetable cowpea pod differed significantly among drip irrigation levels. Significantly higher crude fibre content (14.07 %) was recorded with control 2 (conventional channel irrigation once in 2 days) which was statistically comparable with drip irrigation of 60 per cent Ep (13.62 %). Lower crude fibre (11.69 %) content was recorded with drip irrigation of 80 % Ep. *Rhizobium* seed treatment did not differ significantly with respect to crude fibre content. Foliar nutrition differed significantly with respect crude fibre content. Foliar nutrition reduced the crude fibre content from 12.93 to 12.39 per cent.

Interaction effect drip irrigation x *Rhizobium*, drip irrigation x foliar nutrition and drip irrigation x *Rhizobium* x foliar nutrition did not differ significantly among crude fibre content of pod. *Rhizobium* x foliar nutrition interaction had a significant effect on crude fibre content. Higher crude fibre content (13.96 %) was recorded in the treatment combination of seed treatment with foliar application of nutrients that of without seed treatment and foliar nutrition.

4.3.4.2 Crude protein

The data on the crude protein content in pod is depicted in Table 80. The content of crude protein differed significantly among drip irrigation levels. The highest content of crude protein (19.49 %) was recorded with drip irrigation of 100 per cent Ep (control 1) which was statistically comparable with drip irrigation of 80 per cent Ep (19.39 %). Minimum content of crude protein (18.81 %) was recorded with control 2 (conventional channel irrigation once in 2 days).

Table 80. Quality parameters of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	Crude fibre (%)	Crude protein (%)
Irrigation (I)		
60 % Ep (I_1)	13.62	18.97
80 % Ep (I_2)	11.69	19.39
SE (±m)	0.111	0.126
C.D. at 5%	0.336	0.381
***Rhizobium* (B)**		
With *Rhizobium* (B_1)	12.62	19.27
Without *Rhizobium* (B_2)	12.70	19.09
SE (±m)	0.111	0.126
C.D. at 5%	NS	NS
Foliar nutrition (F)		
With foliar nutrition (F_1)	12.39	19.46
Without foliar nutrition (F_2)	12.93	18.91
SE (±m)	0.111	0.126
C.D. at 5%	0.336	0.381
Interaction		
$I_1B_1F_1$	13.42	19.44
$I_1B_1F_2$	13.73	18.87
$I_1B_2F_1$	13.38	19.38
$I_1B_2F_2$	13.96	18.21
$I_2B_1F_1$	11.69	19.58
$I_2B_1F_2$	11.63	19.19
$I_2B_2F_1$	11.05	19.43
$I_2B_2F_2$	12.40	19.36
SE (±m)	0.222	0.251
C.D. at 5%	NS	NS
Control		
Control 1	13.14	19.49
Control 2	14.07	18.81
SE (±m)	0.239	0.222
C.D. at 5%	0.711	0.661

Rhizobium seed treatment did not produce variation with respect to crude protein content. Crude protein content of pod was differed significantly with respect to foliar nutrition and higher crude protein content (19.46 %) was recorded with foliar application along with fertigation treatments as compared to fertigation alone.

4.3.5 Plant analysis

4.3.5.1.1 Content of nitrogen in plant

The data pertaining to the content of nitrogen in plant are presented in Table 81. Among the drip irrigation levels, drip irrigation of 100 per cent Ep recorded the highest content of nitrogen (1.41 %) followed by drip irrigation of 80 per cent Ep (1.29 %). Minimum content of nitrogen (1.03 %) was recorded in control 2 (conventional channel irrigation once in 2 days). The content of plant nitrogen among different *Rhizobium* seed treatments did not differ significantly.

Foliar application of nutrients had a significant effect on content of nitrogen in plant. The highest content of nitrogen (1.29 %) was observed with foliar application along with fertigation treatments compared to fertigation alone.

Interaction effect of drip irrigation x *Rhizobium*, drip irrigation x *Rhizobium* x foliar nutrition did not differ significantly with respect to plant nitrogen content.

4.3.5.1.2 Content of phosphorus in plant

The data pertaining to the content of phosphorus in plants are represented in Table 81. Among drip irrigation levels highest content of plant phosphorus (0.15 %) was recorded with drip irrigation of 100 per cent Ep and it was on par with drip irrigation of 80 per cent Ep (0.14 %).The lowest phosphorus content (0.05%) was recorded with control 2 (conventional channel irrigation once in 2

Table 81. Plant nutrient content (%) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	**Nutrient content of plant**		
	N	**P**	**K**
Irrigation (I)			
60 % Ep (I_1)	1.19	0.06	1.68
80 % Ep (I_2)	1.29	0.14	2.39
SE (±m)	0.005	0.003	0.023
C.D. at 5%	0.014	0.008	0.071
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	1.24	0.11	2.03
Without *Rhizobium* (B_2)	1.23	0.10	2.05
SE (±m)	0.005	0.003	0.023
C.D. at 5%	NS	NS	0.071
Foliar nutrition (F)			
With foliar nutrition (F_1)	1.29	0.12	2.24
Without foliar nutrition (F_2)	1.20	0.08	1.84
SE (±m)	0.005	0.003	0.023
C.D. at 5%	0.014	0.008	0.071
Interaction			
$I_1B_1F_1$	1.22	0.08	1.89
$I_1B_1F_2$	1.17	0.05	1.53
$I_1B_2F_1$	1.19	0.07	1.81
$I_1B_2F_2$	1.19	0.04	1.52
$I_2B_1F_1$	1.39	0.17	2.59
$I_2B_1F_2$	1.19	0.12	2.10
$I_2B_2F_1$	1.37	0.16	2.65
$I_2B_2F_2$	1.23	0.13	2.22
SE (±m)	0.009	0.006	0.047
C.D. at 5%	NS	0.017	0.141
Control			
Control 1	1.41	0.15	2.33
Control 2	1.03	0.05	1.22
SE (±m)	0.012	0.007	0.063
C.D. at 5%	0.034	0.021	0.186

days). The phosphorus content did not produce any effect due to *Rhizobium* treatment.

Foliar application of nutrients had a significant effect on content of phosphorus in plant. The highest content of plant phosphorus (0.12 %) was observed with foliar application along with fertigation treatments.

Interaction effect of drip irrigation x *Rhizobium* was found significant with respect to content of phosphorous. Higher phosphorus content was recorded with the treatment combination of drip irrigation of 80 per cent Ep with *Rhizobium* treatment (0.17 %).

4.3.5.1.3 Content of potassium in plants

The data related to the content of potassium in plant at harvest is depicted in Table 81. The content of potassium differed significantly among drip irrigation levels. The highest plant potassium content was recorded with drip irrigation of 80 per cent Ep (2.39 %) which was on par with drip irrigation of 100 per cent Ep (2.33 %). The lowest content was recorded with conventional channel irrigation once in 2 days (control 2). The *Rhizobium* seed treatment had no significant influence on potassium in plant.

Among different foliar nutrition treatments, higher content of potassium in plant (2.24 %) was recorded with foliar application along with fertigation treatments and lower potassium content of 1.84 % was observed in plants with fertigation alone.

4.3.5.1.4 Content of nitrogen in pod

The data related to the content of nitrogen in pod is depicted in Table 82. The content of nitrogen in pod differed significantly among drip irrigation levels. The highest content (3.12 %) was recorded by drip irrigation at 100 per cent Ep (control 1) which was statistically comparable with drip irrigation at 80 per cent Ep (3.10 %). The lowest content of 3.01 per cent was recorded in conventional channel irrigation once in 2 days (control 2).

Among different *Rhizobium* seed treatments the content of nitrogen in pods exhibited statically comparable values. Nitrogen content of pod differed significantly with respect to foliar nutrition. Foliar application along with fertigation treatments has recorded higher nitrogen content of 3.11 % as compared to fertigation alone (3.02 %).

4.3.5.1.5 Content of phosphorus in pod

The data pertaining to the content of phosphorus in pod are presented Table 82 .Among different drip irrigation levels, highest content of phosphorus in pod (0.49 %) was recorded in drip irrigation at 80 per cent Ep which was statistically comparable with drip irrigation at 100 per cent Ep (0.44 %). Lowest content of phosphorus in pod (0.28 %) was recorded in conventional channel irrigation once in 2 days (control 2). Among the *Rhizobium* seed treatment levels, the content of phosphorus in pods exhibited statistically comparable values.

Foliar application levels also exhibited significant difference with respect to content of phosphorus in pod. Foliar application along with fertigation treatments produced higher content of phosphorus in pod (0.44 %) as compared to fertigation alone treatments (0.39 %).

Drip irrigation x *Rhizobium* x foliar nutrition interaction was found significant. Higher phosphorus content (0.59 %) was recorded in the treatment combination of irrigation at 80 per cent Ep with *Rhizobium* seed treatment and foliar nutrition ($I_2B_1F_1$).

Table 82. Nutrient content (%) of cowpea pods under drip irrigation, biofertilizers and foliar nutrition

Treatments	Nutrient content of pod		
	N	**P**	**K**
Irrigation (I)			
60 % Ep (I_1)	3.04	0.33	2.34
80 % Ep (I_2)	3.10	0.49	2.45
SE (±m)	0.020	0.008	0.014
C.D. at 5%	0.061	0.023	0.042
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	3.08	0.40	2.40
Without *Rhizobium* (B_2)	3.05	0.42	2.39
SE (±m)	0.02	0.008	0.014
C.D. at 5%	0.06	NS	0.042
Foliar nutrition (F)			
With foliar nutrition (F_1)	3.11	0.44	2.42
Without foliar nutrition (F_2)	3.02	0.39	2.37
SE (±m)	0.02	0.008	0.014
C.D. at 5%	0.06	0.023	0.042
Interaction			
$I_1B_1F_1$	3.11	0.29	2.39
$I_1B_1F_2$	3.02	0.28	2.34
$I_1B_2F_1$	3.10	0.39	2.36
$I_1B_2F_2$	2.91	0.37	2.27
$I_2B_1F_1$	3.13	0.59	2.46
$I_2B_1F_2$	3.07	0.45	2.43
$I_2B_2F_1$	3.11	0.50	2.48
$I_2B_2F_2$	3.10	0.44	2.43
SE (±m)	0.04	0.015	0.028
C.D. at 5%	NS	0.047	NS
Control			
Control 1	3.12	0.44	2.51
Control 2	3.01	0.28	1.52
SE (±m)	0.036	0.017	0.029
C.D. at 5%	0.106	0.051	0.087

4.3.5.1.6 Content of potassium in pod

The data related to the content of potassium in pod are depicted in the Table 82. The content of potassium differed significantly among drip irrigation levels. Drip irrigation at 100 per cent Ep (control 1) recorded higher content of potassium **(**2.51 %) which was statistically comparable with drip irrigation treatment of 80 per cent Ep (2.45 %). The lowest potassium content was observed in conventional channel irrigation once in 2 days (control 2).The content of potassium did not vary due to *Rhizobium* seed treatment.

Foliar application along with fertigation treatments had significant effect on potassium content of pod. Higher potassium content (2.42 %) was recorded with foliar nutrition compared to alone (2.37 %). Interaction effect (drip irrigation x *Rhizobium*, drip irrigation x foliar nutrition, *Rhizobium* x foliar nutrition and drip irrigation x *Rhizobium* x foliar nutrition) were not significant.

4.3.5.2 Nutrient uptake by plant

4.3.5.2.1 Uptake of nitrogen

The data pertaining to the uptake of nitrogen by plant are presented Table 83. Among the drip irrigation levels, drip irrigation of 100 per cent Ep recorded the highest uptake of nitrogen (116.23 kg/ha) followed by drip irrigation of 80 per cent Ep (113.92 kg/ha). Minimum uptake of nitrogen (70.59 kg/ha) was recorded in drip irrigation of 60 per cent Ep. Foliar application had significant effect on uptake of nitrogen by plant. The highest uptake of nitrogen (99.51 kg/ha) was observed in foliar applied treatments compared to fertigation alone.

4.3.5.2.2 Uptake of phosphorus by plant

The data related to the uptake of phosphorous by plant at harvest is depicted in Table 83. The uptake of phosphorus differ significantly among drip

Table 83. Nutrient uptake (kg/ha) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	Nutrient uptake		
	N	**P**	**K**
Irrigation (I)			
60 % Ep (I_1)	70.59	5.32	84.98
80 % Ep (I_2)	113.92	13.87	133.84
SE (±m)	3.269	0.460	2.644
C.D. at 5%	9.915	1.396	8.019
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	95.00	9.76	116.72
Without *Rhizobium* (B_2)	89.52	9.42	102.11
SE (±m)	3.269	0.460	2.644
C.D. at 5%	NS	NS	8.019
Foliar nutrition (F)			
With foliar nutrition (F_1)	99.51	10.87	118.68
Without foliar nutrition (F_2)	85.01	8.32	100.15
SE (±m)	3.269	0.460	2.644
C.D. at 5%	9.915	1.396	8.019
Interaction			
$I_1B_1F_1$	86.74	5.87	88.67
$I_1B_1F_2$	67.68	4.50	75.41
$I_1B_2F_1$	74.09	6.63	108.08
$I_1B_2F_2$	53.85	4.27	67.78
$I_2B_1F_1$	117.18	16.33	158.22
$I_2B_1F_2$	108.39	12.36	144.59
$I_2B_2F_1$	120.01	14.64	119.75
$I_2B_2F_2$	110.11	12.14	112.81
SE (±m)	6.537	0.921	5.288
C.D. at 5%	NS	NS	16.039
Control			
Control 1	116.23	12.64	149.96
Control 2	91.59	6.84	61.96
SE (±m)	8.27	1.10	7.42
C.D. at 5%	24.59	3.28	22.05

irrigation levels. The highest phosphorus uptake was recorded with drip irrigation of 80 per cent Ep (13.87 kg/ha) found on par with drip irrigation of 100 per cent Ep (12.64 kg/ha) .The lowest uptake (5.32 kg/ha) was recorded in drip irrigation of 60 per cent Ep. The uptake of phosphorous in plant exhibited statistically comparable values with and without *Rhizobium* treatment.

With respect to foliar nutrition, higher uptake of phosphorus (10.84 %) was recorded with foliar application along with fertigation treatments compared to fertigation alone

4.3.5.2.3 Uptake of potassium by plant

The data related to the uptake of potassium by plant at harvest is depicted in Table 83. The uptake of potassium differs significantly among drip irrigation levels. The highest plant potassium uptake was recorded with drip irrigation of 100 per cent Ep (149.96 kg/ha) which statistically comparable with drip irrigation of 80 per cent Ep (133.84 kg/ha).The lowest uptake (61. 96 kg/ha) was recorded with conventional channel irrigation once in 2 days (control 2).

Uptake of potassium differed significantly due to *Rhizobium* seed treatment. Higher uptake of potassium of 116.72 kg/ha was recorded with *Rhizobium* treatment compared to that without *Rhizobium*.

Among different levels of foliar nutrition treatments, higher uptake of potassium by plant (118.68 kg/ha) was recorded with foliar application along with fertigation treatments. Lowest uptake (100.15 %) was recorded with fertigation treatments.

Drip irrigation x foliar nutrition, *Rhizobium* x foliar nutrition and drip irrigation x *Rhizobium* x foliar nutrition interaction was found significant. Higher potassium uptake (158.22 kg/ha) was recorded with combination of irrigation at 80 per cent Ep with *Rhizobium* seed treatment and foliar nutrition ($I_2B_1F_1$).

4.3.6. Microbiological observations

4.3.6.1 Number of effective nodules / plant

The data related to number of effective nodules per plant at fifty per cent flowering is depicted in Table 84. The number of effective nodules per plant differs significantly due drip irrigation levels. The maximum number of effective nodules per plant was recorded with drip irrigation of 80 per cent Ep (13.20) which was statistically comparable with drip irrigation with 100 per cent Ep (12.67). The minimum numbers of effective nodules per plant (3.89) were recorded with conventional channel irrigation once in 2 days (control 2).

The number of effective nodules per plant did not differ to *Rhizobium* seed treatment and foliar nutrition.

4.3.6.2 *Rhizobium* count

The data pertaining to the *Rhizobium* count at flowering and harvest are presented Table 84. At flowering, *Rhizobium* count did not differ significantly among different drip irrigation levels. Even so, higher *Rhizobium* count (17.75 x 10^{-6} cfu/g) was recorded with drip irrigation at 60 per cent Ep. It differed significantly among the *Rhizobium* seed treatment levels. Higher number of *Rhizobium* (20.83 x 10^{-6} cfu/g) was recorded with *Rhizobium* seed treatment compared to without *Rhizobium* treatment (13.83 x 10^{-6} cfu/g). The *Rhizobium* count did not duffer due to foliar nutrition. Almost similar trend followed at harvest also.

Table 84. Number of effective nodules (at flowering) and *Rhizobium* count at flowering and at harvest (cfu x 10^{-6} / g) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	**Number of effective Nodules**	***Rhizobium* count**	
		Flowering	**At harvest**
60 % Ep (I_1)	7.83	17.75	1.52
80 % Ep (I_2)	13.20	16.92	1.75
SE (±m)	1.32	1.649	0.090
C.D. at 5%	4.01	NS	NS
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	11.20	20.83	1.85
Without Rhizobium (B_2)	9.83	13.83	1.42
SE (±m)	1.325	1.64	0.09
C.D. at 5%	NS	5.00	0.27
Foliar nutrition (F)			
With foliar nutrition (F_1)	11.09	17.67	1.67
Without foliar nutrition (F_2)	9.94	17.00	1.60
SE (±m)	1.32	1.64	0.09
C.D. at 5%	NS	NS	NS
Interaction			
$I_1B_1F_1$	9.00	26.33	2.00
$I_1B_1F_2$	7.11	16.67	1.67
$I_1B_2F_1$	8.44	9.00	1.07
$I_1B_2F_2$	6.78	19.00	1.33
$I_2B_1F_1$	14.71	17.33	1.87
$I_2B_1F_2$	14.00	23.00	1.87
$I_2B_2F_1$	12.22	18.00	1.73
$I_2B_2F_2$	11.89	9.33	1.55
SE (±m)	2.65	3.29	0.18
C.D. at 5%	NS	10.00	NS
Control			
Control 1	12.67	8.67	1.23
Control 2	3.89	6.67	0.57
SE (±m)	2.36	2.97	0.17
C.D. at 5%	NS	8.84	0.50

4.3.6.3 Dehydrogenase activity

The data related to the dehydrogenase activity is depicted in Table 85. The dehydrogenase activity differed significantly due to drip irrigation levels. At flowering the highest soil dehydrogenase activity was recorded with drip irrigation of 80 per cent Ep (75.49 µg TPF/24 hrs/g soil). The lowest dehydrogenase activity (52.03 µg TPF/24 hrs/g soil) was recorded with conventional channel irrigation once in 2 days (control 2). Almost similar trend followed at harvest also.

Dehydrogenase activity differed significantly due to the *Rhizobium* seed treatment at flowering. Higher dehydrogenase activity (72.98 µg TPF/24 hrs/g soil) was recorded with *Rhizobium* seed treatment compared to without *Rhizobium* treatment. While at harvest dehydrogenase activity of the soil was statistically comparable with respect to treatment with *Rhizobium*.

Higher dehydrogenase activity (80.49 µg TPF/24 hrs/g soil) was recorded with foliar application of 19: 19: 19 compared to fertigation alone at flowering. While at harvest dehydrogenase activity of the soil was statistically comparable with respect to foliar nutrtion treatment.

Interaction effect (drip irrigation x *Rhizobium*, drip irrigation x foliar nutrition, Rhizobium x foliar nutrition and drip irrigation x *Rhizobium* x foliar nutrition) were not significant.

4.3.6.4 Microbial count

4.3.6.4.1 Bacteria

The data pertaining to the bacterial count at flowering and at harvest are presented Table 86. Among different drip irrigation levels, highest bacterial count (26.67 x 10^{-6} cfu/g) was recorded with drip irrigation at 100 per cent Ep (control1

Table 85. Dehydrogenase activity (µg TPF/24 hrs/g soil) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	Dehydrogenase activity	
	Flowering	**At harvest**
Irrigation (I)		
60 % Ep (I_1)	63.48	163.05
80 % Ep (I_2)	75.49	253.51
SE (±m)	1.956	5.745
C.D. at 5%	5.933	17.427
***Rhizobium* (B)**		
With *Rhizobium* (B_1)	72.98	209.63
Without *Rhizobium* (B_2)	66.00	206.93
SE (±m)	1.956	5.745
C.D. at 5%	5.933	NS
Foliar nutrition (F)		
With foliar nutrition (F_1)	80.49	213.28
Without foliar nutrition (F_2)	58.49	203.28
SE (±m)	1.956	5.745
C.D. at 5%	5.933	NS
Interaction		
$I_1B_1F_1$	73.11	144.38
$I_1B_1F_2$	64.23	170.56
$I_1B_2F_1$	74.48	183.90
$I_1B_2F_2$	42.10	153.36
$I_2B_1F_1$	85.13	296.06
$I_2B_1F_2$	89.23	227.54
$I_2B_2F_1$	69.46	228.79
$I_2B_2F_2$	58.16	261.65
SE (±m)	3.91	11.49
C.D. at 5%	NS	NS
Control		
Control 1	59.40	281.47
Control 2	52.03	143.38
SE (±m)	3.64	10.22
C.D. at 5%	10.84	30.37

followed by drip irrigation at 80 per cent Ep (19.08 x 10^{-6} cfu /g) at flowering. Lowest bacterial count (6.0 x 10^{-6} cfu/g) was recorded in conventional channel irrigation once in 2 days (control 2). While, at harvest bacterial count was statistically comparable with respect to drip irrigation levels.The *Rhizobium* seed treatment and foliar nutrition did not influence the bacterial count at flowering and at harvest.

Interaction effects of drip irrigation x foliar nutrition, *Rhizobium* x foliar nutrition and drip irrigation x *Rhizobium* x foliar nutrition interaction were found significant at flowering stage. Higher bacterial count (25.33 x 10^{-6} cfu/ g) was recorded with the treatment combination of irrigation at 80 per cent Ep without *Rhizobium* seed treatment and foliar nutrition ($I_2B_2F_1$).

4.3.6.4.2 Fungi

The data pertaining to the fungal count at flowering and at harvest are presented Table 87. Among different drip irrigation levels, highest fungal count (51.33 x 10^{-3}cfu / g) were recorded with drip irrigation at 100 per cent Ep (control 1) followed by drip irrigation at 80 per cent Ep (44.17 x 10^{-3} cfu/ g) at flowering. Lowest fungal count (19.50 x 10^{-3} cfu / g) was recorded in drip irrigation at 60 per cent Ep at flowering. Almost similar trend followed at harvest also. Among the *Rhizobium* seed treatment and foliar nutrition levels the fungal count exhibited statistically comparable values at flowering and at harvest.

Drip irrigation x foliar nutrition, *Rhizobium* x foliar nutrition and drip irrigation x *Rhizobium* x foliar nutrition interaction was found non- significant at flowering. However, drip irrigation x foliar nutrition, *Rhizobium* x foliar nutrition and drip irrigation x *Rhizobium* x foliar nutrition interaction was found significant at harvest and highest fungal count (3.33 x 10^{-3} cfu / g) was recorded with drip

Table 86. Bacterial count (10^{-6} cfu /g) of vegetable cowpea under drip irrigation,biofertilizers and foliar nutrition

Treatment	**Bacteria**	
Irrigation (I)	**Flowering**	**At harvest**
60 % Ep (I_1)	6.75	0.65
80 % Ep (I_2)	19.08	2.41
SE (±m)	0.793	0.079
C.D. at 5%	2.406	0.241
***Rhizobium* (B)**		
With *Rhizobium* (B_1)	13.33	1.45
Without *Rhizobium* (B_2)	12.50	1.61
SE (±m)	0.793	0.079
C.D. at 5%	NS	NS
Foliar nutrition (F)		
With foliar nutrition (F_1)	12.50	1.58
Without foliar nutrition (F_2)	13.33	1.48
SE (±m)	0.793	0.079
C.D. at 5%	NS	NS
Interaction		
$I_1B_1F_1$	9.33	0.40
$I_1B_1F_2$	6.67	0.67
$I_1B_2F_1$	6.00	0.93
$I_1B_2F_2$	5.00	0.60
$I_2B_1F_1$	21.00	2.63
$I_2B_1F_2$	16.33	2.10
$I_2B_2F_1$	13.67	2.37
$I_2B_2F_2$	25.33	2.53
SE (±m)	1.587	0.159
C.D. at 5%	4.813	NS
Control		
Control 1	26.67	3.53
Control 2	6.00	0.60
SE (±m)	1.49	0.14
C.D. at 5%	4.45	0.43

Table 87. Fungal count (10^{-3} cfu /g) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatment	Fungi	
	Flowering	Harvest
Irrigation (I)		
60 % Ep (I_1)	19.50	2.22
80 % Ep (I_2)	44.17	2.58
SE (±m)	1.180	0.063
C.D. at 5%	3.580	0.192
***Rhizobium* (B)**		
With *Rhizobium* (B_1)	33.25	2.33
Without *Rhizobium* (B_2)	30.42	2.47
SE (±m)	1.180	0.063
C.D. at 5%	NS	NS
Foliar nutrition (F)		
With foliar nutrition (F_1)	31.00	2.41
Without foliar nutrition (F_2)	32.67	2.39
SE (±m)	1.180	0.063
C.D. at 5%	NS	NS
Interaction		
$I_1B_1F_1$	9.33	2.30
$I_1B_1F_2$	6.67	2.33
$I_1B_2F_1$	6.00	2.50
$I_1B_2F_2$	5.00	1.73
$I_2B_1F_1$	21.00	2.53
$I_2B_1F_2$	16.33	2.17
$I_2B_2F_1$	13.67	2.30
$I_2B_2F_2$	25.33	3.33
SE (±m)	1.587	0.127
C.D. at 5%	NS	0.385
Control		
Control 1	51.33	3.50
Control 2	37.00	2.23
SE (±m)	3.80	0.12
C.D. at 5%	11.30	0.35

irrigation at 80 per cent Ep without *Rhizobium* seed treatment and foliar nutrition ($I_2B_2F_2$).

4.3.6.4.3 Actinomycetes

The data pertaining to the actinomycetes count at flowering and at harvest are presented Table 88. The actinomycetes count did not differ significantly among drip irrigation levels at flowering. Among the *Rhizobium* seed treatment levels and foliar nutrition levels the fungal count exhibited statistically comparable values at flowering and at harvest. Interaction effect (drip irrigation x *Rhizobium*, drip irrigation x foliar nutrition, *Rhizobium* x foliar nutrition and drip irrigation x *Rhizobium* x foliar nutrition) was on par with respect to actinomycetes count in soil under open precision farming.

4.3.7 Water productivity

The data regarding the water productivity is depicted in Table 88. Water productivity of bush type vegetable cowpea differed significantly among irrigation levels. Drip irrigation at 80 per cent Ep recorded highest water productivity (105.38 kg/ha-mm) and found on par with drip irrigation at 100 per cent Ep (92.76 kg/ha-mm). Lowest water productivity was recorded with conventional channel irrigation once in 2 days (control 2) (2.38 kg/ha-mm). Water productivity had no significant difference among *Rhizobium* seed treatments. Among different levels of foliar nutrition treatments, higher water productivity (100.52 kg/ha-mm) was recorded with foliar application along with fertigation treatments. Lowest water productivity (86.28 kg/ha-mm) was recorded without foliar application treatments.

Interaction effect (drip irrigation x *Rhizobium*, drip irrigation x foliar nutrition, *Rhizobium* x foliar nutrition and drip irrigation x *Rhizobium* x foliar

Table 88. Actinomycetes count (10^{-5} cfu /g) and water productivity (kg/ha-mm) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Irrigation (I)	**Actinomycetes**		**Water productivity**
	Flowering	**Harvest**	
60 % Ep (I_1)	19.08	2.03	81.42
80 % Ep (I_2)	20.75	1.80	105.38
SE (±m)	1.307	0.123	4.117
C.D. at 5%	NS	NS	12.487
***Rhizobium* (B)**			
With *Rhizobium* (B_1)	21.67	1.88	97.33
Without *Rhizobium* (B_2)	18.17	1.95	89.47
SE (±m)	1.307	0.123	4.117
C.D. at 5%	NS	NS	NS
Foliar nutrition (F)			
With foliar nutrition (F_1)	20.75	2.08	100.52
Without foliar nutrition (F_2)	19.08	1.75	86.28
SE (±m)	1.307	0.123	4.117
C.D. at 5%	NS	NS	12.487
Interaction			
$I_1B_1F_1$	24.33	2.47	101.88
$I_1B_1F_2$	17.67	1.73	79.74
$I_1B_2F_1$	18.00	2.30	84.88
$I_1B_2F_2$	16.33	1.63	59.20
$I_2B_1F_1$	22.33	1.77	104.45
$I_2B_1F_2$	22.33	1.57	103.25
$I_2B_2F_1$	18.33	1.80	110.88
$I_2B_2F_2$	20.00	2.07	102.94
SE (±m)	2.614	0.247	8.234
C.D. at 5%	NS	NS	NS
Control			
Control 1	19.67	1.53	92.76
Control 2	10.00	1.00	2.38
SE (±m)	2.39	0.224	8.24
C.D. at 5%	7.11	0.666	24.50

nutrition) were on par with respect to water productivity of vegetable cowpea at harvest under open precision farming.

4.3.8 Nutrient content of soil

4.3.8.1 EC of the soil

The electrical conductivity of the soil differed significantly among drip irrigation levels (Table 89). Higher electrical conductivity (0.11 dS/m) was recorded with drip irrigation at 60% Ep followed by drip irrigation treatments of 80 and 100 per cent Ep (control 1). Electrical conductivity of soil were statistically comparable with respect to *Rhizobium* seed treatment and foliar nutrition. Interaction effect was also statistically comparable with respect to electrical conductivity of the soil.

4.3.8.2 Soil pH

The pH of the soil did not differ significantly among drip irrigation levels (Table 89). They were also on par with *Rhizobium* seed treatment and foliar nutrition. The interaction effect was also on par.

4.3.8.3 Organic carbon content of soil

Organic carbon content of soil differed significantly with respect to irrigation levels (Table 89). Conventional channel irrigation once in 2 days (control 2) recorded maximum organic carbon content (0.76 %) and lowest organic carbon content was with 80 and 100 per cent Ep (0.64 %). The seed treatment with *Rhizobium* did not produce variation with respect to organic carbon content.

Foliar nutrition levels exhibited significant difference with respect to organic carbon content. Maximum organic carbon content (0.70 %) was recorded with fertigation alone as compared to foliar application along with

Table 89. Electrical conductivity (dS/m), pH, Organic carbon content (%) and available soil nitrogen content (kg/ha) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	EC	pH	OC	N
Irrigation (I)				
60 % Ep (I_1)	0.11	6.24	0.73	160.19
80 % Ep (I_2)	0.08	6.19	0.64	148.74
SE (±m)	0.002	0.017	0.008	0.645
C.D. at 5%	0.006	NS	0.024	1.958
***Rhizobium* (B)**				
With *Rhizobium* (B_1)	0.09	6.19	0.69	155.27
Without *Rhizobium* (B_2)	0.10	6.23	0.68	153.66
SE (±m)	0.002	0.017	0.008	0.645
C.D. at 5%	NS	NS	NS	1.958
Foliar nutrition (F)				
With foliar nutrition (F_1)	0.10	6.20	0.67	153.47
Without foliar nutrition (F_2)	0.09	6.22	0.70	155.46
SE (±m)	0.002	0.017	0.008	0.645
C.D. at 5%	NS	NS	0.67	1.958
Interaction				
$I_1B_1F_1$	0.10	6.24	0.73	160.22
$I_1B_1F_2$	0.11	6.25	0.74	163.11
$I_1B_2F_1$	0.19	6.23	0.71	157.66
$I_1B_2F_2$	0.18	6.23	0.75	159.76
$I_2B_1F_1$	0.09	6.13	0.65	146.74
$I_2B_1F_2$	0.08	6.16	0.66	151.01
$I_2B_2F_1$	0.09	6.22	0.60	149.28
$I_2B_2F_2$	0.08	6.23	0.66	147.95
SE (±m)	0.004	0.034	0.016	1.291
C.D. at 5%	NS	NS	NS	3.916
Control				
Control 1	0.06	6.18	0.64	144.27
Control 2	0.10	6.30	0.76	159.64
SE (±m)	0.002	0.029	0.015	1.819
C.D. at 5%	0.007	0.085	0.044	5.406

fertigation treatments treatments (0.67 %). Interaction effect was on par with respect to organic carbon content of soil.

4.3.8.4 Available nitrogen content of soil

Significantly different available nitrogen content was observed among irrigation levels (Table 89). The available nitrogen content was highest (160.19 kg/ha) with drip irrigation at 60% Ep and minimum of 144.27 kg/ha was recorded with drip irrigation at 100 per cent Ep (control 1). The seed treatment with *Rhizobium* did not produce with respect to available nitrogen content of soil.

Foliar application treatments had a significant effect on available nitrogen content of soil. The higher available nitrogen content of soil (155.46 kg/ha) was observed fertigation alone treatments and lowest was observed with foliar application along with fertigation treatments (153.47 kg/ha). Interaction effect was statistically comparable with respect to available nitrogen content.

4.3.8.5 Available phosphorus content of soil

The data pertaining to the content of available phosphorus in soil are presented Table 90. Among different drip irrigation levels, highest content of available phosphorus in soil was recorded in conventional channel irrigation once in 2 days (control 2) (15.98 kg/ha) which was found on par with that at 60 per cent Ep (15.58 kg/ha). Lowest content of available phosphorus in soil (14.71 kg/ha) was recorded with drip irrigation at 100 per cent Ep. Among the *Rhizobium* seed treatment, the content of phosphorus in soil exhibited statistically comparable values.

Foliar application also exhibited significant difference with respect to content of available phosphorus in soil. Higher available soil phosphorus (16.08 kg/ha) as compared to foliar application along with fertigation treatments

Table 90. Available soil phosphorus, potassium (kg/ha), calcium, magnesium and sulphur (mg/kg) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	P	K	Ca	Mg	S
Irrigation (I)					
60 % Ep (I_1)	15.58	432.38	600.42	129.16	11.35
80 % Ep (I_2)	14.84	416.49	579.06	124.24	10.66
SE (±m)	0.104	2.159	0.998	0.378	0.056
C.D. at 5%	0.316	6.550	3.028	1.148	0.171
***Rhizobium* (B)**					
With *Rhizobium* (B_1)	15.17	422.88	588.36	126.72	11.00
Without *Rhizobium* (B_2)	15.26	425.99	591.12	126.68	11.00
SE (±m)	0.104	2.159	0.998	0.378	0.056
C.D. at 5%	NS	NS	NS	NS	0.171
Foliar nutrition (F)					
With foliar nutrition (F_1)	14.34	420.91	586.14	124.69	10.89
Without foliar nutrition (F_2)	16.08	427.96	593.34	128.70	11.11
SE (±m)	0.104	2.159	0.998	0.378	0.056
C.D. at 5%	0.316	6.550	3.028	1.148	0.171
Interaction					
$I_1B_1F_1$	15.01	430.68	591.42	129.46	11.07
$I_1B_1F_2$	15.99	434.28	604.21	131.64	11.63
$I_1B_2F_1$	15.17	433.84	601.93	126.90	11.22
$I_1B_2F_2$	16.14	430.73	604.12	128.63	11.46
$I_2B_1F_1$	13.62	404.08	575.35	120.70	10.55
$I_2B_1F_2$	16.03	422.49	582.46	125.08	10.76
$I_2B_2F_1$	13.55	415.02	575.86	121.70	10.72
$I_2B_2F_2$	16.16	424.35	582.58	129.48	10.59
SE (±m)	0.209	4.319	1.996	0.757	0.112
C.D. at 5%	NS	NS	NS	NS	0.341
Control					
Control 1	14.71	415.14	568.19	122.49	10.66
Control 2	15.98	424.65	598.73	129.86	11.06
SE (±m)	0.202	3.830	2.390	0.911	0.144
C.D. at 5%	NS	11.379	7.102	2.708	0.428

treatments (14.34 kg/ha) was recorded in plants applied fertilizers through soil alone. Interaction effect was also on par with respect to available phosphorous content of soil.

4.3.8.6 Available potassium content of soil

The data related to the content of available potassium in soil are depicted in the Table 90. The content of potassium differed significantly among drip irrigation levels. The highest potassium content (432.28 kg/ha) in soil was recorded in drip irrigation treatments of 60 per cent Ep which was statistically comparable with conventional channel irrigation once in 2 days (control 2) **(**424.65 kg/ha). The lowest potassium (415.14 kg/ha) content was recorded with 100 per cent Ep and which found on par with that of 80 per cent Ep. The content of available potassium in soil did not differ significantly due to *Rhizobium* treatment.

The foliar nutrition of 19:19:19 had significant effect on available potassium content of soil. Higher soil available potassium content (427.96 kg/ha) was observed under fertigation as compared to foliar application along with fertigation treatments (420.91 kg/ha). Interaction effect was on par with respect to available potassium content of soil under open precision farming.

4.3.8.7 Available calcium content of soil

The available calcium content of soil differed significantly among levels of drip irrigation (Table 90). Among the drip irrigation levels, drip irrigation of 60 per cent Ep recorded the highest calcium (600.42 mg/kg) which was on par with conventional channel irrigation once in 2 days (control 2) (598.73 mg/kg). Minimum available calcium content (568.19 mg/kg) was recorded in 100 per cent Ep (control 1) followed by drip irrigation of 80 per cent Ep.

Foliar application treatments had a significant effect on available calcium content of soil. The highest available calcium content (593.34 mg/kg) was observed under fertigation alone and lowest calcium content (586.14 mg/kg) was observed with foliar application along with fertigation treatments.

Interaction effects (drip irrigation x *Rhizobium*, drip irrigation x foliar nutrition, *Rhizobium* x foliar nutrition and drip irrigation x *Rhizobium* x foliar nutrition) were on par with respect to available soil calcium content.

4.3.8.8 Available magnesium content of soil

The available magnesium content of soil differed significantly among levels of drip irrigation (Table 90). Among the irrigation levels, conventional channel irrigation once in 2 days (control 2) (129.86 mg/kg) recorded the highest magnesium content which was found on par with drip irrigation at 60 per cent Ep (129.16 mg/kg). Minimum available magnesium content was recorded with (122.49 mg/kg) drip irrigation at 100 per cent Ep which was found on par with that 80 per cent Ep (124.24 mg/kg).

Foliar application had a significant effect on available magnesium content of soil. The highest available magnesium content of soil (128.70 mg/kg) was observed with fertigation and lowest magnesium content (124.69 mg/kg) was observed with foliar application along with fertigation treatments.

Interaction effects (drip irrigation x *Rhizobium*, drip irrigation x foliar nutrition, rhizofbium x foliar nutrition and drip irrigation x *Rhizobium* x foliar nutrition) were on par with respect to available soil magnesium content.

4.3.8.9 Available sulphur content of soil

The data pertaining to the content of available sulphur in soil are presented Table 90. Among the drip irrigation levels, drip irrigation at 60 per cent Ep recorded the highest sulphur content of soil (11.35 mg/kg) which was found on par with conventional channel irrigation once in 2 days (control 2) (11.06 mg/kg). Lowest content of available sulphur (10.66 mg/kg) was recorded with drip irrigation at 80 and 100 per cent Ep. The *Rhizobium* seed treatment did not differ with respect to the content of sulphur.

Foliar application also exhibited significant difference with respect to content of available sulphur in soil. Available soil sulphur (11.11 mg/kg) was higher in the treatments with fertigation as compared to foliar application along with fertigation (10.89 mg/kg). Interaction effect was also on par with respect to available sulphur content of soil.

4.3.8.10 Available Iron content of soil

The data pertaining to the content of available iron in soil are presented Table 91. Among the drip irrigation levels, drip irrigation of 60 per cent Ep recorded the highest iron content (16.46 mg/kg) which was found on par with conventional channel irrigation once in 2 days (control 2) (16.20 mg/kg). Lowest content of available iron in soil (15.44 mg/kg) was recorded with drip irrigation at 100 per cent Ep which was found on par with that at 80 per cent Ep (15.72 mg/kg). The *Rhizobium* seed treatment did not affect the content of iron in soil.

Foliar application exhibited significant difference with respect to content of available iron in soil. Higher available iron content of soil was recorded in fertigation treatments (16.36 mg/kg) as compared to foliar application along with fertigation treatments (15.82 mg/kg). Interaction effect was also on par with respect to available iron content of soil.

4.3.8.11 Available zinc content of soil

The data pertaining to the content of available zinc in soil are presented in Table 91 .Among different drip irrigation levels, highest content of available zinc in soil was recorded in conventional channel irrigation once in 2 days (control 2) (3.53 mg/kg) which was found on par with drip irrigation at 60 per cent Ep (3.52 mg/kg). Lowest content of available zinc in soil (3.40 mg/kg) was recorded with drip irrigation at 80 per cent Ep which was found on par with that at 100 per cent Ep (3.43 mg/kg). The *Rhizobium* seed treatment did not influence the content of zinc content of soil.

Foliar application also exhibited significant difference with respect to content of available zinc in soil. Fertigation treatments recorded higher available soil zinc (3.49 mg/kg) as compared to foliar application along with fertigation treatments (3.44 mg/kg). Interaction effect was also on par with respect to available zinc content of soil.

4.3.8.12 Available manganese content of soil

Manganese content of soil differed significantly with respect to irrigation levels (Table 91). Drip irrigation at 60 per cent Ep recorded maximum manganese content (57.83 mg/kg) and lowest with drip irrigation at 80 and 100 per cent Ep (56.75 and 56.79 mg/kg). The seed treatment with and without *Rhizobium* were statistically comparable with respect to manganese content.

Foliar nutrition levels exhibited significant difference with respect to manganese content. Maximum manganese content (57.76 mg/kg) was recorded with fertigation alone as compared to foliar application along with fertigation (56.79 mg/kg). Interaction effect was on par with respect to manganese content of soil.

4.3.8.13 Available copper content of soil

The available copper content of soil differed significantly among levels of drip irrigation (Table 91). Among the drip irrigation levels, drip irrigation of 60 per cent Ep recorded the highest copper (3.57 mg/kg) which was found on par with conventional channel irrigation once in 2 days (control 2) (3.56 mg/kg). Lowest content (3.51mg/kg) was recorded with drip irrigation of 80 per cent Ep followed by drip irrigation of 100 per cent Ep (control 1).

Foliar application treatments had a significant effect on available copper content of soil. The highest available copper content (3.56 mg/kg) was observed in treatments with fertigation alone. Lowest available soil copper content (3.52 mg/kg) was observed under foliar application along with fertigation.

Interaction effects (drip irrigation x *Rhizobium*, drip irrigation x foliar nutrition, *Rhizobium* x foliar nutrition and drip irrigation x *Rhizobium* x foliar nutrition) were on par with respect to available soil copper content.

4.3.8.14 Available boron content of soil

The data pertaining to the content of available boron in soil are presented Table 91. Among the drip irrigation levels, drip irrigation of 60 per cent Ep recorded the highest boron content (0.67mg/kg) which was found on par with conventional channel irrigation once in 2 days (control 2) (0.66 mg/kg). Lowest content of available boron in soil (0.61 mg/kg) was recorded with drip irrigation at 100 per cent Ep which was found on par with that at 80 per cent Ep (0.63 mg/kg). The *Rhizobium* seed treatment had significant effect on the content of boron in soil. The seed treatment with *Rhizobium* recorded lowest content of available boron in soil (0.65 mg/kg)

Table 91. Available soil Iron, Zinc, Manganese, Copper and Boron (mg/kg) under drip irrigation, biofertilizers and foliar nutrition

Treatments	Fe	Zn	Mn	Cu	B
Irrigation (I)					
60 % Ep (I_1)	16.46	3.52	57.83	3.57	0.67
80 % Ep (I_2)	15.72	3.40	56.75	3.51	0.63
SE (±m)	0.085	0.009	0.196	0.011	0.003
C.D. at 5%	0.258	0.026	0.594	0.034	0.009
***Rhizobium* (B)**					
With *Rhizobium* (B_1)	16.21	3.47	57.49	3.54	0.65
Without *Rhizobium* (B_2)	15.96	3.46	57.07	3.54	0.66
SE (±m)	0.085	0.009	0.196	0.011	0.003
C.D. at 5%	0.258	0.026	0.594	0.034	0.009
Foliar nutrition (F)					
With foliar nutrition (F_1)	15.82	3.44	56.79	3.52	0.63
Without foliar nutrition (F_2)	16.36	3.49	57.76	3.56	0.68
SE (±m)	0.085	0.009	0.196	0.011	0.003
C.D. at 5%	0.258	0.026	0.594	0.034	0.009
Interaction					
$I_1B_1F_1$	16.35	3.50	57.51	3.56	0.66
$I_1B_1F_2$	16.96	3.59	58.46	3.58	0.69
$I_1B_2F_1$	15.87	3.48	57.16	3.52	0.67
$I_1B_2F_2$	16.65	3.52	58.12	3.61	0.66
$I_2B_1F_1$	15.60	3.38	56.41	3.47	0.64
$I_2B_1F_2$	15.94	3.40	57.58	3.53	0.66
$I_2B_2F_1$	15.46	3.39	56.10	3.51	0.62
$I_2B_2F_2$	15.88	3.44	56.90	3.52	0.62
SE (±m)	0.170	0.017	0.391	0.023	0.006
C.D. at 5%	0.516	0.052	1.187	0.069	0.019
Control					
Control 1	15.44	3.43	56.79	3.55	0.61
Control 2	16.20	3.53	57.81	3.56	0.66
SE (±m)	0.186	0.020	0.411	0.022	0.006
C.D. at 5%	0.552	0.060	1.221	0.065	0.018

Foliar application exhibited significant difference with respect to content of available boron in soil. Higher available boron content of soil was recorded with fertigation alone (0.68 mg/kg as compared to foliar application along with fertigation (0.63 mg/kg). Interaction effect was also on par with respect to available boron content of soil.

4.3.9 Economics of cultivation

The data regarding net return and B: C ratio is presented in Table 92. The net returns differed significantly with drip irrigation levels. Drip irrigation at 100 per cent Ep recorded maximum net returns of Rs. 173,395 which was on par with that at drip irrigation of 80 per cent Ep (Rs. 166,235) at harvest. Least net return was observed in control 2 (conventional channel irrigation once in 2 days). The seed treatment had no significant effect with respect to net returns at harvest.

Supplementation of nutrients through foliar application also exhibited significant difference with respect to net returns. Foliar application along with fertigation produced higher net return (Rs. 82,880) as compared to fertigation treatments (Rs.18,889). Almost similar trend was observed for B: C ratio also.

Table 92. Net returns (Rs./ha) and B: C Ratio of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatments	Net returns	B:C Ratio
Irrigation (I)		
60 % Ep (I_1)	-64464	0.81
80 % Ep (I_2)	166235	1.40
SE (±m)	12366	0.029
C.D. at 5%	37509	0.087
***Rhizobium* (B)**		
With *Rhizobium* (B_1)	57918	1.11
Without *Rhizobium* (B_2)	43852	1.10
SE (±m)	12366	0.029
C.D. at 5%	NS	NS
Foliar nutrition (F)		
With foliar nutrition (F_1)	82880	1.20
Without foliar nutrition (F_2)	18889	1.01
SE (±m)	12366	0.029
C.D. at 5%	37509	0.087
Interaction		
$I_1B_1C_1$	-29948	0.88
$I_1B_1C_2$	-54222	0.82
$I_1B_2C_1$	-32490	0.94
$I_1B_2C_2$	-141197	0.61
$I_2B_1C_1$	212796	1.55
$I_2B_1C_2$	103048	1.21
$I_2B_2C_1$	181166	1.44
$I_2B_2C_2$	167931	1.41
SE (±m)	24732	0.057
C.D. at 5%	NS	NS
Control		
Control 1	172395	1.37
Control 2	-2846014	1.15
SE (±m)	35305	0.082
C.D. at 5%	104897	0.243

DISCUSSION

5. DISCUSSION

The experiments entitled "Agro techniques for bush type vegetable cowpea (*Vigna unguiculata* (L.) Walp.) under open precision farming" was conducted during 2017 - 19 at Agricultural Research Station, Kerala Agricultural University, Thrissur, Kerala and the results obtained are discussed below.

5.1 Experiment 1: Evaluation of genotypes and optimization of spacing for enhanced growth and yield of bush type vegetable cowpea under open precision farming

5.1.1 Effect of spacing and genotypes on growth and productivity of bush type vegetable cowpea under open precision farming

The growth characters obtained at different growth phases clearly shown the influence of spacing on its growth. The plant height recorded at 20 and 40 DAS and at harvest from different spacing treatments revealed that wider row spacing produced tallest plants at different stages of growth. The wider spacing also recorded higher number of leaves at different growth phases of bush type vegetable cowpea (Fig. 4). This could be due to reduced competition among the plants and also with optimum spacing, the plants would be able to utilize the soil moisture and nutrients more effectively as reported by Galwab and Kamau (2017) and Lum *et al.* (2018) in vegetable cowpea. Plant height of cowpea differed significantly among genotypes. VU-5 was the tallest one among the six genotypes. The maximum number of leaves per plant was recorded with Anaswara.

Wider spacing achieved maximum dry matter production and least from narrow row spacing (Fig. 6). The result complies with the results recorded by Galwab and Kamau (2017) in cowpea. The favorable condition due to reduced competition for better growth led to higher production of dry matter in this treatment. Among different genotypes, Anaswara recorded maximum dry matter production at harvest. Anaswara is a semi trailing variety developed by KAU, which produced maximum plant height and number of leaves per plant. This might have contributed to the higher dry matter production per plant.

The leaf area index was significantly superior with narrow row spacing. The results are in conformity with the work of Abuzar *et al.,* (2011) and Muoneke *et al.,*(2013). This might be due to increased plant density at narrow row spacing which increases leaf area index on account of more area occupied by green canopy of plants per unit area. Higher leaf area index was also reported with higher plant density in the work of Njoku and Muoneke (2008). The genotype Anaswara exhibited significantly higher leaf area index followed by Bhagyalakshmi

Spacing failed to produce significant effect on flowering, pod length and duration of the cowpea. The non-significant effect of spacing on days to 50 per cent flowering, pod length and duration of the cowpea was also reported by Satodiya *et al*. (2015). But days to 50 per cent flowering, pod length and duration of the cowpea was significantly differed among genotypes. Genotype Lalita attained fifty per cent flowering earlier (32.55 days) than the other genotypes and produced longer pods. Among the genotypes, Anaswara attained final maturity lately. Genotypes vary in their potential to express their vigour for growth and yield and Lalita is a commercially exploited high yielding variety with higher yield potential and recorded higher yield in the experiment also.

Number of pods per plant is an important yield attributes of vegetable cowpea. Spacing had a significant effect on number of pods produced per plant (Fig. 7). Wider row spacing produced maximum number of pods per plant. This might be due to, reduction in the mutual shading and competition under wider row spacing which provides more space per plant ultimately leads to enhanced nutrients, moisture and light availability with corresponding increase in the absorption and assimilation of photosynthetic active radiation for the eventual production of dry matter. The results are in conformity with the work of Reddy (2010) for french bean and Patel *et al*. (2010) for moth bean. This corroborates the earlier work of Asiwe *et al.* (2004) who reported that pod yield increased as plant population decreased in comparison to the higher population. The result of Hamad (2004) also indicated that plants produced at the higher densities set fewer pods than those at the lower densities. Among cowpea genotypes higher number of pods per plant was recorded with genotype Bhagyalakshmi, Pusa Komal and Lalita.

Spacing also had significant effect on yield per plant. Higher yield per plant was recorded with wider row spacing. The fresh pod yield was statistically on par with respect to row spacing. This might be due to the positive correlation between increased number of pods and yield per plant at wider row spacing. Moreover, at wider row spacing individual plants might have enjoyed more suitable environment for fully utilizing the available space, light and nutrients and more photosynthates were translocated from source to sink (Satodiya *et al*., 2015). The genotype Lalita recorded the highest yield due to favourable yield attributes produced by it.

5.1.2 Effect of spacing and genotypes on quality, nutrient content and nutrient uptake of bush type vegetable cowpea under open precision farming

Among the spacing treatments, the content of crude protein and crude fibre content in pod did not differ significantly. The non-significant effect of spacing on crude protein and crude fibre content was also reported by many workers (Joshi and Rahevar, 2015; Jagadale *et al.*, 2017) in vegetable cowpea.

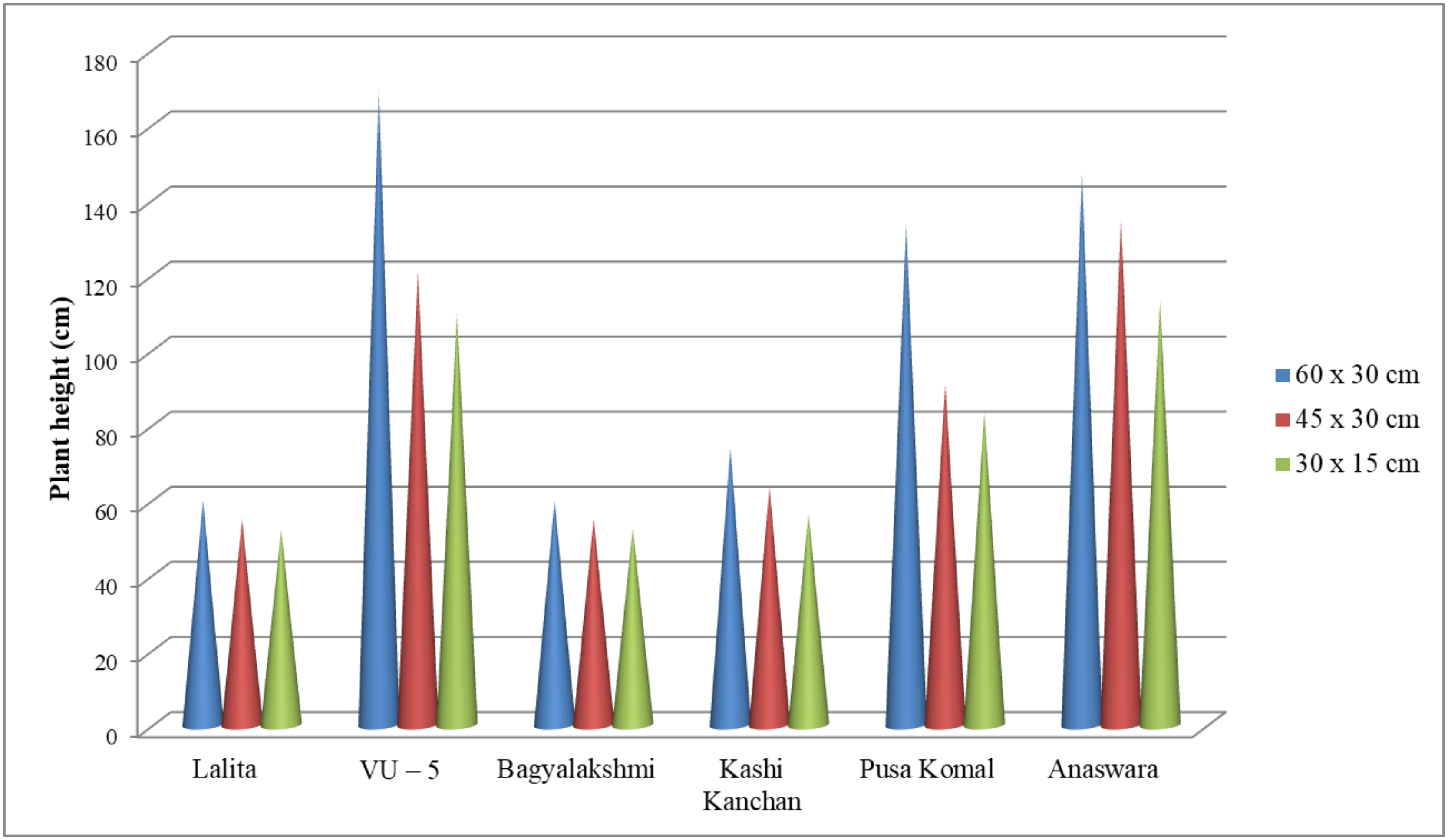


Fig.4 Plant height (cm) of cowpea genotypes influenced by spacing (at harvest)

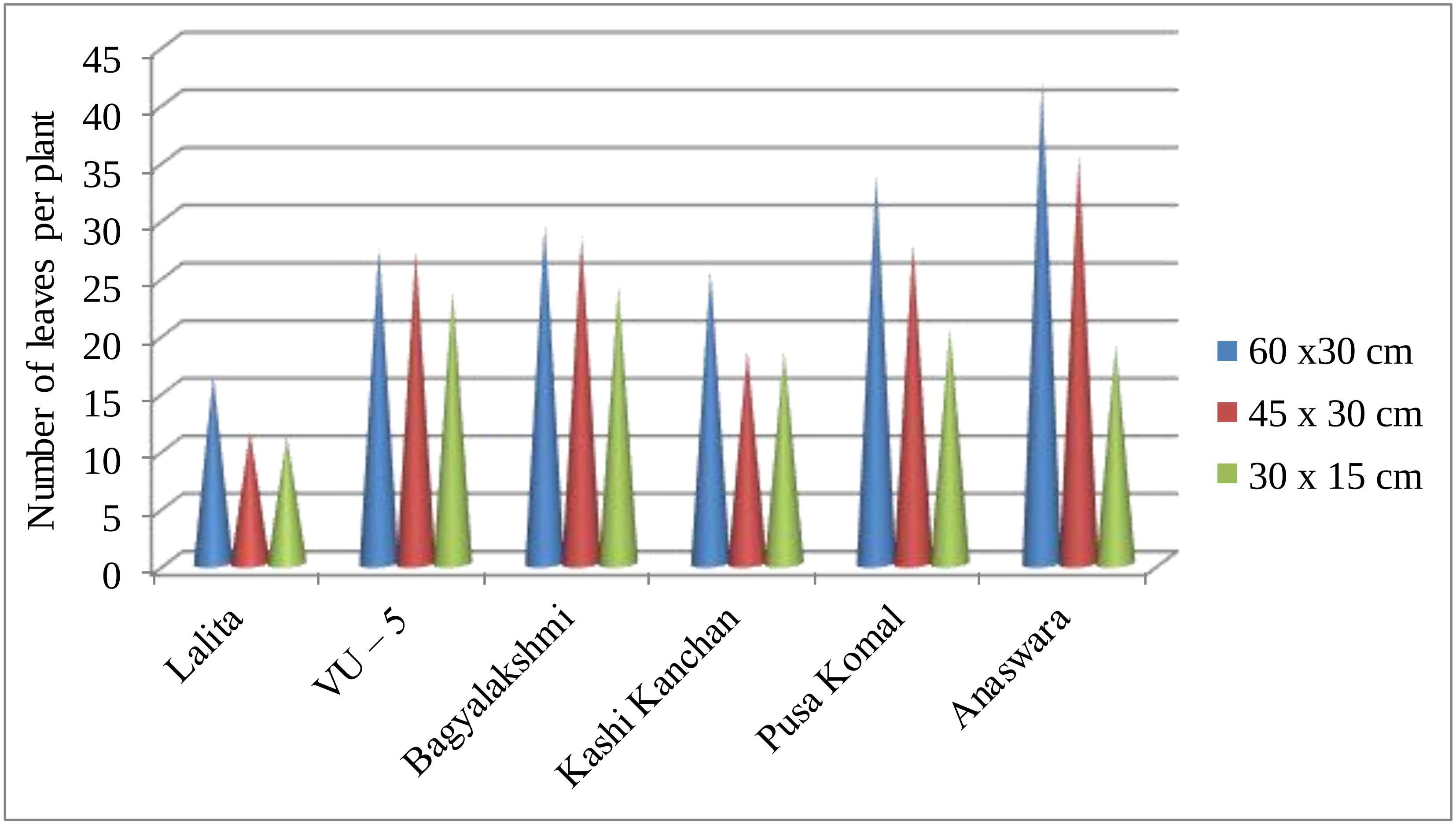


Fig.5 Number of leaves per plant of cowpea genotypes influenced by spacing (at harvest)

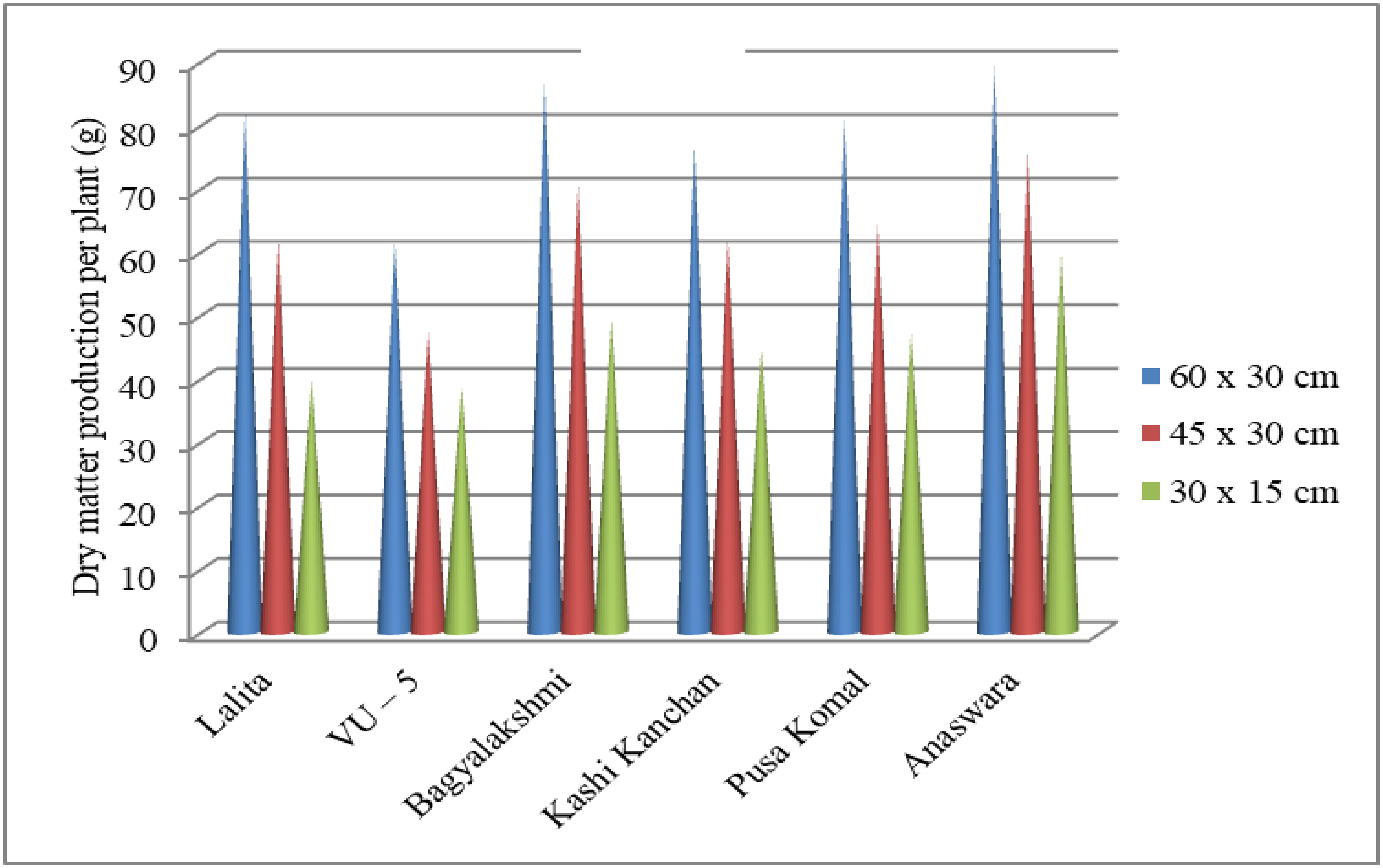


Fig.6 Dry matter production per plant (g) of cowpea genotypes influenced by spacing

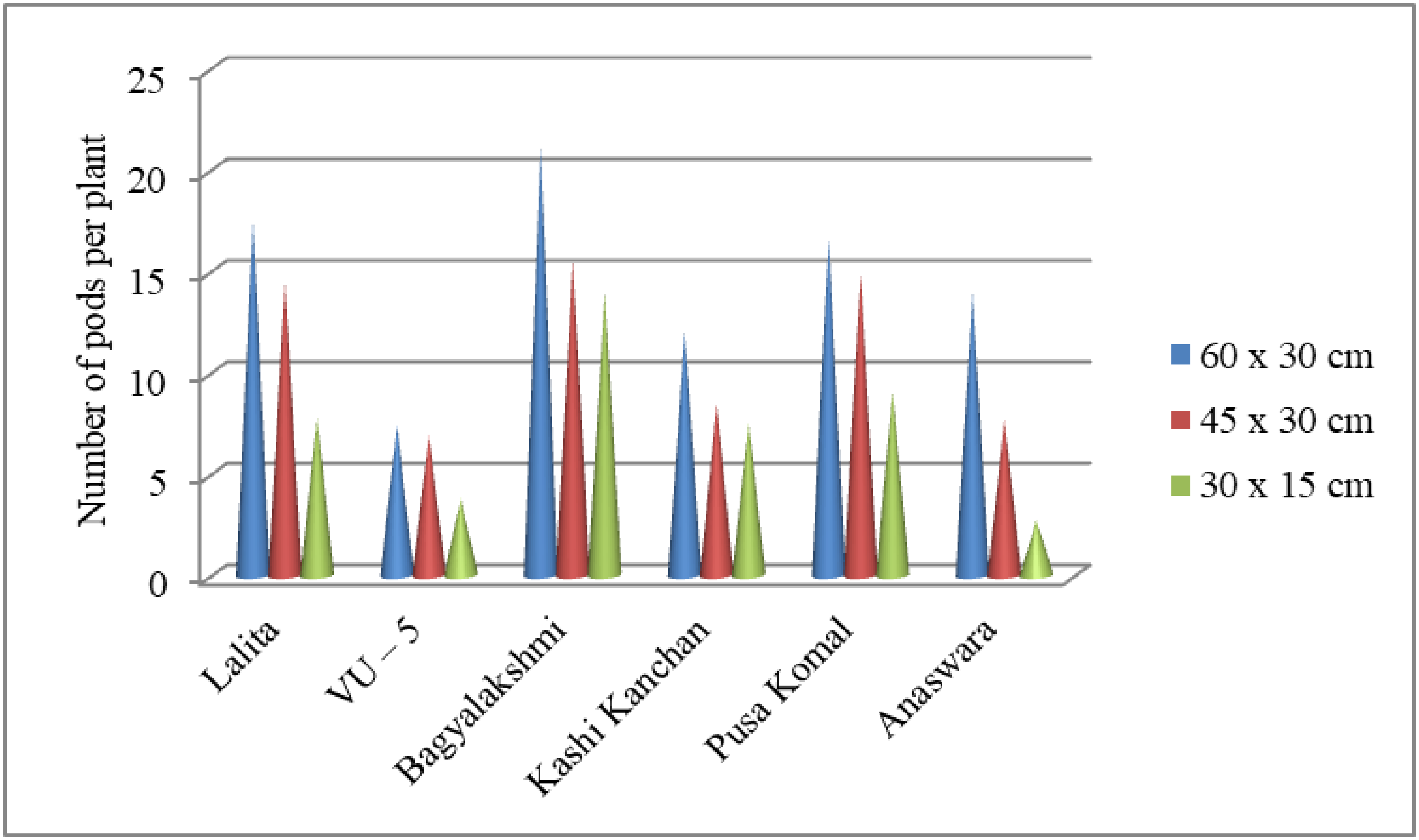


Fig.7 Number of pods per plant of cowpea genotypes influenced by spacing

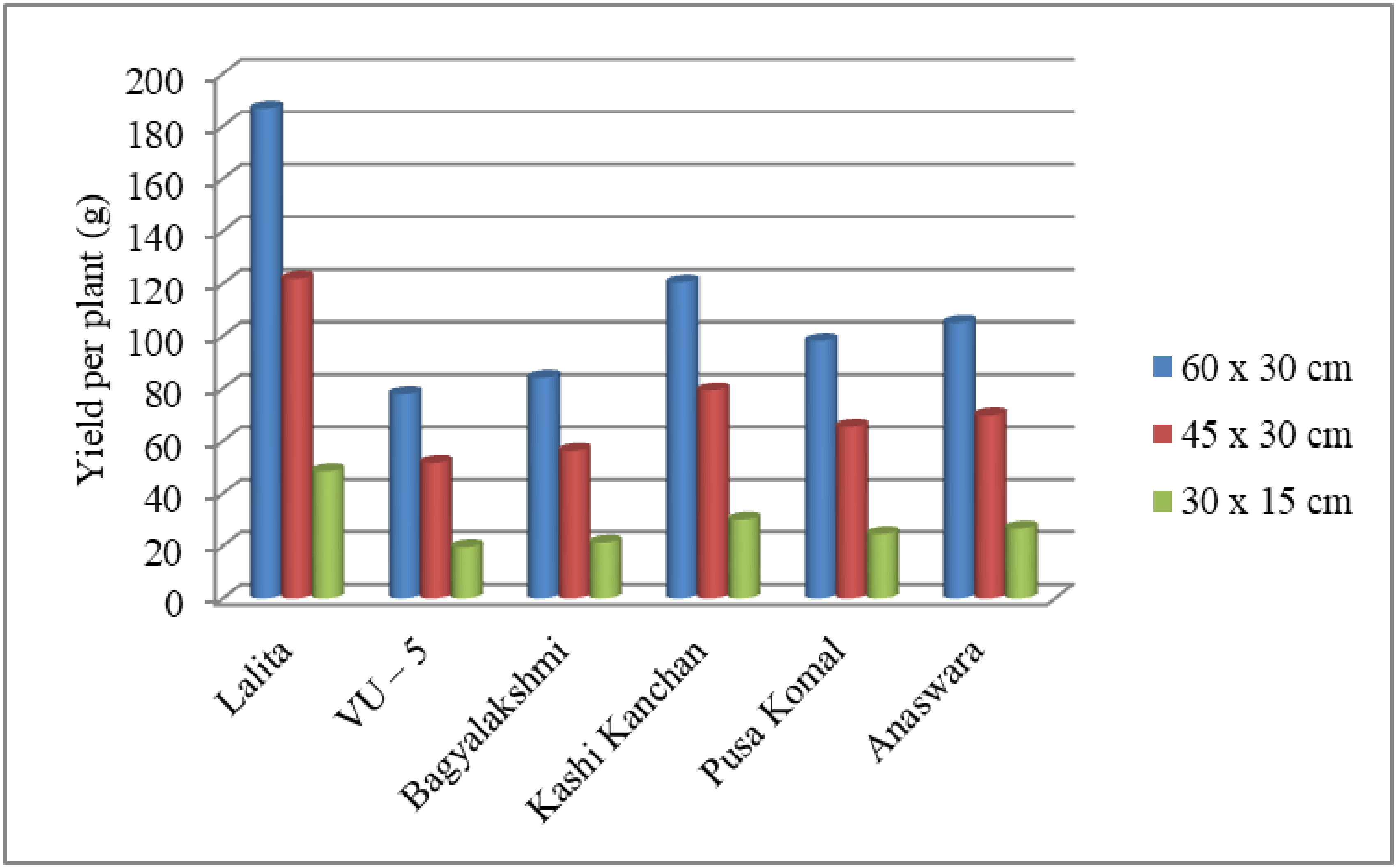


Fig.8 Yield per plant (g) of cowpea genotypes influenced by spacing

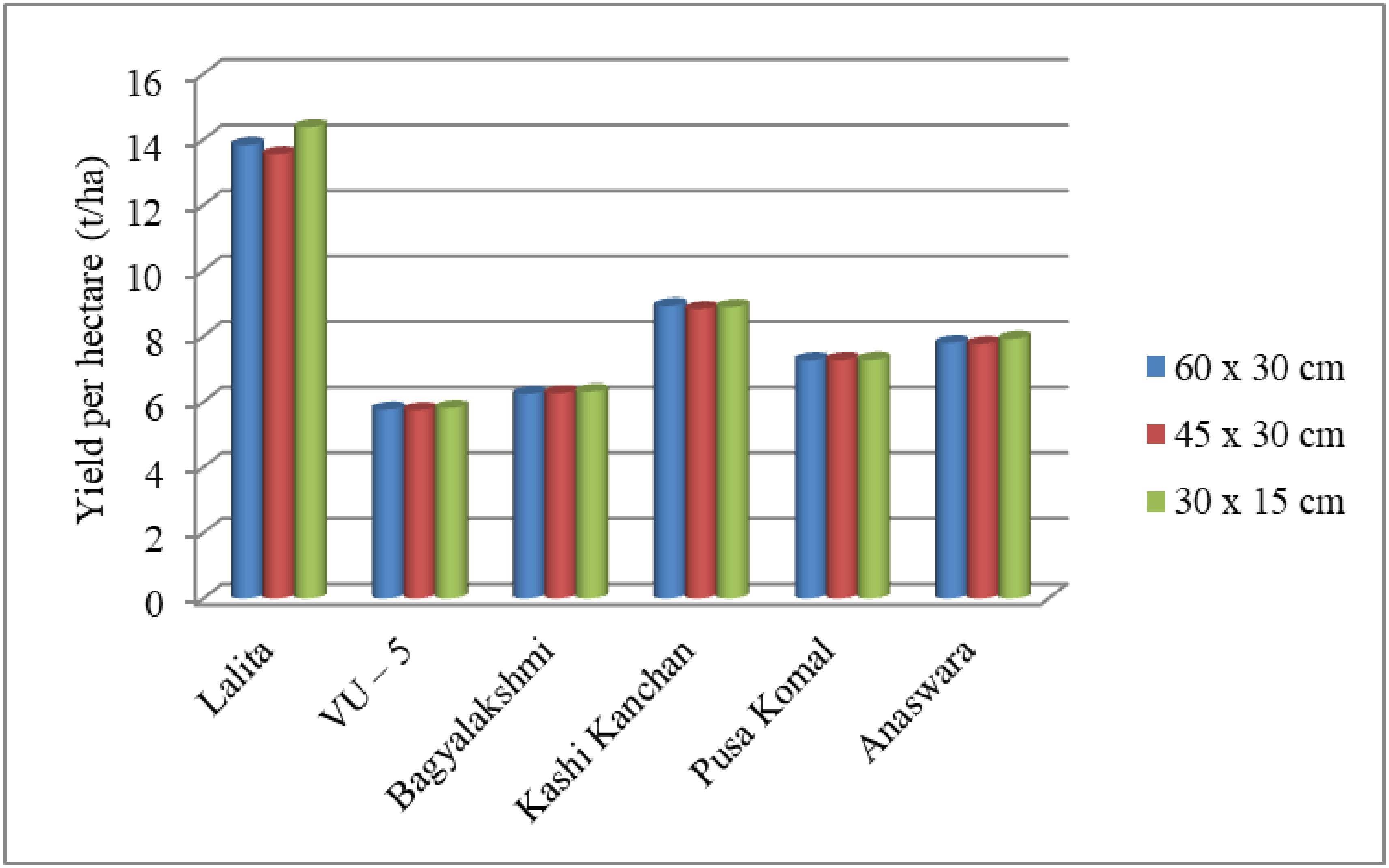


Fig. 9 Yield per hectare (t/ha) of cowpea genotypes influenced by spacing

The higher crude protein and crude fibre content were exhibited by the genotypes Lalita and Pusa Komal respectively. Quality of produce is a specific trait associated with genetic expression of genotype. Content of nitrogen, phosphorus and potassium in plant did not differ significantly among row spacing. The nitrogen, phosphorus and potassium content of plants differed significantly with respect to genotypes. This might be due to genetic character of each genotype for the uptake of different nutrients.

But the uptake of nitrogen, phosphorus and potassium exhibited highest value from the plots of narrow row spacing. The increased uptake of nitrogen, phosphorus and potassium at narrow row spacing was recorded by Ravichandran and Srinivasan (2017). Among different genotypes maximum uptake of nitrogen and potassium was recorded with genotype Lalita and phosphorus uptake was recorded with genotype Anaswara.

5.1.3 Effect of spacing and genotypes on soil chemical property of bush type vegetable cowpea under open precision farming

The EC and pH content of the soil did not differ significantly with respect to spacing. The non-significant effect of spacing on EC and pH was reported by Law- ogbomo and Kolawole (2016). The EC and pH of the soil was statistically comparable with respect to genotypes also.

In the case of organic carbon, available soil nitrogen, phosphorus, potassium, calcium, magnesium and sulphur content of soil, maximum available nutrient content was recorded with spacing 45 x 30 cm. Minimum available nutrient was recorded with 30 x 15 and 60 x 30 cm. This might be due to higher uptake of nutrients at these spacings (30 x 15 and 60 x 30 cm). The findings are in conformity with the findings of Malagi (2005).

Maximum organic carbon content, available nitrogen, phosphorous, potassium, calcium, magnesium and sulphur content were recorded with genotypes VU-5. This might be due to lower uptake of nutrients by these genotype which is a genetically controlled trait of the plant to some extent.

In the case of available soil micronutrients (Iron, zinc manganese and copper), the micro nutrient status of the soil was statistically comparable with respect to spacing. As micro nutrients are required in lower quantity by the plant, the uptake is also less as compared to major nutrients. So the nutrient status was not affected remarkably due to spacing.

Variation in available soil micronutrients (Iron, zinc manganese and copper) was noticed due to cowpea genotypes with maximum available soil micronutrients were recorded with genotype VU -5. This might be due to differential ability of genotypes for the uptake of nutrients.

5.1.4 Effect of spacing and genotypes on benefit: cost ratio of bush type vegetable cowpea under open precision farming

Genotype Lalita recorded the highest B: C ratio (1.3) followed by genotype Anaswara. Among the spacing treatments also the B: C ratio varied significantly. Among spacings wider spacing recorded the highest B:C ratio. This might be due to reduced use of inputs like seeds correspondingly decreased cost of cultivation and higher economic yield produced by the wider row spacing. The results are in conformity with the findings of Jagadale *et al* (2017).

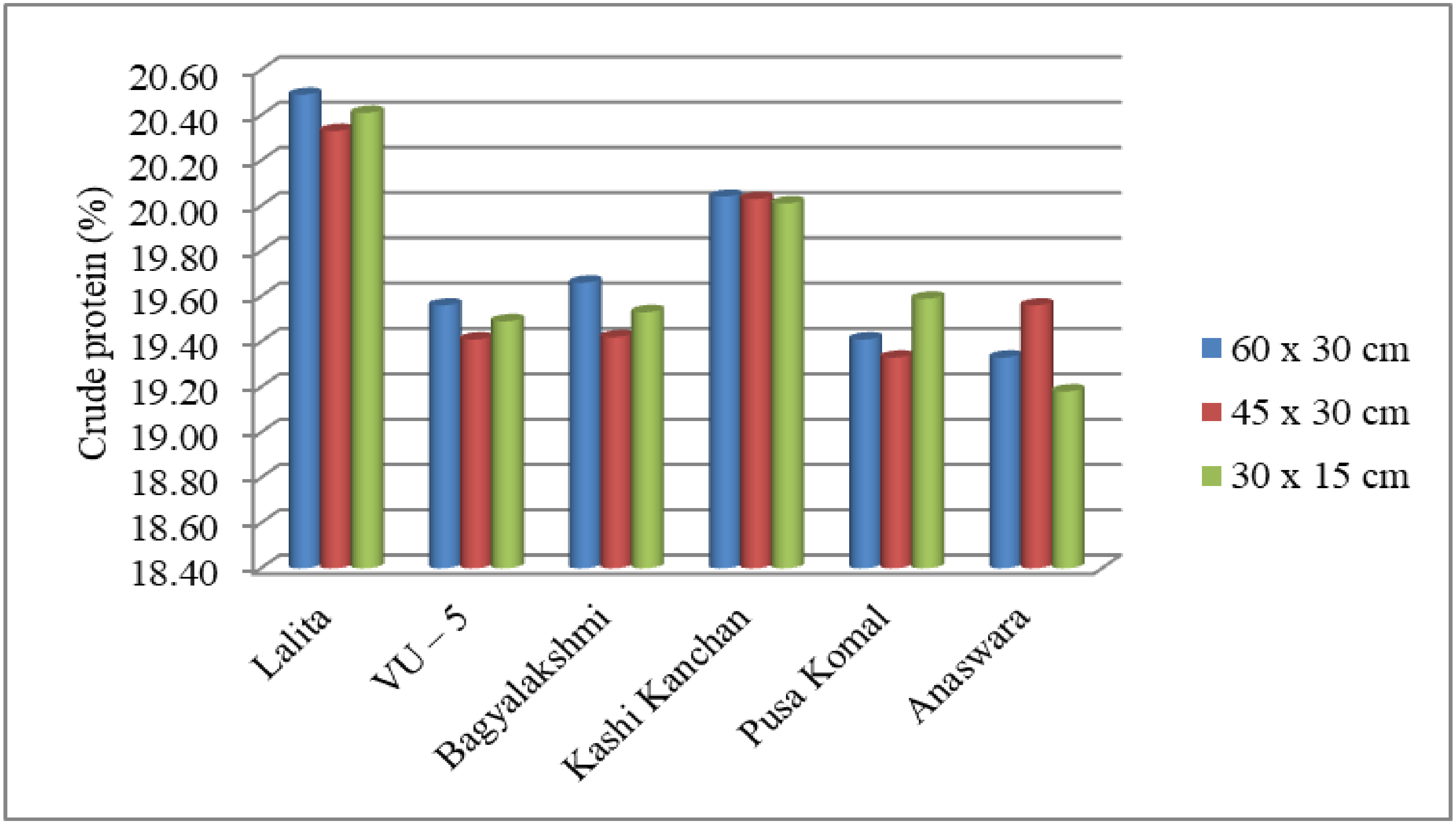


Fig. 10 Crude protein (%) of cowpea genotypes influenced by spacing

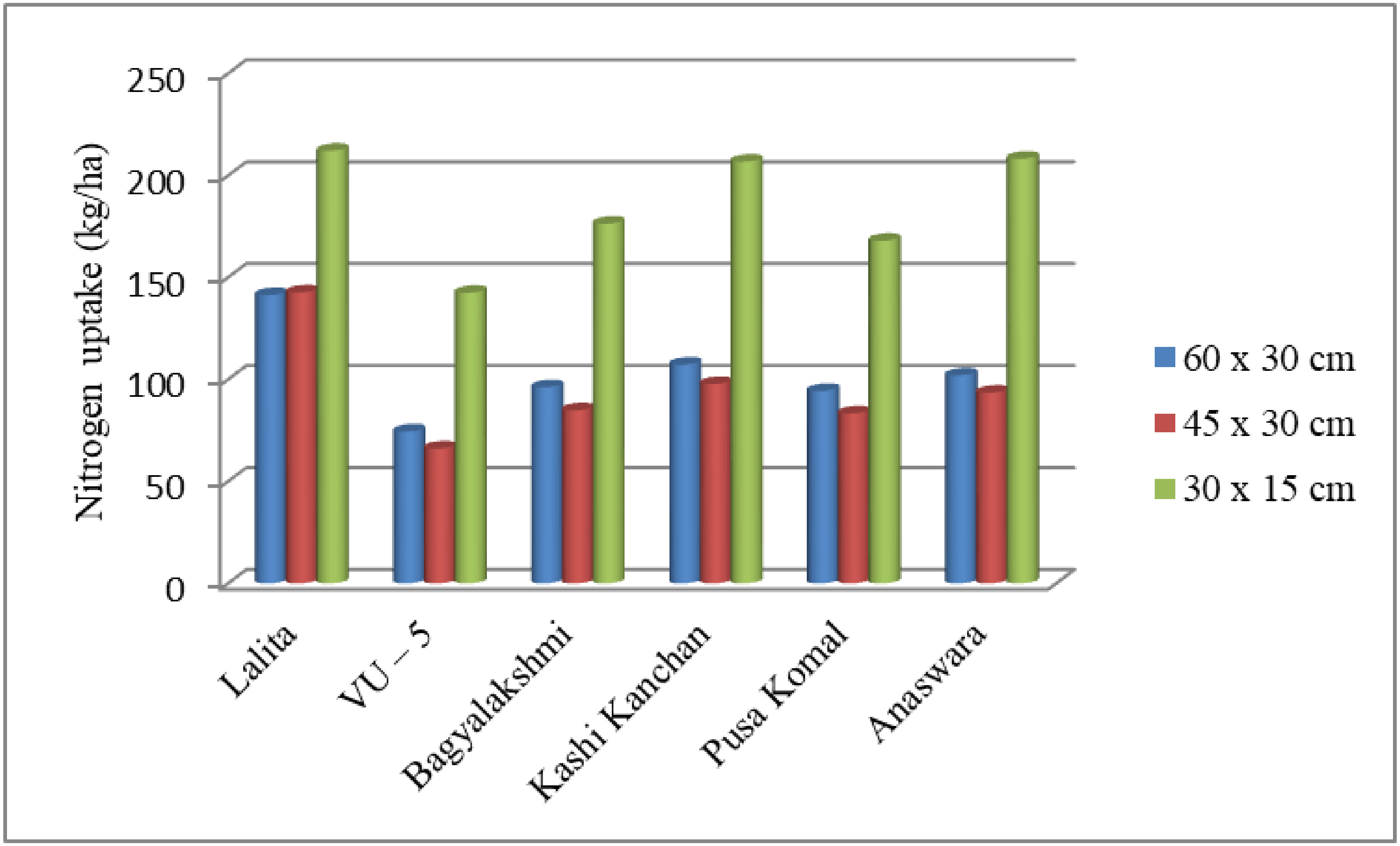


Fig. 11 Nitrogen uptake (kg/ha) of cowpea genotypes influenced by spacing

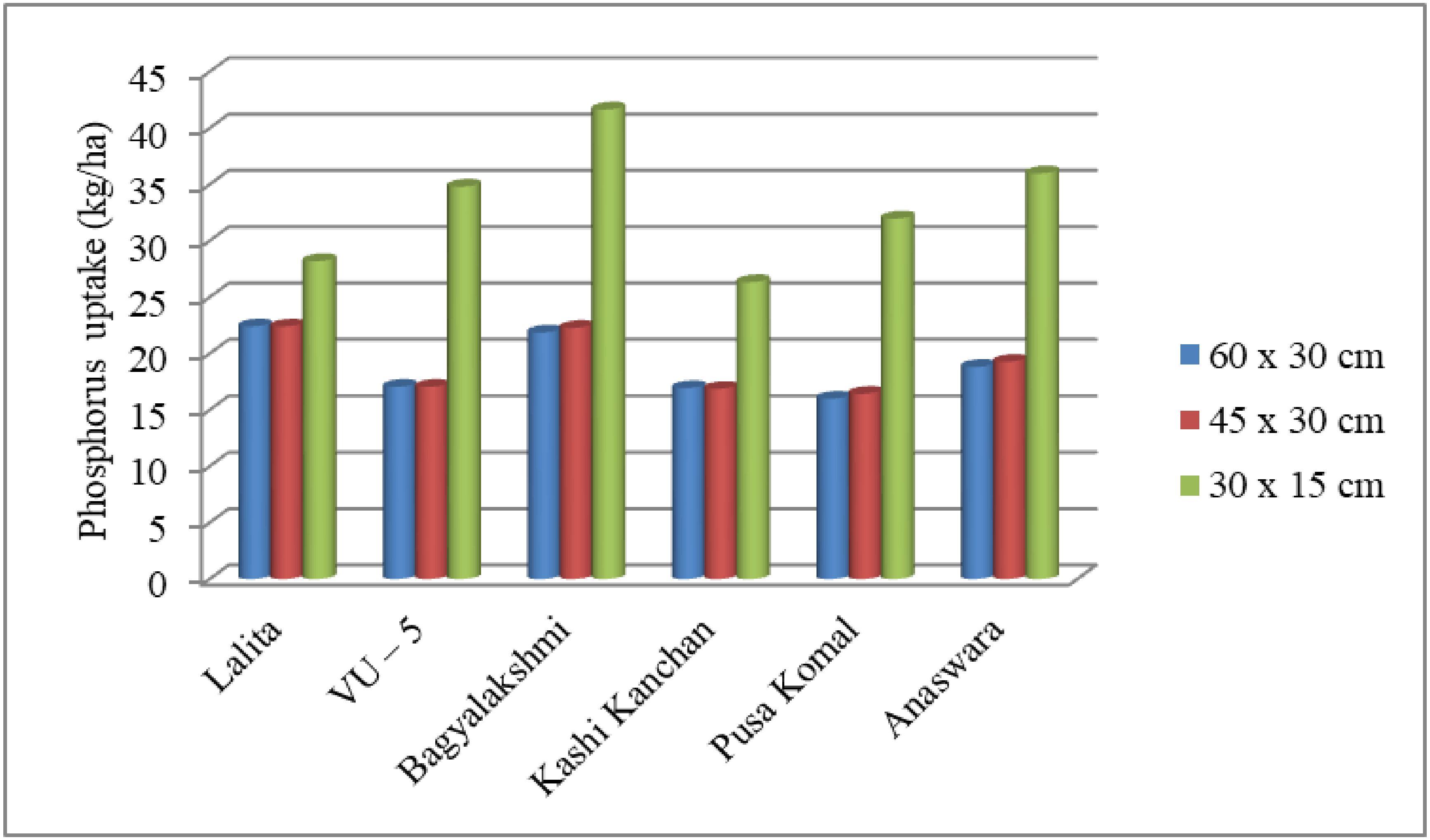


Fig. 12 Phosphorus uptake (kg/ha) of cowpea genotypes influenced by spacing

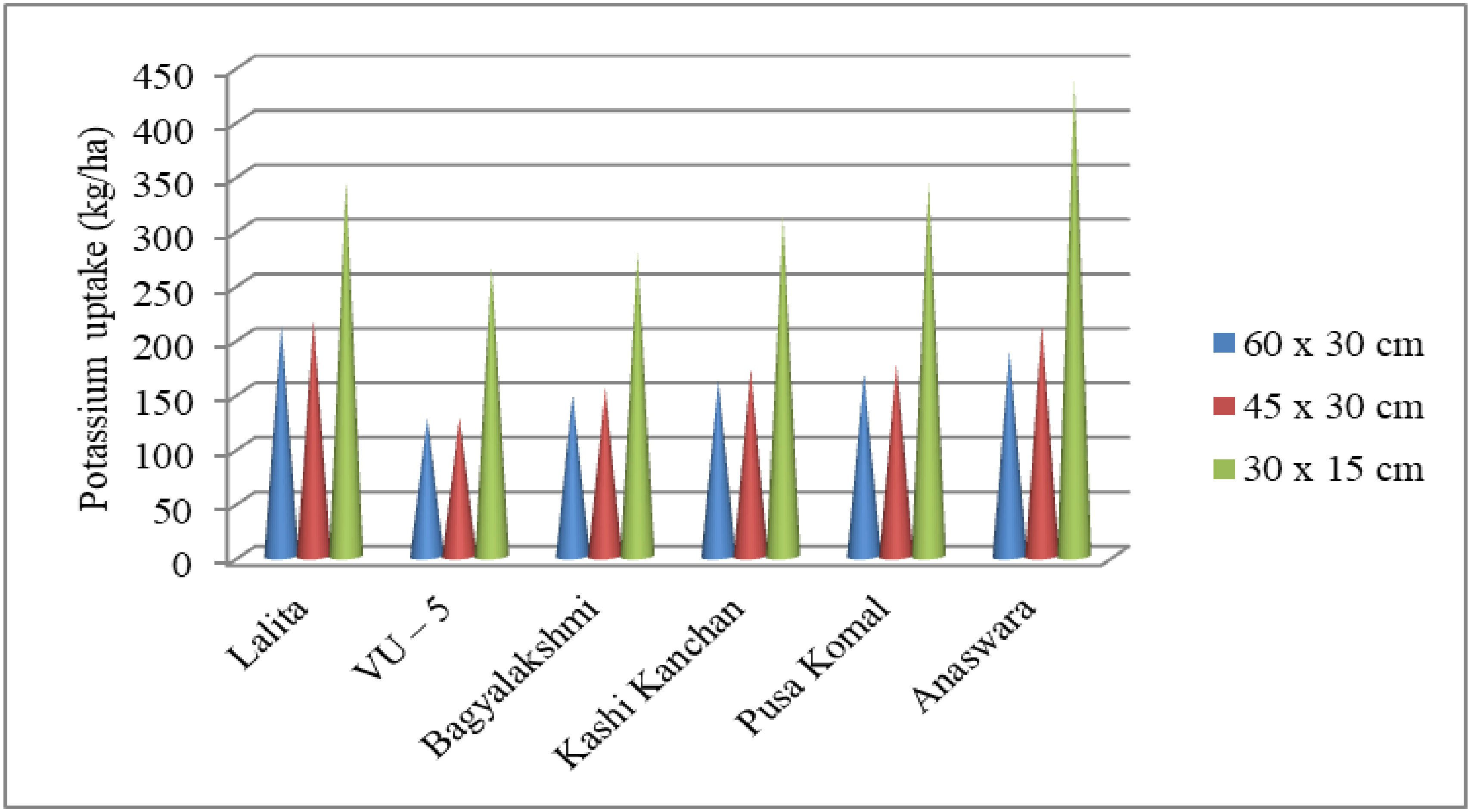


Fig.13 Potassium uptake (kg/ha) of cowpea genotypes influenced by spacing

5.2 Experiment II: Standardization of source of nutrients and levels of fertigation in bush type vegetable cowpea under open precision farming

5.2.1 Effect of fertilizer level and source of nutrients on growth and productivity of bush type vegetable cowpea under open precision farming

The growth characters obtained at different growth of phases clearly shown the influence of fertilizer levels on its growth. The plant height, number of leaves and dry matter production per plant at 20 and 40 DAS and at harvest were statistically comparable with respect to levels of fertilizers (Fig.14, 15 and 16). The non significant effect of applied fertilizer on growth and dry matter yield suggested that the nitrogen requirement of cowpea for growth may be met by its own nitrogen fixation ability (Singh, 1997); hence cowpea could manage its nitrogen requirement without nitrogen fertilization (Smith *et al*., 1986). Another possible explanation in this study might be that as the initial available nutrients in the soil was high (organic carbon content 0.93 %, available phosphorous 41.37 kg/ha and potassium 445.09 kg/ha) and lower dose of fertilizers was sufficient for the growth of cowpea.

Days to fifty per cent flowering differed significantly due to levels of fertilizers. Application of 50 per cent of nutrient uptake and control (package of practice recommendation) attained fifty per cent flowering earlier (32 days) as compared to other treatments. It could be inferred that plants took more days to flower when fertilizer dose was increased. This might be due to the fact that when nutrient availability is more vegetative phase might get prolonged (Narayanankutty *et al*., 2017).

Fresh pod yield did not show variation with respect to levels of fertilizers (Fig. 19). However, higher dry matter production per plant and higher yield were recorded with the treatment combination of application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha as water soluble fertilizers. The non significant effect of applied fertilizer on yield attributes and yield of cowpea are in agreement with findings of IITA (1975) who reported that cowpea produced the same yield under fertilized and unfertilized plot. This might be due to the ability of cowpea to fix nitrogen biologically, which provides the required nitrogen through symbiosis. However these results are contradictory to the findings of Abayomi *et al.* (2008) who reported significant increase in grain yield of cowpea following the application of N fertilizer.

The growth and yield parameters recorded at 20, 40 DAS and at harvest was statistically comparable with respect to sources of fertilizers. Results are in conformity with finding of Rajan *et al*. (2014).

5.2.2 Effect of different fertilizer levels and source of nutrients on quality of bush type vegetable cowpea under open precision farming

The content of crude protein differed significantly among the levels of fertilizers (Fig.20). The highest content of crude protein was recorded with application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha which was statistically comparable with application of fertilizers @ 139:37: 127 kg N: P_2O_5: K_2O /ha. Lowest content was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha. The results are in conformity with the findings of Daramy *et al*. (2016).

5.2.3 Effect of different fertilizer levels and source of nutrients on nutrient content and uptake of bush type vegetable cowpea under open precision farming

The content of nitrogen in plant was significantly influenced levels of fertilizers the highest content nitrogen was recorded with application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha which was followed by application of fertilizers @ 139:37: 127 kg N: P_2O_5: K_2O /ha. This might be due to increased uptake of nitrogen with more available nitrogen in the soil. While, content of phosphorus and potassium did not differ significantly among levels of fertilizers.

Application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha recorded highest plant calcium and magnesium content as compared application of fertilizers at the rate of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha at 20 and 40 DAS and at harvest. This might be due to higher rate of application of phosphorous and potassium hindered the uptake of these elements due to antagonistic effect. In case of sulphur content a positive relationship was found between the rate of application and content at all the stages of crop growth. Higher sulphur content of plant was recorded with application of fertilizers at the rate of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha .

The available content of micro nutrients differed significantly due to levels of fertilizers. Among fertilizer levels, application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha recorded highest iron, zinc, manganese and copper content of plant as compared to 231: 63: 212 kg N: P_2O_5: K_2O /ha at 20 and 40 DAS and at harvest. The antagonistic effect of nitrogen, phosphorus and potassium on uptake of major and micro nutrients are well explained by Fageria *et al.* (2011). The

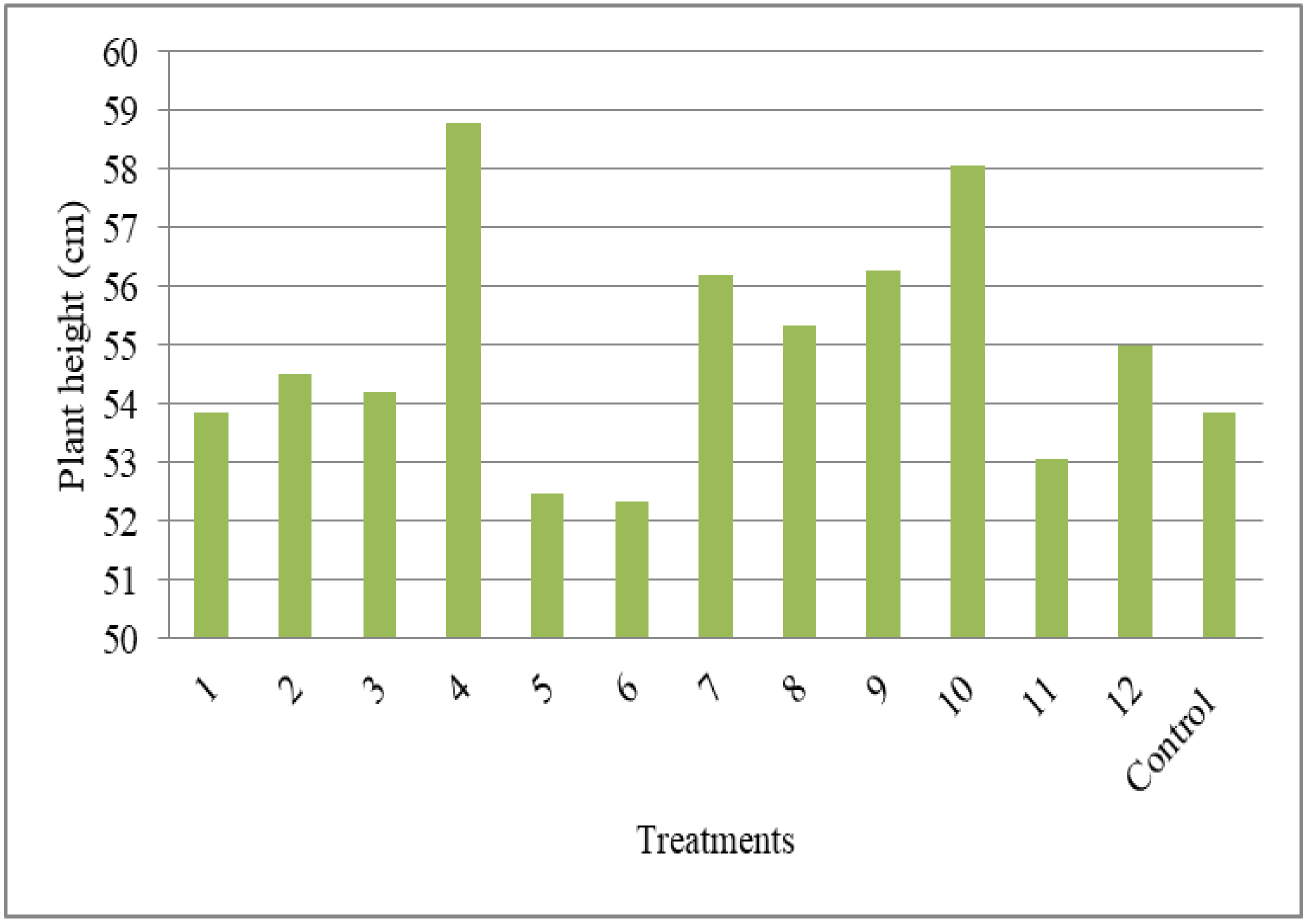
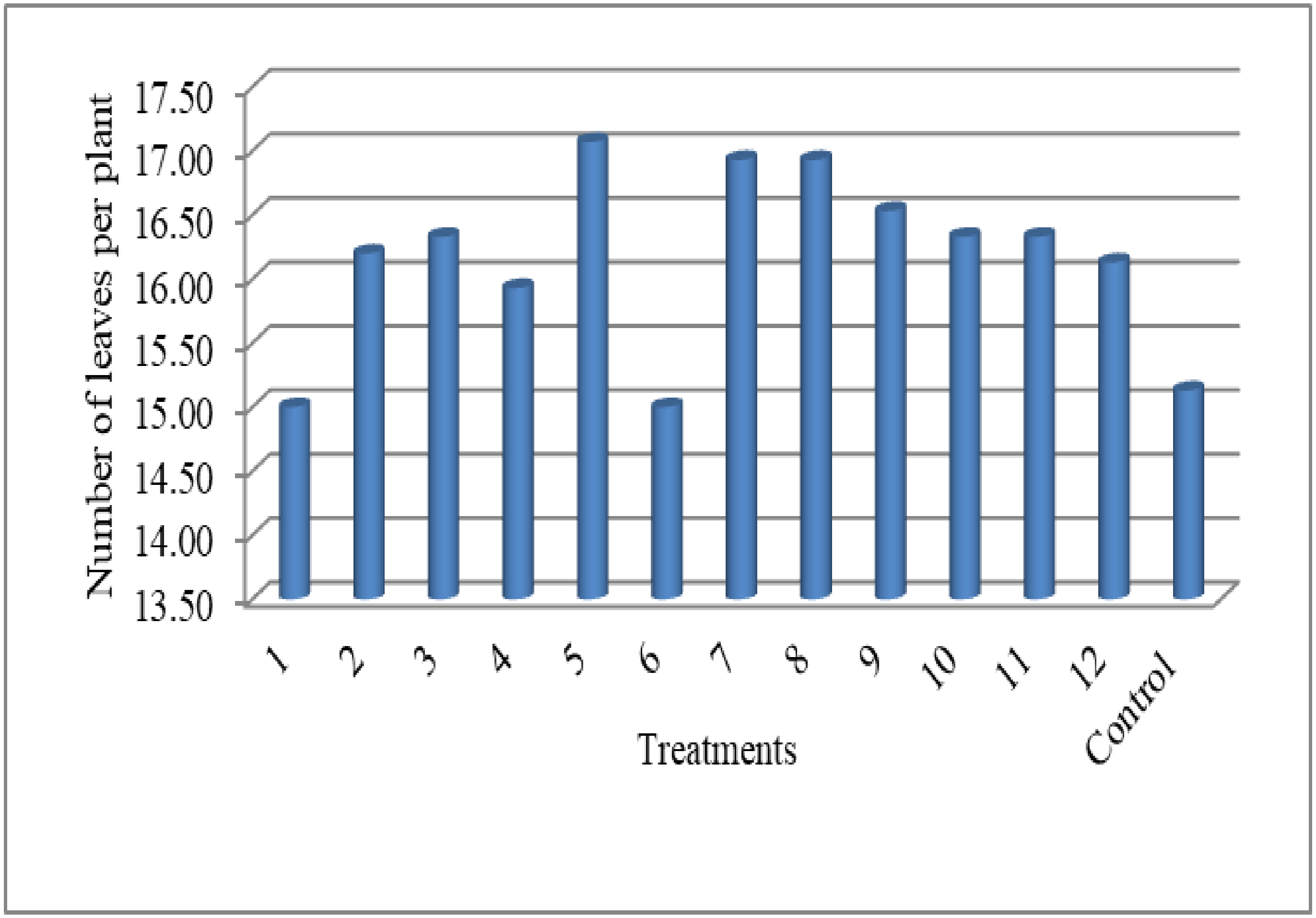


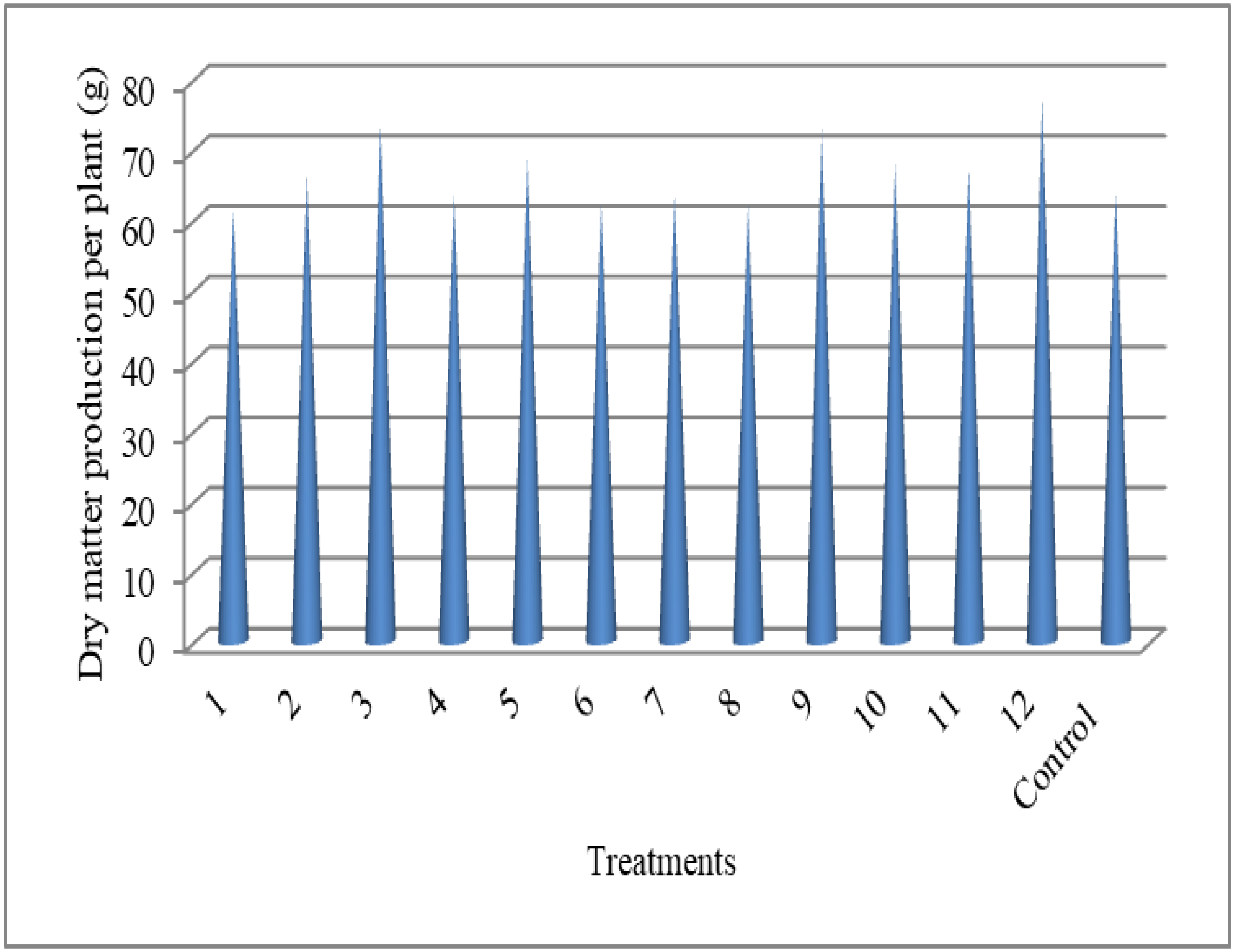
Fig. 14 Plant height (cm) of cowpea genotypes influenced by levels and sources of fertilizers (At harvest)

Treatment combinations	
T_1	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % CF
T_2	93:25:85 kg N: P_2O_5: K_2O / ha + 50% as CF- basal + 50% WSF
T_3	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_4	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % CF
T_5	139:37: 127kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_6	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % WSF
T_7	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % CF
T_8	185: 50: 170 kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_9	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_{10}	231: 63: 212kg N: P_2O_5: K_2O / ha + 100 % CF
T_{11}	231: 63: 212kg N: P_2O_5: K_2O / ha+ + 50 % as CF- basal + 50% WSF
T_{12}	231: 63: 212kg N: P_2O_5: K_2O / ha + + 100 % WSF
Control - 20: 30:10 kg N: P_2O_5: K_2O / ha+ 100 % CF	
CF- Conventional fertilizers WSF – water soluble fertilizers	



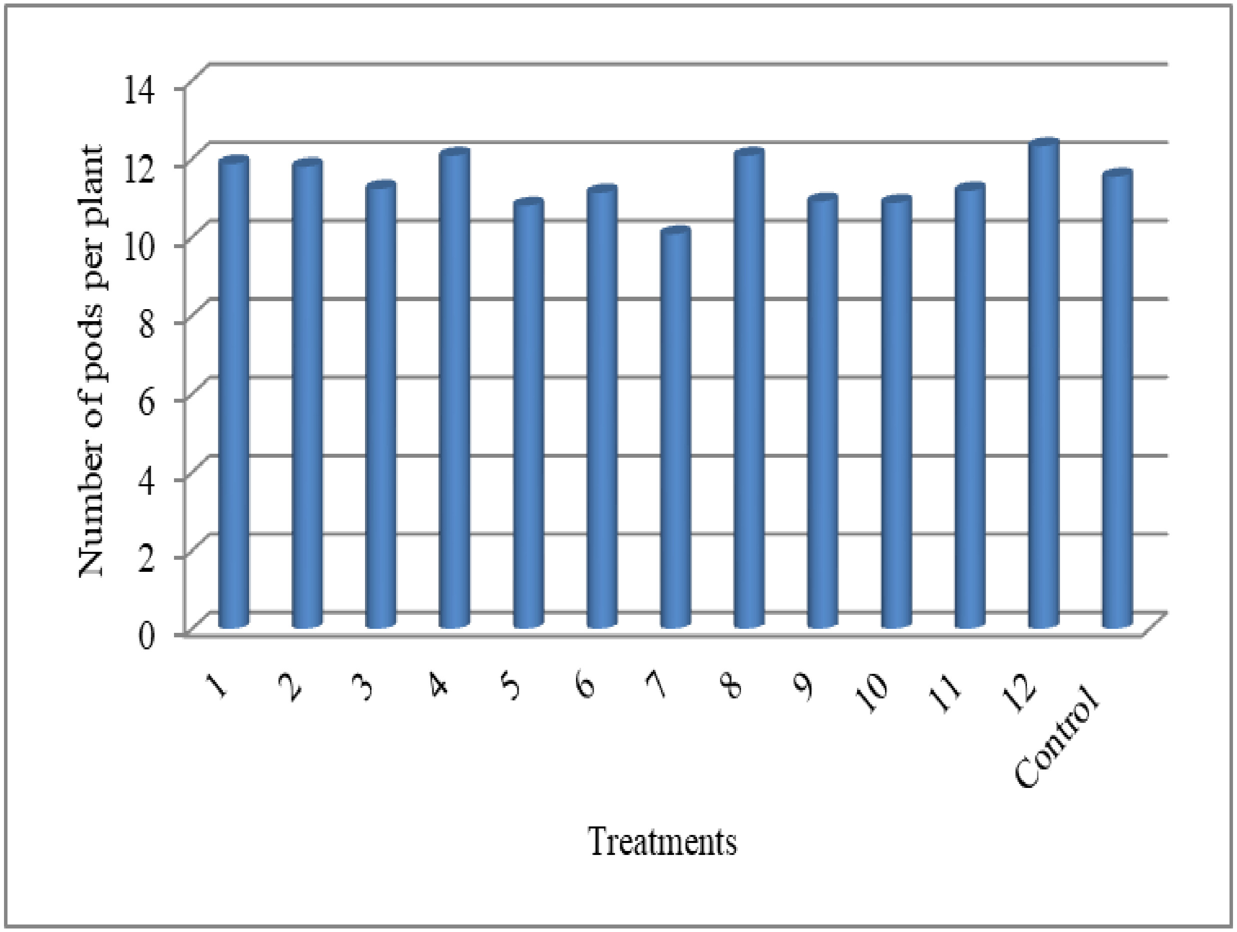
Treatment combinations	
T_1	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % CF
T_2	93:25:85 kg N: P_2O_5: K_2O / ha + 50% as CF- basal + 50% WSF
T_3	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_4	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % CF
T_5	139:37: 127kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_6	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % WSF
T_7	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % CF
T_8	185: 50: 170 kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_9	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_{10}	231: 63: 212kg N: P_2O_5: K_2O / ha + 100 % CF
T_{11}	231: 63: 212kg N: P_2O_5: K_2O / ha+ + 50 % as CF- basal + 50% WSF
T_{12}	231: 63: 212kg N: P_2O_5: K_2O / ha + + 100 % WSF
Control - 20: 30:10 kg N: P_2O_5: K_2O / ha+ 100 % CF	
CF- Conventional fertilizers WSF – water soluble fertilizers	

Fig. 15 Number of leaves per plant of cowpea influenced by levels and sources of fertilizers (At harvest)



Treatment combinations	
T_1	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % CF
T_2	93:25:85 kg N: P_2O_5: K_2O / ha + 50% as CF- basal + 50% WSF
T_3	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_4	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % CF
T_5	139:37: 127kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_6	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % WSF
T_7	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % CF
T_8	185: 50: 170 kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_9	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_{10}	231: 63: 212kg N: P_2O_5: K_2O / ha + 100 % CF
T_{11}	231: 63: 212kg N: P_2O_5: K_2O / ha+ + 50 % as CF- basal + 50% WSF
T_{12}	231: 63: 212kg N: P_2O_5: K_2O / ha + + 100 % WSF
Control - 20: 30:10 kg N: P_2O_5: K_2O / ha+ 100 % CF	
CF- Conventional fertilizers WSF – water soluble fertilizers	

Fig. 16 Dry matter production per plant (g) of cowpea influenced by levels and sourcesof fertilizers



Treatment combinations	
T_1	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % CF
T_2	93:25:85 kg N: P_2O_5: K_2O / ha + 50% as CF- basal + 50% WSF
T_3	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_4	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % CF
T_5	139:37: 127kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_6	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % WSF
T_7	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % CF
T_8	185: 50: 170 kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_9	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_{10}	231: 63: 212kg N: P_2O_5: K_2O / ha + 100 % CF
T_{11}	231: 63: 212kg N: P_2O_5: K_2O / ha+ + 50 % as CF- basal + 50% WSF
T_{12}	231: 63: 212kg N: P_2O_5: K_2O / ha + + 100 % WSF
Control - 20: 30:10 kg N: P_2O_5: K_2O / ha+ 100 % CF	
CF- Conventional fertilizers WSF – water soluble fertilizers	

Fig.17 Number of pods per plant of cowpea influenced by levels and sources of fertilizers (At harvest)

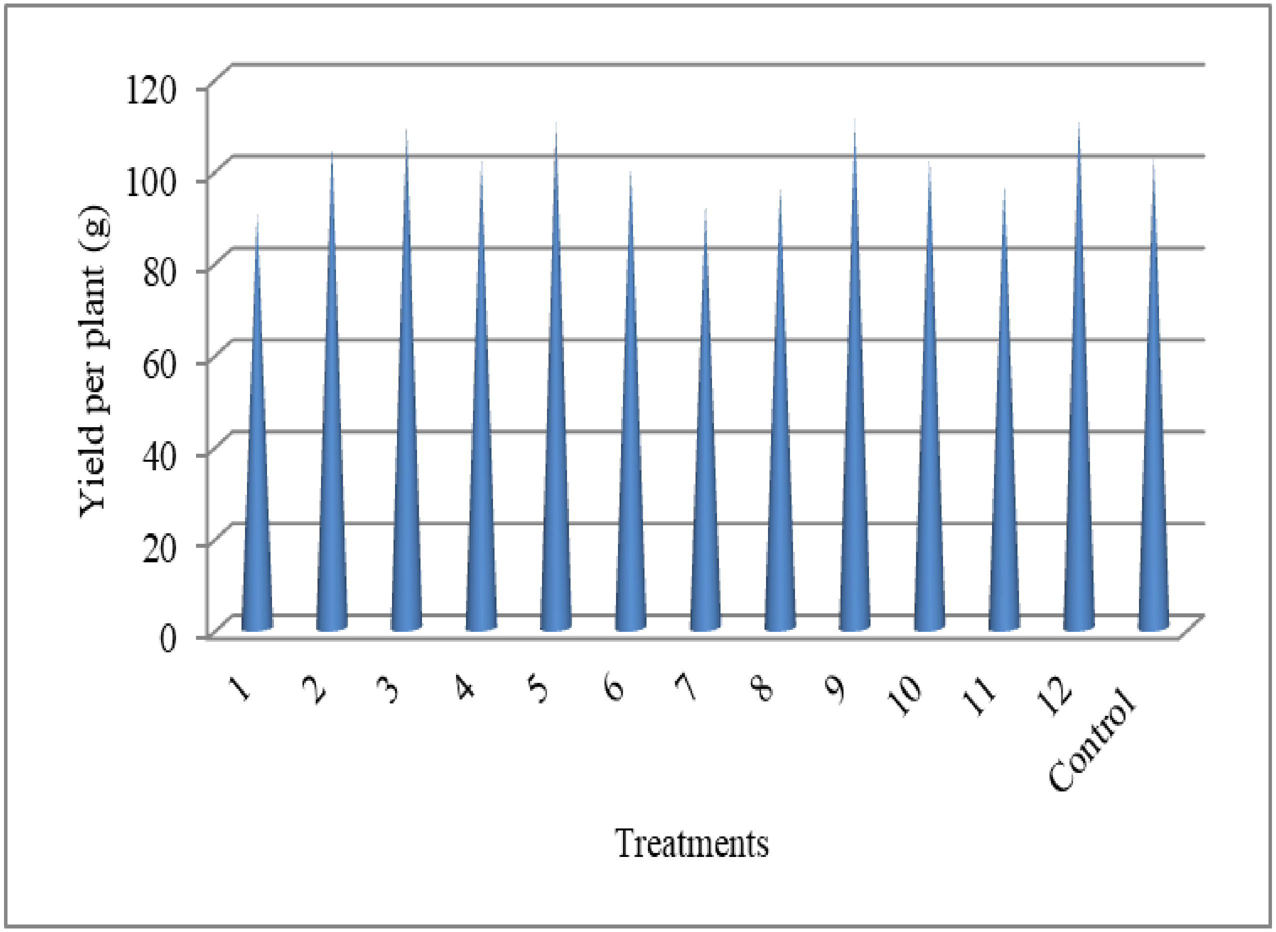
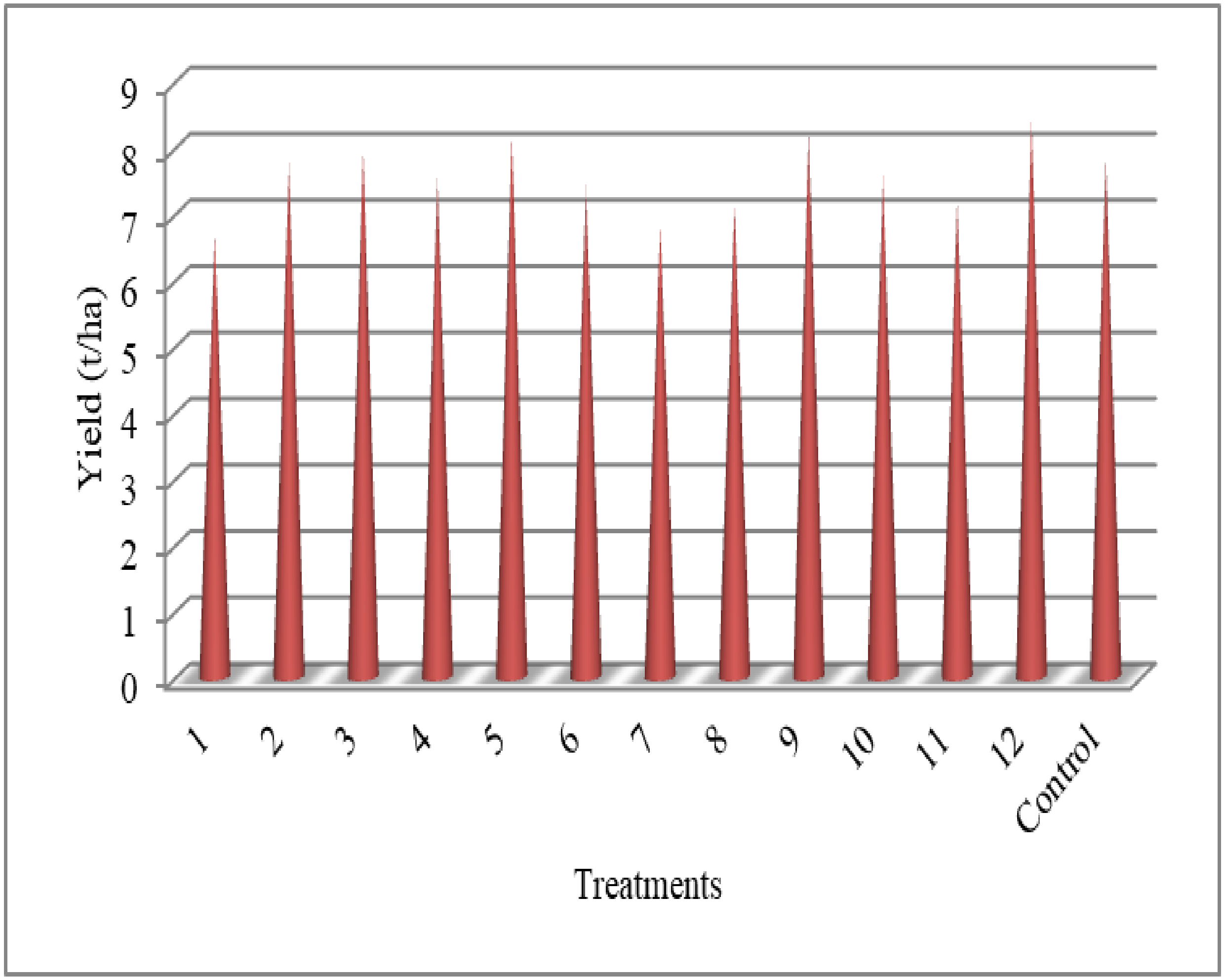


Fig. 18 Yield per plant (g) of cowpea influenced by levels and sources of fertilizers

Treatment combinations	
T_1	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % CF
T_2	93:25:85 kg N: P_2O_5: K_2O / ha + 50% as CF- basal + 50% WSF
T_3	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_4	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % CF
T_5	139:37: 127kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_6	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % WSF
T_7	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % CF
T_8	185: 50: 170 kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_9	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_{10}	231: 63: 212kg N: P_2O_5: K_2O / ha + 100 % CF
T_{11}	231: 63: 212kg N: P_2O_5: K_2O / ha+ + 50 % as CF- basal + 50% WSF
T_{12}	231: 63: 212kg N: P_2O_5: K_2O / ha + + 100 % WSF
Control - 20: 30:10 kg N: P_2O_5: K_2O / ha+ 100 % CF	
CF- Conventional fertilizers WSF – water soluble fertilizers	



Treatment combinations	
T_1	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % CF
T_2	93:25:85 kg N: P_2O_5: K_2O / ha + 50% as CF- basal + 50% WSF
T_3	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_4	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % CF
T_5	139:37: 127kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_6	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % WSF
T_7	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % CF
T_8	185: 50: 170 kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_9	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_{10}	231: 63: 212kg N: P_2O_5: K_2O / ha + 100 % CF
T_{11}	231: 63: 212kg N: P_2O_5: K_2O / ha+ + 50 % as CF- basal + 50% WSF
T_{12}	231: 63: 212kg N: P_2O_5: K_2O / ha + + 100 % WSF
Control - 20: 30:10 kg N: P_2O_5: K_2O / ha+ 100 % CF	
CF- Conventional fertilizers WSF – water soluble fertilizers	

Fig. 19 Yield (t/ha) of cowpea influenced by levels and sources of fertilizers

uptake of nitrogen, phosphorous and potassium was statistically comparable with respect to levels of fertilizers.

Sources of nutrients had significant influence on the nitrogen uptake by plant. Higher uptake of nitrogen was recorded with fertigation through water soluble fertilizers and lower fertilizer application rate with fertigation through conventional fertilizers. This might be due to rapid solubility of water soluble fertilizers which leads to enhanced availability of nutrients in the crop root zone. The results are in confirmity with the finding of Mohammadi (2008) and Reddy *et al.* (2018).

5.2.4 Effect of fertilizer levels and source of nutrients on soil nutrient content of bush type vegetable cowpea under open precision farming

In the case of fertilizer levels, soil pH exhibited on par values at all the four levels of fertilizer. EC of the soil was high at higher levels of fertilizer due to accumulation of salts at the top layers of soil with increased levels of fertilizers. Highest EC was observed from plot under fertigation with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha. The results are in conformity with the findings of Bryla *et al.* (2010). Sources of fertilizer failed to produce variation in pH of the soil. However, EC of soil was significantly influenced by sources of fertilizer and higher EC of soil was recorded with water soluble fertilizers. This might be due to more solubility of water soluble fertilizers which increased the availability and concentration of salts in the soil.

Levels of fertilizer failed to produce variation in organic carbon content of the soil. But higher available nitrogen, phosphorus and potassium contents were

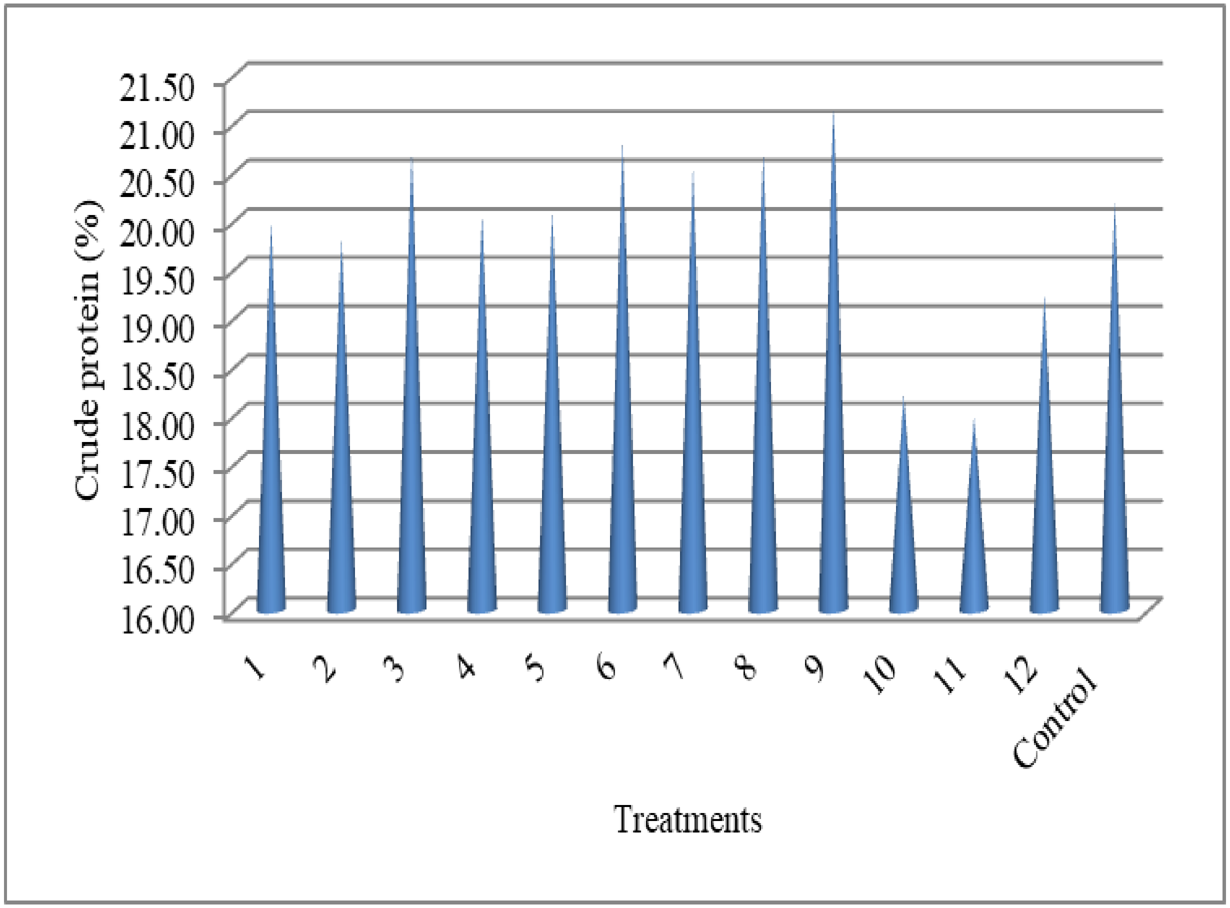
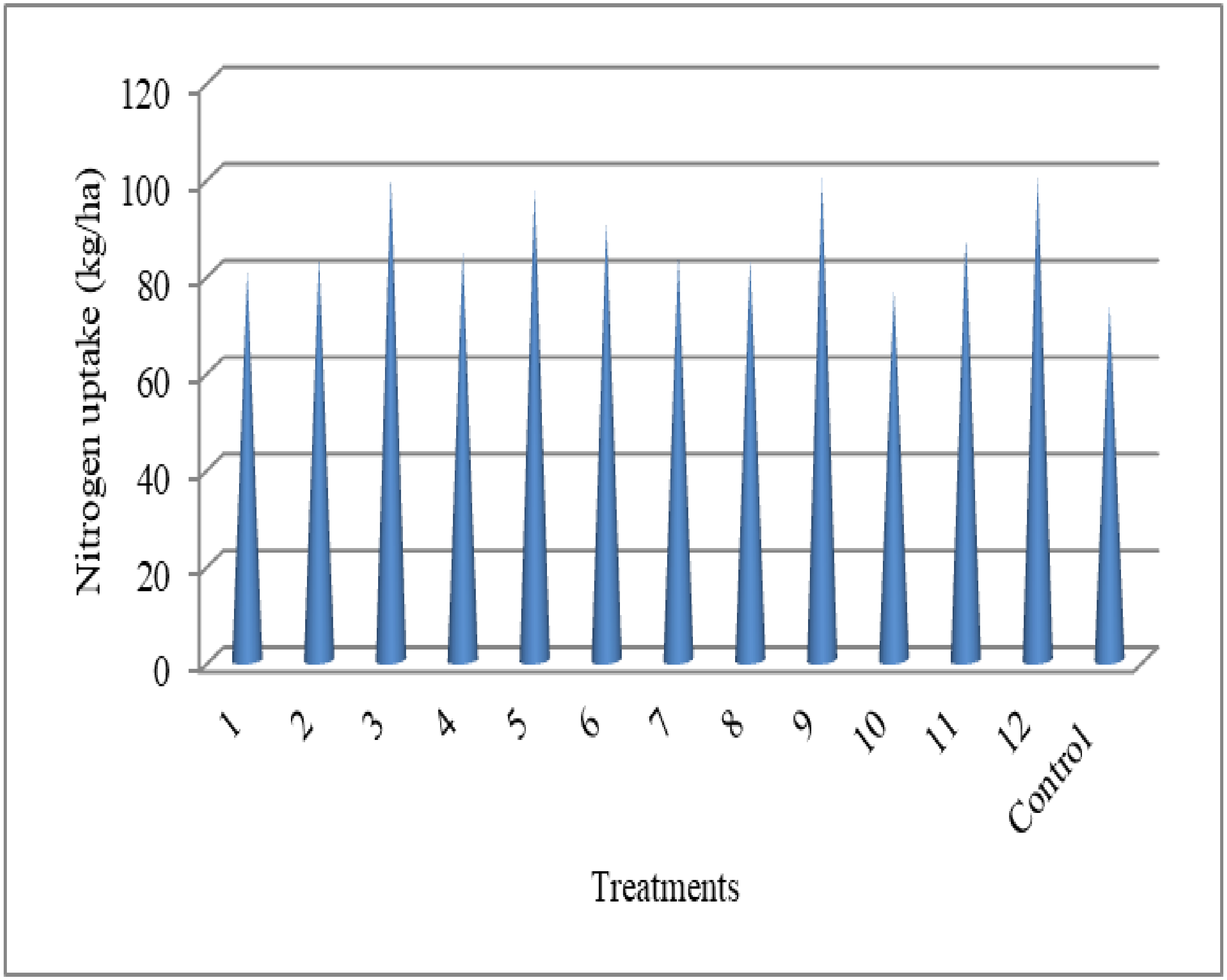


Fig. 20 Crude protein (%) of cowpea influenced by levels and sources of fertilizers

Treatment combinations	
T_1	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % CF
T_2	93:25:85 kg N: P_2O_5: K_2O / ha + 50% as CF- basal + 50% WSF
T_3	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_4	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % CF
T_5	139:37: 127kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_6	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % WSF
T_7	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % CF
T_8	185: 50: 170 kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_9	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_{10}	231: 63: 212kg N: P_2O_5: K_2O / ha + 100 % CF
T_{11}	231: 63: 212kg N: P_2O_5: K_2O / ha+ + 50 % as CF- basal + 50% WSF
T_{12}	231: 63: 212kg N: P_2O_5: K_2O / ha + + 100 % WSF
Control - 20: 30:10 kg N: P_2O_5: K_2O / ha+ 100 % CF	
CF- Conventional fertilizers WSF – water soluble fertilizers	



Treatment combinations	
T_1	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % CF
T_2	93:25:85 kg N: P_2O_5: K_2O / ha + 50% as CF- basal + 50% WSF
T_3	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_4	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % CF
T_5	139:37: 127kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_6	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % WSF
T_7	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % CF
T_8	185: 50: 170 kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_9	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_{10}	231: 63: 212kg N: P_2O_5: K_2O / ha + 100 % CF
T_{11}	231: 63: 212kg N: P_2O_5: K_2O / ha+ + 50 % as CF- basal + 50% WSF
T_{12}	231: 63: 212kg N: P_2O_5: K_2O / ha + + 100 % WSF
Control - 20: 30:10 kg N: P_2O_5: K_2O / ha+ 100 % CF	
CF- Conventional fertilizers WSF – water soluble fertilizers	

Fig. 21 Nitrogen uptake (kg/ha) of cowpea influenced by levels and sources fertilizers

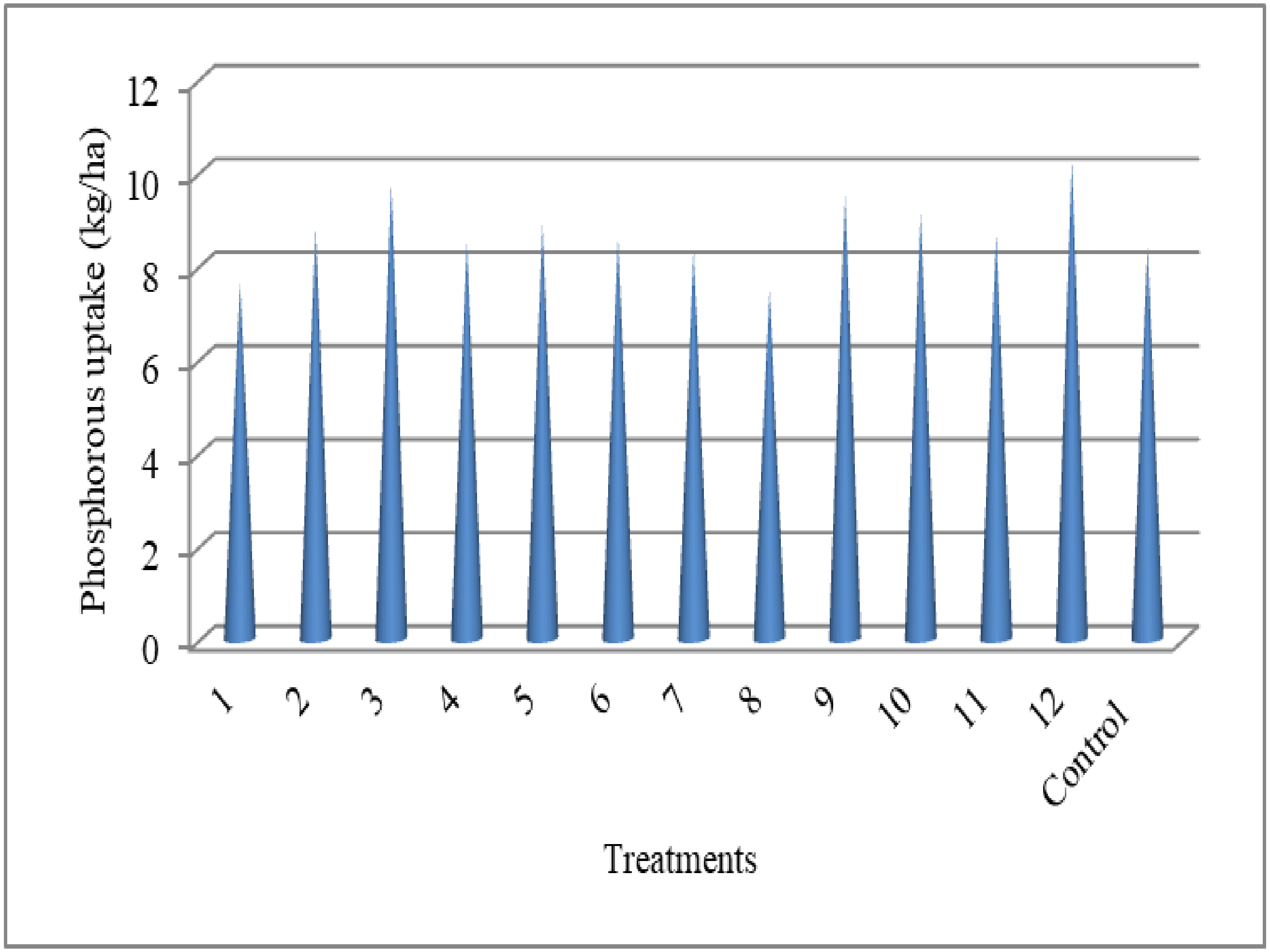
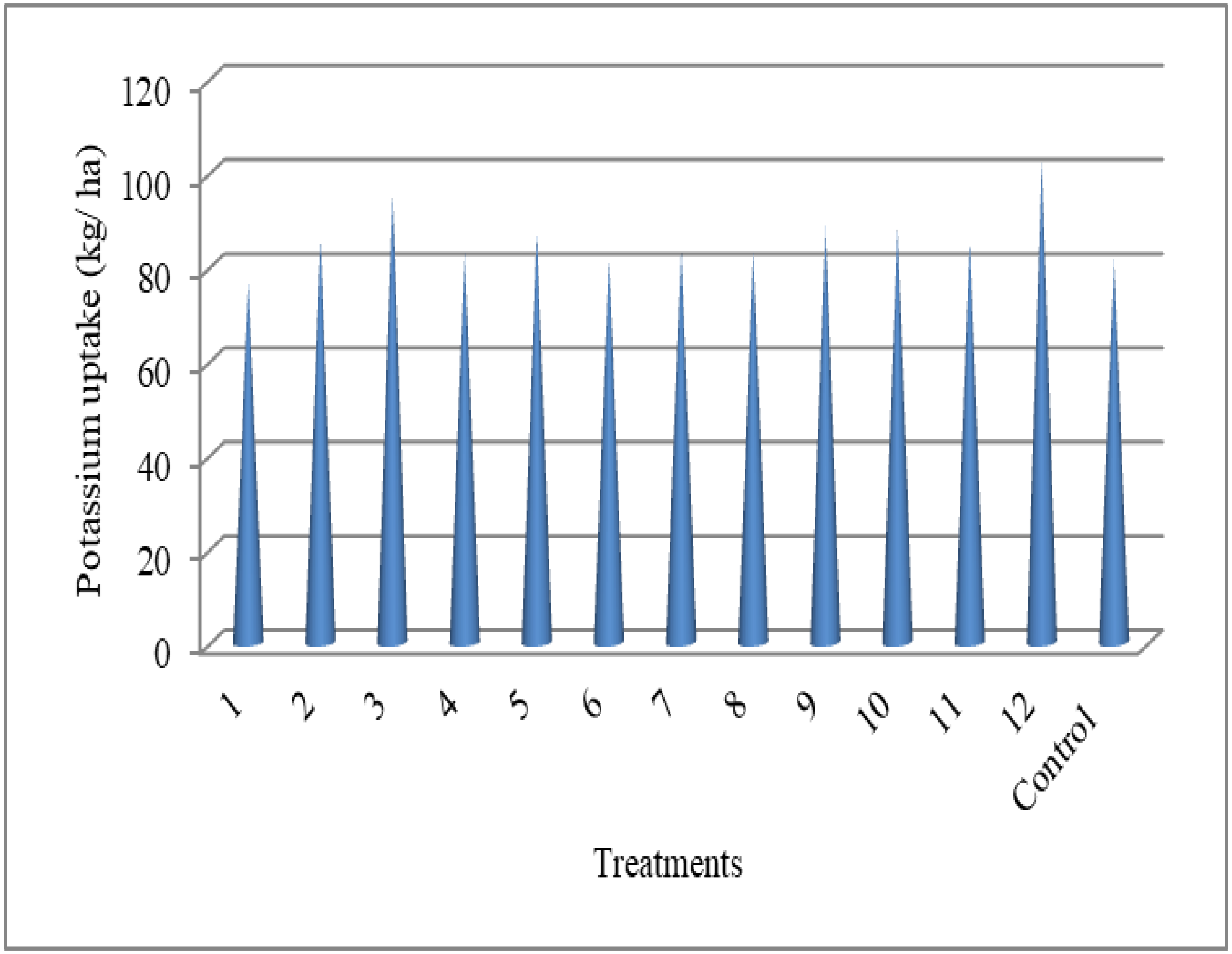


Fig. 22 Phosphorus uptake (kg/ha) of cowpea influenced by levels and sources of fertilizers

Treatment combinations	
T_1	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % CF
T_2	93:25:85 kg N: P_2O_5: K_2O / ha + 50% as CF- basal + 50% WSF
T_3	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_4	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % CF
T_5	139:37: 127kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_6	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % WSF
T_7	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % CF
T_8	185: 50: 170 kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_9	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_{10}	231: 63: 212kg N: P_2O_5: K_2O / ha + 100 % CF
T_{11}	231: 63: 212kg N: P_2O_5: K_2O / ha+ + 50 % as CF- basal + 50% WSF
T_{12}	231: 63: 212kg N: P_2O_5: K_2O / ha + + 100 % WSF
Control - 20: 30:10 kg N: P_2O_5: K_2O / ha+ 100 % CF	
CF- Conventional fertilizers WSF – water soluble fertilizers	



Treatment combinations	
T_1	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % CF
T_2	93:25:85 kg N: P_2O_5: K_2O / ha + 50% as CF- basal + 50% WSF
T_3	93:25:85 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_4	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % CF
T_5	139:37: 127kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_6	139:37: 127kg N: P_2O_5: K_2O / ha + 100 % WSF
T_7	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % CF
T_8	185: 50: 170 kg N: P_2O_5: K_2O / ha + 50 % as CF- basal + 50% WSF
T_9	185: 50: 170 kg N: P_2O_5: K_2O / ha + 100 % WSF
T_{10}	231: 63: 212kg N: P_2O_5: K_2O / ha + 100 % CF
T_{11}	231: 63: 212kg N: P_2O_5: K_2O / ha+ + 50 % as CF- basal + 50% WSF
T_{12}	231: 63: 212kg N: P_2O_5: K_2O / ha + + 100 % WSF
Control - 20: 30:10 kg N: P_2O_5: K_2O / ha+ 100 % CF	
CF- Conventional fertilizers WSF – water soluble fertilizers	

Fig. 23 Potassium uptake (kg/ha) of cowpea influenced by levels and sources of fertilizers

recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha . This might be due to increased rate of application of fertilizers lead to accumulation of more nutrients in the soil. Calcium, magnesium, sulphur, iron, manganese, copper and zinc were statistically comparable with respect to levels of fertilizers. Sources of fertilizers failed to produce significant effect on available nutrient contents of soil except nitrogen and potassium. The application through water soluble fertilizers recorded higher soil nitrogen and potassium. This might be due to higher solubility and availability of potassium nitrate and 19: 19: 19 complex as compared to diammonium phosphate applied through fertigation.

Nutrient use efficiency was significantly differed due to levels of fertilizers. Higher nutrient use efficiency was recorded with lower dose of fertilizer application. The results are in conformity with the findings of Chen *et al*.(2017).

The levels of fertilizers failed to produce significant effect on the yield of cowpea. The application of fertilizers at the rate of 20: 30:10 kg N: P_2O_5: K_2O /ha through fertigation produced the yield in comparison with application of fertilizers at the rate of 231: 63: 212 kg N: P_2O_5: K_2O /ha cowpea. The initial nutrient status of the soil in all the treatments was very high and the uptake of the nutrients by the bush type cowpea was low being short duration and leguminous in nature. So the initial nutrient contents might have been sufficient for the crops as noticed in the experiment. The data on nutrient status of soil after experiment revealed that the balance of nutrients in the soil after the uptake by the crop was high. This is clearly evident in the case of potassium. The initial nutrient content of potassium was 502.80 kg/ha and the crop uptake was only 81.65 kg/ha. Even with addition of other losses and partial utilization by plant, the quantity of 10 kg/ha of potassium applied was sufficient to produce a comparable yield with that of 100–per cent uptake of potassium. So the significant response between the levels of nutrients was not noticed in the experiment. As the nutrients in the available pool of absorption were sufficient with all the levels of fertilizers the remarkable difference between levels was not obtained.

The sources of fertilizers did not produce variation in the absorption and utilization to the final yield. As the nutrients are available with soil medium in sufficient quantities either through conventional or water soluble as evidenced from the balance sheet, the sources of fertilizers did not produce variation. The effect of sources of fertilizers may be evident in poor soils. If the soil is fertile, the conventional fertilizers may be sufficient to express the full potential of the genotype in the fertigation experiment. This is beneficial in economic point of view.

The results of the experiment revealed that application of fertilizers at the rate of 20: 30:10 applied with conventional fertilizers through fertigation was found to be effective for the enhanced growth and yield of cowpea. However, a yield increases of 7.94 t/ha was noticed with application of fertilizers @ 93:25:85 kg N: P_2O_5: K_2O /ha as water soluble fertilizers and it was on par with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through water soluble alone. Though the control treatment had lower cost of production the yield increase of 7.46 t/ha was remarkable with 50 per cent uptake which is equal to application of 93:25:85 kg N, P_2O_5 and K_2O. The yield increase was not statistically significant between the treatments. The higher yield with 50 per cent uptake through water soluble fertilizers was also found to be cost effective. Though higher yield was obtained with application of increasing dose of fertilizers, the substantial increase was noticed with 50 per cent uptake through conventional fertilizers. Cowpea being a leguminous plant has the capacity to fix nitrogen and the nitrogen requirement of the crop can be met through its own source. The availability of nutrients at frequent intervals in the crop root zone helped the plant to absorb and utilize effectively for enhanced yield. The positive response of cowpea to the application of organic and inorganic fertilizers regardless of nitrogen fixing ability is well reported.

The data on nutrient uptake explained that though uptake was higher with higher rate of fertilizers application the plants failed to utilize effectively for higher yield or might have reached the potential yield with lower dose.

The effect of fertigation is well highlighted in this study. The availability of nutrients and water in split doses at different growth stages including critical stages in the active root zone of crop effected the maximum utilization of resources for metabolic activities of the crop by reducing the losses which had resulted in the increased yield.

The study also suggested that the fertigation not only increased the yield and quality but also reduced the cost of cultivation through low cost nutrient sources and limiting the quantity of fertilizers. This eased the farmers to adopt the technology without high investment. The commonly available conventional fertilizers are found to be productive for fertigation which widens the adoption of technologies.

5.2.5 Effect of fertilizer levels and source of nutrients on economics of bush type vegetable cowpea under open precision farming

The B:C ratio did not differ significantly among fertigation levels. Among the sources of nutrients, the B: C ratio exhibited statistically comparable values. The results are in conformity with findings of Rajan *et al*. (2014).

5. 3. Experiment III: Standardization of irrigation schedule and response of bio-fertilisers for bush type vegetable cowpea under open precision farming

The experiment was conducted to study the effect of *Rhizobium* seed treatment and foliar nutrition on the performance of vegetable cowpea *Vigna unguiculata* (L.) Walp.) (var. Lalita) and to standardize optimum level of drip irrigation for maximum yield under open precision farming.

5.3.1.1 Effect of irrigation levels, *Rhizobium* seed treatment and foliar nutrition on growth and productivity of bush type vegetable cowpea under open precision farming

The growth and yield characters obtained at different growth have phases clearly have shown the influence of drip irrigation levels on the growth and productivity vegetable cowpea. Plant height recorded at 20 DAS and 40 DAS and at harvest from different drip irrigation treatments revealed that drip irrigation of 100 per cent Ep had produced the tallest plants followed by drip irrigation at 80 per cent Ep and shortest plants were observed in furrow irrigation treatments at different stages of plant growth. Drip irrigation of 100 per cent Ep also recorded higher number of leaves per plant and lower number of leaves in treatment with furrow irrigation at different growth phases of vegetable cowpea (Fig.24 & 25). This might be due to moisture stress under furrow irrigated condition which lead to poor cell elongation, low rate of photosynthesis and low carbohydrate assimilation resulted in the reduced plant growth and the treatment which received water at 100 and 80 per cent Ep produced better crops due to controlled and continuous availability of moisture as per the requirement of plant growth. These results are in agreement with the findings of Muthuchamy *et al*. (1993) and Reddy *et al*. (2011).

Drip irrigation at 80 and 100 per cent Ep increased the dry matter content of plant by 13.49 and 4.16 per cent over furrow irrigation method (Fig. 26). These results are in conformity with the findings of Singh *et al.* (2009). Leaf area index and leaf area duration also followed the same trend as that of dry matter production. Niveditha and Nagavani (2016) reported significantly higher leaf area index at drip irrigation of 100 per cent Ep.

Levels of irrigation found to influence early flowering. Drip irrigation at 80 and 100 per cent Ep completed flowering earlier than all other treatments. This might be due to low water stress in the canopy which leads to better growth of crop which favored early cessation of vegetative growth leading to earlier initiation of reproductive phase. Results are in conformity with findings of Niveditha and Nagavani (2016) and Narayanankutty *et al*. (2017).

Levels of irrigation had significant effect on number of pods and yield per plant (Fig. 27 & 28). Maximum number of pods and yield per plant was recorded with drip irrigation at 80 and 100 per cent Ep. This may be due to the frequent and consistent application of water in the vicinity of the roots which provided better soil moisture regime in the crop root zone throughout the crop growth period which resulted in enhanced growth and yield of cowpea. Similar results were observed with works of Prabhakar (2000) and Reddy *et al*. (2011).

Among different drip irrigation levels highest fresh pod yield was exhibited with drip irrigation at 100 per cent Ep which was statistically comparable with drip irrigation at 80 per cent Ep and it was 47 and 42 per cent higher than the yield of drip irrigation at 60 per cent Ep. The better performance of plant in terms of growth and yield parameters at 80 and 100 per cent Ep may be attributed to the higher fresh pod yield in these treatments. The results are in conformity with the findings of Reddy *et al*. (2011).

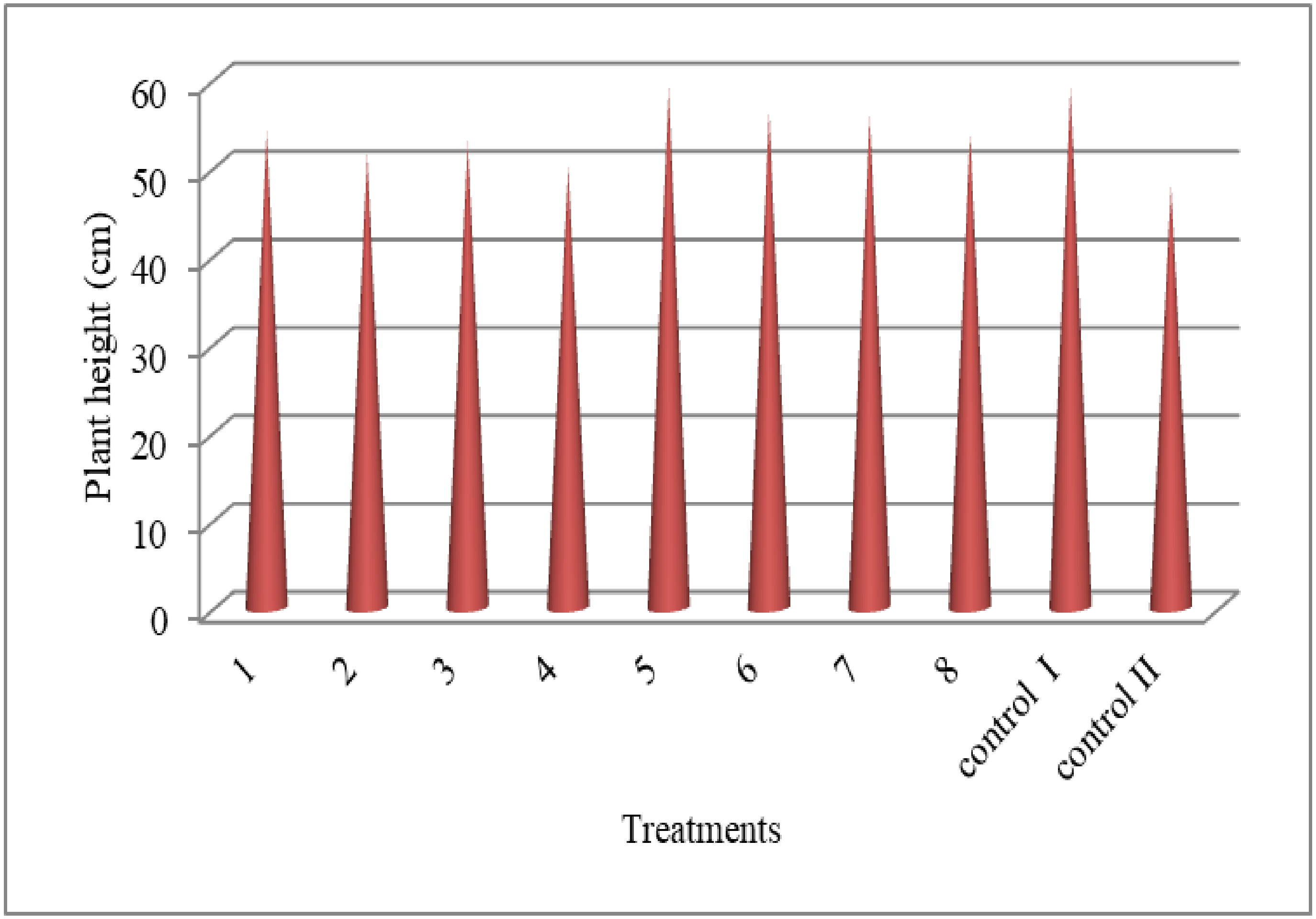


Fig. 24 Plant height (cm) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition (At harvest)

Treatment combinations

T_1	Irrigation @ 60% Ep + rhizobium + foliar nutrition
T_2	Irrigation @ 60% Ep + rhizobium + no foliar nutrition
T_3	Irrigation @ 60% Ep + no rhizobium + foliar nutrition
T_4	Irrigation @ 60% Ep + no rhizobium + no foliar nutrition
T_5	Irrigation @ 80% Ep + rhizobium + foliar nutrition
T_6	Irrigation @ 80% Ep + rhizobium + no foliar nutrition
T_7	Irrigation @ 80% Ep + no rhizobium + foliar nutrition
T_8	Irrigation @ 80% Ep + no rhizobium + no foliar nutrition
Control I	Irrigation at 100% Ep + without rhizobium + without foliar nutrition
Control II	Conventional channel irrigation once in 2 days + without rhizobium + POP level of fertilizer application + without foliar nutrition

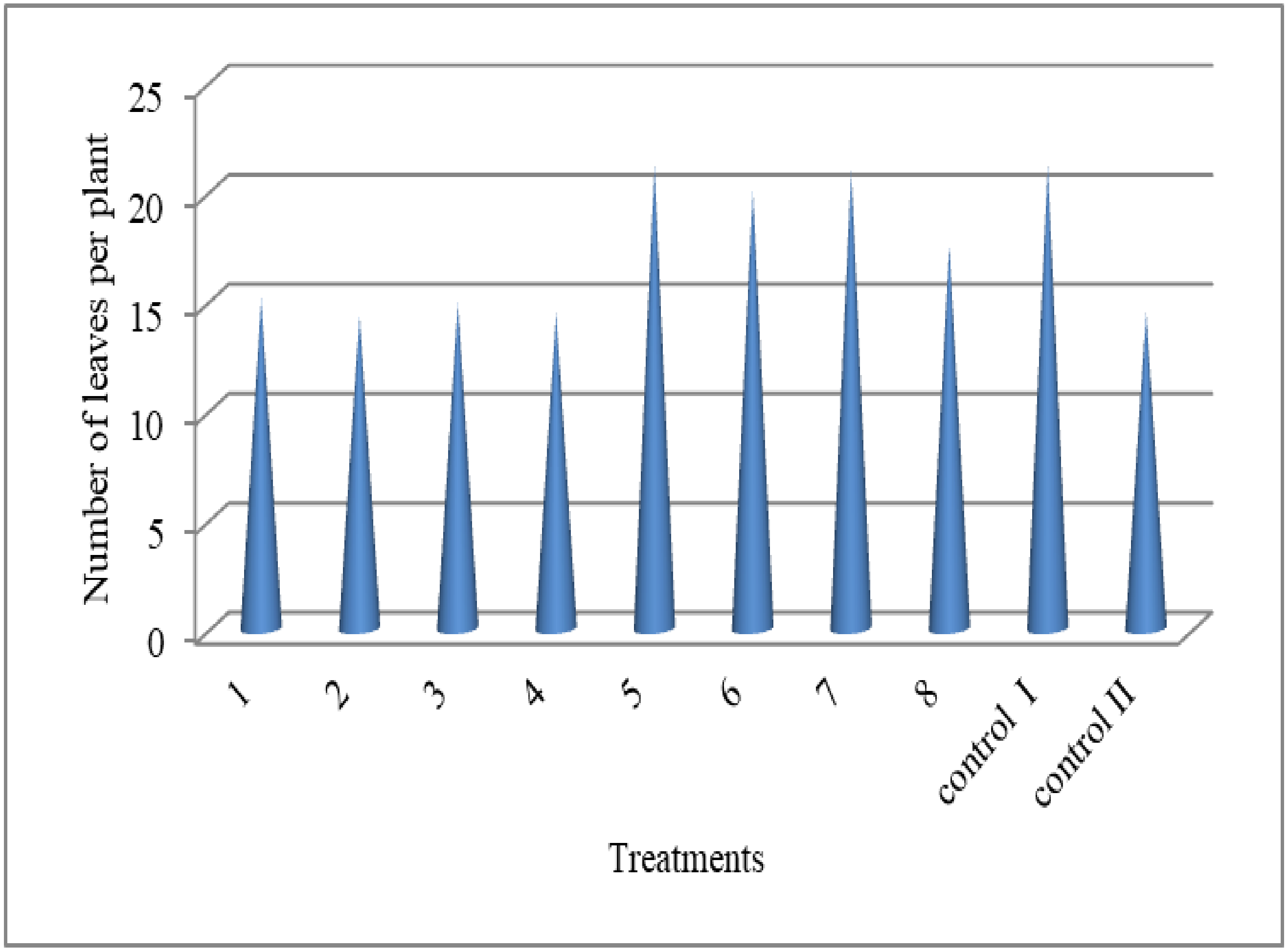


Fig. 25 Number of leaves per plant of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition (At harvest)

Treatment combinations

T_1 Irrigation @ 60% Ep + rhizobium + foliar nutrition

T_2 Irrigation @ 60% Ep + rhizobium + no foliar nutrition

T_3 Irrigation @ 60% Ep + no rhizobium + foliar nutrition

T_4 Irrigation @ 60% Ep + no rhizobium + no foliar nutrition

T_5 Irrigation @ 80% Ep + rhizobium + foliar nutrition

T_6 Irrigation @ 80% Ep + rhizobium + no foliar nutrition

T_7 Irrigation @ 80% Ep + no rhizobium + foliar nutrition

T_8 Irrigation @ 80% Ep + no rhizobium + no foliar nutrition

Control I Irrigation at 100% Ep + without rhizobium + without foliar nutrition

Control II Conventional channel irrigation once in 2 days + without rhizobium + POP level of fertilizer application + without foliar nutrition

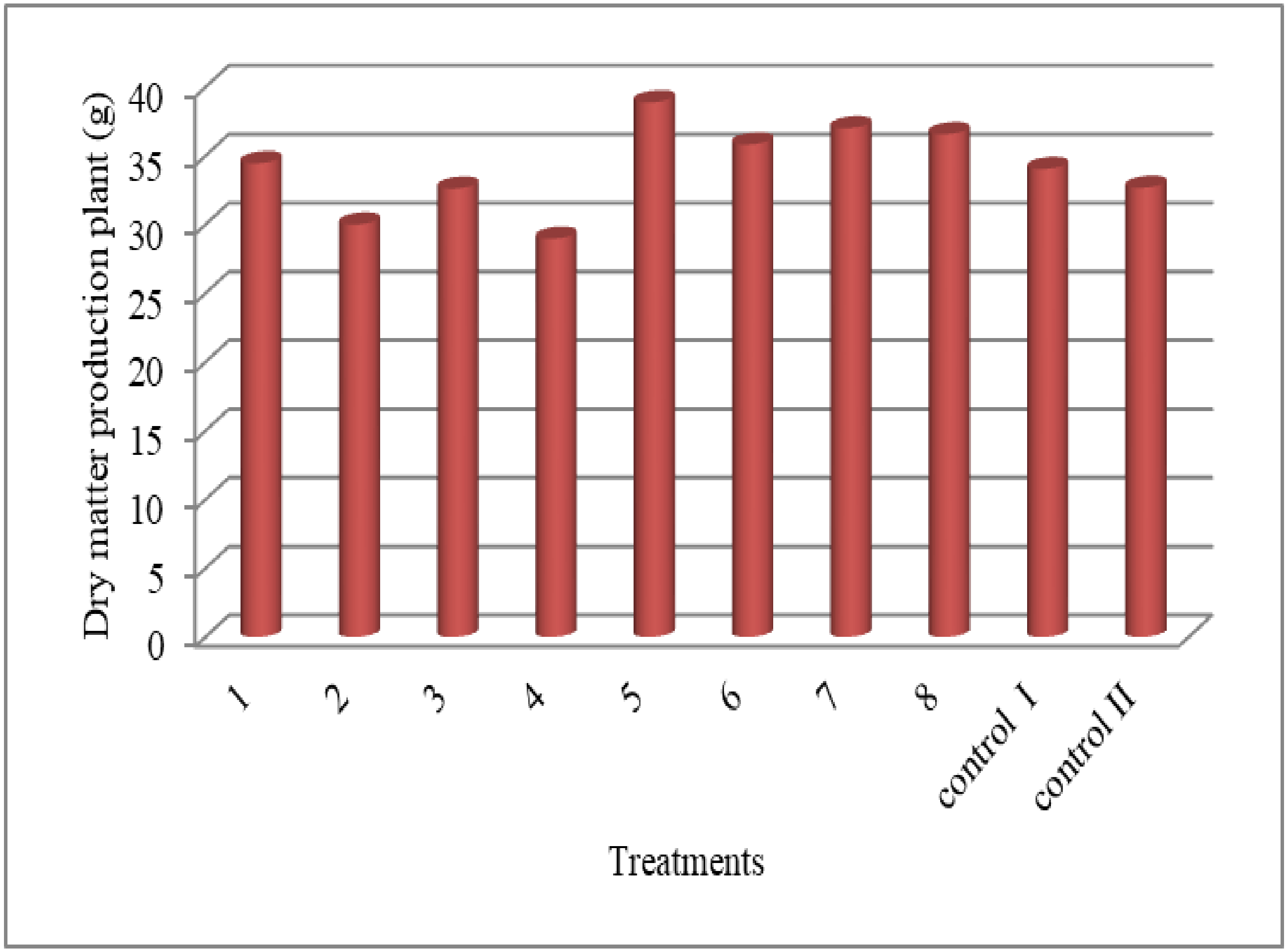


Fig. 26 Dry matter production per plant of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatment combinations

T_1	Irrigation @ 60% Ep + rhizobium + foliar nutrition
T_2	Irrigation @ 60% Ep + rhizobium + no foliar nutrition
T_3	Irrigation @ 60% Ep + no rhizobium + foliar nutrition
T_4	Irrigation @ 60% Ep + no rhizobium + no foliar nutrition
T_5	Irrigation @ 80% Ep + rhizobium + foliar nutrition
T_6	Irrigation @ 80% Ep + rhizobium + no foliar nutrition
T_7	Irrigation @ 80% Ep + no rhizobium + foliar nutrition
T_8	Irrigation @ 80% Ep + no rhizobium + no foliar nutrition
ControlI I	Irrigation at 100% Ep + without rhizobium + without foliar nutrition
Control II	Conventional channel irrigation once in 2 days + without rhizobium + POP level of fertilizer application + without foliar nutrition

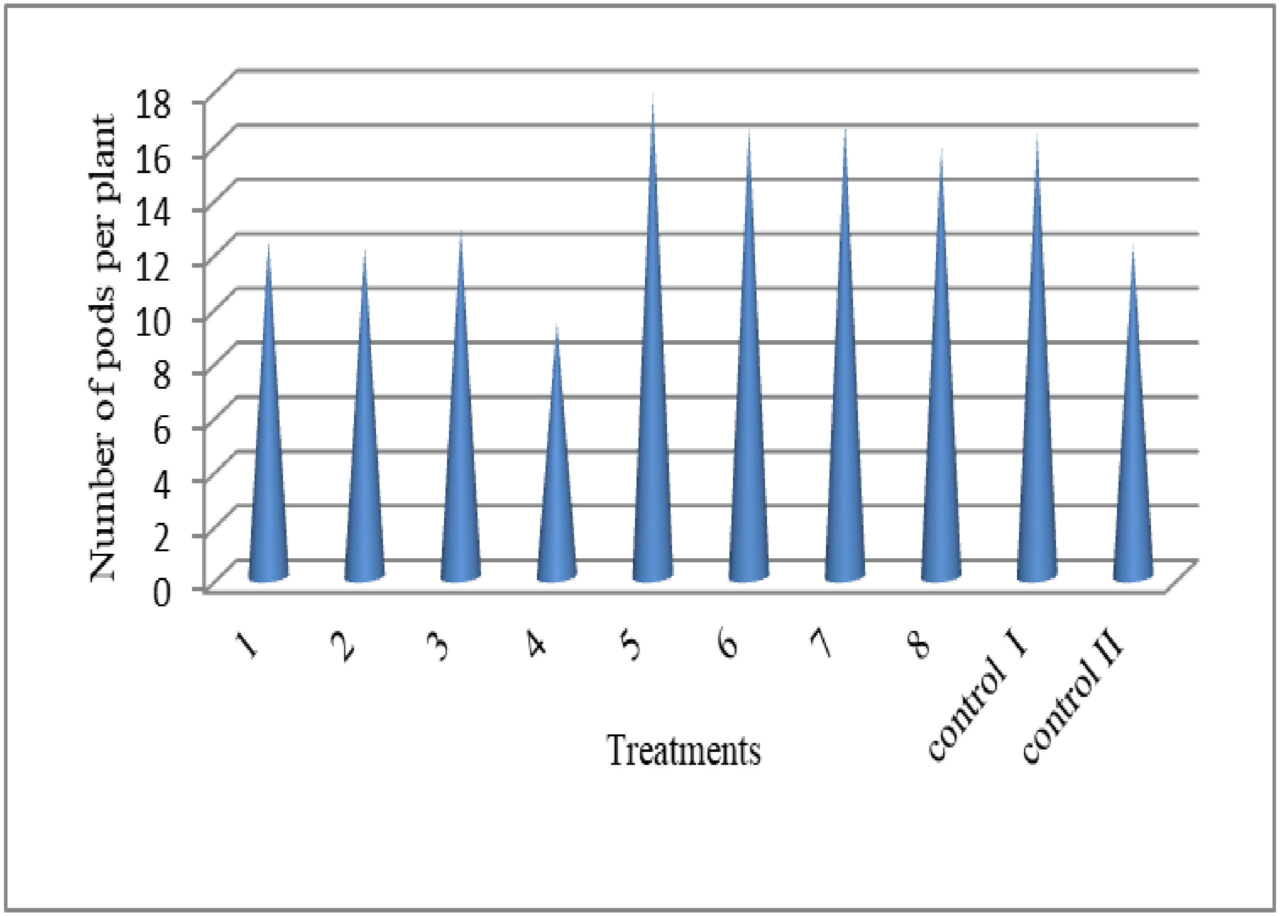


Fig.27 Number of pods per plant of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatment combinations

T_1 Irrigation @ 60% Ep + rhizobium + foliar nutrition

T_2 Irrigation @ 60% Ep + rhizobium + no foliar nutrition

T_3 Irrigation @ 60% Ep + no rhizobium + foliar nutrition

T_4 Irrigation @ 60% Ep + no rhizobium + no foliar nutrition

T_5 Irrigation @ 80% Ep + rhizobium + foliar nutrition

T_6 Irrigation @ 80% Ep + rhizobium + no foliar nutrition

T_7 Irrigation @ 80% Ep + no rhizobium + foliar nutrition

T_8 Irrigation @ 80% Ep + no rhizobium + no foliar nutrition

ControlI I Irrigation at 100% Ep + without rhizobium + without foliar nutrition

Control II Conventional channel irrigation once in 2 days + without rhizobium + POP level of fertilizer application + without foliar nutrition

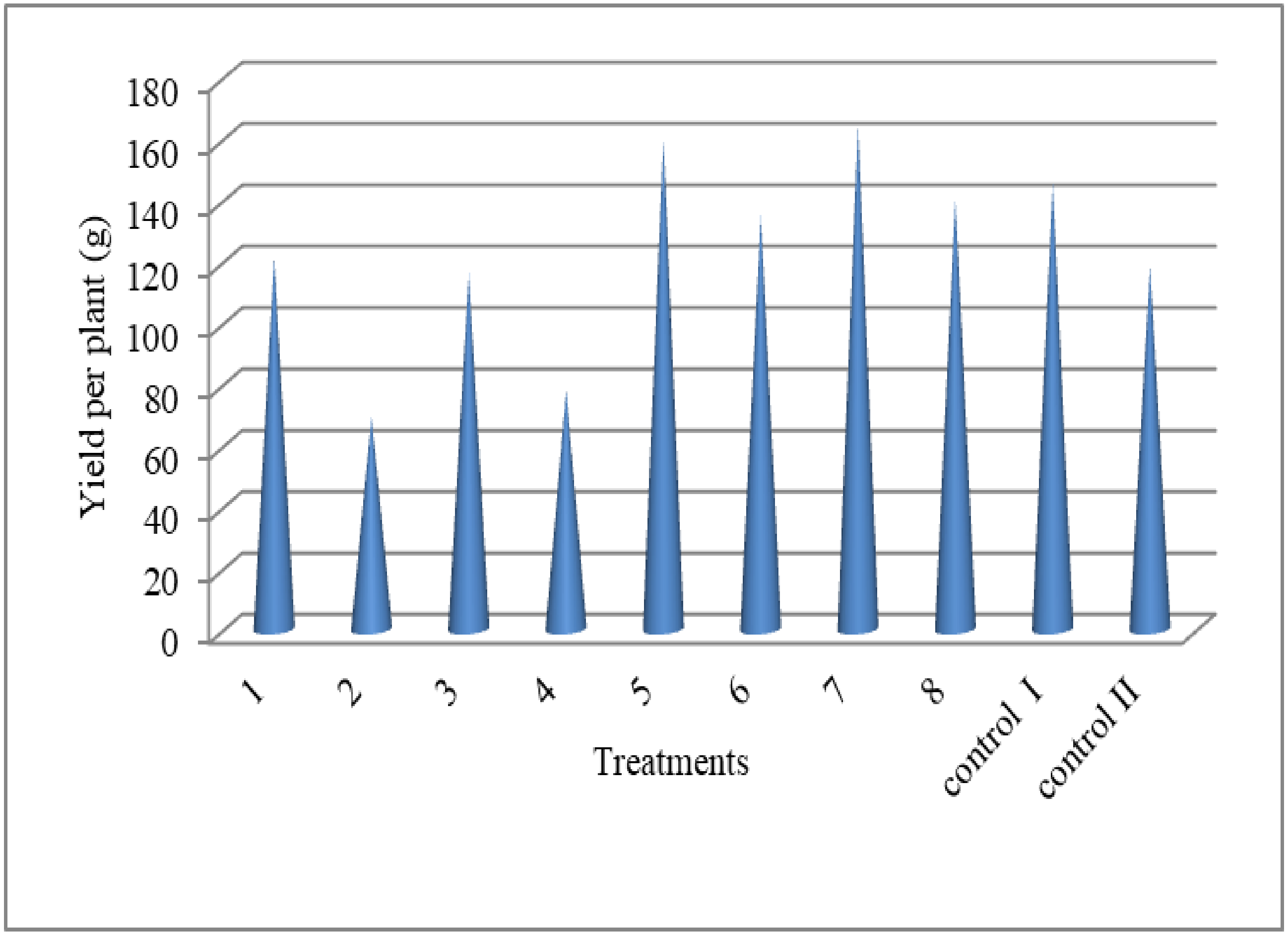


Fig. 28 Yield per plant (g) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatment combinations

T_1 Irrigation @ 60% Ep + rhizobium + foliar nutrition

T_2 Irrigation @ 60% Ep + rhizobium + no foliar nutrition

T_3 Irrigation @ 60% Ep + no rhizobium + foliar nutrition

T_4 Irrigation @ 60% Ep + no rhizobium + no foliar nutrition

T_5 Irrigation @ 80% Ep + rhizobium + foliar nutrition

T_6 Irrigation @ 80% Ep + rhizobium + no foliar nutrition

T_7 Irrigation @ 80% Ep + no rhizobium + foliar nutrition

T_8 Irrigation @ 80% Ep + no rhizobium + no foliar nutrition

ControlI I Irrigation at 100% Ep + without rhizobium + without foliar nutrition

Control II Conventional channel irrigation once in 2 days + without rhizobium + POP level of fertilizer application + without foliar nutrition

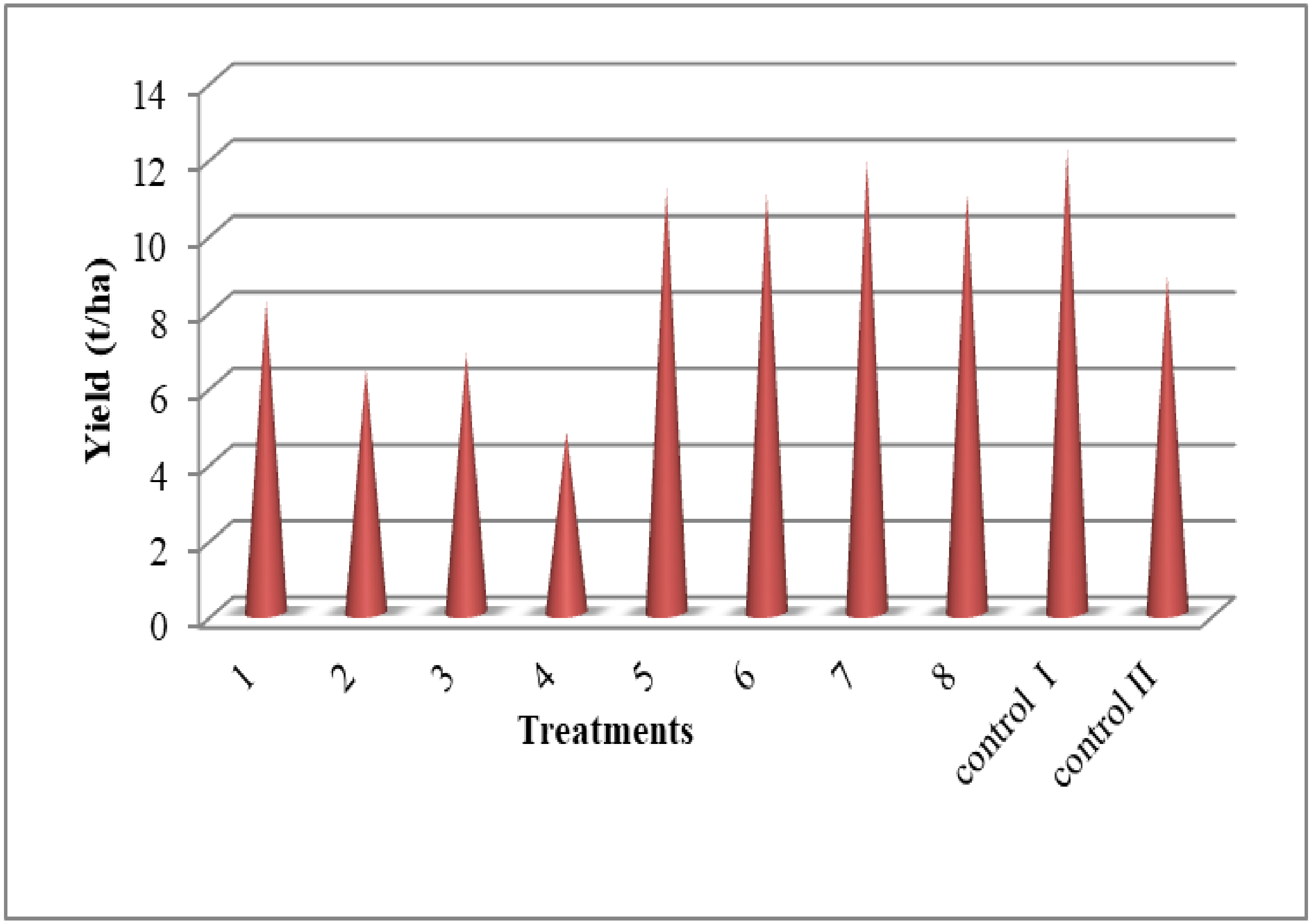


Fig. 29 Yield (t/ha) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatment combinations

T_1	Irrigation @ 60% Ep + rhizobium + foliar nutrition
T_2	Irrigation @ 60% Ep + rhizobium + no foliar nutrition
T_3	Irrigation @ 60% Ep + no rhizobium + foliar nutrition
T_4	Irrigation @ 60% Ep + no rhizobium + no foliar nutrition
T_5	Irrigation @ 80% Ep + rhizobium + foliar nutrition
T_6	Irrigation @ 80% Ep + rhizobium + no foliar nutrition
T_7	Irrigation @ 80% Ep + no rhizobium + foliar nutrition
T_8	Irrigation @ 80% Ep + no rhizobium + no foliar nutrition
ControlI I	Irrigation at 100% Ep + without rhizobium + without foliar nutrition
Control II	Conventional channel irrigation once in 2 days + without rhizobium + POP level of fertilizer application + without foliar nutrition

5.3.1.2 Effect of irrigation levels on quality and water productivity of bush type vegetable cowpea under open precision farming

The highest content of crude protein was recorded with drip irrigation of 100 per cent Ep which was statistically comparable with drip irrigation 80 per cent Ep. Minimum content of crude protein was recorded with conventional channel irrigation once in 2 days. This might be due to regular water supply through drip irrigation; crop plants can complete all metabolic process at appropriate time. The adequate moisture supply also helps in keeping various enzyme systems active. Therefore, quality of the produce is better in drip irrigated crops as compared to surface irrigated crops, Gupta *et al*. (2015).

Being the division of economic yield to water used in the field, water productivity reflects the efficacy of a given treatment in transforming the water used into economic produce ie, pod yield per unit water use. The total water applied among different irrigation methods was lowest in 60 per cent Ep followed by 80 per cent Ep and 100 per cent Ep. Among the drip irrigation levels drip irrigation at 80 per cent Ep recorded highest water productivity and found on par with drip irrigation at 100 per cent Ep. The higher water saving in drip irrigation system is due to the elimination of various forms of water losses during irrigation. These results are in agreement with the earlier findings of Bafna *et al*.(1993) and Reddy *et al*. (2011).

5.3.1.3 Effect of irrigation levels on nutrient uptake and soil nutrient status of bush type vegetable cowpea under open precision farming.

Among the irrigation levels, drip irrigation at 100 % Ep had higher uptake of nitrogen, phosphorus and potassium by plants which was statistically comparable with drip irrigation at 80 % Ep. The increased uptake of nutrients with drip irrigation at 80 % Ep (Aisha mol, 2017) and 100% Ep (Prakash *et al*., 2019) was reported by many workers. Higher soil moisture content in these treatments enhanced the availability of nutrients in soil and absorption of nutrients by plants which leads to increased uptake of nutrients from the plots with drip irrigation at 80 and 100 per cent Ep.

In the case of drip irrigation levels, soil pH exhibited on par values at all the three levels of drip irrigation. EC of the soil was low at higher levels of drip irrigation due to washing of salts to lower layers of soil with increased levels of irrigation. Highest EC was observed from plot under drip irrigation at 60 per cent Ep. The results are in conformity with the findings of Aisha mol (2017).

In case of drip irrigation levels, maximum organic carbon content of major and micro nutrient content of soil was recorded with drip irrigation at 60 per cent Ep and minimum available nutrients was recorded with drip irrigation 80 and 100 per cent Ep. This might be due to higher uptake of nutrients in the treatment with 80 and 100 per cent Ep which led to lower available nutrients in soil.

5.3.1.4 Effect of irrigation levels on benefit: cost ratio of bush type vegetable cowpea under open precision farming

Drip irrigation at 80 per cent Ep recorded maximum B: C ratio of 1.40 which was on par with that at drip irrigation of 100 per cent Ep (1.37) at harvest. Least B: C ratio was with drip irrigation at 60 per cent Ep (0.81). The results are in conformity with the findings of Mila *et al*. (2017).

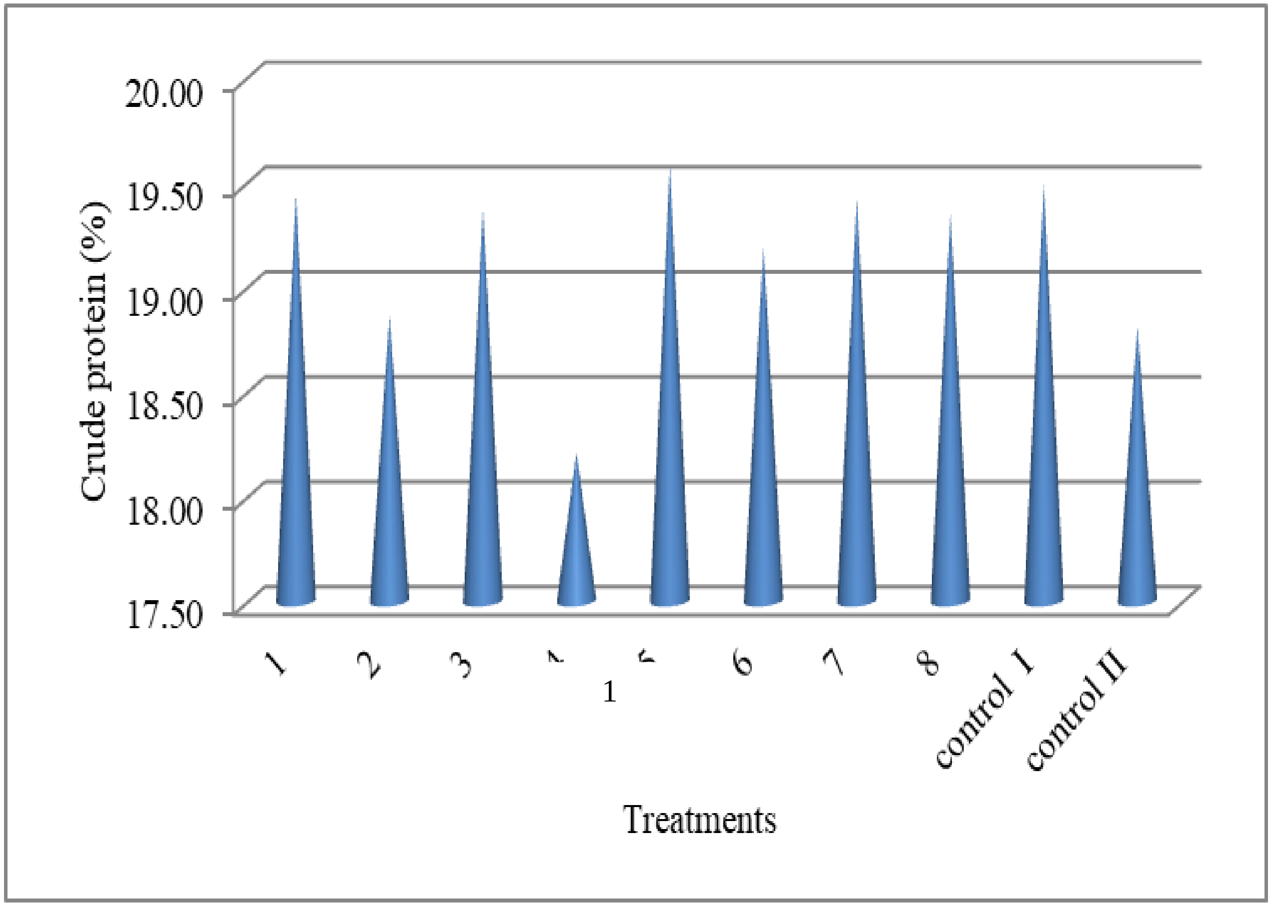


Fig. 30 Crude protein (%) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatment combinations

T_1 Irrigation @ 60% Ep + rhizobium + foliar nutrition

T_2 Irrigation @ 60% Ep + rhizobium + no foliar nutrition

T_3 Irrigation @ 60% Ep + no rhizobium + foliar nutrition

T_4 Irrigation @ 60% Ep + no rhizobium + no foliar nutrition

T_5 Irrigation @ 80% Ep + rhizobium + foliar nutrition

T_6 Irrigation @ 80% Ep + rhizobium + no foliar nutrition

T_7 Irrigation @ 80% Ep + no rhizobium + foliar nutrition

T_8 Irrigation @ 80% Ep + no rhizobium + no foliar nutrition

ControlI I Irrigation at 100% Ep + without rhizobium + without foliar nutrition

Control II Conventional channel irrigation once in 2 days + without rhizobium + POP level of fertilizer application + without foliar nutrition

5.3.2 Effect of *Rhizobium* seed treatment on growth and productivity of bush type vegetable cowpea under open precision farming

The *Rhizobium* seed treatment did not produce significant influence and the growth parameters were statistically comparable with respect to plant height, number of leaves per plant and LAI and LAD at 20, 40 DAS and at harvest. This might be due to reduced *Rhizobia* growth, survival, abundance and competitiveness in nodulation in low pH soil (pH <5.5) (Ferguson *et al*., 2013). The pH of the soil during the experiment was 5.4. Seed treatment with *Rhizobium* failed to produce significant effect on early flowering, nutrient uptake and soil nutrient status at harvest.

5.3.3.1 Effect of foliar nutrition on growth and productivity of bush type vegetable cowpea under open precision farming

The levels of foliar nutrition produced significant effect on growth of vegetable cowpea. The growth was maximum from plots with four spray of 19:19:19 as foliar compared to fertigation alone. This result complies with the results recorded by Ayyadurai *et al.* (2017) in blackgram and Srinivasan and Ramasamy (1992) in cowpea. This could be due to the fact that nutrients applied through foliage would be easily available and translocated in the plants without any loss, hence the plants could put forth better growth which leads to taller plants, higher leaf area index and dry matter production in vegetable cowpea. Interaction between drip irrigation levels and *Rhizobium* seed treatment and foliar nutrition showed that the tallest plants were observed from the treatment combination of drip irrigation at 80 per cent Ep with *Rhizobium* seed treatment and foliar nutrition ($I_2B_1F_1$).

Foliar nutrition failed to produce early flowering. Application of nutrients through fertigation alone completed fifty per cent flowering earlier compared to the combination of fertigation and foliar nutrition. The results are in conformity with findings of Narayan *et al.* (2011).

Foliar nutrition with water soluble fertilizers produced significant effect on number of pods and yield per plant. The increase in numbers of pods and yield per plant due to foliar nutrition might be due to supply of more nutrients at critical stage (i.e. flowering and fruit setting) with a balance of nutrients for photosynthetic activity which ultimately enhanced utilization of photosynthates and increased allocation of photosynthates towards the economic part (Batra *et al.,* 2002). The results of the present investigation are also corroborated by Karpagam *et al.* (2004), Choudhary and Yadav. (2011) and Singhal *et al*.(2015).

Foliar nutrition levels differed significantly with respect to yield of vegetable cowpea and higher yield was recorded with foliar application of treatments as compared to fertigation alone. The increase in yield with foliar nutrition might be due to easy assimilation and uptake of applied nutrients resulting in more photosynthesis and enhanced food accumulation in edible parts (Phandis, 2010). The present findings are found in agreement with Batra *et al*. (2006) and Rahman *et al*. (2014).

Fertigation with foliar nutrition had improved the yield compared to fertigation alone. The basal dose of fertigation might have helped for enhancement of soil and to replenish the pool of nutrients in the soil. Along with absorption of nutrients from soil which is a slow process compared to foliar absorption, availability of nutrients to the target point, “leaves” though foliar nutrition might have resulted in the faster assimilation and deposition resulting in the enhanced yield.

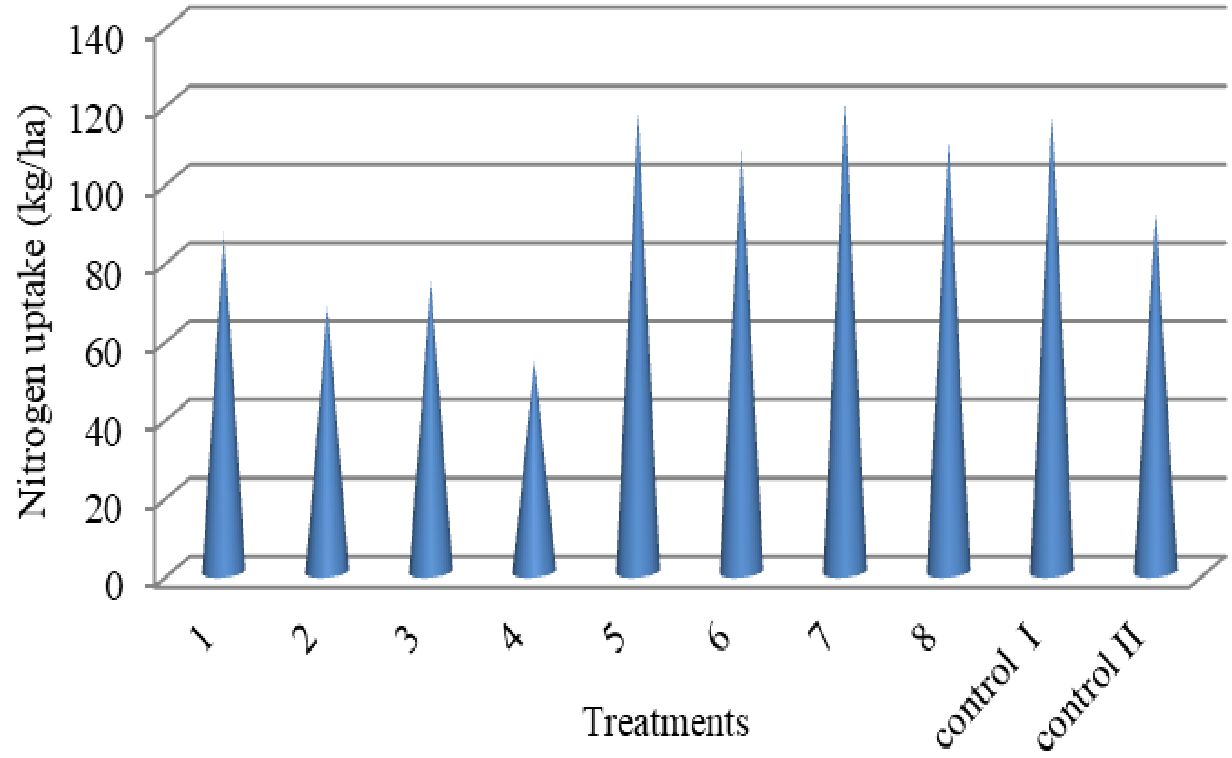


Fig. 31 Nitrogen uptake (kg/ha) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatment combinations

T_1 Irrigation @ 60% Ep + rhizobium + foliar nutrition

T_2 Irrigation @ 60% Ep + rhizobium + no foliar nutrition

T_3 Irrigation @ 60% Ep + no rhizobium + foliar nutrition

T_4 Irrigation @ 60% Ep + no rhizobium + no foliar nutrition

T_5 Irrigation @ 80% Ep + rhizobium + foliar nutrition

T_6 Irrigation @ 80% Ep + rhizobium + no foliar nutrition

T_7 Irrigation @ 80% Ep + no rhizobium + foliar nutrition

T_8 Irrigation @ 80% Ep + no rhizobium + no foliar nutrition

ControlI I Irrigation at 100% Ep + without rhizobium + without foliar nutrition

Control II Conventional channel irrigation once in 2 days + without rhizobium + POP level of fertilizer application + without foliar nutrition

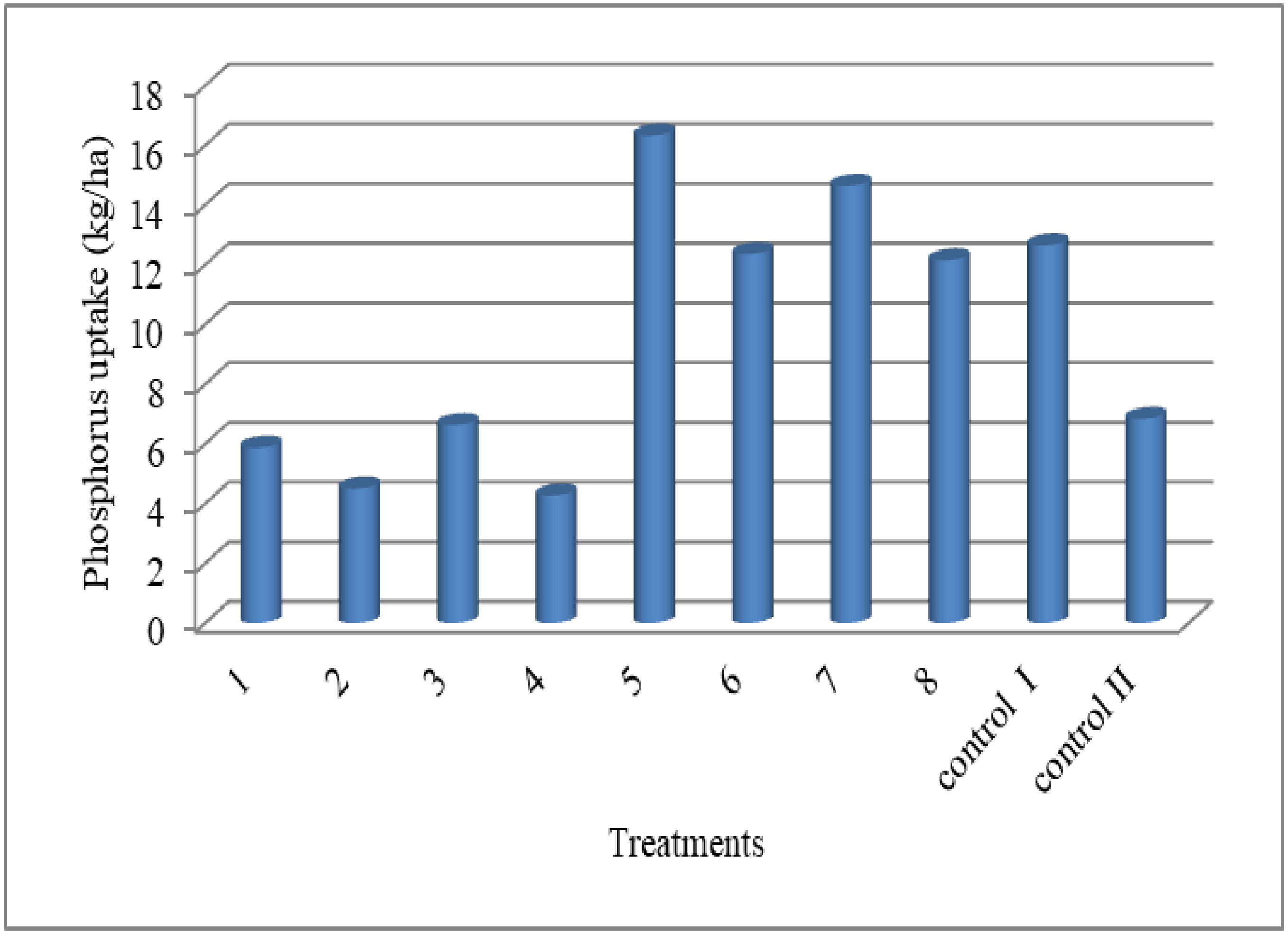


Fig. 32 Phosphorous uptake (kg/ha) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatment combinations

T_1	Irrigation @ 60% Ep + rhizobium + foliar nutrition
T_2	Irrigation @ 60% Ep + rhizobium + no foliar nutrition
T_3	Irrigation @ 60% Ep + no rhizobium + foliar nutrition
T_4	Irrigation @ 60% Ep + no rhizobium + no foliar nutrition
T_5	Irrigation @ 80% Ep + rhizobium + foliar nutrition
T_6	Irrigation @ 80% Ep + rhizobium + no foliar nutrition
T_7	Irrigation @ 80% Ep + no rhizobium + foliar nutrition
T_8	Irrigation @ 80% Ep + no rhizobium + no foliar nutrition
ControlI I	Irrigation at 100% Ep + without rhizobium + without foliar nutrition
Control II	Conventional channel irrigation once in 2 days + without rhizobium + POP level of fertilizer application + without foliar nutrition

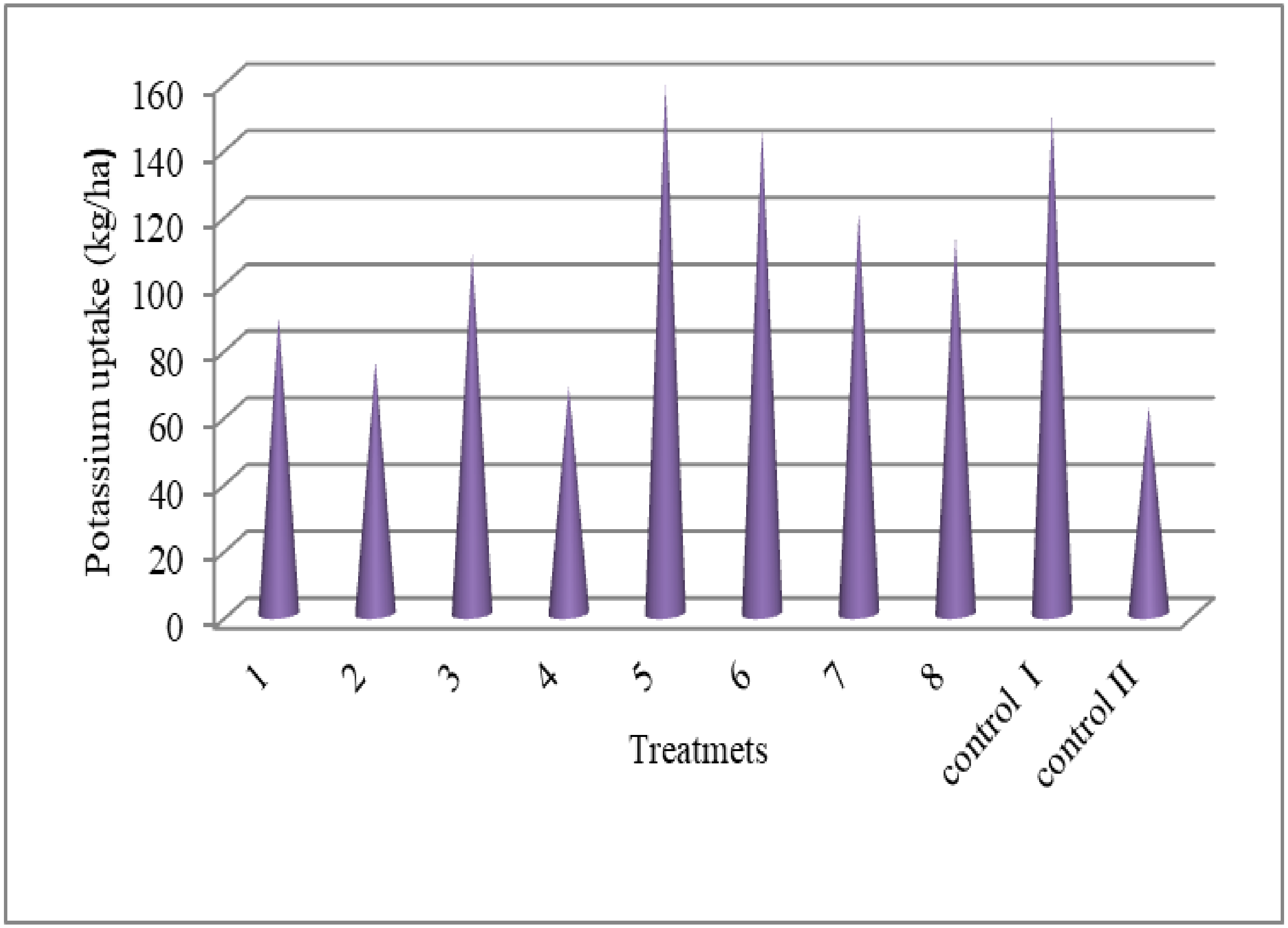


Fig. 33 Potassium uptake (kg/ha) of vegetable cowpea under drip irrigation, biofertilizers and foliar nutrition

Treatment combinations

T_1 Irrigation @ 60% Ep + rhizobium + foliar nutrition

T_2 Irrigation @ 60% Ep + rhizobium + no foliar nutrition

T_3 Irrigation @ 60% Ep + no rhizobium + foliar nutrition

T_4 Irrigation @ 60% Ep + no rhizobium + no foliar nutrition

T_5 Irrigation @ 80% Ep + rhizobium + foliar nutrition

T_6 Irrigation @ 80% Ep + rhizobium + no foliar nutrition

T_7 Irrigation @ 80% Ep + no rhizobium + foliar nutrition

T_8 Irrigation @ 80% Ep + no rhizobium + no foliar nutrition

ControlI I Irrigation at 100% Ep + without rhizobium + without foliar nutrition

Control II Conventional channel irrigation once in 2 days + without rhizobium + POP level of fertilizer application + without foliar nutrition

5.3.3.2 Effect of foliar nutrition on quality and water productivity of bush type vegetable cowpea under open precision farming

Foliar nutrition also had significant effect on crude protein content and higher crude protein content was recorded with four foliar spray of 19:19:19 might be due to enhanced translocation of nitrogen to the pods. The findings are in conformity with the results of Geetha and Velayutham (2009) in black gram and Yadav and Choudhary (2012) in vegetable cowpea. Foliar nutrition also had significant effect on water productivity which might be due to good response by the plants in terms of yield to the foliar applied nutrients.

5.3.3.3 Effect of foliar nutrition on nutrient uptake and soil nutrient status of bush type vegetable cowpea under open precision farming.

Foliar application was found to produce remarkable variation in nutrient uptake. The highest nitrogen, phosphorus and potassium uptake was recorded with four spray of 19: 19:19 as foliar along with fertigation. The increased uptake of nutrients with foliar spray of water soluble fertilizers was also reported by Phandis (2010) and Singhal *et al*. (2015).

Foliar application treatments produced variation on nutrients content of soil. Lower content of available nutrients in soil was recorded with foliar nutrition combined with fertigation. Higher availability of nutrients with the four foliar sprays of 19:19:19 resulted in higher uptake of nutrients which led to lower available nutrients in soil. Similar results were also reported by Gupta *et al.* (2015) and Mamathashree *et al.* (2017).

5.3.3.4 Effect of foliar nutrition on benefit: cost ratio of bush type vegetable cowpea under open precision farming

Supplementation of nutrients through foliar application also exhibited significant difference with respect to B: C ratio. Four spray of 19: 19: 19 as foliar produced higher B: C ratio as compared to fertigation treatments. The results are in conformity with the findings of Chaurasia *et al.* (2005).

SUMMARY

6. SUMMARY

A study entitled "Agro techniques for bush type vegetable cowpea (*Vigna unguiculata* (L.) Walp.) under open precision farming " was conducted during the year 2017-2019 at Agricultural Research Station, Mannuthy. The project was aimed to standardize optimum spacing and irrigation requirement of bush type cowpea for enhanced growth and yield under open precision farming. It also aims to develop a fertigation schedule and response of biofertilisers for bush type vegetable cowpea. The study resulted in the following findings.

Experiment I

- Genotype Lalita produced shortest plants and lower number of leaves per plant at different growth stages. While, tallest and higher number of leaves per plant were produced from wider spacing
- Genotype Anaswara and wider row spacing recorded higher dry matter production per plant, CGR, RGR, NAR,LAI and LAD at 20 and 40 DAS and at harvest
- Genotype Lalita completed fifty per cent flowering earlier than other genotypes while spacing failed to produce significant effect on early flowering
- Significantly longer pods were produced with genotype Lalita and spacing failed to produce significant effect on length of pod
- Maximum number of pods per plant, yield per plant and fresh pod yield were recorded with genotype Lalita and wider spacing
- Maximum crude protein content were recorded with genotype Lalita and spacing treatments failed to produce significant effect on crude fibre and crude protein content

- Higher nitrogen and potassium content of plant was recorded with genotype Lalita. While, high phosphorus content was recorded with genotype VU-5. Spacing treatment failed to produce significant influence on the nitrogen, phosphorus and potassium content of plants.
- Maximum nitrogen uptake was recorded with genotype Lalita. While, higher phosphorus and potassium uptake was recorded with genotype Anaswara
- Among different spacings narrow row spacing recorded higher nitrogen, phosphorus and potassium uptake.
- Highest B:C ratio was recorded with genotype Lalita and at wider spacing

Experiment II

- Fertilizer levels and sources of fertilizers failed to produce significant effect on height of plant and number of leaves per plant at 20 and 40 DAS and at harvest
- CGR, RGR, NAR, LAI and LAD were statistically comparable with respect to levels of fertilizers as well as sources of nutrients at all the stages of crop growth
- Early flowering and harvest was recorded with application of 50 per cent of uptake and control (package of practice recommendation)
- Fertigation levels and sources of fertilizers failed to produce significant effect on number of pods per plant, yield per plant and fresh pod yield of bush type vegetable cowpea
- Application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation attained final maturity lately. Duration of crop was on par among sources of nutrients

- Higher crude protein was recorded with application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha . While, higher crude fibre content was recorded with control treatment. The sources of nutrients were statistically comparable with respect to crude protein and crude fibre content
- The content of nitrogen in plant was recorded highest with application of fertilizer @ 185: 50: 170 kg N: P_2O_5: K_2O /ha through fertigation at harvest. However, content of phosphorus and potassium did not differ significantly among fertilizer levels. While, the content of nitrogen, phosphorus and potassium in plant did not differ significantly among sources of nutrients
- The content of calcium, magnesium sulphur, iron, zinc, manganese and boron in plant were recorded highest with application of fertilizers @ 185: 50: 170 kg N: P_2O_5: K_2O /ha . While, higher content of copper was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha
- The calcium, magnesium and boron content were statistically comparable with respect to sources of nutrients. While, higher iron, zinc, manganese and copper content were recorded with fertigation through 100 per cent water soluble fertilizers
- Nitrogen, phosphorus and potassium content of pod was statistically comparable with respect to levels of fertilizers as well as sources of nutrients
- Uptake of nitrogen, phosphorus and potassium was statistically comparable with respect to fertilizer levels. Among sources of fertilizers, significantly higher uptake of nitrogen and phosphorus was recorded with fertigation through water soluble fertilizers

- Higher nitrogen, phosphorus and potassium use efficiency was recorded with application of POP recommendation through fertigation. Among the sources of nutrients, the nitrogen and potassium use efficiency exhibited statistically comparable values. High phosphorus use efficiency was exhibited by water soluble fertilizers.
- Higher electrical conductivity of soil was recorded with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha of fertilizer through fertigation as water soluble fertilizers
- The pH of the soil did not differ significantly with levels or sources of fertilizers
- Organic carbon content of the soil was statistically comparable with respect to levels of fertilizers and sources of fertilizers
- The available nitrogen, phosphorus and potassium content were highest with application of fertilizers @ 231: 63: 212 kg N: P_2O_5: K_2O /ha through fertigation with fifty per cent of the fertilizers dose through conventional sources as basal and remaining fifty per cent through fertigation as water soluble fertilizers.
- The available calcium, magnesium, sulphur, iron, zinc, manganese, copper and boron content of soil were statistically comparable with respect to levels of fertilizers and sources of fertilizers
- B: C ratio was statistically comparable with respect to levels of fertilizers as well as sources of nutrients.

Experiment III

- The tallest plants, higher number of leaves per plant and maximum dry matter production were recorded with drip irrigation at 100 per cent Ep was on par with drip irrigation at 80 per cent Ep
- The tallest plants, significantly higher number of leaves per plant and maximum dry matter production were recorded with combined application of fertigation and foliar nutrition compared to fertigation alone.
- Drip irrigation at 80 per cent Ep without foliar application attained fifty per cent flowering earlier
- Conventional channel irrigation once in 2 days and fertigation alone treatments attained final maturity earlier than other treatments
- Higher number of pods per plant was recorded with drip irrigation at 80 per cent Ep with combined application of fertigation and foliar nutrition compared to fertigation alone
- Higher yield per plant, fresh pod yield and crude protein content were recorded with drip irrigation at 100 per cent Ep which was found on par with drip irrigation at 80 per cent Ep and combined application of fertigation and foliar nutrition
- Significantly higher crude fibre content was recorded with conventional channel irrigation once in 2 days and with fertigation alone
- Higher content and uptake of nitrogen, phosphorous and potassium were recorded with drip irrigation at 100 per cent Ep which was found on par with drip irrigation at 80 per cent Ep and combined application of fertigation and foliar nutrition
- Drip irrigation of 80 per cent Ep recorded the highest number of effective nodules per plant. Seed treatment with *Rhizobium* and foliar nutrition

failed to produce significant effect on number of effective nodules per plant

- *Rhizobium* and actinomycetes count at flowering and at harvest did not differ significantly among different drip irrigation levels and as well as foliar nutrition
- Higher Dehydrogenase activity of the soil was recorded with drip irrigation at 100 per cent Ep found on par with 100 per cent Ep. Seed treatment with *Rhizobium* and foliar nutrition produced significant effect on the dehydrogenase activity of the soil at harvest.
- Highest bacterial and fungal count was recorded with drip irrigation at 100 per cent Ep. While, seed treatment with *Rhizobium* and foliar nutrition failed to produce significant effect on the bacterial and fungal count in the soil.
- The pH of the soil did not differ with respect to drip irrigation, seed treatment with *Rhizobium* and foliar nutrition.
- The maximum organic carbon content, available nitrogen, phosphorus, potassium, calcium, magnesium and sulphur content of soil were recorded with drip irrigation at 60% Ep and fertigation alone
- Micronutrient (iron, zinc, manganese copper and boron) contents of soil were recorded maximum with drip irrigation at 60% Ep and fertigation alone
- Highest water productivity and B:C ratio was recorded with drip irrigation at 80 per cent Ep and combined application of fertigation and foliar nutrition

Future line of work

- Confirmation trial for evaluation of genotypes and optimization of spacing for enhanced growth and yield of bush type vegetable cowpea under open precision farming.
- Confirmation trial for standardization of source of nutrients and levels of fertigation in bush type vegetable cowpea under open precision farming to be carried out in relation to varied soil fertility.
- Confirmation trial for standardization of irrigation schedule, response of bio-fertilisers and foliar nutrition with water soluble fertilizers for bush type vegetable cowpea under open precision farming to be done in relation to varied soil fertility.
- Varietal screening with promising dual purpose and hybrids varieties of vegetable cowpea under open precesion farming to be conducted.
- Suitability of new nutrient combination for fertigation in cowpea is to be evaluated

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AGRO TECHNIQUES FOR BUSH TYPE VEGETABLE COWPEA (*Vigna unguiculata* (L.) Walp.) UNDER OPEN PRECISION FARMING

by

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Abstract

Cowpea is an important legume vegetable crop known as vegetable meat because of high protein content (24.8 %). The average productivity of cowpea in India is 607 kg/ha (ICAR, 2020) which is considered to be low. Productivity of the crop can be enhanced through selection of appropriate varieties and advanced technologies in management of nutrients and water. Since the research work on cowpea under open precision farming in Kerala is meagre, an attempt was made to standardise the agro techniques for enhancing the yield and profit to the growers.

The research work on the topic "Agro techniques for bush type vegetable cowpea (*Vigna unguiculata* (L.) Walp.) under open precision farming" was undertaken in the Department of Agronomy, College of Horticulture, Vellanikkara during 2017- 2019. The project was aimed to standardize optimum spacing and irrigation requirement of bush type cowpea for enhanced growth and yield under open precision farming. It also aimed to develop a fertigation schedule and to study the response of biofertilisers and foliar nutrition on bush type vegetable cowpea.

The first experiment on "Evaluation of genotypes and optimization of spacing for enhanced growth and yield of bush type vegetable cowpea under open precision farming" was laid out with five genotypes *viz.* Lalita, VU-5, Bhagyalakshmi, Kashi Kanchan, Pusa Komal and Anaswara and three spacings *viz.* 60 cm x 30 cm, 45 cm x 30 cm and 30 cm x 15 cm, replicated thrice. Among the genotypes Lalita performed better in terms of growth characters and yield and the poor performance was recorded by genotype VU-5. The wider row spacing of 60 cm x 30 cm had a significant superior effect on growth characters and yield of

cowpea. The best treatment of genotype Lalita and wider spacing of 60 x 30 cm were selected for the subsequent experiments.

The second experiment on “Standardization of source of nutrients and levels of fertigation in bush type vegetable cowpea under open precision farming” was carried out with four levels of fertilizers and three sources of nutrients replicated thrice under open precision farming. The levels of fertilizers were arrived based on the nutrient uptake pattern. The fertigation was given at twenty equal splits doses with conventional and water soluble fertilizers and their combination. The results revealed that there was no significant difference between the levels of fertilizers with respect to growth and yield of cowpea and the application of 20:30:10 kg N, P_2O_5, K_2O per hectare was found to be sufficient for the comparable performance of cowpea with other levels. Fertigation through conventional fertilizers *viz*. urea, diammonium phosphate and Muriate of potash had comparable effect with water soluble fertilizers and their combination in terms of growth and yield of cowpea.

The third experiment on “Standardization of irrigation schedule and response of biofertilisers on bush type vegetable cowpea under open precision farming” was conducted to standardize the schedule of drip irrigation and to study the response of biofertilisers and foliar nutrition on bush type vegetable cowpea under open precision farming. Drip irrigation at 100 per cent Ep recorded higher fresh pod yield which was on par with 80 per cent Ep. Water productivity was significantly influenced by irrigation levels and higher water productivity was recorded with drip irrigation at 80 per cent Ep. Combined application of 60 per cent of the recommended dose of fertilizers (20:30:10 kg N, P_2O_5, K_2O /ha) through fertigation as conventional fertilizers and 40 per cent through foliar application using water soluble fertilizers recorded higher fresh pod yield as well as quality characteristics compared to fertigation alone.

It is concluded that genotype Lalita at wider spacing of 60 cm x 30 cm was found promising for enhanced growth and yield of bush type vegetable cowpea under open precision farming. Fertigation with conventional fertilizers *viz*. urea, diammonium phosphate and Muriate of potash at the rate of 20:30:10 kg N, P_2O_5, K_2O per hectare found optimum in term of growth and yield under open precision farming. Combined application of 60 per cent of the recommended dose of fertilizers (20:30:10 kg N, P_2O_5, K_2O /ha) through fertigation with conventional fertilizers *viz*. urea, diammonium phosphate and Muriate of potash and 40 per cent through foliar nutrition using water soluble fertilizers with drip irrigation schedule at 80 per cent Ep was found superior for maximum water productivity, yield and profit of bush type cowpea under open precision farming.

APPENDICES

APPENDIX – I

Media composition for microbial study

1. Nutrient agar medium

Sl.No.	Reagents	Quantity
1.	Peptone	5.00 g
2.	Sodium chloride	5.00 g
3.	Beef extract	3.00 g
4.	Agar	20.00 g
5.	Distilled water	1000.00 ml
6.	pH	7.00

2. Kenknight's agar medium

Sl.No.	Reagents	Quantity
1.	Dextrose	1.00 g
2.	KH_2PO_4	0. 10 g
3.	$NaNO_3$	0. 10 g
4.	KCl	0. 10 g
5.	$MgSO_4.7\ H_2O$	0. 10 g
6.	Agar	15.00 g
7.	Distilled water	1000.00 ml

3. Martin's Rose Bengal agar medium

Sl.No.	Reagents	Quantity
1.	Glucose	10.00 g
2.	Peptone	5.00 g
3.	KH_2PO_4	1.00 g
4.	$MgSO_4.7\ H_2O$	0.50 g
5.	Streptomycin	30.00 mg
6.	Agar	15.00 g
7.	Rose Bengal	35.00 mg
8.	Distilled water	1000.00 ml

APPENDIX – II

Details of Cost of cultivation - Experiment I

Sl. No.	Particulars	Women Rs. 500/ day	Men Rs. 600/ day	Total amount (Rs./ha)
1	Land cleaning	14	0	7143
2	Bed preparation	29	29	31429
3	Drip lay out	0	29	17143
4	Mulch sheet laying	29	0	14286
5	Sowing	14	0	7143
6	Spraying	14	0	7143
7	Harvest	57	0	28571

APPENDIX – III

Details of Cost of inputs - Experiment I

Sl. No.	Particulars	Total amount (Rs./ha)
1	Mulching sheet	71429
2	FYM	53571
3	Lime	21429
4	Plant protection chemical	7143
5	NPK Complex	15000
6	KNO_3	40000
7	Urea	1713

APPENDIX – IV

Details of Cost of cultivation - Experiment II

Sl. No.	Particulars	Women Rs. 500/ day	Men Rs. 600/ day	Total amount (Rs./ha)
1	Drip lay out	0	14	8571
2	Mulch sheet laying	0	14	8571
3	Hole	0	14	8571
4	Sowing	14	0	7143
5	Spraying	29	0	28571
6	Harvest	43	0	64286

APPENDIX – V

Details of Cost of inputs - Experiment II

Sl. No.	Particulars	Total amount (Rs./ha)
1	DAP	271
2	KCl	271
3	Plant protection chemical	7142
4	NPK Complex	19420
5	KNO_3	60000
6	Urea	3480

APPENDIX – VI

Details of Cost of cultivation - Experiment III

Sl. No.	Particulars	Men Rs. 630/ day	Women Rs. 600/ day	Total amount (Rs./ha)
1	Bed preparation	29	17143	17143
2	Mulch sheet laying	14	8571	8571
3	Hole	14	8571	8571
4	Sowing	14	8571	8571
5	Spraying	29	17143	17143
6	Harvest	43	25714	25714

APPENDIX – VII

Details of Cost of inputs - Experiment III

Sl. No.	Particulars	Total amount (Rs./ha)
1	Plant protection chemical	7142
2	NPK Complex	271
3	DAP	271
4	Urea	82