NUTRIENT SOURCE EFFICIENCY RELATIONS ON THE PRODUCTIVITY OF COWPEA IN SUMMER RICE FALLOWS

By

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Nutrient source efficiency relations on the productivity of cowpea in summer rice fallows"** is a bona-fide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or society.

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Certified that this thesis, entitled **"Nutrient source efficiency relations on the productivity of cowpea in summer rice fallows"** is a record of research work done independently by **Miss. Lekha B. Nair** 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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We, the undersigned members of the Advisory Committee of **Miss. Lekha B. Nair,** a candidate for the degree of **Master of Science in Agriculture** with major in **Agronomy,** agree that the thesis entitled **"Nutrient source efficiency relations on the productivity of cowpea in summer rice fallows"** may be submitted by Miss. Lekha B. Nair in partial fulfilment of the requirements for the degree.

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Dedicated to

My Parents and My best Friend Jacob

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Introduction

1.INDRODUCTION

More than two lakh hectares of rice lands in Kerala are left fallow in summer months for want of sufficient soil moisture to raise a crop. Even marginal levels of cultivation in summer rice fallows is beset with problems of low response to applied inputs and very low productivity, probably because of the increasing salt index as well as the failure of plants to utilize the elements. Such a situation can only be circumvented through increased release of native contents of elements like phosphorus or foliar application of small levels of most essential inputs. Increased efficiency of nutrients leads to higher productivity of summer crop and indirectly benefits the succeeding rice crop. Cowpea is the most important pulse crop of Kerala and its suitability and advantages of growing in summer rice fallows is well documented (KAU, 1991). Considering the unique properties (both climate and soil) of summer rice fallows, a proper nutrient management is felt necessary.

Presently, sulphur deficiency is becoming widespread in Indian soils (Singh, 2003) and it is found to be sub- optimal in low land rice fields of Kerala (John *et al.*, 2005) due to continuous use of sulphur free fertilizers, leaching and erosion losses and crop rotation including pulses and oil seeds which are high sulphur consuming crops. However, not much work has been conducted to study the effect of sulphur containing fertilizers on crops grown in summer rice fallows of Kerala.

Adequate supply of phosphorus to legumes is more important than that of nitrogen because of its beneficial effect on nodulation, growth and yield. Being acidic in nature, phosphorus fixation and unavailability is common in Kerala soils. Inoculation with phosphate solubilising bacteria is a viable proposition for increasing the phosphorus availability from insoluble sources (Guar, 1990). Efficiency of phosphate solubilising bacteria in solubilising inorganic phosphates in acidic laterite soils of Kerala was noted by Shehana and Abraham (2001). But the results are meagre in the summer rice fallows.

Deficiency of soil moisture leads to low response of soil applied inputs and very low productivity of crops in summer rice fallows. Such a situation can be circumvented through application of nutrients through foliar spray at appropriate stages of growth, which is important for their efficient utilisation and better performance of the crop. However, not much work has been done to study the effect of foliar spray of nutrients on crops grown in summer rice fallows of Kerala.

With this background an investigation was undertaken with the following objectives.

1. To study the effect of different sources of nitrogen and phosphorus on growth, yield and quality of cowpea grown in summer rice fallows.

2. To assess the possibility of reducing the quantity of fertilizers to cowpea grown in summer rice fallows through inoculation of phosphate solubilising bacteria (PSB) and foliar application of diammonium phosphate (DAP).

3. To develop an efficient nutrient management system for higher productivity of cowpea grown in summer rice fallows.

Review of Literature

2.REVIEW OF LITERATURE

A field experiment was conducted in summer rice fallows to study the effect of different sources of nitrogen and phosphorus on growth, yield and quality of cowpea and to assess the possibility of reducing the quantity of fertilizers through inoculation of phosphate solubilising bacteria and foliar application of diammonium phosphate. The literature relevant to the study is reviewed under the following sections. Wherever the literature is insufficient, relevant works on other crops are also included.

2.1.COWPEA IN SUMMER RICE FALLOWS

Cowpea is an important pulse crop of Kerala, which is highly suited to the rice fallows in summer. It can thrive well in such a situation by utilizing the residual soil fertility and moisture and can enrich the soil by fixing atmospheric nitrogen and by addition of organic matter.

The suitability of cowpea variety Kanakamani for cultivation in summer rice fallows of Kerala was proved by the results of research work conducted under Kerala Agricultural University (KAU, 1991, KAU, 1992, Anitha *et al.*, 2004).

2.2. EFFECT OF DIFFERENT SOURCES OF NITROGEN, PHOSPHORUS AND SULPHUR ON GROWTH, YIELD AND QUALITY OF CROP PLANTS

The availability of nutrients varies with sources, which in turn influence the growth, yield and quality of crop plants.

2.2.1. Growth characters

Singh and Gupta (1970) observed that application of nitrogen in the form of ammonium sulphate, ammonium chloride, urea or ammonium sulphate nitrate had no significant influence on dry matter production in wheat. Totawat and Singh (1981) reported that application of nitrogen in the form of urea or ammonium sulphate in conjunction with sulphur upto 60 kg N ha^{-1} significantly increased the total dry matter production in pea compared to control. Chaubey *et al.* (2000) observed that application of 120 kg N ha^{-1} in the form of urea, ammonium sulphate, ammonium nitrate or calcium ammonium nitrate had no significant influence on plant height and tillers per plant in wheat.

Surendra *et al.* (1993) observed that the application of 50 kg P_2O_5 ha^{-1} as diammonium phosphate increased the plant height, number of nodules and nodule weight in black gram compared to nitrogen and phosphorus alone. Similar results in blackgram were reported by Balachandran and Nagarajan (2002). Ramamoorthy *et al.* (1994) reported that application of 12.5 kg N with 37.5 kg P_2O_5 ha^{-1} as Mussorie rock phosphate increased the plant height, number of branches, number of leaves and dry matter yield of pigeon pea compared to other P sources. Srinivasamoorthy (1995) observed that application of rock phosphate and super phosphate (1:1) mixture significantly increased the dry matter yield of cowpea. Santhi and Kothandaraman (1995) obtained the highest dry matter yield of greengram with application of 50 kg P_2O_5 ha^{-1} as diammonium phosphate along with arbuscular mycorrhizal fungi inoculation, compared to application of single super phosphate and Mussorie rock phosphate.

Application of single super phosphate significantly increased the dry matter yield of chickpea compared to Mussorie rock phosphate (Kulkarni *et al* 2000). Kumar *et al.* (2001) reported that application of 50 kg P_2O_5 ha^{-1} as diammonium phosphate was found to be the best source for increasing the plant height, number of branches and leaf area index in cowpea compared to Udaipur rock phosphate with phosphate solubilising microorganisms. A sand culture experiment conducted with KH_2PO_4, $AlPO_4$, $Ca_3(PO_4)_2$ and $FePO_4$ revealed that application of KH_2PO_4 increased the dry matter accumulation in legumes over control (Tamboli and Daffadar, 2002). Pandey *et al.* (2003) reported that combination of vesicular arbuscular mycorrhiza with rhizobium and a mixture of single super phosphate and Mussorie rock phosphate as the source of phosphorus increased the nodulation and growth of pea compared to biofertilizers and phosphorus sources alone. A study conducted by Garai and Dutta (2003) with different sources of P viz., Purila rock phosphate, single super phosphate, cattle urine treated Purila rock phosphate and whey treated Purila rock phosphate showed that whey treated Purila rock phosphate increased the plant height, number of primary branches, root length, and nodules per plant in green gram compared to other P sources.

Bhadoria *et al.* (1997) reported that application of 40kg sulphur in the form of gypsum increased the plant height, number of branches per plant, clusters per plant in cluster bean. Similar results in black gram were reported by Ramamoorthy *et al.* (1997).

2.2.2. Yield attributes and yield

Mandal and Sahu (1978) reported that application of 100–120 kg N as ammonium sulphate and urea resulted in higher grain yield and straw yield in rice compared to calcium ammonium nitrate. Singh and Singh (1975) observed that application of 150 kg N ha^{-1} as ammonium sulphate and calcium ammonium nitrate, gave significantly higher number of tillers per hill, length of spike, grain weight per spike, number of spikelets per spike, number of grains per spike and grain and straw yield in wheat compared to urea. Raghavulu and Sreeramamurthy (1975) found that application of 120 kg N ha^{-1} as ammonium sulphate resulted in higher grain yield in rice compared to other nitrogen sources. Thimmegowda and Krishnamurthy (1975) reported that application of 30 kg N ha^{-1} as calcium ammonium nitrate resulted in more number of pods per plant, and higher seed weight, in limabean compared to other nitrogen sources. Chaubey *et al.* (2000) observed that application of 120 kg N ha^{-1} in the form of urea, ammonium sulphate, ammonium nitrate and calcium ammonium nitrate produced no significant difference in grain yield of wheat.

Pathak (1967) reported that application of phosphorus as rock phosphate increased the yield of green gram compared to super phosphate. Prasad *et al.* (1968) found that dicalcium phosphate was effective as super phosphate in increasing the yield of chickpea, pea, urd, mung, lentil and lathyrus. In Kerala, a trial conducted at Pattambi revealed that application of 50 kg P_2O_5 ha^{-1} in the form of Mussorie rock phosphate gave a better yield of cowpea compared to single super phosphate (KAU, 1981), whereas an experiment conducted at College of Agriculture, Vellayani, Kerala showed that application of P in the form of single super phosphate or Mussorie rock phosphate did not bring about any significant difference on yield and yield components of cowpea (KAU, 1984). Shetty *et al.* (1995) obtained higher green pod yield of french bean with rock phosphate application compared to super phosphate.

Kulkarni *et al.* (2000) reported the superiority of single super phosphate over Mussorie rock phosphate in increasing the yield attributes, seed yield and straw yield in chickpea. Kumar *et al.* (2001) noted that diammonium phosphate was a better source of P for getting higher number of pods per plant, number of seeds per pod, pod length and test weight in cowpea compared to Udaipur rock phosphate with phosphate solubilising micro organisms. Garai and Dutta (2003) observed higher yield attributes and seed yield in green gram with application of whey treated Purila rock phosphate compared to other P sources. The superiority of single super phosphate in increasing the seed yield of soybean over Udaipur rock phosphate and single super phosphate (1:1) mixture was observed by Tanwar and Shaktawat (2003). Pandey *et al.* (2003) found that the dual inoculation of vesicular arbuscular mycorhiza and rhizobium, along with mixture of phosphorus sources ie; single super phosphate and musssorie rock phosphate (50:50) recorded the maximum yield in pea compared to phosphorus source and biofertilizers alone. Luikham *et al.* (2005) reported that application of 60 kg P_2O_5 ha^{-1} as single super phosphate recorded the highest seed yield in green gram and it was on par with diammonium phosphate.

Raghuwanshi *et al.* (1997) observed that the application of 25-50 kg S ha^{-1} in the form of gypsum increased the grain yield of chickpea over control. Bhadoria *et al.* (1997) reported that the application of 40 kg S in the form of gypsum increased the pods per plant, seeds per pod, 100 seed weight, and yield per plant in cluster bean over control. Similar results in black gram were reported by Ramamoorthy *et al.* (1997). Singh and Agarwal (1998) observed that the application of 30 kg S in the form of gypsum produced significantly higher pod length, seeds per pod, and 100 seed weight in blackgram compared to elemental sulphur and pyrite. Results of a demonstration trial conducted in Rajasthan also revealed that sulphur application increased the seed yield of groundnut and soybean (Singh, 2003).

Naagar and Meena (2004) reported that soil application of phosphorus in the form of diammonium phosphate and S as elemental sulphur increased the number of pods per plant, number of seeds per pod, test weight, seed yield and pod yield in cluster bean compared to no application of P and S. An experiment conducted in the clay loam soil of Udaipur, Rajasthan, showed that application of N40+P40+K20+S40 kg ha^{-1}significantly increased all yield attributes and yield of soybean (Menaria and Singh, 2004).

2.2.3. Quality

Dekov *et al.* (1980) observed higher protein and starch content in cowpea seeds with 40 kg N ha^{-1}as urea. Gandhi *et al.* (1991) noted that protein content of cowpea increased from 20.7 to 22.17 per cent when nitrogen was applied as urea at the rate of 25 kg ha^{-1}.Vanaja and Lakshmi (1998) reported that application of 0- 90 kg N ha^{-1}as urea increased the protein content in soybean over no nitrogen. Akbari *et al.* (2001) and Singh *et al.* (2001a) reported that protein and oil contents of soybean grains were not significantly influenced by nitrogen fertilization. Mishra (2003) found that application of 20 kg N as urea with rhizobium inoculation resulted in an increased protein yield in cowpea. Shinde and Bhilare (2003) also obtained similar results in chickpea. Krishna *et al.* (2004) observed that application of 15 kg N through urea and 40 kg S as elemental sulphur increased the protein content in chickpea .

Belikov and Burtseva (1967) observed that application of powdered super phosphate at 100 kg ha^{-1}or 500 ml ha^{-1} of powdered super phosphate solution containing two per cent P_2O_5 at the beginning of pod formation increased the protein per centage of soybean seeds. Singh *et al.* (1969) reported that application of phosphoric acid 0-90 kg ha^{-1} did not influence the protein of pea. Increase in protein content of pea grains due to application of 20 and 40 kg P_2O_5 as single super phosphate was observed by Garg *et al.* (1971). Sunder *et al.* (2003) found that application of P_2O_5 as diammonium phosphate at 40 kg ha^{-1} significantly increased the protein content in clusterbean over control and 20 kg P_2O_5 ha^{-1}.

Bhadoria *et al.* (1997) reported that the application of 40 kg S in the form of gypsum increased the protein and gum content in cluster bean. Singh and Agarwal (1998) observed that application of 30 kg S in the form of gypsum increased the protein content in black gram compared to elemental sulphur and pyrite. Naagar and Meena (2004) observed that application of diammonium phosphate at the rate of 30kg P_2O_5 ha^{-1} and elemental sulphur at the rate of 40 kg ha^{-1} increased the protein content in cluster bean.

2.2.4 Uptake of nutrients

Availability of nutrients varies with sources, which in turn influence their uptake by crop plants.

Application of 60 kg N at sowing with 30 kg N as foliar spray at the start of flowering increased the seed nitrogen content of soybean by seven per cent over control (Penk, 1977). Rabie *et al.* (1979) reported that soybean plants given 20 ml of one per cent urea solution as foliar spray to 18-day-old plants increased the total nitrogen accumulation in plants. Reddy *et al.* (1981) showed that application of 15 or 30 kg N ha^{-1} in the form of urea either as basal or as foliar application to groundnut increased nitrogen content in vegetative and reproductive parts. Application of 20 kg N ha^{-1}as urea with rhizobium inoculation increased the uptake of nitrogen by cowpea (Mishra, 2003). Krishna *et al.* (2004) observed that application of 15 kg N through urea and 40 kg S as elemental sulphur increased the nitrogen and sulphur uptake in chickpea. Sharma and Dyal (2005) reported that application of 37.5 kg N through urea showed the highest uptake of N, P, K and S by cowpea.

Belikov and Burtseva (1967) observed that application of powdered super phosphate at 100 kg ha^{-1} or 500 ml ha^{-1} of super phosphate solution containing two per cent P_2O_5 applied at the beginning of pod formation of soybean increased the total and inorganic P content in grain. Nalamwar (1972) reported that the per centage uptake of P_2O_5 was more in black gram when it was fertilized with phosphatic fertilizer either through soil or through foliage compared to no application of P_2O_5. Foliar application of macro and micronutrients and seed treatment with rhizobium was reported to be efficient in increasing the N, P, and K uptake of pulse crops (Gopalsingh and Sudhakar, 1991). Santhi and Kothandaraman (1995) opined that application of 0, 25, or 50 kg P_2O_5 ha^{-1}as single super phosphate, diammonium phosphate or Mussorie rock phosphate and inoculation with *Glomus fasciculatum* increased the N, P, K, Ca and Mg uptake in greengram. Sonboir and Sarawgi (2000) noted that application of 30 Kg P as single super phosphate increased the total N, P, and K uptake in chickpea. Rhizobium seed inoculation and foliar application of N, P, K and chelated micronutrient mixture (Microsol) thrice at 15,30 and 45 DAS increased the N, P, and K uptake of rice- fallow black gram (Manivannan and Thanunathan, 2003).

Naagar and Meena (2004) observed that in a loamy sandy soil, application of diammonium phosphate at 30 kg and elemental sulphur at 40 kg ha^{-1} increased the N and P uptake in cluster bean.

Magnesium content in plant and kernels of groundnut was found to increase with the corresponding increase in sulphur (Yadav and Singh, 1978). Gupta and Gupta (1972) observed an increased sulphur uptake in pea due to applied sulphur. Aulakh *et al.* (1977) reported that applied sulphur increased the sulphur concentration in moong. In soybean, sulphur content and uptake were increased with increasing level of sulphur application (Sachidanand *et al.*, 1980). Patel *et al.* (2004) reported that application of 40 kg S ha^{-1} in the form of gypsum increased the nitrogen and sulphur uptake by lucerne.

2.3.EFFECT OF FOLIAR APPLICATION OF NUTRIENTS ON CROP PLANTS

Foliar application of macro and micro nutrients and seed treatment with rhizobium were reported to be efficient in increasing the grain yield, haulm yield, N, P, and K uptake and grain protein content of blackgram (Gopalsingh and Sudhakar, 1991).

2.3.1 Growth characters

Verma and Rao (1974) reported that foliar application of 2.5 and 5 per cent solutions of urea on 15 and 30 DAS old *Phaseolus aureus* seedlings inoculated with rhizobium reduced plant growth characters such as height and number of branches per plant and leaf area index. Patra (1974) from an investigation on the response of groundnut to foliar application of urea at pegging stage observed that spraying of urea had no effect on growth of plants because normally growth rate was beyond the stage at which urea was applied. Rabie *et al.* (1978) observed that application of $20 cm^3$ of one per cent urea solution as foliar spray on eighteen days old soybean plants increased dry matter accumulation compared to soil application.

An experiment carried out at IARI to study the response of soil and foliar application of phosphorus alone or in combination with B, Mo, Cu, and Mn on agronomic characters of peas had shown that the treatments did not have any significant influence on any of the growth characters viz., height of plants, leaf area index and dry weight (Kherdae and Yawalkar, 1966). Surendra *et al.* (1993) observed that application of 50 Kg P_2O_5 ha^{-1} as diammonium phosphate through soil and foliar application of two per cent diammonium phosphate increased the plant height , number of nodules per plant and nodule weight in black gram compared to application of N and P alone. Similar results were obtained in black gram variety Vamban 1 by Balachandran and Nagarajan (2002). Foliar application of diammonium phosphate and chelated micronutrient mixture thrice at 15, 30, and 45 DAS helped to improve the plant height, number of branches per plant, leaf area index and dry matter production in groundnut (Revathy *et al.*, 1996) and in soybean (Jeybal *et al.*, 1999). Manivannan *et al.* (2002) observed that rhizobium seed treatment and foliar application of diammonium phosphate and chelated micronutrients at 15, 30 and 45 DAS resulted in significant increase in growth characters viz., plant height, number of branches per plant, leaf area index and dry matter yield in rice fallow urdbean.

2.3.2 Yield attributes and yield

Peeran *et al.* (1970) observed that application of half nitrogen before sowing and the remainder as foliar spray in two split doses, four and six weeks after sowing increased the average seed yield in groundnut compared to soil application of the entire quantity. Patra (1974) reported that foliar spray of four per cent urea increased the yield of groundnut linearly by forty six per cent over control. Syrad *et al.* (1980) noted that foliar application of 20 kg N ha^{-1} in the form of ammonium sulphate increased the yield and seed weight of soybean by 75 per cent while foliar application of urea increased it by 8.1 per cent. Foliar application of urea at early pod formation stage increased seed yield in soybean by 53 per cent over control (Chang, 1980).

Samullah *et al.* (1986) reported that foliar spray of 2 kg P_2O_5 ha^{-1} as sodium dihydrogen orthophosphate at flower initiation stage of mung bean significantly increased the number of pods per plant, pod length, number of seeds per pod and seed yield compared to no foliar application of P. Foliar spray of diammonium phosphate increased the hundred seed weight in arhar over control (Upadhyay *et al.*1988). Foliar application of phosphorus during pod formation stage increased the seed yield by 10 per cent in soybean (Suo and Wu, 1990). Raghavan (1992) reported that the application of 40 kg P_2O_5 ha^{-1} as basal with two per cent P_2O_5 spray on 25 th day produced higher grain and haulm yield in soybean which were on par with basal application of 80 kg P_2O_5 ha^{-1}. Srinivasan and Ramasamy (1992) observed an increased grain yield of 29 per cent in rainfed cowpea with foliar application of diammonium phosphate (two per cent) at 20 and 30 DAS after sowing compared to control.

In a study on phosphorus fertilizing technique for soybean, the basal application of 60 kg P_2O_5 and 20 kg P_2O_5 ha^{-1} by foliar application in three splits gave higher seed yield compared to 80 kg P_2O_5 ha^{-1} applied as basal (Purushothaman *et al.*1994). Raghuwanshi *et al.* (1997) observed the highest seed yield of chickpea when P was applied as diammonium phosphate, 50 per cent basal and 50 per cent by foliar application, 35 and 55 DAS. Effect of foliar application of nitrogen and phosphorus on dry matter production and grain yield of soybean was studied by Ravankar *et al.* (1998) and realized the significance of foliar spray of diammonium phosphate in increasing the grain yield over control. Ponnusamy *et al.* (1999) observed that foliar spray of two per cent diammonium phosphate solution to black gram twice, one at flower initiation and another 15 days later, increased the grain yield.

Subramani and Solaimali (2000) and Yakudri and Thatikunda (2002) found that the application of diammonium phosphate (two per cent) had improved the grain yield in blackgram. Similar results were observed in rainfed cowpea (Parasuraman, 2001). Solaiappan *et al.* (2002) observed that foliar application of diammonium phosphate (two per cent) had improved the grain yield in green gram compared to control. Manivannan *et al.* (2002) opined that rhizobium seed treatment and foliar application of diammonium phosphate and chelated micrónutrient at 15, 30 and 45 DAS resulted in a significant increase in yield parameters viz., number of pods per plant, number of grain per pod, hundred grain weight and grain yield in rice fallow urd bean. Rhizobium seed inoculation and foliar application of N, P, K and chelated micronutrient mixture (Microsol) thrice at 15,30 and 45 DAS increased the grain yield and haulm yield in rice- fallow black gram (Manivannan and Thanunathan , 2003).

2.3.3.Quality

From the trials on podsolized chernozem soils in Ukraine with peas given 150 kg kainite with 50 kg nitrophoska ha^{-1}, foliar spray of 10 kg N as urea in 400 liters of water ha^{-1} at the tendril formation stage increased the seed protein content in pea from 0.8 to 2.92 per cent (Kalashnik, 1976). Lysenko (1979) reported that a foliar spray of nitrogen as urea or ammonium sulphate to pea at the end of the vegetative growth period increased the seed protein content by 4.2 per cent. Late topdressing increased the leaf protein content and nitrogen, as urea was more effective than ammonium nitrite. Rhizobium seed inoculation and foliar application of N, P, K and chelated micronutrient mixture (Microsol) thrice at 15, 30, and 45 DAS increased the protein content of rice fallow black gram. (Manivannan and Thanunathan, 2003).

Shukla (1975) reported that foliar application of 15 or 30 kg P ha^{-1} increased the protein content in soybean significantly compared to its soil application.

2.3.4.Nutrient economy

Foliar application of nutrients reduces the total quantity of fertilizers to be applied and thereby increases the benefit cost ratio. Varughese and Pathak (1987) observed that the application of two per cent diammonium phosphate at two different growth stages increased the gross returns, net returns and benefit cost ratio (2.87) in chickpea compared to one foliar spray and control. Similar results obtained in chickpea were reported by Shindae and Bhilare (2003). In a study on phosphorus fertilizing technique for soybean, the basal application of 60 kg P_2O5 and 20 kg P_2O_5 ha^{-1} by foliar application in three splits gave the highest net returns compared to 80 kg P_2O_5 ha^{-1} applied as basal (Purushothaman *et al.*, 1994). Solaiappan *et al.* (2002) found that application of diammonium phosphate (two per cent) had improved the grain yield and income with high B: C ratio in greengram Chandrasekhar and Bangarusamy (2003) opined that the application of two per cent diammonium phosphate as foliar spray recorded highest cost benefit ratio in mungbean compared to salicylic acid (100 ppm) + diammonium phosphate (two per cent) + potassium chloride (one per cent) + naphthaline acetic acid (40ppm.)

2.4. INOCULATION OF PHOSPHATE SOLUBILISING BACTERIA ON CROP PLANTS

The seed inoculation with phosphate solubilising microorganisms may benefit the crops by increasing phosphorus availability from insoluble sources (Guar, 1990). The phosphate solubilising bacteria help in solubilising insoluble phosphorus into soluble form by secreting organic acids such as formic, acetic, fumaric and succinic acids. These acids lower the pH, calcium and iron resulting in the solubilisation of phosphates (Guar and Ostwal, 1972). These microorganisms can also produce auxins and gibberellins, which have a favourable effect on plant growth.

2.4.1. Growth characters

Taha *et al.* (1969) observed that inoculation of phosphate solubilising bacteria increased the dry matter production in broad bean. Dual inoculation of rhizobium and phosphobacteria along with soil or foliar application significantly increased the plant height, nodule number, and nodule weight in blackgram (Surendra *et al.*, 1993). Similar results obtained in black gram variety Vamban 1 were also reported by Balachandran and Nagarajan (2002). Ramamoorthy *et al.* (1994) reported that application of single super phosphate or Mussorie rock phosphate with or without seed inoculation of phosphobacteria and rhizobium increased the plant height, no of branches per plant and dry matter accumulation in pigeon pea. Kumar *et al.* (2001) observed that the application of diammonium phosphate compared to the application of Udaipur rock phosphate with phosphate solubilising micro-organisms increased the plant height, number of branches per plant, leaf area index and dry matter yield in cowpea. Shivakumar *et al.* (2004) found that application of rhizobium with phosphate solubilising bacteria recorded significantly higher plant height, number of branches and dry matter yield in chickpea.

2.4.2. Yield attributes and Yield

Patil *et al.* (1979) observed that a combination of phosphate solubilising bacteria with rock phosphate and farmyard manure resulted in a higher dry matter yield of 67 g per plot in cowpea compared to the same treatment without inoculation, which yielded 53.9g per plot. Ahmad and Jha (1982) reported that inoculation of phosphate solubilising bacteria increased the yield of soybean. Alagwadi and Guar (1988) found that combined inoculation of rhizobium and phosphate solubilising bacteria significantly increased the dry matter content and grain yield in chickpea over control.

Kuppuswami *et al.* (1991) observed a significant increase in grain and haulm yield of black gram due to seed coating with diammonium phosphate and phosphate solubilising bacteria. However, seed inoculation with phosphate solubilising microorganism did not show any influence on grain and haulm yield of gram over no inoculation (Veer *et al.*, 1991). Ramamoorthy *et al.* (1994) reported that application of single super phosphate or Mussorie rock phosphate with or without seed inoculation with phosphobacteria and or rhizobium gave higher seed yield and returns in pigeon pea than control. Nagaraj and Siddaramappa (1995) noted that the application of phosphorus at 50 kg P_2O_5 ha^{-1} as Mussorie rock phosphate in combination with farmyard manure and phosphate solubilising fungi *Aspergillus awamori* increased the yield in soybean.

Kumar *et al.* (2001) obtained a higher seed yield of cowpea with application of diammonium phosphate compared to the application of Udaipur rock phosphate with phosphate solubilising microorganisms. Meena *et al.* (2002) observed that seed inoculation with phosphate solubilising bacteria increased the yield and yield attributes and water use efficiency of chickpea. Vairavan and Ramasamy (2002) reported that the application of phosphate solubilising bacteria enhanced the grain yield in green gram compared to no inoculation. Saad and Sharma (2003) observed an increased productivity of chickpea due to inoculation of phosphate solubilising bacteria along with phosphatic fertilizers. Tanwar *et al.* (2003) found that inoculation of seeds with phosphate solubilising bacteria significantly increased the yield of black gram. An experiment in sandy loam soil of old alluvial zone in West Bengal revealed that single inoculation with rhizobium or phosphate solubilising bacteria and dual inoculation of rhizobium and phosphate solubilising bacteria increased the nodule number, nodule weight leg haemoglobin content, nitrogenase activity of nodules and pod yield in cowpea over no inoculation (Chattopadhay and Dutta, 2003). Meena *et al.* (2002) observed that dual seed treatment with rhizobium and phosphate solubilising bacteria significantly increased the pods per plant, seeds per pod, pod length, test weight as well as seed and straw yield in cluster bean over no inoculation. Patel and Thakur (2003) noted that application of phosphate solubilising bacteria and farmyard manure significantly improved the length of pod, pods per plant, and seeds per pod in black gram over control. Seed inoculation with phosphate solubilising bacteria significantly increased all yield components viz., seed yield, straw yield and biological yield in clusterbean over control (Naagar and Meena, 2004). Jain and Trivedi (2005) observed that seed inoculation with *Bradyrhizobium* and phosphate solubilising bacteria alone or in combination markedly increased the number of nodules per plant, length of pod, number of pods per plant and number of seeds per plant in soybean over control.

2.4.3.Quality

Tanwar and Shaktawat (2003) noted that incorporation of farmyard manure at 10 t ha^{-1} with and without phosphate solubilising bacteria significantly increased the protein content of soybean. Naagar and Meena (2004) reported that seed inoculation with phosphate solubilising bacteria significantly increased protein content in clusterbean. Shivakumar *et al.* (2004) found that seed inoculation of rhizobium with phophate solubilising bacteria increased the crude protein content in chickpea. Jain and Trivedi (2005) observed that seed inoculation with *Bradyrhizobium* and phosphate solubilising bacteria significantly increased the protein content in soybean over control.

2.4.4. Phosphorus availability

Samilov (1953) observed that the inoculation of phosphate solubilising bacteria increased the content of available P in soil. Guar and Ostwal (1972) found that several soil bacteria, particularly those belonging to the genera *Pseudomonas* and *Bacillus* and fungi belonging to the genera *Penicilium* and *Aspergillus* had the ability to bring insoluble phosphorus in soil into soluble forms by secreting organic acids such as formic, acetic, propionic, lactic and succinic acids. These acids lower the pH and bring about the dissolution of bound forms of phosphates. Some of the hydroxy acids may chelate with calcium and iron resulting in effective solubilisation and utilization of phosphate. Meena *et al.* (2002) found that seed inoculation of rhiozobium and phosphate solubilising bacteria increased the nitrogenase activity and available P in soil.

The above review shows that phosphate solubilising bacteria inoculation increases the available P in soil.

2.4.5.Nutrient economy

Mohammad (1984) observed that the highest net return was obtained in pigeonpea when ¼ dose of N, P, and K was applied along with phosphate solubilising bacteria. Alagwadi and Guar (1988) reported that combined inoculation of rhizobium and phosphate solubilising bacteria along with rock phosphate in chick pea could save 10 kg P_2O_5 ha^{-1} and replace entire super phosphate with rock phosphate and phosphate solubilising bacteria inoculation. Prabhakara and Rai (1995) reported the possibility of replacing single super phosphate with rock phosphate by the dual inoculation of *Azospirillum* and phosphate solubilising bacteria. Ramamoorthy *et al.* (1994) observed that the application of single super phosphate or Mussorie rock phosphate with or without seed inoculation with phosphobacteria and rhizobium gave higher returns in pigeon pea. Chattopadhay and Dutta (2003) found that dual inoculation of rhizobium and phosphate solubilising bacteria resulted in better response than their individual inoculation in cowpea. Economic evaluation revealed that dual inoculation with biofertilizers gave maximum net return and B: C ratio. Jain and Trivedi (2005) noted that 19.65 kg P ha^{-1} with seed inoculation of *Bradyrhizobium* and phosphate solubilising bacteria registered higher return and B: C ratio in soybean over control.

The foregoing review reveals that application of phosphatic fertilizers can be reduced through inoculation of phosphate solubilising bacteria.

Materials and Methods

3. MATERIALS AND METHODS

An investigation was carried out to study the effect of different sources of nitrogen and phosphorus on the growth, yield and quality of cowpea grown in summer rice fallows and to assess the possibility of reducing the quantity of fertilizers through inoculation of phosphate solubilising bacteria (PSB) and foliar application of diammonium phosphate (DAP). The details of the materials used and the methods followed are presented below.

3.1.EXPERIMENTAL SITE

The field experiment was conducted in the summer rice fallows at Agricultural Research Station, Mannuthy, Kerala Agricultural University. It is located at 12^0 32'N latitude and 72^0 20' E longitudes and at an altitude of 22.25 M above mean sea level. The area experiences a typical warm humid tropical climate.

3.1.1. Soil

The soil of the experimental site was sandy clay loam. The important physical and chemical properties of the soil are presented in Table-1.

3.1.2.Season

The experiment was conducted during the summer season (February-April) of 2005.The weather data are presented in Fig.1 and Appendix1.

3.1.3.Cropping history of the field

The experimental site was under rice crop during the previous season.

Table- 1. Physical and chemical properties of the soil before the experiment

A. Physical properties

Particulars	Value	Procedure adopted
Coarse sand (%)	27.1	
Fine sand (%)	23.9	Robinson's International pipette method (Piper, 1966)
Silt (%)	22.8	
Clay (%)	26.2	
Textural class	Sandy clay loam	I.S.S.S system, (1992)

B. Chemical properties

Particulars	Value	Method employed
Organic carbon	0.657%	Wet digestion method (Walkley and Black, 1934)
Available nitrogen	470 kg ha^{-1}	Alkaline permanganate method (Subbiah and Asija, 1956)
Available phosphorus	28.6 kg ha^{-1}	Ascorbic acid blue colour method (Watanabe and Olsen, 1965)
Available potassium	133.6 kg ha^{-1}	Neutral Normal ammonium acetate extract, flame photometry (Jackson, 1958)
Available calcium	36.22 kg ha^{-1}	Versanate titration method (Hesse, 1971)
Available magnesium	56.4 kg ha^{-1}	Versanate titration method (Hesse, 1971)
Available sulphur	24.18 kg ha^{-1}	Colorimetrically using Spectronic–20 Spectrophoto meter (Williams and Steins bergs, 1959)
pH	5.4	1:2.5 Soil-water suspension using a pH meter (Jackson, 1973)
Ec (ds m^{-1})	0.117	1:2.5Soil-watersuspension using a electrical conductivity meter (Jackson, 1973)

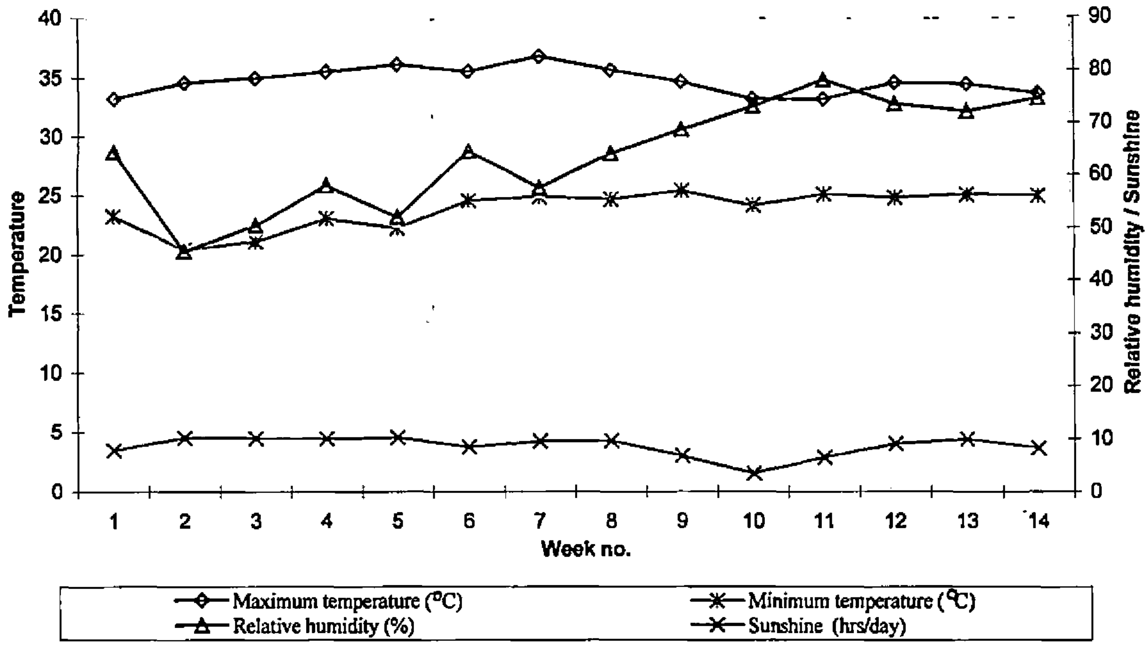

Fig.1. Weather conditions during the experimental period

3.2. MATERIALS

3.2.1. Variety

The dual-purpose cowpea variety Kanakamani was used for the study. It was evolved by pure line selection from the variety Kunnamkulam local. It is a semi trailing type, which matures in 80-85 days.

3.2.2. Seed material

The seeds of the variety Kanakamani were obtained from the Regional Agricultural Research Station, Pattambi, Kerala.

3.2.3. Chemical fertilizers

Chemical fertilizers of the following analytical grade were used as different sources of nitrogen, phosphorus and potassium.

Urea	: 46 %N
Ammonium sulphate	: 20.6%N, 23 % S
Diammonium phosphate	: 18%N, 46%P_2O_5
Rajphos	: 18%P_2O_5
Muriate of Potash	: 60%K_2O

3.2.4. Biofertilizers

Culture of phosphate solubilising bacteria obtained from Tamil Nadu Agricultural University was used for the study.

3.3. METHODS

3.3.1. Design and lay out

The field experiment was laid out in Randomized Block Design with three replications (Fig.2).

Fig. 2. Lay out of the experiment.

R_1T_4	R_1T_8	R_2T_2	R_2T_{10}	R_3T_7	R_3T_{16}
R_1T_6	R_1T_{15}	R_2T_1	R_2T_8	R_3T_9	R_3T_{12}
R_1T_2	R_1T_{12}	R_2T_6	R_2T_{17}	R_3T_1	R_3T_5
R_1T_7	R_1T_{17}	R_2T_3	R_2T_{14}	R_3T_6	R_3T_{13}
R_1T_3	R_1T_{14}	R_2T_9	R_2T_{16}	R_3T_2	R_3T_{17}
R_1T_9	R_1T_{11}	R_2T_5	R_2T_{13}	R_3T_4	R_3T_{14}
R_1T_5	R_1T_{16}	R_2T_7	R_2T_{11}	R_3T_8	R_3T_{10}
R_1T_1	R_1T_{13}	R_2T_4	R_2T_{15}	R_3T_3	R_3T_{11}
	R_1T_{10}		R_1T_{12}		R_3T_{15}
$\mathbf{R_I}$		$\mathbf{R_{II}}$		$\mathbf{R_{III}}$	

3.3.2.Treatment details

The experiment consisted of seventeen treatments as detailed below.

T_1: Ammonium sulphate + diammonium phosphate (complete basal)

T_2: Ammonium sulphate + diammonium phosphate (50 %basal)+ foliar spray of diammonium phosphate(two percent)twice.

T_3: Ammonium sulphate + rock phosphate (complete basal)

T_4: Ammonium sulphate + rock phosphate (50% basal)+ foliar spray of diammonium phosphate +(two percent) twice.

T_5: Ammonium sulphate + rock phosphate (complete basal) + phosphate solubilising bacteria inoculation.

T_6: Ammonium sulphate + rock phosphate (50%basal) + phosphate solubilising bacteria inoculation + foliar spray of diammonium phosphate(two percent) twice.

T_7: Ammonium sulphate (complete basal)+ phosphate solubilising bacteria inoculation.

T_8: Ammonium sulphate (50% basal) +phosphate solubilising bacteria inoculation + foliar spray of diammonium phosphate (two percent) twice.

T_9: Urea +diammonium phosphate (complete basal)

T_{10}: Urea +diammonium phosphate (50% basal)+ foliar spray of diammonium phosphate (two percent) twice.

T_{11}: Urea + rock phosphate (complete basal)

T_{12}: Urea + rock phosphate (50% basal)+ foliar spray of diammonium phosphate (two percent) twice.

T_{13}: Urea+ rock phosphate (complete basal) + phosphate solubilising bacteria inoculation

T_{14}: Urea + rock phosphate (50% basal) + phosphate solubilising bacteria inoculation + foliar spray of diammonium phosphate (two percent) twice.

T_{15}: Urea (complete basal) + phosphate solubilising bacteria inoculation

T_{16}: Urea (50% basal) + phosphate solubilising bacteria inoculation + foliar spray of diammonium phosphate (two percent) twice

T_{17}: Package of practices (20:30:10 kg N, P, and K ha^{-1})

3.3.3.Plot size

Gross plot size : 5.5m x 3.75m

Net plot size : 4.25m x 3.45m

Sampling area : $1.725m^2$

3.3.4.Field culture

The field was ploughed and harrowed with a tractor and the stubbles were removed. Then the field was laid out into three blocks, each with seventeen plots and individual plots were levelled. Basal dose of fertilizers was applied as per treatments and incorporated.

3.3.5. Seed treatment

Seeds were treated with PSB culture as per treatment on the day of sowing. The culture was mixed with jaggery solution and the slurry thus obtained was thoroughly mixed with the seeds and dried under shade for half an hour.

3.3.6. Sowing

Cowpea seeds were dibbled at a spacing of 25 cm x 15 cm.

3.3.7.After cultivation

Gap filling was done within one week after sowing and one weeding was given three weeks after sowing. Top dressing of urea was given as per treatments. Spraying of DAP was done at pre flowering and flowering stages.

3.3.8. Irrigation

The plots were irrigated immediately after sowing and thereafter at fortnightly intervals.

3.3.9. Plant protection

Necessary plant protection measures were taken against the infestation of thrips in the early stages and pod borer in the later stages.

3.3.10.Harvesting

The dry pods from the net plot were picked two times, sun dried and threshed. Seeds were cleaned, sun dried and weighed. After the final picking, plants from each plot were pulled out and weighed.

3.4.BIOMETRIC OBSERVATIONS

The following biometric observations were taken from five random plants in the net plot at 20 DAS, 40DAS, 60DAS, and at harvest.

3.4.1. Growth characters

3.4.1.1. Height of plants

Height was measured from the base of the plant to the tip of the growing point and mean plant height was expressed in cm.

3.4.1.2.Number of leaves per plant

Total number of leaves was counted at 20 days interval and average recorded.

3.4.1.3.Number of branches per plant

Number of branches in each plant was counted and the average recorded.

3.4.1.4. Leaf area index

The length and breadth of 10 leaf samples in each plant were taken from 3 plants uprooted from the destructive sampling area.

Leaf area was calculated using the standard formula given by Sharma *et al.* (1987).

Leaf area = Length x breadth x 0.6654

Leaf area index was calculated using the formula LAI = Leaf area per plant / Land area occupied per plant.

3.4.1.5.Dry matter production

From each plot 5 plants were uprooted from the destructive sampling area, sun dried and dried to a constant weight in a hot air oven and the dry matter production was worked out and expressed in kg per hectare.

3.4.1.6.Number of nodules per plant

At flowering, five plants from the destructive sampling row were dug out with least disturbance to the roots, washed carefully and the nodules were separated, counted and the average recorded.

3.4.1.7.Dry weight of nodules per plant

The nodules used for nodule count were oven dried, weighed and average recorded.

3.4.2. Yield and yield attributes

3.4.2.1.Days to 50 % flowering

After commencement of flowering the crop was observed daily and the number of days taken for 50 per cent flowering was recorded.

3.4.2.2.Number of pods per plant

Pods collected from the observation plants were counted and the average recorded.

3.4.2.3.Weight of pods per plant

Pods collected from the observation plants were dried, weighed and the average recorded.

3.4.2.4.Weight of grains per plant

Pods collected from the observation plants were dried, threshed and the grains obtained were weighed, and the average recorded.

3.4.2.5.Number of grains per pod

Pods collected from the observation plants were threshed separately and the number of seeds in each pod was counted and the average recorded.

3.4.2.6.100 Seed weight

This was obtained by weighing 100 randomly selected seeds from the bulk in each plot and recorded in grams.

3.4.2.7.Pod yield per hectare

Pods obtained from each net plot were sun dried, weighed and expressed in kg per hectare.

3.4.2.8.Grain yield per hectare

Grains obtained from each net plot were sun dried, weighed and expressed in kg per hectare.

3.4.2.9.Bhusa (haulm) yield per hectare

After the last picking of pods from net plot, the plants were uprooted, weighed and expressed in kg per hectare.

3.5. QUALITY

3.5.1.Protein content of grains

Protein content of grains was worked out by multiplying the nitrogen content of grains with a constant, 6.25.

3.52.Protein content of Bhusa (haulm)

Protein content of Bhusa was worked out by multiplying the nitrogen content of Bhusa with a constant, 6.25.

3.6.UPTAKE STUDIES

From each plot, five plants were collected from the area left for destructive sampling at 20, 40, 60 DAS and at harvest, oven dried, powdered and the contents of N, P, K, Ca, Mg, and S were determined by the following methods.

3.6.1.Nitrogen

Total nitrogen content of the plant samples was determined by modified micro kjeldahl method (Jackson, 1967).

3.6.2.Phosphorus

Phosphorus content of plant samples was determined by vanado molybdo phosphoric yellow colour method (Koenig and Johnson, 1942).

3.6.3.Potassium

Potassium content of plant samples was estimated by flame photometry.

3.6.4. Calcium

Calcium content of plant samples was determined using the versanate titration method (Hesse, 1971).

3.6.5.Magnesium

Magnesium content of plant samples was determined using the versanate titration method (Hesse, 1971).

3.6.6.Sulphur

Sulphur content of plant samples was determined by turbidimetry using Spetronic 20-spectro photometer (Williams and Steinsbergs, 1959).

Values of nutrient content were multiplied by dry matter production to obtain Nutrient uptake.

3.7.SOIL NUTRIENT STATUS

Soil samples were analyzed for available N, P and K before and after the experiment and the methods used were as follows.

3.7.1.Organic carbon

Organic carbon content in the soil samples was determined by wet digestion method (Walkley and Black, 1934).

3.7.2.Available nitrogen

Available nitrogen content in the soil samples was determined by alkaline permanganate method (Subbiah and Asija, 1956).

3.7.3.Available phosphorus

Available phosphorus content in the soil samples was determined by extracting with Bray no.1 reagent (Bray and Kurtz, 1945) and estimated colorimetrically by reduced molybdate ascorbic acid blue colour method using Spectronic-20 Spectrophotometer (Genessy's) (Watanabe and Olsen, 1965).

3.7.4.Available potassium

Available potassium content of the soil samples was extracted with Neutral normal ammonium acetate solution and its content in the extract was determined by flame photometry (Jackson, 1958).

3.7.5.Available calcium

Available calcium content in the soil samples was determined from the ammonium acetate extract by versanate titration method (Hesse, 1971).

3.7.6.Available magnesium

Available magnesium content in the soil samples was determined from the ammonium acetate extract by versanate titration method (Hesse, 1971).

3.7.7.Available sulphur

Available sulphur in the soil samples was determined by turbidimetry using Spectronic20- Spectrophotometer (Williams and Steinsbergs, 1959).

3.8.STATISTICAL ANALYSIS

The data were tabulated and analyzed statistically using M Stat – C and MS Excel soft wares.

Results

4. RESULTS

A field experiment was conducted in the summer rice fallows to study the effect of different sources of nitrogen and phosphorus on growth, yield and quality of cowpea and to assess the possibility of reducing the quantity of fertilizers through inoculation of phosphate solubilising bacteria and foliar application of diammonium phosphate. The observations recorded were analyzed statistically and the results obtained are presented in this chapter.

In general, cowpea variety Kanakamani shows a slight trailing tendency only during the rainy season. But in the present study it showed a heavy trailing habit and luxuriant growth even though the crop was grown in summer rice fallows. This is probably due to the high soil fertility status especially that of available nitrogen coupled with favourable moisture content in the soil obtained through irrigation.

4.1.GROWTH CHARACTERS

4.1.1. Plant height

The data presented in Table 2 showed that the height of cowpea plants was steadily increased from 20 DAS to harvest.

In general, the treatment which received nitrogen in the form of urea recorded higher plant height than those which received nitrogen in the form of ammonium sulphate, especially during the early stage of growth.

Application of rock phosphate along with ammonium sulphate or urea resulted in a higher plant height than soil application of diammonium phosphate.

Table 2. Effect of different sources of nutrients on height of cowpea

Tr. No.	Treatments	Height (cm)			
		20DAS	40DAS	60DAS	Harvest
T_1	AS+DAP (complete basal)	9.83	28.20	77.60	94.73
T_2	AS+ DAP (50 % basal)+DAP spray	9.00	29.40	91.73	131.80
T_3	AS+RP (complete basal)	10.03	36.60	106.54	119.67
T_4	AS+RP (50% basal)+DAP spray	9.13	36.37	105.13	139.33
T_5	AS+RP (complete basal)+PSB	10.70	35.63	89.47	113.80
T_6	AS+RP (50% basal)+PSB+DAP spray	9.73	32.33	92.27	128.87
T_7	AS (complete basal)+PSB	10.07	33.70	86.67	94.60
T_8	AS+RP (50% basal)+PSB+DAP spray	9.90	29.07	88.60	95.07
T_9	Urea +DAP (complete basal)	10.07	34.70	82.47	105.66
T_{10}	Urea +DAP (50% basal)+DAP spray	11.20	35.67	115.73	116.20
T_{11}	Urea +RP (complete basal)	11.47	35.30	111.60	116.67
T_{12}	Urea +RP (50% basal)+DAP spray	12.20	41.13	139.13	156.67
T_{13}	Urea +RP (complete basal)+PSB	10.57	31.93	104.13	129.13
T_{14}	Urea + RP (50% basal)+PSB DAP spray	11.67	39.37	142.33	153.50
T_{15}	Urea (complete basal)+PSB	11.30	30.27	91.33	94.93
T_{16}	Urea +RP (50% basal)+PSB+DAP spray	11.43	31.07	116.47	127.87
T_{17}	Package of practices recommendations	10.63	29.88	102.27	109.67
	CD (0.05)	0.93	3.56	3.67	3.31

Foliar application of diammonium phosphate (2%) at pre-flowering and flowering stages either along with a basal dose of 50 per cent nitrogen as ammonium sulphate or urea and 50 per cent phosphorus as rock phosphate or diammonium phosphate resulted in a higher plant height at 60DAS and at harvest compared to no foliar application of diammonium phosphate.

Phosphate solubilising bacteria inoculation did not bring about any influence on the height of cowpea plants compared to no inoculation. However, phosphate solubilising bacteria inoculation along with rock phosphate resulted in a higher plant height compared to its inoculation with out rock phosphate.

Among the various treatments, T_{12} (50 per cent N and P as urea and rock phosphate + diammonium phosphate spray) recorded the highest plant height and it was on par with T_{14} (50 per cent N and P as urea and rock phosphate + phosphate solubilising bacteria + diammonium phosphate spray) at all stages.

4.1.2. Number of leaves

The data presented in Table 3 showed that the number of leaves per plant increased from 20 DAS to 60 DAS and decreased at harvest due to the falling of some of the older leaves.

Effect of treatments on the number of leaves per plant showed almost the same trend as that of the plant height.

Treatments which received nitrogen in the form of urea recorded a higher number of leaves per plant compared to ammonium sulphate.

Application of rock phosphate either along with ammonium sulphate or urea resulted in a higher number of leaves per plant compared to soil application of diammonium phosphate.

Table3.Effect of different sources of nutrients on number of leaves of cowpea

Tr. No.	Treatments	Number of leaves / plant			
		20DAS	40DAS	60DAS	Harvest
T_1	AS+DAP (complete basal)	10.20	28.67	36.00	30.13
T_2	AS+ DAP (50 % basal)+DAP spray	9.77	27.93	39.07	37.93
T_3	AS+RP (complete basal)	10.60	31.47	35.13	33.13
T_4	AS+RP (50% basal)+DAP spray	10.80	32.07	39.53	38.80
T_5	AS+RP (complete basal)+PSB	10.20	29.93	37.27	37.53
T_6	AS+RP (50% basal)+PSB+DAP spray	10.73	30.73	38.53	39.40
T_7	AS (complete basal)+PSB	10.93	27.87	35.33	31.73
T_8	AS+RP (50% basal)+PSB+DAP spray	9.60	28.27	38.73	39.73
T_9	Urea +DAP (complete basal)	9.67	29.87	39.26	34.13
T_{10}	Urea +DAP (50% basal)+DAP spray	10.60	33.60	43.07	41.73
T_{11}	Urea +RP (complete basal)	11.00	34.37	41.33	39.80
T_{12}	Urea +RP (50% basal)+DAP spray	11.06	36.00	45.40	42.27
T_{13}	Urea +RP (complete basal)+PSB	10.50	33.27	38.67	37.53
T_{14}	Urea +RP (50% basal)+PSB+DAP spray	11.06	35.93	47.13	43.67
T_{15}	Urea (complete basal)+PSB	10.80	33.67	37.67	34.73
T_{16}	Urea +RP (50% basal)+PSB+DAPspray	10.73	32.93	43.73	41.27
T_{17}	Package of practices recommendations	10.73	33.07	41.13	41.07
	CD (0.05)	1.14	2.96	4. 52	1.38

Foliar spray of two per cent diammonium phosphate at pre- flowering and flowering stages with a basal dose of 50 per cent of N as ammonium sulphate or urea along with 50 per cent of p as rock phosphate or diammonium phosphate or phosphate solubilising bacteria inoculation showed an increase in number of leaves per plant at 60DAS and at harvest compared to no foliar application of diammonium phosphate.

Inoculation of phosphate solubilising bacteria did not increase the number of leaves per plant compared to no inoculation. But its inoculation along with rock phosphate favourably influenced the leaf production.

Among the various treatments, T_{14} (50 per cent N and P as urea and rock phosphate + phosphate solubilising bacteria + diammonium phosphate spray) recorded the highest number of leaves at 60DAS and at harvest, which was on par with T_{12} (50 per cent N and P as urea and rock phosphate + diammonium phosphate spray).

4.1.3. Number of branches per plant

The data presented in Table 4 showed that the number of branches per plant increased from 40 DAS to harvest, which is due to the indeterminate growth habit of the crop.

Comparing the sources of nitrogen, application of urea resulted in more number of branches per plant than ammonium sulphate. Between the sources of phosphorus, application of rock phosphate increased the number of branches per plant compared to soil application of diammonium phosphate.

Foliar spray of two per cent diammonium phosphate at pre- flowering and flowering stages resulted in a higher number of braches per plant compared to no foliar spray of diammonium phosphate.

Table 4. Effect of different sources of nutrients on number of branches / plant

Tr. No.	Treatments	Number of branches / plant		
		40DAS	60DAS	Harvest
T_1	AS+DAP (complete basal	1.67	3.24	4.20
T_2	AS+ DAP (50 % basal)+DAP spray	1.80	3.40	4.66
T_3	AS+RP (complete basal)	2.33	32.0	4.58
T_4	AS+RP (50% basal)+DAP spray	2.40	3.86	4.80
T_5	AS+RP (complete basal)+PSB	1.70	3.26	4.47
T_6	AS+RP (50% basal)+PSB+DAP spray	1.93	3.80	4.73
T_7	AS (complete basal)+PSB	1.33	2.36	4.13
T_8	AS+RP (50% basal)+PSB+DAP spray	1.64	3.46	4.51
T_9	Urea +DAP (complete basal)	2.53	3.45	4.95
T_{10}	Urea +DAP (50% basal)+DAP spray	2.20	3.52	5.00
T_{11}	Urea +RP (complete basal)	2.53	3.73	4.60
T_{12}	Urea +RP (50% basal)+DAP spray	2.60	3.86	5.20
T_{13}	Urea +RP (complete basal)+PSB	1.93	3.46	4.55
T_{14}	Urea +RP (50% basal)+PSB+DAP spray	2.67	3.93	5.55
T_{15}	Urea (complete basal)+PSB	1.89	2.64	4.32
T_{16}	Urea +RP (50% basal)+PSB+DAP spray	1.80	3.26	4.58
T_{17}	Package of practices recomeendations	1.70	3.46	3.60
	CD (0.05)	0.13	0.08	0.95

Phosphate solubilising bacteria inoculation did not influence the number of branches per plant. However, its inoculation along with application of rock phosphate resulted in a higher number of branches per plant compared to phosphate solubilising bacteria inoculation without application of rock phosphate.

Among the different treatments, T_{14} (50 per cent N and P as urea and rock phosphate+ phosphate solubilising bacteria + diammonium phosphate spray) recorded the highest number of branches per plant, which was on par with T_{12} (50 per cent N and P as urea and rock phosphate + diammonium phosphate spray).

4.1.4. Leaf area index

Data presented in Table 5 showed that the leaf area index of cowpea was increased from 20 DAS to 60DAS and was influenced by different sources of nutrients.

With respect to N,application of urea resulted in more leaf area per unit land area compared to ammonium sulphate.

With regard to P, application of rock phosphate increased the leaf area index compared to soil application of diammonium phosphate.

Foliar spray of two per cent diammonium phosphate at pre flowering and flowering stages showed more leaf area index at 60 DAS and at harvest compared to no foliar application of diammonium phosphate.

Inoculation of phosphate solubilising bacteria along with ammonium sulphate or urea and rock phosphate increased the leaf area index compared to no inoculation. Moreover, its inoculation along with application of rock phosphate increased the leaf area index compared to that without application of rock phosphate.

Table 5. Effect of different sources of nutrients on leaf area index in cowpea

Tr. No.	Treatments	Leaf area index		
		20DAS	40DAS	60DAS
T_1	AS+DAP (complete basal	0.35	4.06	5.42
T_2	AS+ DAP (50 % basal)+DAP spray	0.29	4.29	5.52
T_3	AS+RP (complete basal)	0.41	4.25	5.50
T_4	AS+RP (50% basal)+DAP spray	0.27	4.47	5.94
T_5	AS+RP (complete basal)+PSB	0.45	4.23	5.70
T_6	AS+RP (50% basal)+PSB+DAP spray	0.31	4.32	5.86
T_7	AS (complete basal)+PSB	0.30	4.08	5.30
T_8	AS+RP (50% basal)+PSB+DAP spray	0.22	4.07	5.47
T_9	Urea +DAP (complete basal)	0.63	4.21	5.46
T_{10}	Urea +DAP (50% basal)+DAP spray	0.53	4.43	5.73
T_{11}	Urea + RP (complete basal)	0.75	4.23	5.60
T_{12}	Urea + RP (50% basal)+DAP spray	0.97	4.62	6.03
T_{13}	Urea + RP (complete basal)+PSB	0.82	4.49	5.91
T_{14}	Urea + RP (50% basal)+PSB DAP spray	0.97	4.67	5.27
T_{15}	Urea (complete basal)+PSB	0.38	4.26	5.62
T_{16}	Urea +RP (50% basal)+PSB+DAP spray	0.33	4.36	5.80
T_{17}	Package of practices recommendations	0.41	4.00	5.24
	CD (0.05)	0.10	0.07	0.10

Among the treatments, T_{14} (50 per cent N and P as urea and rock phosphate + phosphate solubilising bacteria + diammonium phosphate spray) recorded the highest leaf area index followed by T_{12} (50 per cent N and P as urea and rock phosphate + diammonium phosphate spray).

4.1.5. Number and dry weight of nodules

Both number and dry weight of nodules per plant were not significantly influenced by various treatments (Table 6). The highest number and dry weight of nodules per plant were noted in T_4 (50 per cent N and P as ammonium sulphate and rock phosphate +2 per cent diammonium phosphate spray) and lowest in T_{12} (50 per cent N and P as urea and rock phosphate + diammonium phosphate spray).

4.1.6. Dry matter production

Data presented in Table7 showed that the total dry matter production of cowpea grown in summer rice fallows was influenced by different sources of nitrogen and phosphorus.

Application of nitrogen as urea resulted in an increase in total dry matter production of cowpea at all stages of observation compared to ammonium sulphate.

Treatments which received rock phosphate recorded a higher total dry matter production compared to those received a basal dose of phosphorus in the form of diammonium phosphate.

Foliar spray of two per cent diammonium phosphate at pre flowering and flowering stages resulted in a higher dry matter production at 60DAS and at harvest compared to no foliar spray of diammonium phosphate.

Table 6. Effect of different sources of nutrients on number and dry weight of nodules / plant in cowpea

Tr.No.	Treatments	Number of nodules	Dry weight of nodules (g)
T_1	AS+DAP (complete basal	6.16	0.513
T_2	AS+ DAP (50 % basal)+DAP spray	7.17	0.523
T_3	AS+RP (complete basal)	6.66	0.523
T_4	AS+RP (50% basal)+DAP spray	8.80	0.533
T_5	AS+RP (complete basal)+PSB	8.10	0.530
T_6	AS+RP (50% basal)+PSB+DAP spray	8.30	0.533
T_7	AS (complete basal)+PSB	7.10	0.523
T_8	AS+RP (50% basal)+PSB+DAP spray	6.52	0.523
T_9	Urea +DAP (complete basal)	6.47	0.533
T_{10}	Urea +DAP (50% basal)+DAP spray	8.10	0.530
T_{11}	Urea +RP (complete basal)	6.80	0.523
T_{12}	Urea +RP (50% basal)+DAP spray	6.10	0.499
T_{13}	Urea +RP (complete basal)+PSB	7.60	0.523
T_{14}	Urea +RP (50% basal)+PSB+DAP spray	7.37	0.523
T_{15}	Urea (complete basal)+PSB	8.31	0.523
T_{16}	Urea +RP (50% basal)+PSB+DAP spray	7.50	0.523
T_{17}	Package of practices recommendations	6.50	0.523
		NS	NS

Table 7. Effect of different sources of nutrients on dry matter production in cowpea (kg ha^{-1})

Tr. No	Treatments	Dry matter production (kg ha^{-1})			
		20DAS	40DAS	60DAS	Harvest
T_1	AS+DAP (complete basal	100	900	2952	6945
T_2	AS+ DAP (50 % basal)+DAP spray	90	946	3137	7086
T_3	AS+RP (complete basal)	110	1000	3103	7077
T_4	AS+RP (50% basal)+DAP spray	119	1022	3367	7270
T_5	AS+RP (complete basal)+PSB	126	1022	3369	7463
T_6	AS+RP (50% basal)+PSB+DAP spray	124	1024	3371	7537
T_7	AS (complete basal)+PSB	108	946	3107	6455
T_8	AS+RP (50% basal)+PSB+DAP spray	100	992	3315	6748
T_9	Urea +DAP (complete basal)	129	919	3489	7275
T_{10}	Urea +DAP (50% basal)+DAP spray	133	1068	3723	7298
T_{11}	Urea +RP (complete basal)	131	1011	3559	7557
T_{12}	Urea +RP (50% basal)+DAP spray	149	1106	3735	8261
T_{13}	Urea +RP (complete basal)+PSB	144	1097	3623	7847
T_{14}	Urea +RP (50% basal)+PSB+DAP spray	153	1143	3761	8289
T_{15}	Urea (complete basal)+PSB	138	1027	3243	7636
T_{16}	Urea +RP (50% basal)+PSB+DAP spray	142	1092	3559	8251
T_{17}	Package of practices recommendations	149	1024	3346	7555
	CD (0.05)	7.34	27.96	458.77	42.48

Inoculation of phosphate solubilising bacteria along with application of rock phosphate increased the total dry matter production at all stages of observation compared to its inoculation with out application of rock phosphate.

Among the various treatments, T_{14} (50 per cent N and P as urea and rock phosphate + phosphate solubilising bacteria + diammonium phosphate spray) recorded the highest dry matter production followed by T_{12} (50 per cent N and P as urea and rock phosphate + diammonium phosphate spray).

4.2. YIELD ATTRIBUTES AND YIELD

In general, there was luxuriant growth of plants irrespective of treatments. The photosynthates were mainly used for the vegetative growth of plants. Partitioning of assimilates to the reproductive parts was very poor which reflected in poor flowering and pod development and ultimately resulted in an extremely poor grain yield. However, the observations were recorded on whatever yield was produced and presented below.

4.2.1.Days to 50 per cent flowering

Data presented in Table 8 showed that the number of days to 50 per cent flowering of cowpea was not influenced either by different sources of nitrogen and phosphorus or by phosphate solubilising bacteria inoculation or by foliar application of diammonium phosphate.

4.2.2.Number of pods per plant

Data presented in Table 8 showed that the number of pods per plant was significantly influenced by treatments.

Treatments which received nitrogen in the form of urea recorded more number of pods per plant compared to those which received nitrogen in the form of ammonium sulphate.

Among the phosphorus-applied treatments, application of rock phosphate resulted in more number of pods per plant compared to soil application of diammonium phosphate. Application of rock phosphate along with inoculation of phosphate solubilising bacteria resulted in more number of pods per plant compared to either application of rock phosphate alone or inoculation of phosphate solubilising bacteria alone.

Foliar spray of two per cent diammonium phosphate at pre- flowering and flowering stages resulted in a lesser number of pods per plant compared to no foliar spray of diammonium phosphate especially in most of the treatments which received nitrogen in the form of ammonium sulphate.

Among the various treatments, T_{13} (complete N and P as urea and rock phosphate + phosphate solubilising bacteria) recorded the highest number of pods per plant and it was on par with T_{14} (50 per cent N and P as urea and rock phosphate +phosphate solubilising bacteria + diammonium phosphate spray) and T_4 (50 per cent N and P as urea and rock phosphate + diammonium phosphate spray)

4.2.3. Number of grains per pod

Data presented in Table 8 showed that the number of grains per pod followed almost the same trend as that of number of pods per plant.

Sources of nitrogen did not bring about any significant influence on the number of grains per pod. However, between the sources of phosphorus, application of rock phosphate resulted in more number of grains per plant compared to soil application of diammonium phosphate. Inoculation of phosphate solubilising bacteria did not increase the number of grains per pod significantly compared to no inoculation of phosphate solubilising bacteria. Foliar spray of two per cent diammonium phosphate at pre flowering and flowering stages also could not influence the number of grains per plant compared to no foliar spray of diammonium phosphate.

Among the various treatments, T_{13} (complete N and P as urea and rock phosphate + phosphate solubilising bacteria) recorded the highest number of grains per pod followed by T_{14} (50 per cent N and P as urea and rock phosphate + phosphate solubilising bacteria + diammonium phosphate spray) and T_4 (50 per cent N and P as ammonium sulphate and rock phosphate + diammonium phosphate spray)

4.2.4. Weight of pods per plant and weight of grains per plant

Data presented in Table 8 showed that both the weight of pods per plant and weight of grains per plant followed almost the same trend of number of pods per plant and number of grains per pod.

Weight of pods per plant was not significantly influenced by the sources of either nitrogen or phosphorus, whereas the weight of grains per plant was significantly influenced by the sources of both nitrogen and phosphorus .The treatments which received nitrogen in the form of urea and phosphorus in the form of rock phosphate recorded more grain weight per plant compared to those received urea and soil applied diammonium phosphate respectively.

Foliar spray of two per cent diammonium phosphate at pre- flowering and flowering stages decreased the weight of pods and grains per plant compared to no foliar spray of diammonium phosphate and the effect was significant for per plant grain weight.

Among the various treatments, T_{13} (complete N and P as urea and rock phosphate + phosphate solubilising bacteria inoculation) recorded the highest pod weight and grain weight per plant followed by T_{14} (50 per cent N and P as urea and rocl: phosphate + phosphate solubilising bacteria + diammonium phosphate spray) and T_4 (50 per cent N and P as ammonium sulphate and rock phosphate + diammonium phosphate spray).

4.25.100 seed weight

Data presented in Table 8 showed that the hundred seed weight was influenced by sources of nutrients.

Comparing the sources of nitrogen, application of urea resulted in more seed weight compared to application of ammonium sulphate.

Treatments which received phosphorus in the form of rock phosphate recorded more hundred seed weight compared to soil application of diammonium phosphate.

Most of the diammonium phosphate sprayed treatments recorded a lesser hundred seed weight compared to no foliar spray of diammonium phosphate.

Application of rock phosphate along with urea resulted in more seed weight and the effect was more in combination with phosphate solubilising bacteria inoculation.

Among the treatments, T_{13} (complete N and P as urea and rock phosphate + phosphate solubilising bacteria inoculation) recorded the highest hundred seed weight followed by T_{14} (50 per cent N and P as urea and rock phosphate + phosphate solubilising bacteria inoculation + diammonium phosphate spray).

Table 8. Effect of different sources of nutrients on yield attributes of cowpea

Tr. No.	Treatments	Days to 50 % flowering	No. of pods / plant	No. of grains / pod	Wt. of pods plant (g)	Wt. of grains/ plant (g)	Wt. of 100 grains (g)
T_1	AS+DAP (complete basal	40.333	1.96	14.12	4.35	3.10	11.03
T_2	AS+ DAP (50 % basal)+DAP spray	40.67	1.88	13.75	4.29	3.07	11.03
T_3	AS+RP (complete basal)	40.33	1.88	14.17	4.37	3.37	11.04
T_4	AS+RP (50% basal)+DAP pray	40.67	2.13	14.93	4.50	3.59	11.69
T_5	AS+RP (complete basal)+PSB	40.33	2.03	14.90	4.42	3.43	11.69
T_6	AS+RP 50%basal)+PSB+DAP spray	40.67	1.84	14.71	4.15	3.09	11.02
T_7	AS (complete basal)+PSB	40.33	2.02	14.60	4.37	3.41	11.69
T_8	AS+RP (50% basal)+PSB+DAP spray	40.67	1.88	14.06	4.11	3.06	11.36
T_9	UREA+DAP (complete basal)	40.33	1.97	14.71	4.37	3.24	11.37
T_{10}	UREA+DAP (50% basal)+DAP spray	40.67	1.93	14.06	4.31	3.23	11.30
T_{11}	UREA+RP(complete basal)	40.33	2.04	14.54	4.43	3.48	11.69
T_{12}	UREA+RP (50% basal)+DAP spray	40.67	2.03	14.38	4.19	3.17	11.68
T_{13}	UREA+RP (complete basal)+PSB	40.33	2.17	14.97	4.88	3.95	11.83
T_{14}	UREA+RP (50% basal)+PSB+DAP spray	40.67	2.14	14.93	4.57	3.68	11.70
T_{15}	UREA (complete basal)+PSB	40.33	2.05	14.77	4.49	3.54	11.69
T_{16}	UREA+RP (50% basal)+PSB+DAP spray	40.67	1.98	14.50	4.15	3.16	11.64
T_{17}	Package of practices	40.33	1.97	14.41	4.28	3.30	11.03
	CD (0.05)	NS	0.04	0.40	0.48	0.07	0.05

4.2.6. Pod yield and grain yield

Data presented in Table 9 showed that the pod yield and grain yield of cowpea were very poor in all the treatments. However a significant influence of treatments was noticed on both these parameters.

Most of the treatments which received nitrogen in the form of urea recorded a comparatively higher yield of pods and grains than those that received ammonium sulphate.

Between the sources of phosphorus, application of rock phosphate resulted in more pod and grain yield compared to soil application of diammonium phosphate and the effect was more when it was applied along with urea and phosphate solubilising bacteria inoculation.

Foliar application of two per cent diammonium phosphate at pre flowering and flowering stages reduced the pod and grain yield in most of the treatments compared to no foliar spray.

Among the various treatments, T_{13} (complete N and P as urea and rock phosphate + phosphate solubilising bacteria inoculation) recorded the highest pod yield and grain yield followed by T_{14} (50 per cent N and P as urea and rock phosphate + phosphate solubilising bacteria inoculation + diammonium phosphate spray).

4.2.7. Bhusa (haulm) yield

Data presented in Table 9 showed that the haulm yield was very high and it was more or less equal to that of fodder cowpea irrespective of the treatments.

Table 9. Effect of different sources of nutrients on yield of cowpea

Tr. No.	Treatments	Pod yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Bhusa (haulm) yield (t ha^{-1})
T_1	AS+DAP (complete basal	22.04	15.21	20.42
T_2	AS+ DAP (50 % basal)+DAP spray	21.51	14.98	20.95
T_3	AS+RP (complete basal)	21.92	15.22	20.54
T_4	AS+RP (50% basal)+DAP spray	23.19	19.17	21.68
T_5	AS+RP (complete basal)+PSB	22.49	16.81	22.90
T_6	AS+RP (50% basal)+PSB+DAP spray	21.03	14.66	23.08
T_7	AS (complete basal)+PSB	22.59	17.40	20.08
T_8	AS+RP (50% basal)+PSB+DAP spray	21.76	15.06	20.36
T_9	Urea + DAP (complete basal)	22.02	15.32	22.02
T_{10}	Urea + DAP (50% basal)+DAP spray	22.04	16.18	22.71
T_{11}	Urea + RP (complete basal)	22.49	17.33	23.36
T_{12}	Urea + RP (50% basal)+DAP spray	22.27	17.00	23.62
T_{13}	Urea +RP (complete basal)+PSB	24.88	21.28	23.48
T_{14}	Urea +RP (50% basal)+PSB+DAP spray	23.48	20.12	23.96
T_{15}	Urea (complete basal)+PSB	22.92	18.67	23.47
T_{16}	Urea + RP (50% basal)+PSB+DAP spray	21.92	15.72	23.58
T_{17}	Package of practices recommendations	21.17	14.80	23.17
	CD (0.05)	1.17	0.49	0.17

Treatments that received urea as the form of nitrogen and rock phosphate as the source of phosphorus recorded higher haulm yield compared to ammonium sulphate and diammonium phosphate respectively. The positive effect of rock phosphate on haulm yield was more when it was applied along with inoculation of phosphate solubilising bacteria.

Foliar spray of two per cent diammonium phosphate at pre flowering and flowering stages increased the haulm yield compared to no foliar spray of diammonium phosphate.

Among the various treatments, T_{13} (complete N and P as urea and rock phosphate + phosphate solubilising bacteria inoculation) recorded the highest haulm yield followed by T_{14} (50 per cent N and P as urea and rock phosphate + phosphate solubilising bacteria inoculation + diammonium phosphate spray).

4.3. QUALITY

4.3.1.Protein content of grain

Data presented in Table10 showed that the protein content of cowpea grain was not significantly influenced by treatments. It varied from 19.37 to 21.87 per cent and the highest protein content was observed in T_{13} (complete N and P as urea and rock phosphate + phosphate solubilising bacteria inoculation).

4.3.2. Protein content of Bhusa (haulm)

Data presented in Table 10 showed that the protein content of haulm was not significantly influenced by treatments. It varied from 21.18 to 22.38 per cent and the highest protein content was observed in T_{12} (50 per cent N and P as urea and rock phosphate + diammonium phosphate spray).

Table 10. Effect of different sources of nutrients on protein content of cowpea

Tr. No.	Treatments	Protein content (%)	
		Grain	Bhusa
T_1	AS + DAP (complete basal	19.75	11.87
T_2	AS + DAP (50 % basal)+DAP spray	21.12	12.37
T_3	AS +RP (complete basal)	20.56	11.37
T_4	AS + RP (50% basal)+DAP spray	21.25	12.37
T_5	AS+RP (complete basal)+PSB	20.81	12.06
T_6	AS+RP (50% basal)+PSB+DAP spray	21.75	12.36
T_7	AS (complete basal)+PSB	19.75	12.12
T_8	AS + RP (50% basal)+PSB+DAP spray	20.62	12.33
T_9	Urea + DAP (complete basal)	21.81	12.23
T_{10}	Urea + DAP (50% basal)+DAP spray	21.00	12.31
T_{11}	Urea +RP (complete basal)	19.75	11.62
T_{12}	Urea + RP (50% basal)+DAP spray	19.37	12.38
T_{13}	Urea + RP (complete basal)+PSB	21.87	11.18
T_{14}	Urea + RP (50% basal)+PSB+DAP spray	21.00	12.37
T_{15}	Urea (complete basal)+PSB	21.18	11.18
T_{16}	Urea + RP (50% basal)+PSB+DAP spray	21.62	11.62
T_{17}	Package of practices recommendations	21.18	11.18
		NS	NS

4.4.UPTAKE OF NUTREINTS

4.4.1 Nitrogen

Uptake of nitrogen by plants at different stages of observation followed almost the same trend of dry matter production. (Table 11 and Table 7).

Comparing the sources of nitrogen, application of urea resulted in higher uptake of nitrogen compared to ammonium sulphate. Between the sources of phosphorus, application of rock phosphate increased the uptake of nitrogen over soil application of diammonium phosphate. Moreover, application of rock phosphate along with phosphate solubilising bacteria inoculation resulted in a higher uptake of nitrogen compared to its application without inoculation of phosphate solubilising bacteria

Foliar spray of two per cent diammonium phosphate at pre - flowering and flowering stages increased the nitrogen uptake by plants compared to no foliar spray of diammonium phosphate.

4.4.2 Phosphorus

Uptake of phosphorus by plants also followed almost the same trend of dry matter production at various stages (Table 12 and Table 7).

Application of urea as the source of nitrogen and rock phosphate as the source of phosphorus resulted in an increased phosphorus uptake by plants compared to ammonium sulphate and diammonium phosphate respectively. Treatments which received rock phosphate along with inoculation of phosphate solubilising bacteria recorded a higher phosphorus uptake by plants compared to its application with out phosphate solubilising bacteria inoculation.

Tablel 1.Effect of different sources of nutrients on the nitrogen uptake by cowpea (kg ha^{-1})

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Table11.Effect of different sources of nutrients on the nitrogen uptake by cowpea (kg ha^{-1})

Tr. No.	Treatments	Nitrogen uptake (kg ha^{-1})			
		20DAS	40DAS	60DAS	Harvest
T_1	AS+DAP (complete basal	1.61	16.84	84.72	243.07
T_2	AS+ DAP (50 % basal)+DAP spray	1.44	17.50	94.12	276.35
T_3	AS+RP (complete basal)	1.77	18.66	90.04	219.39
T_4	AS+RP (50% basal)+DAP spray	1.95	18.91	110.46	271.90
T_5	AS+RP (complete basal)+PSB	1.98	18.91	99.39	264.30
T_6	AS+RP (50% basal)+PSB+DAP spray	1.93	19.26	103.49	296.20
T_7	AS (complete basal)+PSB	1.68	17.61	84.83	238.83
T_8	AS+RP (50% basal)+PSB+DAP spray	1.61	18.56	95.80	258.45
T_9	Urea+ DAP (complete basal)	2.07	17.19	103.63	266.99
T_{10}	Urea +DAP (50% basal)+DAP spray	2.18	20.20	119.96	272.21
T_{11}	Urea +RP (complete basal)	2.10	18.92	106.77	261.47
T_{12}	Urea +RP (50% basal)+DAP spray	2.37	20.97	121.02	299.87
T_{13}	Urea +RP (complete basal)+PSB	2.26	20.64	115.21	266.02
T_{14}	Urea + RP (50% basal)+PSB+DAP spray	2.45	21.61	128.25	323.27
T_{15}	Urea (complete basal)+PSB	2.27	19.01	99.24	246.64
T_{16}	Urea +RP (50% basal)+PSB+DAP spray	2.30	20.53	116.38	285.83
T_{17}	Package of practices recommendations	2.43	19.37	100.06	244.03
	CD (0.05)	0.17	1.35	2.97	22.23

Table12.Effect of different sources of nutrients on the phosphorus uptake by cowpea (kg ha^{-1})

Tr. No.	Treatments	Phosphorus uptake (kg ha^{-1})			
		20DAS	40DAS	60DAS	Harvest
T_1	AS+RP (50% basal)+DAP spray	0.21	2.28	9.15	21.53
T_2	AS+DAP (complete basal	0.18	2.56	10.35	22..67
T_3	AS+RP (complete basal)	0.24	2.63	9.97	21.94
T_4	AS+RP (50% basal)+DAP spray	0.25	2.76	11.45	23.26
T_5	AS+RP (complete basal)+PSB	0.25	2.57	10.78	24.08
T_6	AS+RP (50% basal)+PSB+DAP spray	0.27	2.67	11.46	25.62
T_7	AS (complete basal)+PSB	0.23	2.37	9.32	20.66
T_8	AS+RP (50% basal)+PSB+DAP spray	0.20	2.48	10.27	21.60
T_9	Urea +DAP (complete basal)	0.30	2.39	10.82	23.28
T_{10}	Urea +DAP (50% basal)+DAP spray	0.29	2.78	12.29	24.08
T_{11}	Urea +RP (complete basal)	0.30	2.74	11.39	24.93
T_{12}	Urea +RP (50% basal)+DAP spray	0.32	2.94	12.70	26.43
T_{13}	Urea +RP (complete basal)+PSB	0.33	2.75	11.23	25.11
T_{14}	Urea +RP (50% basal)+PSB+DAP spray	0.35	2.86	12.79	27.35
T_{15}	Urea (complete basal)+PSB	0.29	2.67	9.73	23.67
T_{16}	Urea +RP (50% basal)+PSB+DAP spray	0.28	2.73	11.39	25.61
T_{17}	Package of practices recommendations	0.32	2.66	10.70	23.42
	CD (0.05)	0.06	0.49	1.46	3.59

Foliar application of two per cent diammonium phosphate at pre- flowering and flowering stages increased the phosphorus uptake compared to no foliar application of diammonium phosphate.

4.4.3 Potassium

Plant uptake of potassium also followed the same trend of dry matter production at various stages of observation. (Table 13 and Table 7).

Potassium uptake by plants was influenced by sources of nitrogen and phosphorus. Urea and rock phosphate were found to be better than ammonium sulphate and diammonium phosphate in increasing the potassium uptake respectively. Phosphate solubilising bacteria inoculation along with rock phosphate application increased the uptake of potassium compared to its application with out phosphate solubilising bacteria inoculation.

Foliar spray of two per cent diammonium phosphate on the plants at pre flowering and flowering stages increased the potassium uptake by plants compared to no foliar spray of diammonium phosphate.

4.4.4 Calcium, Magnesium and Sulphur

Uptake of Ca, Mg, S followed the same trend of dry matter production and uptake of major nutrients (Table 14 and Table 7).

The results showed that application of urea as the source of nitrogen and rock phosphate as the source of phosphorus increased the uptake of Ca, Mg, and S compared to application of ammonium sulphate and diammonium phosphate respectively. Phosphate solubilising bacteria inoculation along with rock phosphate recorded a higher plant uptake of secondary nutrients compared to application of rock phosphate with out phosphate solubilising bacteria inoculation.

Table13. Effect of different sources of nutrients on the potassium uptake by cowpea (kg ha^{-1})

Tr. No.	Treatments	Potassium uptake (kg ha^{-1})			
		20DAS	40DAS	60DAS	Harvest
T_1	AS+RP (50% basal)+DAP spray	2.12	22.71	84.43	195.85
T_2	AS+DAP (complete basal	1.92	23.94	90.97	199.12
T_3	AS+RP (complete basal)	2.38	25.00	91.04	200.28
T_4	AS+RP (50% basal)+DAP spray	2.58	25.76	95.98	203.56
T_5	AS+RP (complete basal)+PSB	2.66	25.05	96.69	210.09
T_6	AS+RP (50% basal)+PSB+DAP spray	2.63	25.10	97.76	212.54
T_7	AS (complete basal)+PSB	2.29	23.37	89.18	182.03
T_8	AS+RP (50% basal)+PSB+DAP spray	2.15	25.00	94.812	189.62
T_9	Urea +DAP (complete basal)	2.76	22.98	101.53	205.15
T_{10}	Urea +DAP (50% basal)+DAP spray	2.86	26.50	108.37	205.08
T_{11}	Urea +RP (complete basal)	2.79	25.19	102.25	212.35
T_{12}	Urea +RP (50% basal)+DAP spray	3.22	27.83	109.81	231.31
T_{13}	Urea +RP (complete basal)+PSB	3.07	27.22	105.07	220.50
T_{14}	Urea +RP (50% basal)+PSB+DAP spray	3.24	28.01	109.46	233.75
T_{15}	Urea (complete basal)+PSB	2.95	25.17	92.43	215.33
T_{16}	Urea +RP (50% basal)+PSB+DAP spray	3.05	26.98	101.79	232.96
T_{17}	Package of practices recommendations	3.18	25.31	97.04	213.81
	CD (0.05)	0.37	1.67	4.44	16.09

Table 14. Effect of different sources of nutrients on the calcium, magnesium and sulphur uptake by cowpea (kg ha^{-1}) at flowering

Tr. No.	Treatments	Ca	Mg	S
T_1	AS+RP (50% basal)+DAP spray	9.15	6.64	6.28
T_2	AS+DAP (complete basal	9.66	6.82	6.26
T_3	AS+RP (complete basal)	10.26	7.26	6.84
T_4	AS+RP (50% basal)+DAP spray	10.44	7.27	7.19
T_5	AS+RP (complete basal)+PSB	10.23	7.37	6.76
T_6	AS+RP (50% basal)+PSB+DAP spray	10.46	7.49	6.86
T_7	AS (complete basal)+PSB	9.75	7.01	6.44
T_8	AS+RP (50% basal)+PSB+DAP spray	10.03	5.43	6.85
T_9	Urea +DAP (complete basal)	9.38	6.53	6.26
T_{10}	Urea +DAP (50% basal)+DAP spray	10.79	7.81	7.07
T_{11}	Urea +RP (complete basal)	10.33	7.50	6.74
T_{12}	Urea +RP (50% basal)+DAP spray	11.34	8.20	7.60
T_{13}	Urea +RP (complete basal)+PSB	11.41	8.01	7.25
T_{14}	Urea +RP (50% basal)+PSB+DAP spray	11.78	8.23	7.66
T_{15}	Urea (complete basal)+PSB	10.58	7.30	6.89
T_{16}	Urea +RP (50% basal)+PSB+DAP spray	11.14	7.86	7.21
T_{17}	Package of practices recommendations	10.55	7.38	6.87
	CD (0.05)	0.86	1.47	1.22

Spraying of two per cent diammonium phosphate on plants at pre flowering and flowering stages resulted in a higher uptake of Ca, Mg and S compared to no foliar spray of diammonium phosphate.

4.5. NUTRIENT STATUS OF THE SOIL

4.5.1. Nitrogen

The data presented in Table 15 showed that the nitrogen content in the soil was at medium level even after the harvest of the crop.

Among the various treatments, T_{12} (50 per cent N and P as urea and rock phosphate + diammonium phosphate spray) recorded the lowest nitrogen content in the soil and it was on par with most of the treatments.

4.5.2. Phosphorus

Data presented in Table15 showed that none of the treatments could bring about any significant influence on soil phosphorus status. Highest value was recorded by T_{13} complete N and P as urea and rock phosphate + phosphate solubilising bacteria inoculation) followed by T_3 (complete N and P as ammonium sulphate and rock phosphate).

4.5.3. Potassium

Data presented in Table 15 showed that the least potassium content was noted in T_{12} (50 per cent N and P as urea and rockphosphate + diammonium phosphate spray) and it was on par with all treatments which received nitrogen in the form of urea and foliar spray of diammonium phosphate .

Table 15. Soil nutrient status as influenced by different sources of nutrients in cowpea (kg ha^{-1})

Tr. No.	Treatments	N	P	K	Ca	Mg	S
T_1	AS+DAP (complete basal	267.69	26.68	224.57	173.84	48.19	15.27
T_2	AS+ DAP (50 % basal)+DAP spray	265.55	25.27	224.34	173.20	43.73	14.72
T_3	AS+RP (complete basal)	267.87	28.40	221.81	176.32	43.67	14.86
T_4	AS+RP (50% basal)+DAP spray	265.79	25.21	211.00	170.08	40.48	13.90
T_5	AS+RP (complete basal)+PSB	267.15	25.65	227.44	176.32	48.83	15.27
T_6	AS+RP (50% basal)+PSB+DAP spray	263.42	23.85	222.57	170.72	46.82	14.29
T_7	AS (complete basal)+PSB	266.56	24.87	226.32	172.56	46.81	15.00
T_8	AS+RP (50% basal)+PSB+DAP spray	265.20	21.18	223.39	170.73	42.24	14.54
T_9	Urea +DAP (complete basal)	263.41	22.27	214.37	177.96	48.49	11.28
T_{10}	Urea +DAP (50% basal)+DAP spray	261.00	22.47	223.69	173.60	43.68	10.90
T_{11}	Urea +RP (complete basal)	261.23	26.83	212.48	177.20	48.84	11.01
T_{12}	Urea +RP (50% basal) + DAP spray	260.68	23.08	222.46	170.70	46.36	11.63
T_{13}	Urea + RP (complete basal) + PSB	262.83	28.84	213.76	177.60	49.81	11.27
T_{14}	Urea +RP (50% basal) + PSB + DAP spray	261.05	24.98	221.98	173.84	45.62	10.82
T_{15}	Urea (complete basal) + PSB	262.92	23.83	214.52	175.62	48.83	11.17
T_{16}	Urea +RP (50% basal)+PSB+DAP spray	262.41	23.74	214.52	171.94	45.82	10.81
T_{17}	Package of practices recommendations	262.86	24.74	220.84	173.20	46.65	10.28
	CD (0.05)	6.81	NS	6.04	NS	NS	NS

4.5.4. Calcium, Magnesium and Sulphur

Data presented in Table 15 showed that the content of all secondary nutrients ie; Ca, Mg, and S in the soil was not influenced by various treatments. However, lower values were observed wherever there was a higher dry matter production and uptake (Table 14 and Table 7). With regard to S content, numerically higher values were noted in treatments which received N in the form of ammonium sulphate.

4.6.NUTRIENT ECONOMY

Among the various treatments, T_{14} (50 per cent N and P as urea and rock phosphate + phosphate solubilising bacteria inoculation + diammonium phosphate spray) recorded the highest growth of plants followed by T_{12} (50 per cent N and P as urea and rock phosphate + diammonium phosphate spray).

Highest yield was observed in T_{13} (complete N and P as urea and rock phosphate+ phosphate solubilising bacteria inoculation) followed by T_{14} (50 per cent N and P as urea and rock phosphate + phosphate solubilising bacteria inoculation + diammonium phosphate spray).

Considering both growth and yield of cowpea, T_{14} (50 per cent N and P as urea and rock phosphate + phosphate solubilising bacteria inoculation + diammonium phosphate spray) was found to be the best treatment.

Discussion

5. DISCUSSION

A field experiment was conducted in the summer rice fallows to study the effect of different sources of nitrogen and phosphorus on growth, yield and quality of cowpea and to assess the possibility of reducing the quantity of fertilizers through inoculation of phosphate solubilising bacteria and foliar application of diammonium phosphate. The observations recorded were analyzed statistically and the results obtained are discussed in this chapter.

5.1.GROWTH CHARACTERS

5.1.1.Plant height

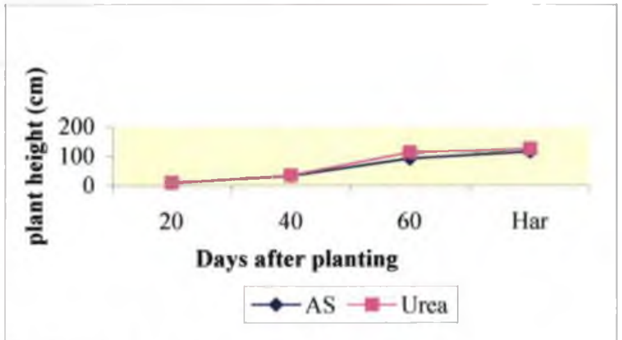
Application of nitrogen in the form of urea resulted in a higher plant height compared to ammonium sulphate especially during the early stages of crop growth (Fig. 3). This is probably due to the higher availability of nitrogen from urea in acid soils compared to ammonium sulphate (Tisdale *et al.*, 1997), which is utilized for the growth of plants.

Application of rock phosphate along with ammonium sulphate or urea resulted in higher plant height than soil application of diammonium phosphate. This might be due to the higher availability of phosphorus from rock phosphate in acid soils (Tisdale *et al.*, 1997), which helped in proper development of root system and consequently more absorption of nutrients and more growth. Increased plant height with rock phosphate application compared to other P sources was also observed by Ramamoorthy *et al.*, (1994) in pigeonpea.

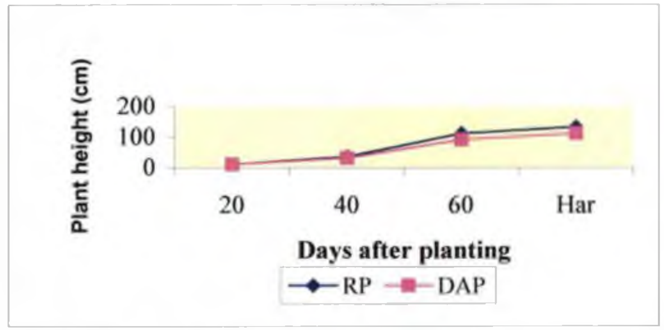
Foliar application of two per cent diammonium phosphate at pre flowering and flowering stages either along with a basal dose of 50 per cent ammonium sulphate or urea with 50 per cent rock phosphate or diammonium phosphate resulted in a higher plant height at 60 DAS and at harvest which can be attributed to the availability of nitrogen and

Fig.3. Effect of different sources of nutrients on plant height (cm)

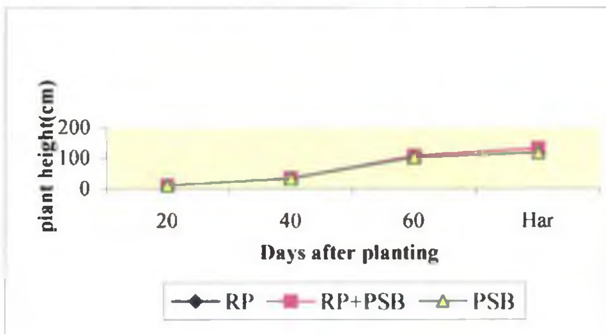
a.Urea Vs ammonium sulphate



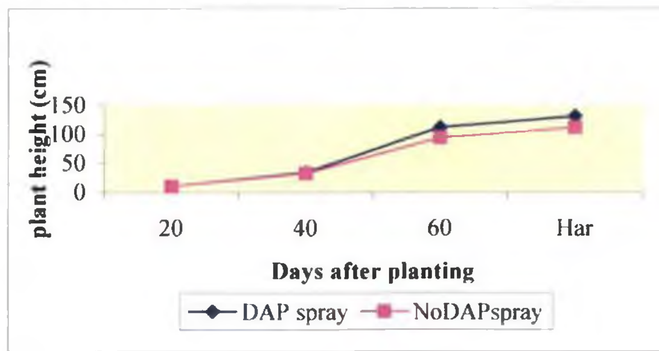
b.Rockphosphate Vs diammonium phosphate



c. Effect of phosphate solubilising bacteria



c.DAP spray Vs no DAP spray



phosphorus after the start of flowering as a result of their absorption through foliage and was utilized for growth of plants after flowering since cowpea is an indeterminate crop. Increased plant height with foliar spray of two per cent diammonium phosphate in urd bean was reported by Surendra *et al.*, (1993), Balachandran and Nagarajan (2002) and Manivannan *et al.*, (2002).

Inoculation of phosphate solubilising bacteria did not bring about any influence on plant height compared to no inoculation probably due to the presence of sufficient inoculum of native phosphate solubilising bacteria in the soil. However, its inoculation along with application of rock phosphate resulted in a better availability of phosphorus to plants than its inoculation without rock phosphate and might have resulted in a higher growth in the former treatment. Favourable influence of phosphate solubilising bacteria inoculation on plant height of chickpea was observed by Shivakumar *et al.*, (2004).

Among the various treatments, foliar application of two per cent diammonium phosphate at pre flowering and flowering stages along with a basal dose of 50 per cent of the recommended dose of N and P in the form of urea and rock phosphate with (T_{14}) or with out (T_{12}) phosphate solubilising bacteria inoculation recorded the highest plant height at all stages. This can be attributed to the higher availability of N and P during the early stages from soil applied urea and rock phosphate and during later stages through foliage from foliar spray of diammonium phosphate.

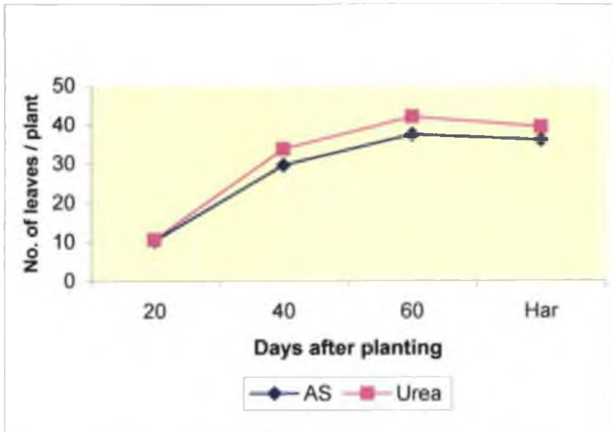
5.1.2. Number of leaves per plant

Treatments which received nitrogen in the form of urea recorded a higher number of leaves per plant compared to ammonium sulphate (Fig. 4). This can be attributed to the higher availability of nitrogen from urea in acid soils, which is absorbed by the plants and utilized for the growth.

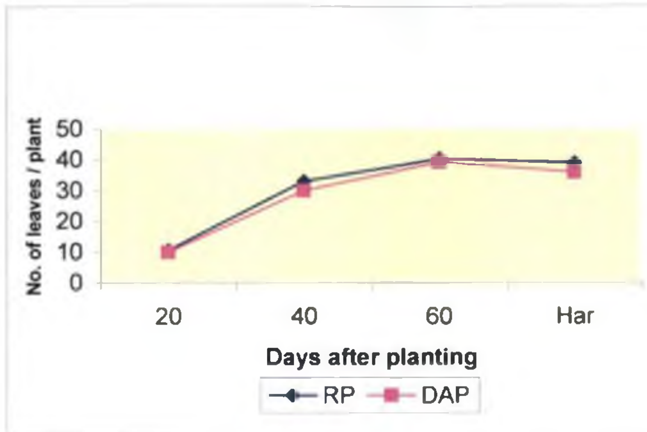
Application of phosphorus in the form of rock phosphate along with ammonium sulphate or urea increased the number of leaves per plant compared to soil application of

Fig.4. Effect of different sources of nutrients on number of leaves per plant

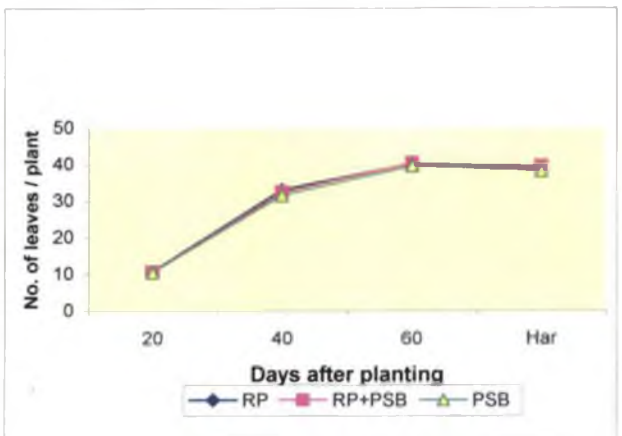
a.Urea Vs ammonium sulphate



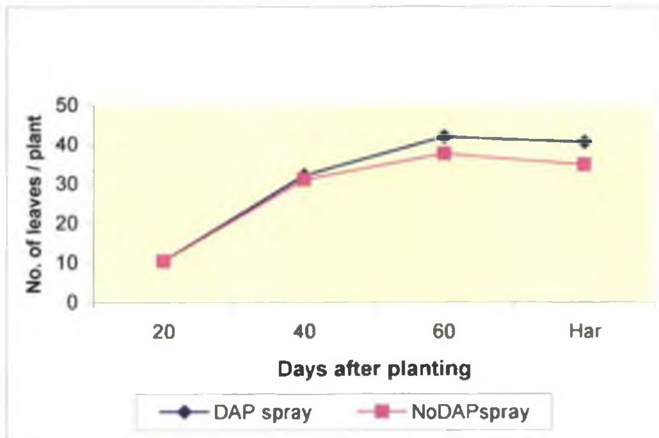
b.Rockphosphate Vs diammonium phosphate



c.Effect of phosphate solubilising bacteria



d. DAP spray Vs no DAP spray



diammnium phosphate. This is probably due to the higher availability of P from rock phosphate compared to diammonium phosphate in acid soils and might have been utilized by the plants for the development of root system, which in turn helped for the more absorption of nutrients and thereby resulted in more plant growth. Ramamoorthy *et al.* (1994) observed an increase in the number of leaves per plant in pigeon pea with rock phosphate application.

Foliar spray of two per cent diammnium phosphate at pre flowering and flowering stages subsequent to basal application of 50 per cent of the recommended dose of nitrogen either as urea or as ammonium sulphate along with 50 per cent of the recommended dose of phosphorus either as rock phosphate or diammonium phosphate or phosphate solubilising bacteria inoculation increased the number of leaves per plant at 60 DAS and at harvest compared to no foliar spray of diammonium phosphate. This might be due to the increased availability of N and P through foliage at flowering stage, which is utilized by the plants for their growth and resulted in more number of leaves per plant.

Inoculation of phosphate solubilising bacteria did not show much influence on leaf production, which might be due to the influence of native phosphate solubilising bacteria already present in the soil. However, its inoculation along with rock phosphate might have increased the availability of P, led to better development of root system, more absorption of nutrients and better leaf production.

The superiority of T_{14} and T_{12} over other treatments can be attributed to the higher availability of nutrients throughout the crop period either through soil or through foliage.

5.1.3.Number of branches per plant

Treatments which received nitrogen on the form of urea recorded a higher number of branches per plant compared to those that received nitrogen in the form of ammonium sulphate. This can be attributed to the higher availability of nitrogen to the plants for their growth when urea was applied.

Soil application of rock phosphate resulted in more number of branches per plant compared to soil application of diammonium phosphate. More availability of phosphorus for proper root growth and subsequent absorption of more nutrients might have contributed for the production of more number of branches per plant in the former treatment. Ramamoorthy *et al.* (1994) also noted an increase in the number of branches in pigeon pea with rock phosphate application.

Treatments that received foliar spray of two per cent diammonium phosphate at pre flowering and flowering stages recorded a higher number of branches per plant compared to no foliar spray of diammonium phosphate, which can be attributed to the higher availability of nitrogen and phosphorus during the reproductive stage also, in an indeterminate crop like cowpea. An increased number of branches per plant with foliar spray of two per cent diammonium phosphate were also observed in rice fallow urd bean (Manivannan *et al.*, 2002) and in soybean (Jeyabal *et al.*, 1999).

Inoculation of phosphate solubilising bacteria along with rock phosphate might have helped the plants to get more available P for the development of the root system which led to more absorption of nutrients and thereby more number of branches per plant. Positive effect of phosphate solubilising bacteria inoculation on the number of branches in chickpea was observed by Shivakumar *et al.* (2004).

Basal application of 50 per cent of the recommended dose of nitrogen and phosphorus as urea and rock phosphate and subsequent spraying of two per cent diammonium phosphate at pre- flowering and flowering stages with or without phosphate solubilising bacteria inoculation recorded higher number of branches per plant compared to other treatments. Availability of more nutrients throughout the crop growth period both from the soil and through foliage absorption might be the reason for the higher number of branches per plant in the above treatments.

5.1.4. Leaf area index

Between the sources of N, application of urea resulted in more leaf area index compared to ammonium sulphate. More available nitrogen from urea might have been utilized by the plants for their vegetative growth especially for the production of more number of leaves and more leaf expansion and resulted in more leaf area index.

Among the sources of P, application of rock phosphate might have led to more availability of P compared to diammonium phosphate which was utilized by the plants for the development of root system and the consequent absorption of more nutrients helped in more leaf development and thereby the higher leaf area index.

Foliar spray of two per cent diammonium phosphate at pre flowering and flowering stages of cowpea in addition to basal application of nitrogen and phosphorus might have resulted in the availability of nutrients through out the crop period which was also utilized for the leaf development and there by more leaf area, since the crop had an indeterminate growth habit. Manivannan *et al.* (2002) also observed an increase in leaf area index with foliar spray of two per cent diammonium phosphate in rice fallow urd bean.

Inoculation of phosphate solubilising bacteria especially along with the application of rock phosphate might have increased the availability of P, which was utilized for the development of root system, which in turn led to more absorption of nutrients and resulted in more leaves and leaf area.

Superiority of the treatments T_{14} followed by T_{12} was reflected in leaf area index also, the reason for which was discussed earlier.

5.1.5. Number and dry weight of nodules

Different sources of nitrogen and phosphorus, inoculation of phosphate solubilising bacteria and foliar spray of two per cent diammonium phosphate could not bring about any significant influence on nodulation of cowpea. This can be attributed to the higher initial content of available nitrogen in the soil irrespective of treatments.

5.1.6. Dry matter production

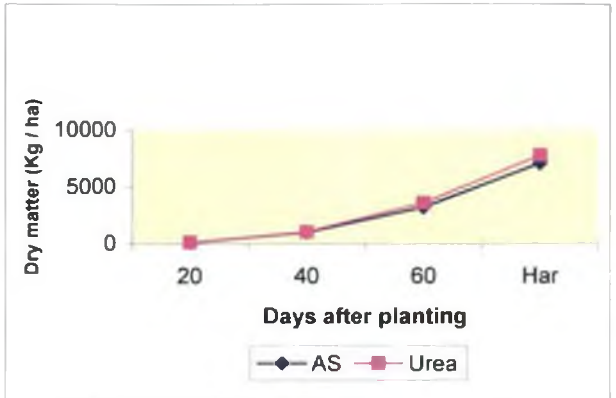
Between the sources of soil-applied nitrogen, urea had a positive influence on the total dry matter production at all stages of observation compared to ammonium sulphate (Fig. 5). This can be attributed to the effect of higher available nitrogen from urea in increasing all growth characters viz; plant height, number of leaves, number of branches and there by an increase in total dry matter production (Table 2-4).

Application of rock phosphate resulted in a higher total dry matter production compared to soil application of diammonium phosphate. This is probably due to the better availability of phosphorus from rock phosphate, which might have helped for the better development of root system and a better absorption of nutrients which in turn contributed to the better development of all growth characters and ultimately reflected in the total dry matter production. Ramamoorthy *et al.* (1994) also reported an increased dry matter yield in pigeon pea with rock phosphate application compared to other P sources.

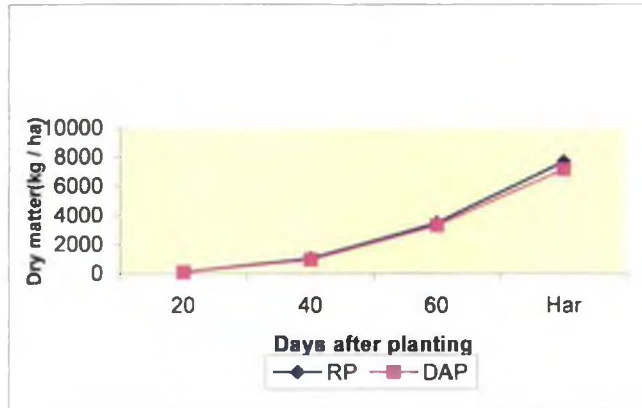
Foliar spray of two per cent diammonium phosphate at pre flowering and flowering stages resulted in a comparatively higher dry matter production at 60 DAS and at harvest compared to no foliar application of diammonium phosphate. This might be due to the more availability of nitrogen and phosphorus at flowering stage as a result of their absorption through foliage and might have been utilized for the growth of the plant (Table 2-5), since cowpea is an indeterminate crop. Favourable influence of foliar spray of two per cent diammonium phosphate on the dry matter yield of rice - fallow urd bean was reported by Manivannan *et al.* (2002).

Fig. 5. Effect of different sources of nutrients on dry matter production (kg / ha)

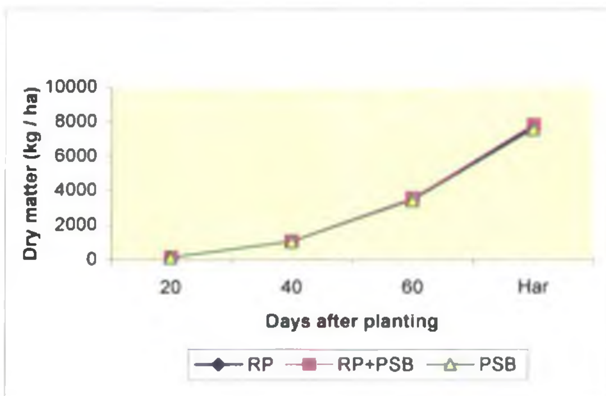
a.Urea Vs ammonium sulphate



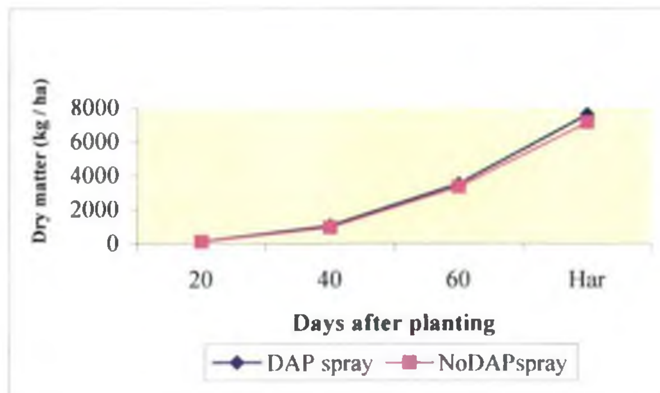
b.Rockphosphate Vs diammonium phosphate



c.Effect of phosphate solubilising bacteria



d. DAP spray Vs no DAP spray



Inoculation of phosphate solubilising bacteria, especially along with rock phosphate, recorded a higher total dry matter production compared to its inoculation without rock phosphate. This can be attributed to the better availability of P from rock phosphate due to the action of phosphate solubilising bacteria which might have resulted in better root system and thereby an improved nutrient uptake and consequent development of more growth characters and ultimately a higher total dry matter production. Higher dry matter yield in cowpea with inoculation of phosphate solubilising bacteria along with rock phosphate application was also observed by Patil *et al.* (1979).

The continuous availability of more nutrients both from soil and through foliage and their effective utilisation for growth and dry matter accumulation might be the reason for the highest dry matter production in T_{14} followed by T_{12}. A significant positive correlation was observed between dry matter production and all growth characters (Table 16).

5.2. YIELD ATTRIBUTES AND YIELD

5.2.1.Days to 50 per cent flowering

None of the treatments could bring about any influence on the 50 per cent flowering of cowpea.

5.2.2. Number of pods per plant

Application of nitrogen as urea resulted in more availability of nitrogen, which is essential for cell division and cell expansion, and therefore more growth. Though excess availability of nitrogen resulted in luxuriant growth, a comparatively better partitioning of assimilates to reproductive parts might have resulted in a more number of pods per plant in urea applied plots.

Table 16. Correlation of dry matter production and grain yield of cowpea with growth characters at 60DAS

Growth character	Dry matter	Grain yield
Height	0.75*	0.40
Leaves	0.49	0.23
Branches	0.83*	0.06
Leaf area index	0.74*	0.60*
Dry matter production	1.00	0.42

* Significant at 5 percent level

Table 17. Correlation of grain yield with yield attributes of cowpea

Yield character	Grain yield
Number of pods per plant	0.92*
Number of grains per pod	0.74*
100 seed weight	0.80*

* Significant at 5 percent level

Among the treatments, which received nitrogen in the form of urea, application of phosphorus as rock phosphate recorded more number of pods per plant and the effect was more in combination with phosphate solubilising bacteria inoculation. An adequate supply of phosphorus in the early life of a plant is important in laying down the primordia for its reproductive parts. Saad and Sharma (2003) also reported an increase in the yield attributes of chickpea with phosphate solubilising bacteria inoculation along with phosphatic fertilizer application.

The availability of excess nitrogen especially during the reproductive stage of the crop and its utilisation for the vegetative growth might have led to lesser pod development in diammonium phosphate sprayed plots.

Better supply of phosphorus in the early life of the plant might have helped for the better development of reproductive parts and thereby more number of pods in T_{13}.

5.2.3. Number of grains per pod

The positive effect of rock phosphate on the number of grains per pod can be attributed to the relatively higher availability of phosphorus for the plants and its relatively better utilisation for the development of grains.

5.2.4. Weight of pods per plant and weight of grains per plant

Weight of pods and grains per plant followed almost the same trend of number of pods per plant and number of grains per pod. The higher number of pods per plant together with more number of grains per pod resulted in more weight of pods per plant and more weight of grains per plant in these treatments, the reason for which is discussed earlier.

5.2.5. 100 seed weight

The favourable effect of the nitrogen source urea and phosphorus source rock phoshate along with phosphate solubilising bacteria inoculation on 100 seed weight can be attributed to their relatively better efficiency in increasing the nutrient availability both for the vegetative and reproductive growth of the plants. Sharma and Dyal (2005) observed an increase in yield attributes of cowpea with urea application. Similir results were reported by and Saad and Sharma (2003) in chickpea with phosphate solubilising bacteria inoculation along with application of phosphatic fertilizer.

The excessive vegetative growth and relatively lesser translocation of assimilates to economic part might be the reason for the negative effect of foliar spray of diammonium phosphate on 100 seed weight.

5.2.6. Pod yield and grain yield per hectare

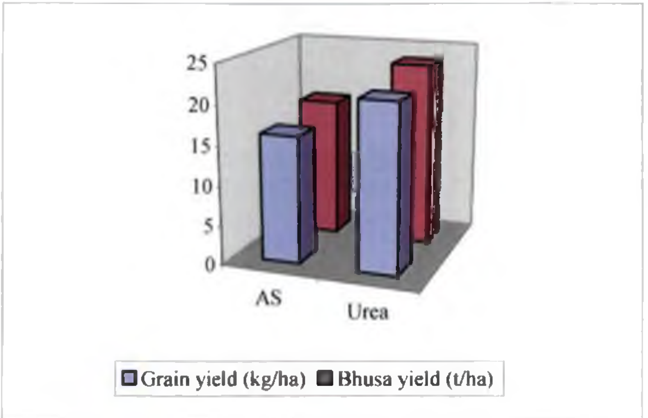
Pod yield and grain yield were very poor in all the treatments due to the excessive vegetative growth of plants and less efficient partitioning of assimilates to reproductive parts.

Pod yield and grain yield followed the same trend. Most of the treatments received nitrogen in the form of urea and recorded a comparatively higher yield of pods and grains than those that received ammonium sulphate (Fig.6). This can be attributed to the relatively better translocation of nutrients to the economic part of the plant which resulted in better development of yield attributes and thereby yield (Table 8).

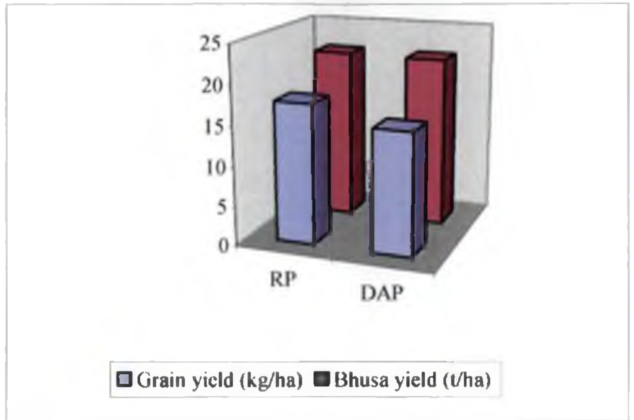
Application of phosphorus in the form of rock phosphate resulted in more pod and grain yield compared to soil application of diammonium phospate and the effect was more when it was applied along with urea and phosphorus solubilising

Fig. 5. Effect of different sources of nutrients on yield of cowpea

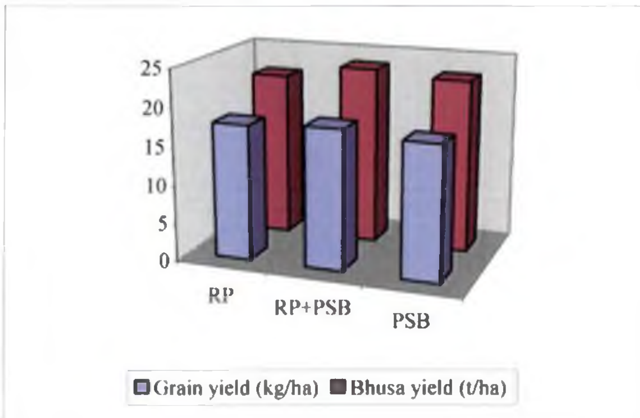
a. Urea Vs ammonium sulphate



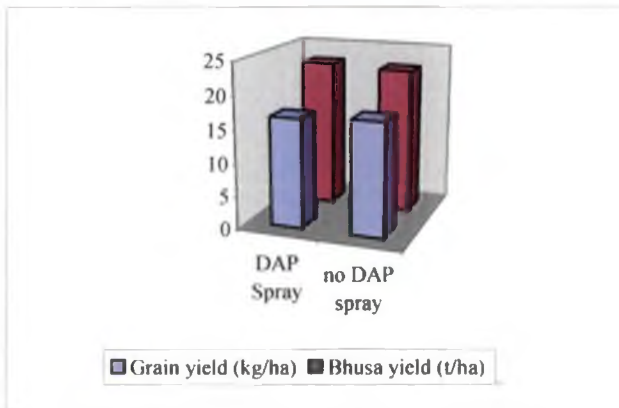
b. Rock phosphate Vs diammonium phosphate



c. Effect of phosphate solubilising bacteria



d. DAP spray Vs no DAP spray



bacteria inoculation. Adequate availability of phosphorus helped the plants for the relatively better production of yield attributes and hence yield. Increased yield in cowpea through rock phosphate application over super phosphate application was already observed in Kerala (KAU, 1981). Favourable influence of inoculation of phosphate solubilising bacteria along with phosphatic fertilizer application on the yield of chickpea was reported by Saad and Sharma (2003).

Foliar spray of diammonium phosphate at pre- flowering and flowering stages reduced the yield in most of the treatments compared to no foliar spray. This is probably due to the excess availability of nitrogen and less partitioning to economic part which leads to excessive vegetative growth thereby a reduction in yield attributes and yield (Table 8).

Among the various treatments T_{13} recorded the highest pod yield and grain yield followed by T_{14} . This can be attributed to the better availability of nutrients throughout the crop growth period combined with their comparatively better utilisation both for the growth and yield. A significant positive correlation was observed between grain yield and yield attributes (Table 17).

5.2.7. Bhusa (haulm) yield

The very high vegetative growth and high Bhusa yield irrespective of treatments might be due to the high initial nitrogen content of the soil.

Application of urea as the source of nitrogen and rock phosphate as the source of phosphorus increased all the growth characters (Table 2-5) and thereby increased the Bhusa yield compared to application of ammonium sulphate and diammonium phosphate respectively (Fig. 6). The influence of rock phosphate on growth and thereby on Bhusa yield was more in treatments where phosphate solubilising bacteria inoculated seeds were used.

Treatments which received foliar spray of two per cent diammonium phosphate recorded more growth of plants and thereby higher Bhusa yield compared to those that received no foliar spray of diammonium phosphate. Raghavan (1992) noted an increase in haulm yield of soybean with foliar spray of P_2O_5.

The increased availability of nutrients and the higher partitioning of assimilates to vegetative parts lead to more growth and thereby more Bhusa yield.

5.3.Quality

5.3.1. Protein content of grain and Bhusa

The non- influence of treatments on the protein content of grain and Bhusa can be attributed to the lesser variation in nitrogen content of grain and Bhusa among treatments as a result of dilution effect of nutrients consequent to luxuriant growth of plants irrespective of treatments.

5.4. UPTAKE OF NUTRIENTS

In general, uptake of both primary and secondary nutrients at different stages of observation followed almost the same trend of dry matter production which can be attributed to the lesser influence of treatments on the content of these nutrients in plants (Table 7 and Appendix 2-5) and more uptake and utilisation of these nutrients by plants for higher growth and thereby more dry matter production. Sharma and Dyal (2005) found an increase in the uptake of N, P, K and S by cowpea with urea application. Increased uptake of N, P, K, Ca and Mg with application of phosphatic fertilizer was reported by Santhi and Kothandaraman (1995).

5.5. NUTRIENT STATUS OF THE SOIL

None of the treatments could bring about much impact on soil nutrient status. In general, a slightly lesser content of primary and secondary nutrients was recorded by the treatments which resulted a higher dry matter production. This can be attributed to the better uptake and utilization of the nutrients by the crop for the growth and yield.

5.6. NUTRIENT ECONOMY

Among the various treatments, considering both growth and yield of cowpea, application of 50 per cent N and P as urea and rock phosphate along with phosphate solubilising bacteria inoculation and foliar spray of two per cent diammonium phosphate at pre- flowering and flowering stages was found to be the best. This shows that 50 per cent of N and P application can be saved through Inoculation of phosphate solubilising bacteria and diammonium phosphate spray twice. Saving in nitrogen fertilizer through two sprays of two per cent diammonium phosphate spray twice was already observed in cowpea (KAU, 1981) and saving in phosphatic fertilizer through inoculation of phosphate solubilising bacteria along with rock phosphate application was reported by Alagwadi and Guar (1988) in chickpea.

Summary & Conclusion

SUMMARY

A field experiment was conducted in the rice fallows of Agricultural Research Station, Mannuthy during the summer season (February- April) of 2005, to study the effect of different sources of nitrogen and phosphorus on the growth, yield and quality of cowpea and to asses the possibility of reducing the quantity of fertilizers through inoculation of phosphate solubilising bacteria and foliar application of diammonium phosphate.

The experiment was laid out in randomized block design with seventeen treatments and three replications. The treatments included were different sources of nitrogen and phosphorus along with and without phosphate solubilising bacteria inoculation foliar application of two percent diammonium phosphate twice and package of practices recommendation alone.

The growth characters such as plant height, number of leaves per plant, number of branches per plant, leaf area index and dry matter production were higher in treatments which received nitrogen in the form of urea compared to ammonium sulphate .

Application of phosphorus as rock phosphate along with nitrogen either as urea or ammonium sulphate resulted in higher plant height, number of leaves per plant, number of branches per plant, leaf area index and dry matter production than soil application of diammonium phosphate and the effect was more when it was applied along with phosphate solubilising bacteria inoculation.

Foliar application of two percent diammonium phosphate at pre flowering and flowering stages along with a basal dose of 50 percent nitrogen either as ammonium sulphate or as urea and 50 percent phosphorus either as rock phosphate or as diammonium phosphate resulted in higher plant height, number of

leaves, number of branches per plant, leaf area index and dry matter production compared to no foliar spray of diammonium phosphate.

Number and dry weight of nodules per plant were not significantly influenced by various treatments. The highest number and dry weight of nodules per plant were observed in treatments which received nitrogen in the form of ammonium sulphate.

In general, the plants showed luxuriant growth and very poor yield irrespective of treatments. This might be due to the high initial nitrogen content of the soil coupled with the utilisation of photosynthates mainly for vegetative growth of plants and less efficient partitioning of assimilates to the reproductive parts. This led to very poor flowering and pod development, which ultimately resulted in extremely poor grain yield.

However, the yield attributes such as number of pods per plant, number of grains per pod, 100 seed weight, grain yield and Bhusa (haulm) yield were highest in treatments which received nitrogen in the form of ammonium sulphate.

Application of rock phosphate along with nitrogen either as urea or ammonium sulphate increased the yield and yield attributes compared to soil application of diammonium phosphate.

Application of rock phosphate along with phosphate solubilising bacteria inoculation resulted in more number of pods per plant, number of grains per pod, 100 seed weight, grain yield and Bhusa yield.

Foliar application of two percent diammonium phosphate at pre-flowering and flowering stages resulted in a lesser number of pods per plant, number of grains per pod, weight of pods and grains per plant, 100 seed weight, pod yield and grain yield compared to no foliar spray of diammonium phosphate. This is probably due to the excess availability of nitrogen and less partitioning to economic part which leads to excessive vegetative growth thereby a reduction in yield attributes and yield.

Protein content of grain and Bhusa were not significantly influenced by treatments, the highest protein content of grain and Bhusa were observed in treatments, which received nitrogen in the form of urea.

The N, P, K, Ca, Mg, and S uptake were higher in treatments, which received nitrogen as urea and phosphorus as rock phosphate. Application of rock phosphate with phosphate solubilising bacteria inoculation and foliar spray of diammonium phosphate increased the uptake of nutrients compared to no phosphate solubilising bacteria inoculation and no foliar spray of diammonium phosphate respectively.

Nitrogen content in the soil was at medium level after the harvest of the crop. None of the treatments could bring about much impact on soil nutrient status. However, complete basal application of nitrogen and phosphorus showed a slightly higher content of N, P, K, Ca, Mg and S over their 50 percent application. Moreover, application of nitrogen as ammonium sulphate resulted in a slightly higher content of sulphur in the soil compared to application of urea.

Basal application of 50 percent nitrogen as urea and 50 percent phosphorus as rock phosphate along with phosphate solubilising bacteria inoculation and subsequent foliar spray of two percent diammonium phosphate at pre flowering and flowering stages was found to be the best for cowpea grown in summer rice fallow.

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* Originals not seen.

APPENDIX 1

Weather conditions during the crop period from 29-1-05 to 6-5-05

Week number	Week	Maximum temperature^{0}C	Minimum temperature ^{0}C	Relative humidity (%)	Rain fall (mm)	Sunshine hrs day^{-1}
1	29-1-05 to 4-2-05	33.2	23.2	64.5	-	7.8
2	5-2-05 to 11-2-05	34.5	20.4	45.5	-	10.2
3	12-2-05 to18-2-05	34.9	21.1	50.5	-	10.1
4	19-2-05 to 25-2-05	35.4	23	58	-	10
5	26-2-05 to 4-3-05	36	22.2	52	-	10.2
6	5-3-05 to 11-3-05	35.4	24.5	64.5	-	8.4
7	12-3-05 to 18-3-05	36.7	24.8	57.5	-	9.5
8	19-3-05 to 25-3-05	35.5	24.6	64	-	9.6
9	26-3-05 to 1-4-05	34.5	25.3	68.5	-	6.7
10	2-4-05 to 8-4 -05	33.1	24.1	73	-	3.3
11	9-4-05 to 15-4-05	33	25	78	-	6.4
12	16-4-05 to 22-4-05	34.4	24.7	73.5	-	9
13	23-4-05 to 29-4-05	34.3	25	72	-	9.8
14	30-4-05 to 6-5-05	33.5	24.9	74.5	-	8.1

APPENDIX 11

Nitrogen content of cowpea at different stages (%)

Tr. No.	Treatments	20DAS	40DAS	60DAS	Haulm	Shell	seed
T_1	AS+DAP (complete basal)	1.61	1.86	2.87	1.85	1.54	4.00
T_2	AS+ DAP (50 % basal) ++DAP spray	1.60	1.85	3.00	1.93	1.68	3.76
T_3	AS+RP (complete basal)	1.59	1.86	2.90	1.81	1.56	3.48
T_4	AS+RP (50 % basal) +DAP spray	1.61	1.87	3.28	1.94	1.50	3.50
T_5	AS+RP (complete basal)+PSB	1.56	1.85	2.95	1.90	1.58	3.45
T_6	AS+RP (50% basal) +PSB+DAP spray	1.55	1.88	3.07	1.93	1.82	3.67
T_7	AS (complete basal)+PSB	1.55	1.86	2.73	1.90	1.48	3.90
T_8	AS (50% basal)+PSB+DAP spray	1.60	1.88	2.89	1.94	1.72	3.40
T_9	Urea +DAP (complete basal)	1.60	1.87	2.97	1.92	1.56	3.68
T_{10}	Urea +DAP (50 % basal)+DAP spray	1.61	1.89	3.22	1.93	1.52	3.64
T_{11}	Urea +RP (complete basal)	1.60	1.87	3.00	1.86	1.64	3.10
T_{12}	Urea +RP (50 % basal)+DAP spray	1.58	1.89	3.24	1.93	1.86	3.30
T_{13}	Urea +RP (complete basal)+PSB	1.56	1.88	3.18	1.89	1.60	3.60
T_{14}	Urea +RP (50%basal)+PSB+DAP spray	1.59	1.89	3.41	1.92	1.77	3.59
T_{15}	Urea (complete basal)+PSB	1.61	1.85	3.06	1.83	1.61	3.15
T_{16}	Urea (50%basal)+PSB+ DAP spray	1.62	1.88	3.27	1.86	1.46	3.40
T_{17}	Package of practices recommendations	1.62	1.89	2.99	1.83	1.48	3.30

APPENDIX 111

Phosphorus content of cowpea at different stages (%)

Tr. No.	Treatments	20DAS	40DAS	60DAS	Haulm	Shell	Seed
T_1	AS+DAP (complete basal)	0.21	0.25	0.31	0.31	0.23	0.68
T_2	AS+ DAP (50 % basal) ++DAP spray	0.20	0.27	0.33	0.32	0.18	0.50
T_3	AS+RP (complete basal)	0.22	0.26	0.32	0.31	0.31	0.55
T_4	AS+RP (50 % basal) +DAP spray	0.21	0.27	0.33	0.32	0.21	0.73
T_5	AS+RP (complete basal)+PSB	0.20	0.25	0.32	0.32	0.24	0.72
T_6	AS+RP (50% basal) +PSB+DAP spray	0.22	0.26	0.34	0.33	0.26	0.56
T_7	AS (complete basal)+PSB	0.21	0.25	0.30	0.32	0.24	0.47
T_8	AS (50% basal)+PSB+DAP spray	0.20	0.25	0.31	0.32	0.19	0.56
T_9	UREA+DAP (complete basal)	0.23	0.26	0.31	0.32	0.24	0.60
T_{10}	UREA+DAP (50 % basal)+DAP spray	0.22	0.26	0.33	0.33	0.24	0.57
T_{11}	Urea +RP (complete basal)	0.23	0.27	0.32	0.33	0.29	0.62
T_{12}	Urea +RP (50 % basal)+DAP spray	0.21	0.26	0.34	0.32	0.23	0.65
T_{13}	Urea +RP (complete basal)+PSB	0.23	0.25	0.31	0.32	0.25	0.57
T_{14}	Urea +RP (50%basal)+PSB+DAP spray	0.23	0.25	0.34	0.33	0.24	0.64
T_{15}	Urea (complete basal)+PSB	0.21	0.26	0.30	0.31	0.26	0.74
T_{16}	Urea (50%basal)+PSB +DAP spray	0.20	0.25	0.32	0.31	0.24	0.70
T_{17}	Package of practices recommendations	0.21	0.26	0.32	0.31	0.19	0.74

APPENDIX 1V

Potassium content of cowpea at different stages (%)

Tr. No.	Treatments	20DAS	40DAS	60DAS	Haulm	Shell	seed
T_1	AS+DAP (complete basal)	2.10	2.51	2.86	2.82	1.14	1.10
T_2	AS+ DAP (50 % basal) + DAP spray	2.12	2.53	2.90	2.81	1.33	1.25
T_3	AS+RP (complete basal)	2.10	2.49	2.93	2.83	1.04	1.24
T_4	AS+RP (50 % basal) +DAP spray	2.13	2.52	2.85	2.80	1.29	1.16
T_5	AS+RP (complete basal)+PSB	2.11	2.45	2.87	2.80	1.23	0.80
T_6	AS+RP (50% basal) +PSB+DAP spray	2.11	2.45	2.90	2.82	1.23	1.25
T_7	AS (complete basal)+PSB	2.10	2.47	2.87	2.82	1.23	1.20
T_8	AS (50% basal)+PSB+DAP spray	2.12	2.52	2.86	2.81	1.45	1.30
T_9	Urea +DAP (complete basal)	2.13	2.50	2.91	2.82	1.33	1.44
T_{10}	Urea+ DAP (50 % basal)+DAP spray	2.13	2.48	2.91	2.81	1.09	1.42
T_{11}	Urea +RP (complete basal)	2.11	2.49	2.87	2.81	1.38	1.40
T_{12}	Urea +RP (50 % basal)+DAP spray	2.13	2.51	2.94	2.80	1.17	1.32
T_{13}	Urea +RP (complete basal)+PSB	2.12	2.48	2.90	2.82	1.37	1.30
T_{14}	Urea +RP (50%basal)+PSB+DAP spray	2.11	2.45	2.91	2.81	1.10	1.26
T_{15}	Urea (complete basal)+PSB	2.13	2.45	2.85	2.82	1.40	1.33
T_{16}	Urea (50%basal)+PSB +DAP spray	2.12	2.47	2.86	2.82	1.19	1.33
T_{17}	Package of practices	2.12	2.47	2.90	2.83	1.11	1.24

APPENDIX V

Calcium, Magnesium and sulphur content in cowpea at flowering stage (%)

Tr. No.	Treatments	Ca	Mg	S
T_1	AS+DAP (complete basal)	1.01	0.73	0.68
T_2	AS+ DAP (50 % basal) ++DAP spray	1.02	0.72	0.66
T_3	AS+RP (complete basal)	1.02	0.72	0.68
T_4	AS+RP (50 % basal) +DAP spray	1.02	0.71	0.67
T_5	AS+RP (complete basal)+PSB	1.00	0.72	0.66
T_6	AS+RP (50% basal) +PSB+DAP spray	1.02	0.73	0.67
T_7	AS (complete basal)+PSB	1.03	0.74	0.68
T_8	AS (50% basal)+PSB+DAP spray	1.01	0.72	0.69
T_9	Urea +DAP (complete basal)	1.02	0.71	0.68
T_{10}	Urea +DAP (50 % basal)+DAP spray	1.01	0.72	0.66
T_{11}	Urea +RP (complete basal)	1.02	0.74	0.67
T_{12}	Urea +RP (50 % basal)+DAP spray	1.02	0.74	0.68
T_{13}	Urea +RP (complete basal)+PSB	1.04	0.73	0.66
T_{14}	Urea +RP (50%basal)+PSB+DAP spray	1.03	0.72	0.67
T_{15}	Urea (complete basal)+PSB	1.03	0.71	0.67
T_{16}	Urea (50%basal)+PSB +DAP spray	1.02	0.72	0.66
T_{17}	Package of practices	1.03	0.72	0.67

NUTRIENT SOURCE EFFICIENCY RELATIONS ON THE PRODUCTIVITY OF COWPEA IN SUMMER RICE FALLOWS

By

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ABSTRACT OF THE THESIS

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ABSTRACT

A field experiment was conducted in the rice fallows of Agricultural Research Station, Mannuthy, during the summer season (February – April) of 2005, to study the effect of different sources of nitrogen and phosphorus on growth, yield and quality of cowpea and to asses the possibility of reducing the quantity of fertilizers through inoculation of phosphate solubilising bacteria and foliar application of diammonium phosphate.

The experiment was laid out in randomized block design with seventeen treatments and three replications. The treatments included were, different sources of nitrogen and phosphorus along with or with out phosphate solubilising bacteria inoculation and foliar application two percent diammonium phosphate twice and package of practices recommendation alone.

Most of the growth characters, dry matter production, yield and yield attributes and uptake of N, P, K, Ca, Mg, and S were higher in the treatments which received nitrogen in the form of urea and phosphorus in the form of rock phosphate. The influence of rock phosphate was more when it was applied along with phosphate solubilising bacteria inoculation. Foliar application of two percent diammonium phosphate at pre flowering and flowering stages increased the growth characters and drymatter production but showed a reduction in yield and yield attributes of cowpea.

The protein content of grain and Bhusa was not significantly influenced by various sources of nitrogen and phosphorus, phosphate solubilising bacteria inoculation and foliar spray of two percent diammonium phosophate.

None of the treatments could bring about much impact on soil nutrient status. However, complete basal application of nitrogen and phosphorus showed a slightly higher content of N, P, K, Ca, Mg and S over their 50 percent application.

Moreover, application of nitrogen as ammonium sulphate resulted in a slightly higher content of sulphur in the soil compared to application of urea.

Among the various treatments, considering the growth and yield of cowpea as well as economics, basal application of 50 percent nitrogen as urea and 50 percent phosphorus as rock phosphate along with phosphate solubilising bacteria inoculation and subsequent foliar spray of two percent diammonium phosphate at pre flowering and flowering stages was found to be the best.