EFFECT OF DIFFERENT TYPES OF FERTILIZERS AS INFLUENCED BY ADJUVANTS ON FUE AND YIELD OF UPLAND RICE

by

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(2014-11-132)

THESIS

Submitted in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

2016

Department of Agronomy

COLLEGE OF AGRICULTURE

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DECLARATION

I, hereby declare that this thesis entitled **"Effect of different types of fertilizers as influenced by adjuvants on FUE and yield of upland rice"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled **"Effect of different types of fertilizers as influenced by adjuvants on FUE and yield of upland rice"** is a record of research work done independently by Ms. Sheeba,S.S under my guidance and supervision and it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Acknowledgement

With all incessant pleasure and gratification, it is an opportunity of life time to work under the esteemed guidance of **Dr. T. Sajitha Rani,** Professor Department of Agronomy, Major Advisor for her fervent interest, motherly approach, conscientious guidance with constructive suggestions, ceaseless inspiration, affectionate advice, unaccountable help and care bequeath during my study epoch.

I wish to express my sincere thanks to the members of the advisory committee, **Dr. Sheela, K.R.** Professor, Department of Agronomy and **Dr. Babu Mathew, P** Professor and Head, Instructional Farm, College of Agriculture Vellayani and **Dr. Biju Joseph** Assistant Professor (SS and Agrl. Chemistry), Instructional Farm, for their, infallible guidance with ingenious suggestions and vivid support in carrying out the research work.

I am thankful to **Dr. Geethakumari, V.L,** Professor (Retd) and **Dr. M.Meerabai**, Professor (Retd), Department of Agronomy for their guidance and encouragement throughout the course of this study.

I am pleased to thank **Dr.K. Sreekumar** Professor (Plant Breeding and Genetics), Instructional Farm **and Dr. V. Jayakrishnakumar,** Associate Professor, Department of Agronomy and all the staff members of Department of Agronomy and Instructional farm, Vellayani for the help rendered during the span of this study.

I express my heartfelt thanks to my classmates **Dona, Amala, Anjali A Hari, Ishrath, Anjali. K, Eldose, Vinod Alur, Vinod Mavarkar, and Elsa** for their encouragement and co-operation during the study tenure. I am also indebted to express my thanks to my senior friends and also for my juniors.

I find no words to express my boundless gratitude to Suma chechi and Narmada chechi, Aswini chechi for their love, motivation, blessings, sacrifice and prayers for keeping me in high spirit in pursuing this research programme.

Personally I would like to express my gratitude to my beloved father **A. Suran,** mother **C. Syamala** for their mellifluous love and appealing affection on me which helped me in maintaining the joy in fulfilling my education. Finally I would express my thanks to my beloved brothers **Mr. Shibu. S** and **Mr. Shibin. S.S** for their constant affection.

My sincere thanks to the Kerala Agricultural University for providing the Kerala Agricultural University Junior Fellowship.

I owe my gratitude and salutations to the **ALMIGHTY GOD** who stood by my side and encouraged me at times of distress and guided me till now to complete my task.

SHEEBA, S. S.

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LIST OF ABBREVIATIONS AND SYMBOLS USED

%	Per cent
@	at the rate of
₹	Rupees
°C	Degree celsius
AT	Active tillering
B:C ratio	Benefit: Cost ratio
CD (0.05)	Critical difference at 5% level
CEC	Cation exchange capacity
Cm	Centimetre
cm^2	Centimetre squre
DMP	Dry matter production
dS m^{-1}	Deci Siemens per metre
EC	Electrical conductivity
et al.	Co-workers
Fig.	Figure
FYM	Farmyard manure
FUE	Fertilizer use efficiency
G	Gram
ha^{-1}	Per hectare
i.e.	that is
K/ K_2O	Potassium
K_2SO_4	Potassium sulphate
KNO_3	Potassium nitrate
Kg	Kilogram

kg ha^{-1}	Kilogram per hectare
LAI	Leaf area index
M	Metre
m^{-2}	Per square metre
Mg	Milli gram
mm	Millimeter
MOP	Muriate of potash
MSL	Mean sea level
N	Nitrogen
nos.	Numbers
NO_3-N	Nitrate nitrogen
NS	Non significant
P/ P_2O_5	Phosphorus
RH	Relative humidity
SEm	Standard error of mean
SOP	Sulphate of potash
S	Sulphur
t	Tonnes
t ha^{-1}	Tonnes per hectare
viz.,	Namely

INTRODUCTION

1. INTRODUCTION

Rice is the most important food crop of the world, and is the staple food of almost 3 billion people. Rice is grown in as many as 114 countries across the world, in an area of 150 million hectare, which constitutes nearly 11 per cent of the world's cultivated land. In India, rice is grown in an area of 43.95 million hectare annually with a production of 106.54 million tonnes, and an average productivity of 2424 kg ha^{-1} during 2013-2014 (GOI, 2014). Among the food grains, the demand for rice continues to grow and is projected to increase by more than 50 per cent over the next few decades (Zeigler, 2012). Geometric growth of population and arithmetic increase in food grain production leave a wide gap in food grain supply.

An appropriate crop management strategy to increase the efficient use of inputs is needed to enhance the productivity. Foliar application of fertilizers can guarantee the availability of nutrients to rice for obtaining higher yield. Pandey (1999) reported that nutrient management technology should be oriented towards better utilization of organic sources that may be available cheaply or improving the formulation, timing and placement of chemical fertilizers so that the nutrient uptake by plants is maximized.

In the case of mobile nutrients, availability changes periodically with the mineralization of organic matter and loss due to leaching, denitrification and volatilization in soil plant systems. Foliar nutrition when used as a supplement to the recommended soil fertilizer application is highly beneficial, as the crop gets benefited from foliar applied nutrients when the roots are unable to meet the nutrient requirement of the crop at its critical growth stages.

Foliar spray of fertilizer not only increases the crop yield but also reduces the quantities of fertilizer applied through soil. Foliar fertilization of rice with micro and macronutrients during critical growth stages promises to increase yield and improve grain quality. Ward and Schroeder (1994) reported that foliar spray of nutrients resulted in effective absorption by plants and translocation of assimilates more efficiently to the developing grains for proper filling by increased leaf nitrogen content, chlorophyll synthesis and by regulating cellular functions.

The ability of foliar sprays to stick to leaves is essential to enable uptake of nutrients. Adjuvants are used to improve spreading and sticking properties of fertilizer solution on the leaf surface and increase the amount of leaf area interacting with the fertilizer. Surfactants (Adjuvants) can also directly influence the absorption of agrichemical by changing the viscosity and crystalline structure of waxes on leaf and stem surfaces, so that they are more easily penetrated by the applied chemical (Kirkwood, 1999). Surfactants, humectants and stickers increase the amount of time that the applied chemical is retained on the leaf, in a form available for uptake (Penner, 2000). The use of adjuvants as management tools for agricultural chemicals can modify spray solutions by improving the physical characteristics, reducing or minimizing chemical losses and maximizing efficacy by enhancing penetration. Adjuvants maximize product efficacy when conditions are less than ideal, when low spray volumes are used or when product performance needs to be modified or improved.

Keeping the above in view, the present study was undertaken with the objectives to assess the possibility of enhancing nutrient use efficiency of rice by using water soluble fertilizers and adjuvants and to study the impact of foliar fertilizers and adjuvants on growth and productivity of upland rice and to work out the economics.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Area under rice cultivation is diminishing day by day. In order to meet the demand, we have to find out new area for rice cultivation. As the major cropping system of Kerala is coconut based, upland rice can be cultivated as an intercrop in coconut gardens as well as cultivable waste lands. Yield of upland rice is very low compared to low land rice. Farmer friendly, eco-friendly and cost effective new nutrient management intervention has to be find out for increasing the productivity of upland rice

The relevant literature on effect of N, P, K and S as foliar nutrients along with adjuvants on growth characters, yield attributes, yield and nutrient uptake by crop and quality of produce are reviewed in this chapter.

2.1 EFFECT OF DIFFERENT NUTRIENTS IN RICE

2.1.1 Growth and yield characters

2.1.1.1 Nitrogen

Nitrogen is the one of the major plant nutrients required for plant growth. It is essential for the synthesis of protein, which is the constituent of protoplasm and chloroplast. Venkateswarlu and Vispearas (1987) reported that even within a crop source-sink balance varies based on the nutrients availability. Pandian (1989) observed that significant increase in plant height was brought about by the application of nitrogen.

Mae (1997) observed that nitrogen absorbed during panicle initiation increased specific leaf weight and nitrogen contents in leaves which lead to enhancement of photosynthetic capacity and promotion of carbohydrate accumulation in culms and leaf sheath. Nitrogen is a constituent of numerous important compounds found in living cells, including amino acid, protein, nucleic acid and chlorophyll (Traore and Maranville, 1999).

Application of N was known to promote tillering in rice due to increased photosynthetic activity and also increased DMP, which might have contributed to the increased biological yield (Chopra and Chopra, 2000). Thomas (2000) reported significant increase in plant height, number of tillers and productive tillers, LAI, DMP, longest panicle, spikelets number, filled grains panicle^{-1}, thousand grain weight, grain yield, straw yield and HI of upland rice with higher levels of N up to 60 kg ha^{-1}.

Anu (2001) observed increased LAI and DMP in upland rice with incremental levels of N up to 80 kg ha^{-1}. Ranjini (2002) observed increased plant height, tiller production and LAI when N levels were increased up to 90 kg ha^{-1}. Sharief *et al.* (2006) observed increased plant height due to cell elongation and increased photosynthetic rate with higher amount of N addition.

2.1.1.2 Phosphorus

Phosphorus availability from soil to the plants is a key to sustain higher yields. Phosphorus is a major component in ATP, the molecule that provides energy to the plant for the processes like photosynthesis, protein synthesis, nutrient translocation, nutrient uptake and respiration. Phosphorus is also a component of other compounds necessary for protein synthesis and transfer of genetic material such as DNA and RNA (Wilson *et al.*, 2006)

Application of P aided in more vigorous root development, early tillering capacity, early tillers, more panicles, per cent of filled spikelets and good grain quality (Bhattacharyya and Chatterjee, 1978).

Though the response of rice to applied P was observed up to 60-90 kg P_2O_5 ha^{-1}, the higher rate had no beneficial effect (Beltran, 1982). Singh *et al.* (1985) reported a rice grain yield of 3.9 and 7.3 q ha^{-1} due to the application of 30 kg and 60 kg P_2O_5 ha^{-1} respectively. Phosphorus is an essential nutrient and no plant can produce good yield if it suffers from P deficiency (Tandon, 1987).

Mandai and Ghosh (1988) observed that application of higher dose of P (100 kg P_2O_5 ha^{-1}) in winter months helped quick establishment of seedlings, accelerated plant growth, early flowering and increased grain yield of rice. Dry matter, plant height and number of tillers were increased significantly with increasing P levels upto 160 kg ha^{-1} (Alam and Azml, 1989). Thakur (1992) reported that application of 60 kg P_2O_5 ha^{-1} resulted in maximum panicles m^{-2}, panicle length, grains $panicle^{-1}$, test weight and grain yield

2.1.1.3 Potassium

Potassium is an important nutrient for upland rice in Indian soil. Potassium helps in root development and enhances the growth of rice plants (Vijayan and Sreedharan, 1972). Tiller production in rice was influenced by K application (Kulkarni *et al.*, 1975). Yoshida (1976) reported that K is an essential element for the growth of rice plant and takes part in various physiological processes.

Yoshida (1981) reported that higher foliar NPK concentration at booting to one week after flowering stages resulted in higher photosynthetic efficiency due to increased productive tillers and filled spikelets percentage.

Sakeena and Salam (1989) observed that DMP improved substantially due to the addition of K up to 35 kg ha^{-1}. Sarkar *et al.* (1995) reported that application of K at appropriate physiological growth stages may be an effective means for minimising the losses of applied nutrients, increasing its availability throughout the growth period and their by resulting in higher yield. Babu (1996) found higher leaf area due to K application in rice. Cassman *et al.* (1996) observed that in rice cultivation, K application is partially or completely ignored by farmers which resulted in the imbalanced fertilization which affects rice productivity.

Fageria *et al.* (1997) reported that the physiological functions of K in plants are enzyme activation, osmoregulation and formation of carbohydrates, nucleic acids, proteins, photosynthesis, enhancement of rooting and early establishment, drought tolerance, wear resistance and maintenance of crop quality.

Sahai (2004) reported that application of K increased the availability of N and P. Imas and Magen (2007) observed that K helps in photosynthesis, carbohydrate distribution and starch synthesis in the storage organs.

2.1.1.3 Sulphur

Sulphur is a micronutrient required by plant for good crop growth. Sulphur is an important nutrient for the normal growth of plant. It plays an important role for normal metabolism and synthesis of amino acids, oils, glycosides, enzymes and protein configuration during the plant growth. Tisdale *et al.* (1995) opined S needed by plants is about the same quantities as phosphorus.

George (1978) observed significant increase in LAI of rice up to 30 kg S ha $^{-1}$. Suzuki (1978) reported significantly higher DMP in rice with sulphur application and reduced number of tillers due to sulphur deficiency. Blair *et al.* (1979) reported significantly increased tiller number at active tillering, maximum tillering and at maturity stages due to S application. Ahamed *et al.* (1988) observed significant increase in tiller production of rice with 30 kg ha^{-1} S. Muraleedharan and Jose (1993) observed increased tiller number with the application of 30 kg S ha^{-1}. Sulphur application up to 25 kg ha^{-1} increased plant height and number of tiller m^{-1} (Sudha, 1999).

The yield of rice was significantly influenced by S application irrespective of source and dose (Singh *et al.*, 1993). Higher S levels enhanced uptake of N, K and S in rice (Nair, 1995). Lin and Zhu (2000) reported increased grain and straw yield due to the availability of N, K and S.

2.2 EFFECT OF FOLIAR NUTRITION

Foliar fertilization has been widely adopted in modern crop management where it is used to ensure optimal crop performance when nutrient supply from the soil is inadequate or uncertain. Subramanian and Palaniappan (1981) opined that generally foliar application of major nutrients was found to be as good as soil application. Foliar fertiliser application enables directed timing of nutrient applications to coincide with critical stress events such as growth flushes, flowering and fruit set (Weinbaum 1988). This is possible because, in general, responses to foliar nutrients are much more rapid than those to soil applications (Knight 1991). Gooding and Davis (1992) observed that foliar application provides more rapid utilization of nutrients and permits correction of observed deficiency in less time. Ward and Schroeder (1994) reported that foliar spray of nutrients resulted in effective absorption by plants, more efficient translocation of assimilates, proper grain filling by increased N content. Amberger (1996) reported that foliar application reduced the losses of nutrients through immobilization, denitrification or volatilization and leaching especially with N and increased the utilization rate of nutrients.

Hasewaga *et al.* (2000) reported that foliar spray of nutrients increased the photosynthesis, dry matter accumulation, tiller number, dry weight, leaf area, and number of fertile spikelets in the panicle and grain yield of rice. Lin and Zhu (2000) found that foliar spray of fertilizers at heading stage increased grain yield of rice. Among the methods of fertilizer application, foliar nutrition is recognised as an important method as it facilitates easy and rapid· utilization of nutrients (Latha and Nadanassababady, 2003).

Ahamad and Jabeen (2005) observed that foliar spray of fertilizer did not only increase the crop yield but also reduced the quantities of fertilizer applied through soil. Ali *et al.* (2005) reported that foliar spray increased the metabolic activity of plant. Girma *et al.* (2007) found that foliar application is a visible economic way to supplement the plant nutrients for more efficient fertilization. Fageria *et al.* (2009) also reported that crops respond to soil applied fertilizers in five to six days, while the response is faster (48 hours) in foliar application.

Foliar application helps in effective absorption of nutrients at critical growth stages and resulted in enhanced physiological activity leading to better growth (Kundu and Sarkar, 2009). Alam *et al.* (2010) opined that foliar application could be considered only as a supplement to soil application of N Bhuyan *et al.* (2012) reported that foliar application of N during the late growth stages reduced sterility per cent and increased thousand grain weight and yield.

Jagathijothi *et al.* (2012) reported that foliar nutrients improved the photosynthetic rate and carbohydrate translocation and in turn increased the DMP. They have also reported that the combined application of organic and inorganic sources with foliar spray enhanced the growth of rice.

Kundu and Sarkar (2009) observed pronounced effect on net return and B:C ratio in rice by the foliar application of potassium nitrate and calcium nitrates. Habibi *et al.* (2014) observed improved DMP and remobilization in rice by the application of 0.5 % of potassium.

2.2.1 EFFECT OF FOLIAR NUTRITION OF 19:19:19

FAO (2000) recommended the application of 19:19:19 for rice at tillering, one week before flowering and at panicle emergence stages @ 5g $litre^{-1}$ of water as a supplement to soil application.

Chaurasia *et al.* (2005) reported maximum plant height, number of branches $plant^{-1}$, fruit length, yield, net profit and maximum B: C ratio by 5 foliar sprays of water soluble liquid fertilizers, 19:09:19 followed by NPK 19:19:19.

Rani *et al.* (2014) conducted a field experiments to study the effect of foliar fertilization on growth, yield, economics and nutrient uptake of rice and reported significantly higher grain yield when the recommended dose of fertilizers were supplemented with foliar application of 19:19:19 @ 2.5 kg ha^{-1} at tillering and panicle initiation stages. Gross returns and net returns were also the highest with foliar application of 19:19:19 @ $2.5kgha^{-1}$ at tillering and panicle initiation stages.

Studies conducted in wetland rice by Surya (2015) revealed higher grain and straw yield by flag leaf nutrition with 0.5 per cent KNO_3 and it was on a par with 19:19:19 complex.

2.2.2 EFFECT OF FOLIAR NUTRITION OF POTASSIUM NITRATE (13:0:46)

Howard *et al.* (1998) Robert (1999) reported that higher yields and net revenues from cotton plant by the foliar applications of KNO_3 from soils low in K content. Foliar application of KNO_3 3% at panicle initiation and flowering stages improved the grain filling and consequently the grain yield of rice (Son *et al.*, 2012).

Khan *et al.* (2012) also found that foliar application 2% KNO_3 solution resulted in the highest thousand grain weight which was statistically at par to foliar application of 1.5% KNO_3. Minimum thousand grain weight (17.63 g) was recorded by the foliar application of 1% KNO_3. Ahmad and Jabeen (2005) observed that foliar application of K could be an economical way to fulfil the potassium deficiency against soil incorporation of K as it is required in lesser amounts.

In a study on the effect of foliar application of KNO_3 and urea on performance of late transplanted rice, Mahajan *et al.* (2012) reported that grain yield improved substantially with single foliar spray of urea (0.5% or 1%) or 1% KNO_3 at flowering stage. No yield advantages were found with two sprays of 1% KNO_3 as compared to single spray of 1% KNO_3.

2.2.3 EFFECT OF FOLIAR NUTRITION OF UREA

Wither and Teubner (1959) opined foliar feeding of urea as a convenient method to augment N fertilization for cereals.

From a field trial to study the effect of foliar urea spraying on three rice cultivars, Sarandon (1996) observed increased grain yield, grain number m^{-2} and a more efficient dry matter partition to the grain (harvest index), without changes in the biomass production with foliar application of urea (30 kg N ha^{-1}) at heading stage. No apparent change in grain production was observed when urea spraying was done at tillering, but it increased to 70 % when applied at heading and to 47 % when applied at post anthesis.

Alam *et al.* (2010) reported that foliar application of 2 % urea solution (92 kg N ha^{-1}) to boro rice gave a statistically comparable yield with soil application of 130 kg N ha^{-1}.

Parvin (2013) observed taller rice plants with either three or four times urea spray @ 120 kg ha^{-1}. The highest number of tillers $hill^{-1}$, effective tillers $hill^{-1}$, highest panicle length, grains $panicle^{-1}$and highest grain yield was obtained with five times urea spray @ 100 kg ha^{-1}.

2.2.4 EFFECT OF FOLIAR NUTRITION OF K_2SO_4

Glass and Siddiqi (1984) observed that foliar application of K_2SO_4 produced better grain and straw yield of rice. Ali *et al.* (2005) reported that foliar applications of K_2SO_4 have positive response on rice and wheat. Foliar application of 1.5 % K_2SO_4 produced better paddy and straw yields as compared to KNO_3 and KCl. Soil application of sulphate of potash @ 50 kg K_2O ha^{-1} along with foliar application of the same enhanced the rice yield (Ali *et al.*, 2007).

Khan *et al.* (2012) reported that both soil incorporated K_2SO_4 and foliar applied KNO_3 @ 1.5 and 2% solutions significantly influenced thousand grain weight of rice.

2.3 EFFECT OF ADJUVANTS

An adjuvant is a material added to aid or modifies the action of an agrichemical, or the physical characteristics of the mixture (Devisety and Hall, 1998). Adjuvants can be defined as any substance included in a formulation or which is added to the spray tank that modifies the nutrient active ingredient activity or the spray solution characteristics (Hazen, 2000). Adjuvants are generally classified as (i) activator adjuvants (e.g. surface active agents) which increase the activity, penetration, spreading and retention of the active ingredient or; (ii) utility adjuvants (e.g. acidifiers) that modify the properties of the solution without directly affecting the efficacy of the formulation (Penner, 2000) and (Chen, 2015)

Reductions in the efficiency of translocation are commonly more than compensated for by increases in absorption afforded by surfactants. When stomata infiltration occurs, nutrients are likely to be brought directly into close proximity with the vascular tissues. Such increases in nutrient export have been observed when L-77 was incorporated in the spray solution (Weinbaum and Neumann 1977). There is evidence that surfactants inhibit basipetal translocation in the phloem (Coupland 1989). Ruiter *et al.* (1990) reported that many plant species have been shown to have low wettability due to leaf surface roughness which is caused by waxes and hairs.

Spray adjuvants can be employed in the foliar application of fertiliser to ensure adhesion of aqueous sprays to the waxy surfaces of foliage (wetters), to improve coverage of spray on foliage (spreaders), to minimise weathering of fertiliser deposits on foliage (stickers/extenders), and to increase the uptake of fertiliser into foliage (humectants, pH modifiers, and penetrants). The ability of foliar sprays to stick to leaves is essential to enable uptake of nutrients. Surfactants (surface active agents), by virtue of their amphipathic nature (part watery, part oily), adsorb at the surface of spray droplets, effectively making the surface partially oily in nature so that it can wet the foliage (Stevens, 1993). The use of adjuvants may promote absorption of foliar-applied nutrients into leaves compared with solutions without adjuvants reducing nutrient loss and enhancing yield (Howard *et al.*, 1993).

The addition of adjuvants and, in particular, surface-active agents to modify the physico-chemical properties of the spray solution, can enable effective wetting of the leaf surface (Schonherr, 2000). Tu *et al.* (2001) reported that adjuvants having sticking and translocation character improved the contact between spray droplets and plant surface, thereby enhancing the absorption by increasing the retention of spray droplets on the plant, increasing penetration through hairs, scales or other leaf surface structures, preventing crystallization of spray deposits, which resulted in better uptake of foliar nutrients with improved vegetative growth. Addition of suitable adjuvants into spray formulations helped to increase the rate of retention, spreading, penetration and drying of the solution, thereby improving the performance of fertilisers.

Robert (1999) observed that adding an adjuvant to the foliar K solution promoted absorption of foliar applied nutrients into leaves and further enhanced yield of cotton. Fernandez and Eichert (2009) found that surfactants are often added to adjuvants to improve spreading and sticking of the fertilizer on the leaf surface and increase the amount of leaf interacting with the fertilizer. Blanco (2010) opined that addition of suitable adjuvants into spray formulations can help to increase the rate of retention, spreading, penetration and drying of the solution, thereby improving the performance of fertilizers

2.4 NUTRIENTS UPTAKE

Johnson and Wallingford (1983) observed significantly higher grain yield with higher level of N due to better N uptake and greater DMP in rice. Bhattacharya and Singh (1992) reported that application of appropriate quantity of nitrogen at right time is beneficial and is one of the important agronomic techniques to improve yield and N uptake of rice. Muthuswamy *et al.* (1974) reported higher P uptake with high N and K application.

Pandey *et al.* (2001) observed that combined use of organic manures and inorganic fertilizers was found to be significantly better than inorganic fertilizer alone for nitrogen uptake. Sharpley *et al.* (1994) observed that foliar application of nutrients not only increased the efficiency of nutrient uptake but also decreased the cost of production of cereal crops. Nair (1995) observed that higher sulphur levels enhanced uptake of N, K and S in rice.

In upland rice maximum N uptake values were registered when N was applied at the rate of 60 kg ha^{-1} (Thomas, 2000). Anu (2001) reported that the uptake of N, P and K were the highest with 80 kg N ha^{-1} and 45 kg K_2O ha^{-1} in upland rice under shaded situation.

Ranjini (2002) also found that the uptake of N, P and K were the highest with 90 kg N ha^{-1} and 45 kg K_2O ha^{-1} in upland rice. Gopalakrishnan (2005) observed higher N uptake by the application of higher amount of N.

2.5 EFFECT ON GRAIN QUALITY

Tisdale *et al.* (1995) reported that higher N uptake enhanced the protein content of the grain. Nishizawa *et al.* (1997) reported that spraying urea on the rice leaves at heading stage increased the grain protein content of rice.

Strong (1982) opined that foliar N application as a liquid spray resulted in higher grain protein concentration than when N was broadcast as dry granular fertilizer at late growth stages on wheat. Juliano and Duff (1991) observed that late N application increased protein content of grain.

Rao *et al.* (1993) reported that N application at higher dosage increased the amylase content in long slender rice varieties. Increasing dose of N fertilizers increased protein content of grain (Sikka *et al.*, 1993). Perez *et al.* (1996) opined that late N application at flowering stage is a management tool for obtaining higher grain protein content.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The field experiment entitled "Effect of different types of fertilizers as influenced by adjuvants on FUE and yield of upland rice" was conducted during the first crop season (May to September) of 2015. The primary objectives of the study were to assess the possibility of enhancing nutrient use efficiency of rice by using water soluble fertilizers and adjuvants and to study the impact of foliar fertilizers and adjuvants on growth and productivity of upland rice and to work out the economics. The details of materials used and methods adopted are presented in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani, Kerala, located at 8.5°N latitude and 76.9°E longitude at an altitude of 29 m above mean sea level.

3.1.1 Soil

The physico-chemical properties of the soil of the experimental site are given in Table 1.

The soil of the experimental site was sandy clay loam, which belongs to the taxonomical order oxisol acidic in reaction, high in organic carbon, medium in available nitrogen, phosphorus and potassium.

Table.1.Soil characteristics of the experimental field

Sl.No	Parameters	Content (%)	Methods used
A. Mechanical composition			
1.	Coarse sand	47.56	Bouyoucos hydrometer method (Bouyoucos, 1962)
2.	Fine sand	10.84	
3.	Silt	8.42	
4.	Clay	33.18	
B.Chemical composition			
1.	Available N	285.68 kg ha^{-1} (Medium)	Alkaline permanganate method (Subbiah and Asija, 1956)
2.	Available P_2O_5	24.64 kg ha^{-1} (Medium)	Bray colorimeter method (Jackson, 1973)
3.	Available K_2O	149.27 kg ha^{-1} (Medium)	Ammonium acetate method (Jackson, 1973)
4.	Organic carbon	0.98 per cent (High)	Walkley and Black's rapid titration method (Jackson, 1973)
5.	Soil pH	4.1 (Acidic)	1 : 2.5 soil solution ratio using pH meter with glass electrode (Jackson, 1973)

3.1.2 Climate

The experimental site enjoys a warm humid tropical climate. The field experiment was conducted during the first crop season *kharif* (May to September) of the year 2015. The data on various weather parameters during the cropping period are given in the Appendix I and illustrated in Fig.1.

3.1.3 Cropping History of the Field

The experimental area was kept under fallow prior to the layout of the experiment.

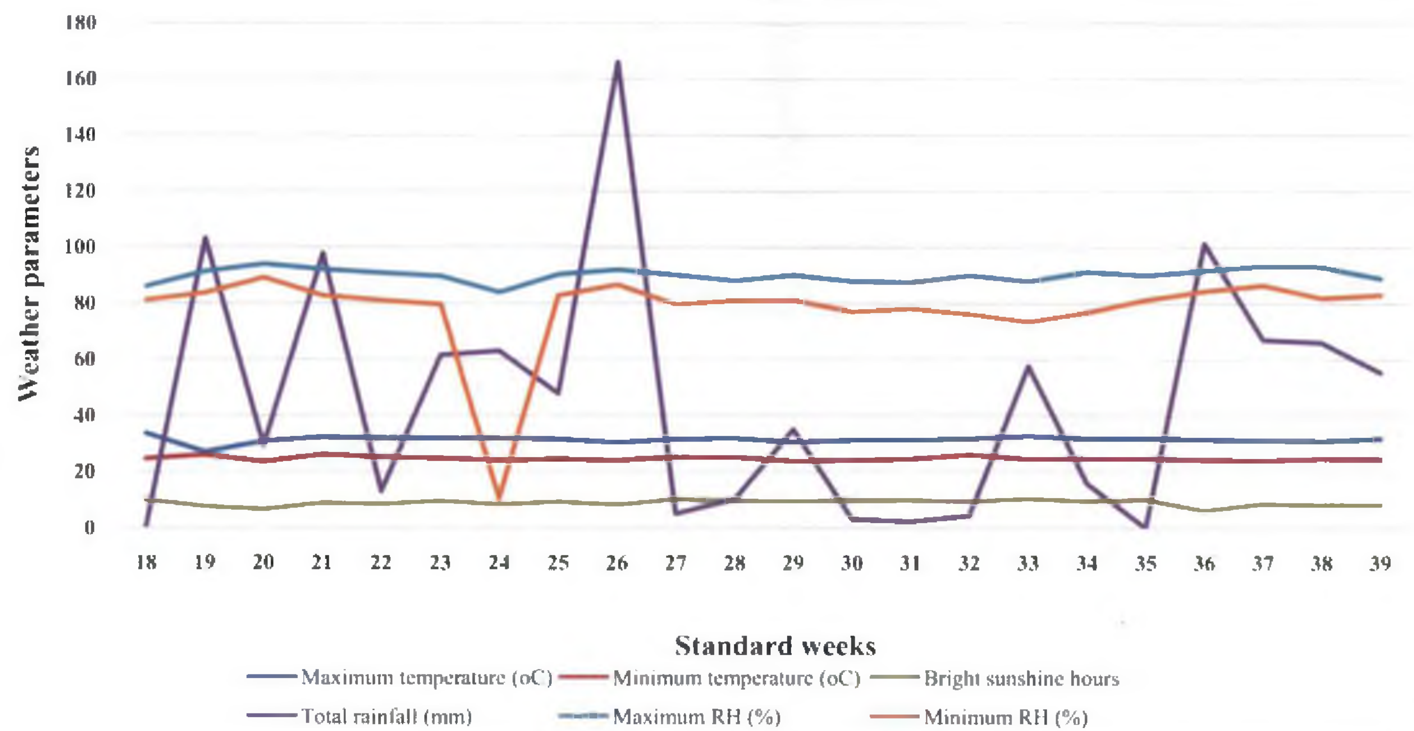

Fig. 1. Weather data during the cropping period (May to September)

3.2 MATERIALS

3.2.1 Seeds

The rice variety, selected for the experiment was 'Prathyasa' (MO 21) released from Rice Research Station, Moncompu. It is non lodging, photo insensitive and semi tall variety with 105-110 days duration. The grains are red, long and bold and the variety is moderately resistant to gall midge, brown plant hopper, sheath blight and sheath rot.

3.2.2 Manures and Fertilizers

Well decomposed farmyard manure (0.35 per cent N, 0.21 per cent P_2O_5 and 0.41 per cent K_2O) was used as organic source. Calcium carbonate was used as liming material and fertilizer sources like urea (46 per cent N), rajphos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used as the inorganic nutrient sources for the experiment.

3.2.3 Nutrient Sources for Foliar Nutrition

Urea, potassium nitrate, sulphate of potash and complex water soluble fertilizer 19:19:19 were used as the nutrient sources for foliar nutrition. The composition of nutrient sources used for foliar nutrition are presented in Table 2

Table 2. Nutrient sources used for foliar nutrition

SI No	Nutrient source	Chemical formula	Chemical composition
1	Urea	$CO(NH_2)_2$	45-46 % N-amide
2	Potassium nitrate	KNO_3	13% N $-NO_3$, 46 % K_2O
3	Sulphate of potash (SOP)	K_2SO_4	50-52 % K_2O, 17% SO_2
4	19:19:19 foliar fertilizer	-	10.5 % N-amide, 4.5 % N-NH_4, 4% N-NO_3,19.0 % P_2O_5 and 19.0 %K_2O

3.2.4 Adjuvants

Two types of adjuvants were used for the experiment. The properties of adjuvants are presented in Table 3.

Table 3. Adjuvant sources used for foliar nutrition

Sl. No.	Adjuvant type	Properties
1	Adjuvant category I (Dhanuvit)	Wetting, spreading and deep penetrating
2	Adjuvant category II (Sticklin)	Wetting and spreading

3.3 METHODS

3.3.1 Design and Layout

The treatments consisted of four foliar nutrients along with two types of adjuvants applied at three growth stages of upland rice. The treatments were compared against two controls. The field experiment was laid out as detailed below. The layout plan of the experiment is given in Fig. 2.

Design	:	Randomised Block Design
Treatments	:	10
Replications	:	3
Gross plot size	:	5 m x 4 m
Net plot size	:	4 m x 3 m
Variety	:	Prathyasa (MO 21)
Spacing	:	15 cm x 10 cm
Season	:	*Kharif* 2015

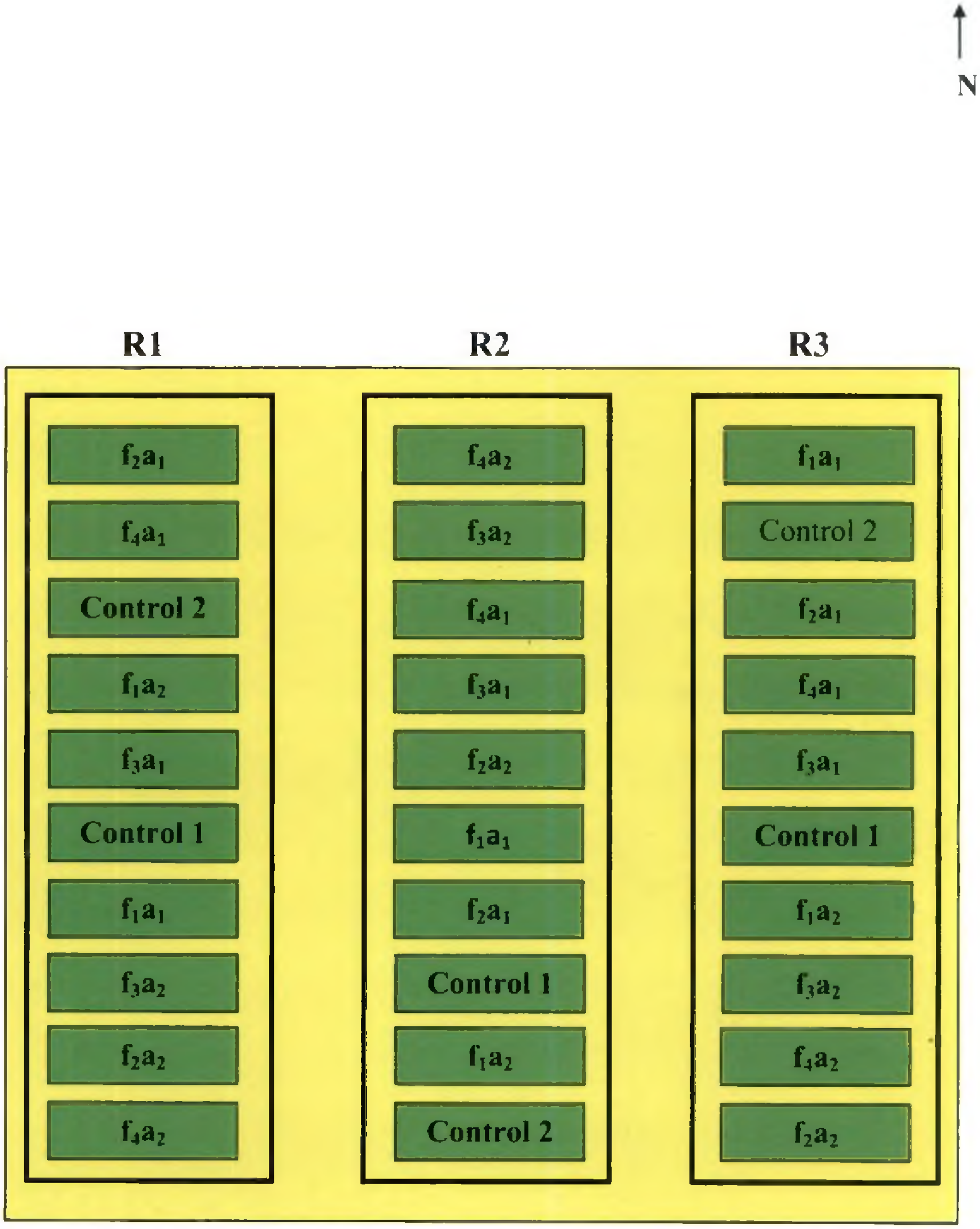

Fig. 2. Layout of the experimental plot

Plate 1. General view of the field experiment

3.3.1.1 Treatments

A) Foliar nutrients (F) – 4

F_1- Foliar application of 19:19:19

F_2- Foliar application of 13:0:46

F_3- Foliar application of urea (1.5 %) + SOP (1.5%)

F_4- Foliar application of urea (5 %) + SOP (5%)

B) Adjuvants (A) – 2

A_1- Adjuvant category I

A_2 - Adjuvant category II

C) KAU POP (Soil application of FYM 5t ha^{-1}) + 60:30:30 kg N P_2O_5 and K_2O ha^{-1}(Control 1)

D) Soil application of FYM 5t ha^{-1} alone (Control 2)

Treatment combinations

T_1-Foliar application of 19:19:19 (1.0 %) + Adjuvant1

T_2 -Foliar application of 19:19:19 (1.0 %) +Adjuvant 2

T_3 -Foliar application of 13:0:46 (1.0%) + Adjuvant 1

T_4 - Foliar application of 13:0:46 (1.0%) + Adjuvant 2

T_5- Foliar application of Urea (1.5 %) and SOP (1.5 %) + Adjuvant 1

T_6-Foliar application of Urea (1.5 %) and SOP (1.5 %) + Adjuvant 2

T_7- Foliar application of Urea (5 %) and SOP (1.5 %) + Adjuvant 1

T_8-Foliar application of Urea (5 %) and SOP (1.5 %) + Adjuvant 2

T_9- KAU POP (Soil application of FYM 5t ha^{-1}) + 60:30:30 kg N P_2O_5 and K_2O ha^{-1}.

(Nitrogen was applied in three equal split doses, as basal at maximum tillering and panicle initiation stages. Full dose of phosphorus as basal and potash in two split doses half as basal and half at panicle initiation stage)

T_{10}-Soil application of FYM @ 5t ha^{-1}.

For treatments 1to 8 soil application of $^1/_2$ N and K, full P and FYM @ 5t ha^{-1} were given as basal.

Foliar applied fertilizers were given at three stages *viz.*, maximum tillering, panicle emergence and flowering stages. Spray volume was fixed as 500 litre ha^{-1}.

3.3.2 Crop Management

3.3.2.1 Land Preparation

The experimental area was ploughed twice and levelled. Weeds and stubbles were removed. The experimental area was divided into 3 blocks of 10 plots each. The blocks and plots were separated with bunds of 30 cm width.

3.3.2.2 Application of Lime

Lime @ 600 kg ha^{-1} was applied in two split doses *i.e.*, 350 kg ha^{-1} just after the second tillage and the remaining at 250 kg ha^{-1} at tillering stage (25DAS).

3.3.2.3 Manures and Fertilizers

For treatments 1 to 8 soil application of $^{1}/_{2}$ N, $^{1}/_{2}$ K and full P and well decomposed farmyard manure @ 5 t ha^{-1} were applied as basal. Subsequent application of nitrogen and potassium fertilizers was given as foliar spray at maximum tillering, panicle emergence and flowering stages. Foliar nutrients were given along with adjuvant I and II accordingly.

3.3.2.4 Dibbling

Healthy pre-germinated seeds @ 80 kg ha^{-1} were dibbled on the main field area during the last week of May 2015. Pre-germinated seeds were dibbled @ 2-3 seed $hill^{-1}$ at a spacing of 15 cm x10 cm, and to a depth of 3-4 cm. Gap filling was done one week after dibbling so as to maintain uniform plant population, maintaining two seedlings.

3.3.2.5 Weed Management

The field was maintained weed free during the entire crop period. Two hand weedings were done on 20 DAS and 40 DAS. Periodic weeding were done in all the plots.

3.3.2.6 Irrigation

Irrigation was scheduled as per the requirement of crop. A total of 10 irrigations were given.

3.3.2.7 Foliar Nutrition

Foliar nutrition was done at maximum tillering, panicle emergence and flowering stages as per the treatments. 19:19:19 (1%), potassium nitrate (1%), combination of urea (5%) and SOP (1.5%) and combination of urea (1.5%) and SOP (1.5%) were used as the nutrient sources for foliar nutrition along with two types of adjuvants as per the technical programme. Adjuvant I (Dhanuvit) having wetting, spreading and deep penetrating properties and Adjuvant II (Sticklin) having wetting and spreading properties.

3.3.1.8 Plant Protection

Poison baits were used as a prophylactic measures to control pests like rodents. No disease attack was noticed at magnitude requiring chemical control.

3.4.2.9 Harvest

The crop was harvested at full maturity. The border and sampling rows were harvested separately. Net plot areas of individual plots were harvested and the weight of grain and straw were recorded separately.

3.4 OBSERVATIONS

3.4.1 Growth and Growth Attributes

Ten hills were selected randomly from the net plot area of each plot and tagged as sample plants. Two rows from all sides of the plots were left as border rows. The following observations were recorded from the sample plants and the mean values were worked out.

3.4.1.1 Height of Plant

Plant height was recorded at maximum tillering, panicle emergence, flowering and at maturity stages. Height was measured from the base of the plant to the tip of the longest leaf or to the tip of the longest ear head whichever was taller.

3.4.1.2. Total number of tillers m^{-2}

In each net plot, four quadrates each of 0.25 m^2 size were placed at random in three stages *viz.*, maximum tillering, panicle initiation, flowering stages and the total tillers were counted and expressed as total number of tillers m^{-2}.

3.4.1.3 Leaf Area Index

The leaf area index (LAI) was calculated at maximum tillering, panicle emergence, flowering and harvest stages. The total number of green leaves, length and breadth of the third leaf from the top in the tagged plants were measured in each plot. The leaf area index was worked out as reported by Palanisamy and Gomez (1974), using the formula given below.

$$LAI = \frac{L \times B \times K \times \text{No. of green leaves hill}^{-1}}{\text{Spacing } (cm^2)}$$

Where,

L – Length of the third leaf from the top (cm)

B – Maximum breadth of the same leaf (cm)

K – Adjustment factor (0.75 at panicle initiation, booting and flowering stages and 0.67 at harvest stage).

3.4.1.4 Dry Matter Production

Dry matter production at maximum tillering, panicle emergence, flowering and harvest stage were recorded. The sample plants were uprooted, washed, air dried and oven dried at 60 ±5°C till constant weight was attained. Dry matter production was computed for each treatment and expressed in kg ha^{-1}.

3.4.2 Yield Components

3.4.2.1 Days to 50 per cent Flowering

Number of days from sowing till the date when approximately 50 per cent of the plants flowered were counted and recorded.

3.4.2.2 Drymatter Partitioning at Harvest

Sample plants were uprooted, washed and plant parts (root, leaves, culms and panicle) separated, dried under shade and later oven dried at 60 ±5°C to a constant weight. Dry weight of each plant part was recorded separately using an electronic balance and expressed as the percentage of the total dry weight.

3.4.2.3 Number of Productive Tillers m^{-2}

The ear bearing tillers in four quadrats of 0.25 m^2 were counted and expressed as number of productive tillers m^{-2}.

3.4.2.4 Length of Panicle

Ten panicles were collected from each plot and panicle length was measured from the neck to the tip and the average was expressed in cm.

3.4.2.5 Grain Weight Panicle^{-1}

The grains from the ten randomly selected panicles were removed, dried, weighed and the weight was recorded as grain weight panicle^{-1}.

3.4.2.6 Spikelets Panicle^{-1}

The number of spikelet panicle^{-1} was recorded by counting the spikelets separated from the ten randomly selected panicles.

3.4.2.7 Filled Grains Panicle^{-1}

The filled grains were counted from the ten randomly selected panicles from each plot and expressed as the mean number of filled grains panicle^{-1}.

3.4.2.8 Thousand Grain Weight

One thousand grains were counted from the cleaned and dried produce from net plot area of each plot and the weight was expressed in g.

3.4.2.9 Sterility Percentage

Number of spikelets and unfilled grains per panicle were counted and sterility percentage was calculated using the following formula and expressed as percentage.

$$\text{Sterility percentage} = \frac{\text{Number of unfilled grains panicle}^{-1}}{\text{Number of filled grains per panicle}^{-1}} \times 100$$

3.4.2.10 Grain Yield

The net plot area of each treatment was harvested separately, cleaned, dried to constant weight, weighed and expressed in kg ha^{-1}.

3.4.2.11 Straw Yield

The straw harvested from each net plot was dried to a constant weight under sun and the weight was expressed in kg ha^{-1}.

3.4.2.12 Harvest Index

Harvest index was calculated using the formula suggested by Donald and Hamblin (1976).

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.5 CHEMICAL ANALYSIS

3.5.1 Plant Analysis

Sample plants collected from each plot at harvest were sun dried and, oven dried to a constant weight, ground and passed through a 0.5 mm sieve. The required quantity of sample was weighed out, subjected to acid extraction and analyzed for total N,P and K. The total N content was estimated by modified microkjeldahl method (Jackson, 1973). Total P content was found out using Vanado molybdo phosphoric yellow colour method (Jackson, 1973). Total K was determined using EEL Flame photometer method (Jackson, 1973).

3.5.1.2 Uptake of Nutrients

The total uptake of nitrogen, phosphorus and potassium by the plant at harvest was calculated as the product of the respective nutrient content and plant dry weight and expressed as kg ha^{-1}.

3.5.1.3 Crude protein content of Grain

The crude protein content of the grain was calculated by multiplying the N content of grains by a factor, 6.25 (Simpson *et al.*, 1965).

3.5.2 Soil Analysis

Samples collected before and after the experiment were dried in shade, sieved through 2 mm sieve and analysed to determine the available N content of the soil by alkaline permanganate method (Subbiah and Asija, 1956), available P by Bray's method and available K by ammonium acetate method (Jackson, 1973).

3.5.3 Scoring of Major Pests and Diseases

3.5.3.1 Leaf folder

The number of total and folded leaves was counted from ten randomly selected hills from each plot and the percentage of attack was calculated from the average value.

$$\text{Percentage pest infestation} = \frac{\text{Number of folded leaves hill}^{-1}}{\text{The number of leaves hill}^{-1}} \times 100$$

Scoring was done based on the following scale developed by International Rice Research Institute (2002).

Scale	Damaged plants
0	No damage
1	1-10
3	11-20
5	21-35
7	36-50
9	51-100

3.6 ECONOMIC ANALYSIS

Economic analysis was done after taking into account the cost of cultivation and prevailing market price of rice and straw.

3.6.1 Net Returns

Net returns were calculated using the formula.

Net returns (₹ ha^{-1}) = Gross returns – Total expenditure

3.6.2 Benefit Cost Ratio (BCR)

Benefit: cost ratio was worked out using the formula.

$$\text{BCR} = \frac{\text{Gross return } (₹\ ha^{-1})}{\text{Cost of cultivation } (₹\ ha^{-1})}$$

3.6.3 Return per Rupee Invested on Nutrient sources including Manures

$$\text{Return per rupee} = \frac{\text{Gross returns - Cost of cultivation excluding expenses for nutrient sources including manures}}{\text{Cost of manures and fertilizers}}$$

3.6.4 Per Day Returns

$$\text{Per day returns} = \frac{\text{Net returns (₹ ha}^{-1}\text{)}}{\text{Crop duration (days)}}$$

3.7 Statistical Analysis

The data generated for the characters studied under different treatments were subjected to analysis of variance (Panse and Sukhatme, 1978). Wherever the results were significant, the critical difference was worked out at five or one per cent probability level.

RESULTS

4. RESULTS

The experiment entitled "Effect of different types of fertilizers as influenced by adjuvants on FUE and yield of upland rice" was undertaken in the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, during May to September, 2015. The main objectives of the study was to assess the possibility of enhancing nutrient use efficiency of rice by using water soluble fertilizers and adjuvants and to study the impact of foliar fertilizers and adjuvants on growth and productivity of upland rice and to work out the economics. The results of the experiment are presented in this chapter.

4.1 GROWTH AND GROWTH ATTRIBUTES

4.1.1 Plant Height

The results of the plant height at different growth stage *viz.*, maximum tillering, panicle emergence, flowering and harvest are presented in the Table 4.

The perusal of the data showed that foliar fertilizers did not have any significant influence of plant height at all the stages of growth except harvest stage. At harvest stage the plant height was significantly higher with foliar nutrition F_4 (urea - 5% + SOP -1.5%) with a maximum plant height (101.98 cm) and it was comparable with F_3 (100.98 cm). The lowest plant height of 81.36 cm was recorded by F_1 (19:19:19 -1%)

Adjuvants had no significant impact on plant height at all stages of crop growth.

The foliar fertilizers and their interaction with adjuvants had no significant effect on plant height at all stages of growth.

Table 4. Effect of foliar nutrients, adjuvants and their interaction on plant height, cm

Treatments	Maximum tillering	Panicle emergence	Flowering	Harvest
Foliar nutrients				
F_1	62.03	69.30	79.03	81.36
F_2	61.82	72.25	83.48	90.18
F_3	63.95	73.57	80.57	100.98
F_4	65.55	74.26	82.27	101.98
SEm (±)	1.27	1.73	1.80	2.31
CD (0.05)	NS	NS	NS	7.020
Adjuvants				
A_1	63.59	72.14	81.95	94.46
A_2	63.09	72.55	80.73	92.79
SEm (±)	0.90	1.23	1.27	1.64
CD (0.05)	NS	NS	NS	NS
Interaction effects				
f_1a_1	62.18	68.17	78.67	83.33
f_1a_2	61.88	70.43	79.40	79.40
f_2a_1	62.30	72.53	85.90	88.96
f_2a_2	61.34	71.97	81.07	91.40
f_3a_1	62.72	71.50	80.17	101.39
f_3a_2	65.18	75.63	80.97	100.57
f_4a_1	67.17	76.35	83.07	104.16
f_4a_2	63.93	72.17	81.47	99.80
Treatments mean	63.33	72.34	81.34	82.59
SEm (±)	1.79	2.46	2.54	3.28
CD (0.05)	NS	NS	NS	NS
Control 1	62.88	76.07	83.30	83.30
Control 2	62.22	70.53	78.80	79.13
Treatments *Vs* Control 1	NS	NS	NS	NS
Treatments *Vs* Control 2	NS	NS	NS	S
Between controls	NS	NS	NS	S

Comparing treatments with control it was observed that there was no significant variation on plant height between treatments and control 1 (KAU POP) at all growth stages. But at harvest stage, control 2 (5 t ha^{-1} FYM alone) recorded significantly lower plant heights compared to all other treatment combinations. Between the controls, control 1 (KAU POP) was significantly superior to control 2 (5 t ha^{-1} FYM alone) at harvest stage.

4.1.2 Total Number of Tillers m^{-2}

Total number of tillers m^{-2} influenced by foliar nutrients, adjuvants and their interactions at different crop growth stages are presented in Table 5.

The total number of tillers m^{-2} varied significantly with different foliar nutrients at all growth stages. Among the foliar nutrients, significantly higher number of tillers m^{-2} was noticed in F_4 *i.e,* with the combined application of urea (5%) + SOP (1.5%) at maximum tillering (700.23), panicle emergence (695.87) and flowering stages (693.33).

Adjuvants could not significantly influence the total number of tiller production.

F x A interaction had no significant influence on tiller production at all the stages of growth.

Considering the effect of treatments against the KAU POP (Control 1), it was observed that tiller m^{-2} at maximum tillering stage was significantly superior for treatment mean. While considering the effect of treatments against control 2, it was observed that treatment means were significantly superior at all stages of growth. Between the controls, control 1 (KAU POP) was significantly superior to control 2 at maximum tillering stage.

Table 5. Effect of foliar nutrients, adjuvants and their interaction on tillers m^{-2}, nos.

Treatments	Maximum tillering	Panicle emergence	Flowering
Foliar nutrients			
F_1	589.95	587.72	598.50
F_2	572.17	586.83	583.33
F_3	625.47	613.07	609.40
F_4	700.23	695.87	693.33
SEm (±)	13.42	20.88	21.76
CD (0.05)	40.622	63.221	65.876
Adjuvants			
A_1	634.58	633.95	631.45
A_2	609.33	607.79	610.83
SEm (±)	9.49	14.76	13.38
CD (0.05)	NS	NS	NS
Interaction effects			
f_1a_1	623.33	614.00	612.00
f_1a_2	556.57	561.43	585.00
f_2a_1	568.67	578.33	576.00
f_2a_2	575.67	595.33	590.67
f_3a_1	623.93	616.47	612.13
f_3a_2	627.00	609.67	606.67
f_4a_1	722.40	727.00	725.67
f_4a_2	678.07	664.73	661.00
Treatment mean	621.95	620.87	621.14
SEm (±)	18.98	29.63	30.87
CD (0.05)	NS	NS	NS
Control 1	570.33	575.67	572.33
Control 2	497.33	544.33	543.67
Treatments *Vs* Control 1	S	NS	NS
Treatments *Vs* Control 2	S	S	S
Between controls	S	NS	NS

4.1.3 Leaf Area Index

The LAI recorded at maximum tillering, panicle emergence, flowering and harvest stages are presented in the Table 6.

The foliar nutrients showed positive influence on LAI at all growth stages. Higher LAI was noticed with F_4 (urea- 5% + SOP- 1.5%) at maximum tillering (3.94) panicle emergence (4.91), flowering (5.02) and harvest (3.89) stages and it was on a par with F_3 at all these stages.

The effect of adjuvants on LAI was significant only at panicle emergence and harvest stages and at both these stages A_1 (adjuvant I) having deep penetrating property recorded higher LAI compared to A_2 having sticking property.

Interaction between the treatments was significant at panicle emergence and harvest stages. Foliar nutrition with urea (5%) + SOP (1.5 %) along with adjuvant 1 (f_4a_1) was significantly superior in terms of LAI compared to all other treatment combinations.

Comparison of treatments against controls was found to be non significant at all growth stages. Between the controls, KAU POP (Control 1) recorded higher LAI compared to the application of 5 t ha^{-1} FYM alone (Control 2) at harvest stage.

4.1.4. Dry Matter Production (DMP)

The DMP assessed at various stages of crop growth are presented in Table 7.

Significant variation in DMP was found due to various foliar nutrients at all growth stages. Among the foliar nutrients, significantly higher DMP was noticed with F_4 (urea- 5% + SOP - 1.5%) at all stages of growth, recording maximum value of (1850 kg ha^{-1}) at maximum tillering, (3489 kg ha^{-1}) at panicle emergence, (7268 kg ha^{-1}) at flowering, and 12,335 kg ha^{-1} at harvest stages respectively and at panicle emergence stage it was on a par with F_2 and F_3.

Table 6. Effect of foliar nutrients, adjuvants and their interaction on leaf area index

Treatments	Maximum Tillering	Panicle emergence	Flowering	Harvest
Foliar nutrients				
F_1	3.90	4.46	4.68	3.25
F_2	3.67	4.40	4.86	3.34
F_3	3.93	4.81	4.97	3.72
F_4	3.94	4.91	5.02	3.89
SEm (±)	0.03	0.06	0.03	0.06
CD (0.05)	0.113	0.201	0.106	0.190
Adjuvants				
A_1	3.94	4.73	4.90	3.58
A_2	3.84	4.59	4.87	3.44
SEm (±)	0.02	0.04	0.02	0.04
CD (0.05)	NS	0.131	NS	0.130
Interaction effects				
f_1a_1	3.95	4.39	4.66	3.26
f_1a_2	3.86	4.82	4.70	3.24
f_2a_1	3.62	4.55	4.89	3.42
f_2a_2	3.72	4.50	4.83	3.26
f_3a_1	3.79	4.82	4.99	3.66
f_3a_2	3.89	4.80	4.94	3.58
f_4a_1	3.91	4.99	5.05	3.99
f_4a_2	3.97	4.89	5.00	3.71
Treatment mean	3.83	4.72	4.94	3.51
SEm (±)	0.05	0.02	0.04	0.08
CD (0.05)	NS	0.081	NS	0.271
Control 1	3.81	4.63	4.81	3.31
Control 2	3.79	4.29	4.30	3.01
Treatments *Vs* Control 1	NS	NS	NS	NS
Treatments *Vs* Control 2	NS	NS	NS	NS
Between controls	NS	NS	NS	S

Table 7. Effect of foliar nutrients, adjuvants and their interaction on total dry matter production, kg ha^{-1}

Treatments	Maximum tillering	Panicle emergence	Flowering	Harvest
Foliar nutrients				
F_1	1371	2998	6186	9828
F_2	1566	3159	5771	10298
F_3	1699	3109	6225	10723
F_4	1850	3489	7268	12335
SEm (±)	35.04	129.04	160.96	132.38
CD (0.05)	106.042	390.471	487.070	400.600
Adjuvants				
A_1	1652	3079	6525	11028
A_2	1591	2893	6200	10564
SEm (±)	24.78	97.48	113.81	93.61
CD (0.05)	NS	NS	NS	283.274
Interaction effects				
f_1a_1	1446	2999	6296	9945
f_1a_2	1297	2997	6077	9711
f_2a_1	1577	3257	5978	105560
f_2a_2	1554	3061	5563	10036
f_3a_1	1716	3152	6237	11017
f_3a_2	1682	3066	6213	10429
f_4a_1	1868	2909	7589	12590
f_4a_2	1831	2450	6948	12079
Treatment means	1621	2999	6612	10803
SEm (±)	49.56	85.24	227.63	187.2
CD (0.05)	NS	NS	NS	NS
Control 1	1419	2620	5510	9566
Control 2	1229	2429	4941	8411
Treatments *Vs* Control 1	NS	NS	S	S
Treatments *Vs* Control 2	S	S	S	S
Between controls	NS	S	NS	S

Adjuvants selected for the experiment exerted significant influence effect on the DMP only at harvest stage and adjuvant 1 recorded a higher DMP of 11,028 kg ha^{-1} compared to adjuvant 2 (10,564 kg ha^{-1})

The interaction effect was absent at all stages of growth with regard to DMP.

In the comparison of treatments against controls, it was observed that KAU POP was significantly inferior on DMP at flowering and harvest stages. While control 2 was significantly inferior on DMP at all growth stages. Between the controls control 1 was significantly superior to control 2.

4.3 YIELD AND YIELD ATTRIBUTES

4.3.1. Days to 50 per cent Flowering

Number of days taken to attain 50 per cent flowering for various treatments is presented in Table 8.

Foliar nutrition with F_3 (urea (1.5%) + SOP (1.5 %) and F_4 (urea (5%) + SOP (1.5 %) registered significantly lesser number of days to attain 50 per cent flowering while F_2 (13:0:45 -1%) recorded longer days to attain 50 per cent flowering.

Adjuvants could not influence the days taken for 50 per cent flowering.

The interaction between foliar nutrients and adjuvants had significant effect on days to 50 per cent flowering. The treatment (f_2a_1) (13:0:45 -1% along with adjuvant I) needed significantly longer days to attain 50 per cent flowering (74.03 days) and it was on par with f_2a_2. (73.57 days)

4.3.2. Drymatter Partitioning at Harvest

The result on dry matter partitioning at harvest are presented in Table 9

The foliar nutrients, adjuvants and their interaction had no significant influence on the percentage of dry matter that accounted for the root weight.

The foliar nutrients have significantly influenced the percentage of dry matter partitioned towards the shoot portion. Among the foliar nutrients significantly higher shoot weight percentage was noticed with the combined application of urea (5%) + SOP (1.5 %) and it was on par with (1.5%) + SOP (1.5%). Adjuvants and their interaction with foliar nutrients had no significant influence on the percentage of dry matter that accounted for the shoot weight.

The effect of the foliar nutrients on the dry matter partitioning towards panicle weight was found significant. Among the foliar nutrients significantly higher panicle weight percentage was noticed with F_1 (19:19:19 - 1%). Adjuvants and their interaction with foliar fertilizers had no significant influence on the percentage of dry matter that accounted for the panicle weight.

Comparison of treatments against controls and comparison between controls were not significant with respect to percentage of dry matter that accounted for the root weight and shoot weight. KAU POP was significantly inferior to treatments in terms of panicle weight percentage.

4.3.3. Productive Tillers m^{-2}

Total number of productive tillers m^{-2} as influenced by foliar nutrients, adjuvants and their interactions are presented in Table 8.

The foliar nutrients had significant effect on productive tillers m^{-2}. Combined application of urea (5%) + SOP (1.5%) resulted in maximum productive tillers (482.50 m^{-2}).

Different adjuvants did not show any significant variation on total number of productive tillers m^{-2}.

Interaction effect between the treatments was found significant. Among the treatments, significantly higher number of productive tillers m^{-2} (498.00) was noticed by foliar nutrition with urea (5%) + SOP (1.5%) along with adjuvant I (f_4a_1) and it was on a par with f_4a_2 urea (5%) + SOP (1.5%) along with adjuvant II).

The comparison between treatments and controls were not significant, while the comparison between controls revealed that KAU POP was significantly superior to the application of 5 t ha^{-1} FYM alone (control 2) with respect to productive tillers m^{-2}.

4.3.4. Panicle Length

The data on panicle length as influenced by foliar nutrient, adjuvants and their interactions are presented in Table 8.

The panicle length varied significantly among different foliar nutrients. Panicles were significantly longer (26.66 cm) with foliar nutrition of urea (5%) + SOP (1.5 %). The lowest panicle length was recorded by F_1 (22.05 cm).

The adjuvants had significant effect on the panicle length. Among the adjuvants, adjuvant I (A_1) recorded maximum panicle length (24.58 cm).

The interaction between foliar nutrients and adjuvants had significant effect on panicle length. The treatment f_4a_1 (urea - 5% + SOP-1.5% along with adjuvant I) recorded highest panicle length (27.25 cm). The lowest panicle length of 21.53 cm was registered with f_2a_1 (foliar application of 13:0:46 (1 %) along with adjuvant 1).

Considering the effect of treatments against controls, it was observed that the panicle length was significantly superior for treatments against controls. The comparison between controls revealed that KAU POP was significantly superior to the application of 5 t ha^{-1} FYM alone with respect to panicle length.

4.3.5. Grain Weight Panicle^{-1}

The results on the effect of foliar nutrients, adjuvants and their interaction on grain weight per panicle are presented in Table 8.

The perusal of the data showed that foliar fertilizers, adjuvants and their interaction could not significantly influence the grain weight panicle^{-1}.

Comparison of treatments against controls and comparison between the controls were also not found significant.

4.3.6. Spikelets Panicle^{-1}

The results on the effect of foliar nutrients on spikelets panicle^{-1} are presented in Table 10.

Foliar nutrients had significant effect on the number of spikelets panicle^{-1}. Foliar nutrition of urea (5%) + SOP (1.5%) recorded the highest number of spikelets panicle^{-1} (137.22). Lowest number of spikelets panicle^{-1} was registered by F_1 (86.48) and it was on par with F_2 (88.67).

The effect of different types of adjuvants and their interaction with foliar nutrients failed to exert any significant effect on spikelets panicle^{-1}.

In the comparison made between the treatment combinations and controls showed that KAU POP produced more spikelets panicle^{-1} (119.67) compared to treatment mean, while application of 5 t ha^{-1} FYM alone recorded lesser spikelets

Table 8. Effect of foliar nutrients, adjuvants and their interaction on days to 50 % flowering, productive tiller m^{-2}, panicle length and grain weight panicle^{-1}

Treatments	Days to 50 % Flowering (days)	Productive tillers m^{-2}	Panicle length(cm)	Grain weight panicle^{-1}(g)
Foliar nutrients				
F_1	68.68	373.16	22.05	1.096
F_2	73.80	417.78	23.45	1.193
F_3	63.65	445.16	25.60	2.033
F_4	63.67	482.50	26.66	2.685
SE+m	0.53	4.06	0.104	0.08
CD (0.05)	1.624	12.300	0.317	NS
Adjuvants				
A_1	67.78	439.92	24.58	1.801
A_2	67.13	419.71	24.29	1.695
SEm (±)	0.37	4.06	0.10	0.06
CD (0.05)	NS	NS	0.221	NS
Interaction effects				
f_1a_1	70.00	417.00	23.28	1.09
f_1a_2	67.37	384.00	23.62	1.09
f_2a_1	74.03	398.00	21.53	1.27
f_2a_2	73.57	380.67	22.56	1.11
f_3a_1	65.47	446.67	25.11	2.08
f_3a_2	61.83	431.83	26.08	1.98
f_4a_1	61.60	498.00	27.25	2.79
f_4a_2	65.73	482.33	26.07	2.58
Treatment mean	67.45	382.22	24.43	1.75
SEm (±)	0.75	5.74	0.14	0.129
CD (0.05)	2.298	17.393	0.452	NS
Control 1	66.13	420.50	24.01	1.57
Control 2	67.47	323.13	22.64	1.01
Treatments *Vs* Control 1	NS	NS	S	NS
Treatments *Vs* Control 2	NS	NS	S	NS
Between controls	NS	S	S	NS

panicle^{-1} compared to treatment means. Between the controls KAU POP produced more spikelets panicle^{-1} compared to control 2.

4.3.7. Number of Filled Grains Panicle^{-1}

The result on the effect of foliar nutrients and adjuvants, and interaction on number of filled grains panicle^{-1} are presented in Table 10.

The effect foliar nutrients on filled grains panicle^{-1} were observed to be significant. Urea (5%) + SOP (1.5 %) recorded the maximum filled grains panicle^{-1} (131.22) followed by F_3 urea (5%) + SOP (1.5 %). F_1 recorded the lowest filled grains panicle^{-1} (80.10) and it was on a par with F_2 (82.07)

No significant variation among different adjuvants and their interaction with foliar nutrients was observed with respect to filled grains panicle^{-1}.

Considering the treatments against controls, it was observed that KAU POP produced more filled grain panicle^{-1} (123.70) compared to treatment means. While application of 5 t ha^{-1} FYM alone recorded lesser number of filled grains panicle^{-1}. The comparison between controls revealed that KAU POP was significantly superior to the application of 5 t FYM alone with respect to filled grains panicle^{-1}.

4.3.8. Sterility Percentage

The results on the effect of foliar nutrients and adjuvants, and their interaction on sterility percentage are presented in Table 10.

Neither foliar nutrients, adjuvants nor their interaction had any significant influence on sterility percentage.

The comparison of treatments against controls and comparison between the controls were also not significant with respect to sterility percentage.

Table 9. Effect of foliar nutrients, adjuvants and their interaction on dry matter partitioning at harvest as influenced by different foliar nutrients, adjuvants and their interaction, per cent

Treatments	Root weight	Shoot weight	Panicle weight
Foliar nutrients			
F_1	33.78	22.01	44.22
F_2	35.60	22.13	42.27
F_3	32.99	25.19	41.82
F_4	35.19	27.09	37.72
SEm (±)	0.98	1.47	0.95
CD (0.05)	NS	4.474	1.092
Adjuvants			
A_1	34.21	24.86	40.93
A_2	34.56	23.35	42.08
SEm (±)	0.69	1.04	0.67
CD (0.05)	NS	NS	NS
Interaction effects			
f_1a_1	34.07	23.28	42.64
f_1a_2	33.48	20.73	45.79
f_2a_1	36.06	23.27	40.67
f_2a_2	35.13	21.00	43.87
f_3a_1	32.39	25.37	42.23
f_3a_2	33.58	25.01	41.41
f_4a_1	34.31	27.51	38.18
f_4a_2	36.06	26.67	37.27
Treatment means	30.63	24.10	41.50
SEm	1.38	2.08	0.67
CD (0.05)	NS	NS	NS
Control 1	34.21	24.03	40.93
Control 2	34.56	16.19	44.36
Treatments *Vs* Control 1	NS	NS	S
Treatments *Vs* Control 2	NS	NS	NS
Between controls	NS	NS	NS

4.3.9. Thousand Grain Weight

The data on thousand grain weight as affected by foliar nutrients, adjuvants and their interaction are presented in Table 10.

The effect of various foliar nutrients on thousand grain weight was observed to be significant recording the highest value for F_4 (25.98 g), and it was at par with (F_3).

Adjuvants and interaction between foliar nutrients and adjuvants failed to exert any significant effect on thousand grain weight.

Considering the effect of treatments against controls it was observed that the thousand grain weight of controls were significantly inferior to treatment means. The comparison between controls revealed that KAU POP was significantly superior to the application of 5 t ha^{-1} FYM alone with respect to thousand grain weight.

4.3.10 Grain Yield

The data on the effect of foliar nutrients, adjuvants and their interaction on the grain yield are presented in Table 11.

The effect of foliar nutrients had significant effect on grain yield. The foliar nutrient F_4 (urea 5% + SOP 1.5%) recorded highest grain yield (5.76 t ha^{-1}) followed by foliar nutrition with F_3 (4.89 t ha^{-1}). The lowest grain yield of 4.09 t ha^{-1} was registered by F_2 (foliar application of 13:0:46 -1%) and it was at par with F_1 (19:19:19 -1%)

The adjuvants selected for foliar nutrition exerted significant effect on grain yield. A_1 (Adjuvant 1) registered a higher grain yield of 5.02 t ha^{-1}

The interaction effect between foliar nutrients and adjuvants failed to exert any significant effect on grain yield.

Considering the effect of treatments against controls it was observed that the grain yileld of control 1(KAU POP) and control 2 (5 t ha^{-1}FYM alone) were lower than treatment means and no significant difference in grain yield was observed between controls.

4.3.11. Straw Yield

The straw yields of various treatments are presented in Table 11.

The effect of foliar nutrients on straw yield was observed to be significant. Urea- 5% + SOP -1.5% (F_4) recorded highest straw yield (6.99 t ha^{-1}), followed by F_3 (6.53 t ha^{-1}).

The perusal of the data showed that adjuvants and their interaction with foliar nutrients did not have any significant influence on straw yield.

In the comparison made between the treatment combinations and controls showed that treatment means produced significantly more straw yield than controls. The comparison between controls revealed that KAU POP was significantly superior to the application of 5 t FYM alone with respect to straw yield.

4.3.12. Harvest Index

The data on harvest index is presented in Table 11.

The perusal of the data showed that foliar nutrients, adjuvants and their interaction did not have any significant influence harvest index.

Considering the effect of treatments against controls it was observed that the harvest index was significantly higher for treatment means compared to controls. Between controls, there was no significant variation with respect to HI.

Table 10. Effect of foliar nutrients, adjuvants and their interaction on spikelets panicle^{-1}, filled grains panicle^{-1}, sterility percentage and thousand grain weight

Treatments	Spikelets panicle^{-1}	Filled grains panicle^{-1}	Sterility percentage	Thousand grain weight (g)
Foliar nutrients				
F_1	86.48	80.10	8.90	24.27
F_2	88.67	82.07	8.19	24.25
F_3	114.38	109.48	8.75	25.57
F_4	137.22	131.22	6.31	25.98
SEm (±)	3.79	4.10	0.91	0.43
CD (0.05)	11.494	12.419	NS	1.321
Adjuvants				
A_1	110.95	101.62	8.10	25.19
A_2	102.43	99.82	7.98	24.85
SEm (±)	3.79	2.89	0.65	0.43
CD (0.05)	NS	NS	NS	NS
Interaction effects				
f_1a_1	81.80	75.06	8.73	25.24
f_1a_2	81.13	74.70	9.07	23.30
f_2a_1	89.86	82.43	8.77	25.05
f_2a_2	87.46	81.70	7.62	23.45
f_3a_1	113.96	108.30	8.26	24.71
f_3a_2	121.70	110.66	9.24	26.43
f_4a_1	140.43	134.00	6.63	25.75
f_4a_2	134.0	128.43	5.99	26.22
Treatments mean	106.2	99.41	8.03	25.01
SEm (±)	5.36	5.80	1.29	0.61
CD (0.05)	NS	NS	NS	NS
Control 1	119.67	123.70	6.30	24.91
Control 2	88.17	81.73	7.86	24.47
Treatments *Vs* Control 1	S	S	NS	S
Treatments *Vs* Control 2	S	S	NS	S
Between controls	S	S	NS	S

Table 11. Effect of foliar nutrients, adjuvants and their interaction on grain yield, straw yield and harvest index

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index
Foliar nutrients			
F_1	4.37	5.91	0.42
F_2	4.09	5.65	0.40
F_3	4.89	6.53	0.42
F_4	5.76	6.99	0.44
SEm (±)	0.19	0.21	0.02
CD (0.05)	0.598	0.453	NS
Adjuvants			
A_1	5.02	6.50	0.43
A_2	4.54	6.04	0.41
SEm (±)	1.39	0.14	0.01
CD (0.05)	0.432	NS	NS
Interaction effects			
f_1a_1	4.64	6.16	0.42
f_1a_2	4.09	5.66	0.41
f_2a_1	4.22	5.99	0.42
f_2a_2	3.97	5.32	0.38
f_3a_1	5.13	6.54	0.43
f_3a_2	4.64	6.54	0.41
f_4a_1	6.06	7.36	0.45
f_4a_2	5.46	6.68	0.44
Treatment means	4.78	6.36	0.42
SEm (±)	0.27	0.30	0.10
CD (0.05)	NS	NS	NS
Control 1	3.79	5.91	0.39
Control 2	3.27	5.23	0.37
Treatments *Vs* Control 1	S	S	S
Treatments *Vs* Control 2	S	S	S
Between controls	NS	S	NS

4.4 PLANT ANALYSIS

4.4.1 Nutrient Uptake

4.4.1.1 Nitrogen Uptake

The nitrogen uptake at harvest stage is presented in Table 12.

Foliar nutrients had significant effect on N uptake. Foliar nutrition with F_4 recorded significantly higher nitrogen uptake (145.35 kg ha^{-1}), followed by F_3 (110.82 kg ha^{-1}). The lowest uptake was registered by F_1 (79.67 kg ha^{-1}).

The adjuvants selected for the experiment exerted significant effect on N uptake. Among the adjuvants, A_1 recorded higher N uptake (158.20 kg ha^{-1}).

Interaction between foliar nutrients and adjuvants did not have any significant influence on N uptake.

The treatment combinations compared against controls revealed that treatment mean was significantly superior to both controls. The comparison between controls revealed that KAU POP was significantly superior to the application of 5 t ha^{-1} FYM alone with respect N uptake.

4.4.1.2 Phosphorus Uptake

The phosphorus uptake at harvest stage is presented in Table 12.

Foliar nutrients had significant effect on phosphorus uptake. Foliar nutrition with urea (5%) + SOP (1.5%) recorded significantly higher phosphorus uptake (10.49 kg ha^{-1}) followed by foliar nutrition with F_3 (urea -1.5% + SOP -1.5%).

The adjuvants chosen for foliar nutrition exerted significant effect on P uptake. The treatment A_1 (Adjuvant I) recorded maximum P uptake of 9.41 kg ha^{-1}.

Interaction of foliar nutrients and adjuvants could not influence P uptake.

Considering the treatments mean against control 1 it was observed that significantly higher phosphorus uptake (8.09 kg ha^{-1}) was reported by KAU POP. Between controls application of 5 t ha^{-1} FYM alone recorded significantly lower phosphorus uptake compared to KAU POP.

4.4.1.3 Potassium Uptake

Potassium uptake estimated at harvest is shown in Table 12.

Foliar nutrients had significant effect on potassium uptake. Foliar nutrition with F_4 (urea -5% + SOP- 1.5%) recorded significantly higher potassium uptake (145.05 kg ha^{-1}) followed by foliar nutrition with F_3 (120.72 kg ha^{-1}). The lowest potassium uptake was recorded by F_1 (95.54 kg ha^{-1}).

The adjuvants used for foliar nutrition exerted significant effect on potassium uptake. The treatment A_1 (Adjuvant 1) recorded higher K uptake 120.82 kg ha^{-1}.

The interaction of treatments did not have any significant influence on K uptake.

In the comparison made between the treatments and controls, it is shown that application of 5 t FYM recorded lower uptake of potassium (71.52 kg ha^{-1}) compared to treatment mean. The comparison between controls revealed that KAU POP was significantly superior to the application of 5 t ha^{-1} FYM alone, with respect potassium uptake.

Table 12. Effect of foliar nutrients, adjuvants and their interaction on NPK uptake at harvest, kg ha^{-1}

Tretments	N	P	K
Foliar nutrients			
F_1	79.67	8.39	95.54
F_2	91.39	8.69	106.54
F_3	110.82	9.15	120.72
F_4	145.35	10.49	145.05
SEm (±)	2.13	0.08	2.54
CD (0.05)	6.450	0.260	7.691
Adjuvants			
A_1	158.20	9.41	120.82
A_2	152.67	8.96	113.10
SEm (±)	1.50	0.06	1.79
CD (0.05)	4.562	0.188	5.422
Interactions			
f_1a_1	89.10	8.50	100.74
f_1a_2	70.24	8.29	90.34
f_2a_1	97.79	9.00	111.60
f_2a_2	84.99	8.38	101.49
f_3a_1	122.84	9.41	125.47
f_3a_2	98.80	8.89	115.97
f_4a_1	155.59	10.70	145.49
f_4a_2	135.12	10.27	144.61
Treatments mean	106.80	8.05	116.96
SEm (±)	3.01	0.12	3.59
CD (0.05)	NS	NS	NS
Control 1	92.76	8.09	94.85
Control 2	59.45	6.67	71.52
Treatments *Vs* Control 1	S	S	NS
Treatments *Vs* Control 2	S	NS	S
Between controls	S	S	S

4.4.2 Crude Protein Content of Grain

The result on crude protein content of grain as affected by foliar nutrients, adjuvants and their interaction are presented in Table 13.

The crude protein content varied significantly with different foliar nutrient sources. Foliar nutrition with F_4 (urea-5%) + SOP-1.5%) recorded significantly maximum crude protein content (8.31 per cent), followed by foliar nutrition with F_3 (7.44). Foliar nutrition with F_1 (19:19:19 - 1 %) recorded the lowest crude protein content (5.81 %).

Adjuvants and their interaction with foliar nutrients had no significant influence on crude protein content.

The treatment mean compared against control 1 was not significant while the treatment mean compared against control 2 revealed that application of 5 t FYM alone, recorded lower crude protein content (5.47 %) compared to all treatment combinations. The comparison between controls revealed significantly superior crude protein content for KAU POP than the application of 5 t ha^{-1} FYM alone.

4.5. SOIL ANALYSIS AFTER THE EXPERIMENT

4.5.1 Organic Carbon

The data on soil organic carbon content after the experiment is presented in Table 14.

The soil organic carbon was not observed to vary significantly under the influence of foliar nutrients, adjuvants and their interactions. The comparison made between treatments and controls and between the controls themselves were also proved to be non significant

Table 13. Effect of foliar nutrients, adjuvants and their interaction on crude protein content of grain, per cent

Foliar nutrient	Crude protein content of grain
F_1	5.81
F_2	6.72
F_3	7.44
F_4	8.31
SEm (±)	0.06
CD (0.05)	0.187
Adjuvants	
A_1	7.10
A_2	7.04
SEm (±)	0.04
CD (0.05)	0.137
Interaction effects	
f_1a_1	5.90
f_1a_2	5.70
f_2a_1	6.67
f_2a_2	6.78
f_3a_1	7.48
f_3a_2	7.41
f_4a_1	8.34
f_4a_2	8.28
Treatments mean	7.07
CD (0.05)	NS
SEm (±)	0.08
Control 1	7.00
Control 2	5.46
Treatments *Vs* Controls 1	NS
Treatments *Vs* Controls2	S
Between controls	S

4.5.2. Available Nitrogen

The data on available soil N content after the experiment are presented in Table 14.

Foliar nutrition had significant effect on available soil nitrogen status. The treatment F_4 (foliar nutrition with urea -5% + SOP 1.5%) recorded highest available nitrogen (198.93 kg ha^{-1}). Foliar nutrition with F_2 recorded the lowest available nitrogen (132.16 kg ha^{-1}) and it was on par with F_1 (133.72).

Effect of foliar nutrients, adjuvants, and the interaction failed to exert any significant effect on the available nitrogen status of soil.

Considering the effect of treatments against controls it was observed that available N status was significantly superior for controls compared to treatment means. Between the controls, KAU POP was significantly superior.

4.5.3. Available Phosphorus

The data on available soil phosphorus status after the experiment is presented in Table 14.

The available soil phosphorus content did not vary significantly under the influence of foliar nutrients, adjuvants and their interaction.

The comparison made between the treatments and controls showed higher phosphorus availability by treatment means compared to controls. Between the controls, no significant variation was observed.

Table 14. Effect of foliar nutrients, adjuvants and their interaction on organic carbon and available NPK status of soil after the experiment

Tretments	Organic Carbon(per cent)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Foliar nutrients				
F_1	0.66	133.72	25.36	165.93
F_2	0.65	132.16	27.32	156.14
F_3	0.69	156.93	25.25	170.48
F_4	0.68	198.93	26.02	168.40
SEm (±)	0.05	1.93	0.73	14.73
CD (0.05)	NS	5.852	NS	NS
Adjuvants				
A_1	0.76	152.67	26.61	120.82
A_2	0.69	158.20	25.07	113.10
SEm (±)	0.03	1.36	0.51	10.42
CD (0.05)	NS	NS	NS	NS
Interactions				
f_1a_1	0.69	131.12	26.01	154.56
f_1a_2	0.66	136.33	24.69	177.31
f_2a_1	0.68	127.89	26.43	175.46
f_2a_2	0.67	136.44	28.22	136.82
f_3a_1	0.64	154.60	35.94	155.34
f_3a_2	0.65	159.26	33.37	185.62
f_4a_1	0.67	197.08	24.60	195.16
f_4a_2	0.69	200.76	24.00	141.64
Treatments mean	0.65	155.43	26.66	165.23
SEm (±)	0.07	2.73	1.03	20.84
CD (0.05)	NS	NS	NS	NS
Control 1	0.68	198.05	25.69	138.93
Control 2	0.69	188.58	24.55	115.23
Treatments *Vs* Control 1	NS	S	S	S
Treatments *Vs* Control 2	NS	S	S	S
Between controls	NS	S	NS	S

4.5.4. Available Potassium

The data on available soil potassium content after the experiment is presented in Table 14.

There was no significant variation in the available potassium status of soil due to foliar nutrients, adjuvants and their interactions.

Considering the effect of treatments against controls, it was noticed that controls were significantly inferior to treatment means. Between the controls KAU POP recorded significantly superior available potassium status.

4.6 ECONOMIC ANALYSIS

The data on the effect of nutrient sources, foliar adjuvants and their interaction on gross income, net income and benefit cost ratio are presented in Table 15.

4.6.1 Gross income

The foliar nutrients had significant effect on gross income. Significantly higher gross income (₹1,21,494 ha^{-1}) was recorded by the application by F_4 (urea -5% + SOP -1.5%) followed by F_3 (₹1,06,200 ha^{-1}). The treatment F_2 recorded lowest gross income (₹ 91,793 ha^{-1}) and it was on par with F_1.

The different adjuvants selected for foliar nutrition and the interaction between foliar nutrients and adjuvants did not have any significant effect on gross income.

In comparison made between treatments *Vs* controls, it was noticed that controls were significantly inferior to all treatments.

4.6.2 Net returns

The foliar nutrients had significant effect on net income. Significantly higher net income (₹ 51,036 ha^{-1}) was recorded by the application of urea - 5% + SOP -1.5%

(F_4) followed by F_3 (urea (1.5%) + SOP (1.5%). The treatment (F_2) foliar nutrition of 13:0:46 – 1% recorded lowest net income (₹ 20,773ha^{-1}).

The different adjuvants selected for foliar nutrition exerted significant effect on net returns. The treatment A_I (Adjuvant I) recorded the highest net return (₹37,100 ha^{-1})

The interaction between foliar nutrients and adjuvants did not have any significant effect on net returns.

Comparing treatment *Vs* control 1, it was observed that KAU POP recorded significantly higher net returns compared to treatment means. While control 2 was significantly inferior to treatment mean on net returns. Between controls, KAU POP was significantly superior.

4.6.3 Benefit Cost Ratio

Benefit cost ratio also showed significant difference among the different foliar nutrients. The highest benefit cost ratio (1.72) was recorded by application of urea - 5% + SOP -1.5 % (F_4) followed by (F_3) urea - 1.5% + SOP -1.5 % recording a B:C ratio of (1.51).

The adjuvants used for foliar nutrition exerted significant effect on benefit cost ratio. A_I (Adjuvant I) recorded highest benefit cost ratio (1.52).

The interaction between foliar nutrients and adjuvants did not have any significant effect on benefit cost ratio. Comparing treatment *Vs* controls, it is revealed that treatment means were significantly superior than both the controls.

4.6.4 Per Day Returns

The data on per day returns is presented in Table 15.

The highest per day returns (₹ 464) was recorded by application of urea - 5% + SOP -1.5 % (F_4) followed by urea - 1.5% + SOP -1.5 % (F_3) recording a per day returns of (₹ 329).

The adjuvants used for foliar nutrition exerted significant effect on per day returns. A1 (Adjuvant 1) recorded highest per day returns (₹ 337).

Interaction between foliar nutrients and adjuvants did not have any significant effect on per day returns.

The interaction between foliar nutrients and adjuvants did not have any significant effect on per day returns. Comparing treatment *Vs* controls, it is revealed that treatment means were significantly superior to both the controls.

4.6.5 Return per Rupee Invested on Nutrient Sources Including Manures

The data on the effect of foliar nutrients (including manures) on returns per rupee invested are presented in Table 16.

The foliar nutrients had significant effect on return per rupee invested. The highest returns per rupee invested (₹ 2.53) was recorded by the application of urea - 5% + SOP -1.5 % (F_4). The lowest return per rupee invested was recorded by F_1 and it was on a par with F_2.

The effect of different types of adjuvants and their interaction with foliar fertilizers failed to exert any significant effect on return per rupee invested. The comparison made between treatments and controls and between the controls themselves were also proved to be non significant

Table 15. Effect of foliar nutrients, adjuvants and their interaction on cost of cultivation, gross income, net income and BC ratio and per day return

Foliar nutrients	Cost of cultivation (₹ ha^{-1})	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	BC ratio	Per day return (₹)
F_1	71271	95112	24841	1.35	226
F_2	71020	91793	20773	1.29	186
F_3	70038	106200	36162	1.51	329
F_4	70458	121494	51036	1.72	464
SEm (±)		3246.92	3246	0.043	24.61
CD (0.05)		9825.06	9825	0.132	74.47
Adjuvants					
A_1	70353	107453	37100	1.52	337
A_2	70540	99846	29306	1.41	266
SEm (±)		2295.94	2295	0.04	17.34
CD (0.05)		NS	6947	0.094	52.520
Interaction effects					
f_1a_1	70177	100513	30336	1.43	249
f_1a_2	70365	89711	19346	1.27	206
f_2a_1	70927	91900	20973	1.29	163
f_2a_2	71114	91687	20573	1.29	159
f_3a_1	68994	109819	39875	1.57	335
f_3a_2	70132	102581	32449	1.46	267
f_4a_1	70364	127581	57217	1.81	493
f_4a_2	70551	115407	44856	1.63	381
Treatments mean		103650	33203	1.47	282
SEm (±)		4591.92	13894.91	0.19	34.66
CD (0.05)		NS	NS	NS	NS
Control 1	56804	87489	44856	1.28	0.18
Control 2	42633	76219	19415	1.18	0.28
Treatments *Vs* Controls 1		100513	S	S	S
Treatments *Vs* Controls 2		89711	S	S	S
Between controls		91900	S	NS	NS

Table 16. Effect of foliar nutrients, adjuvants and their interaction on returns per rupee invested on manures and fertilizers, ₹.₹$^{-1}$.

Foliar nutrient	Net returns per rupee invested
F_1	1.74
F_2	1.83
F_3	2.24
F_4	2.53
SEm (±)	0.08
CD (0.05)	0.248
Adjuvants	
A_1	2.08
A_2	2.09
SEm (±)	0.05
CD (0.05)	NS
Interaction effects	
f_1a_1	1.81
f_1a_2	1.66
f_2a_1	1.72
f_2a_2	1.94
f_3a_1	2.23
f_3a_2	2.25
f_4a_1	2.57
f_4a_2	2.50
Treatments mean	2.08
CD (0.05)	NS
Control 1	2.50
Control 2	2.45
Treatments *Vs* Controls 1	NS
Treatments *Vs* Controls 2	NS
Between controls	NS

DISCUSSION

5. DISCUSSION

The experiment entitled "Effect of different types of fertilizers as influenced by adjuvants on FUE and yield of upland rice" was undertaken to assess the possibility of enhancing nutrient use efficiency of rice by using water soluble fertilizers and adjuvants and to study the impact of foliar fertilizers and adjuvants on growth and productivity of upland rice and to work out the economics. The results of the experiment are discussed briefly in this chapter.

5.1 GROWTH CHARACTERS

The foliar nutrients, adjuvants and their interaction significantly influenced the plant height, total number of tillers m^{-2}, LAI and DMP.

At harvest stage foliar fertilizers significantly influenced plant height recording a maximum plant height of 101.98 cm by the treatment F_4 (urea-5 % + SOP -1.5 %) followed by F_3 (urea-1.5 % + SOP-1.5 %) with a plant height of 100.98 cm. It could be seen from the results presented in Table 5 that application of urea - 5% + SOP -1.5% recorded the highest number of tillers m^{-2} at all growth stages and the same treatment registered higher LAI at maximum tillering (3.94), panicle emergence (4.91), flowering (5.02) and harvest (3.89) stages and it was on a par with urea -1.5% + SOP- 1.5 % (F_3) at all these stages. Maximum DMP of 1850 kg ha^{-1} at maximum tillering, panicle emergence (3489 kg ha^{-1}), flowering (7268 kg ha^{-1}) and harvest (12,335 kg ha^{-1}) stages was also recorded by the application of urea-5% + SOP - 1.5%. The increased growth attributes by the application of urea - 5% + SOP -1.5% might be due to the higher availability of NPK at different growth stages *viz.*, maximum tillering, panicle emergence and flowering stages. The maximum availability of N for the treatment F_4 might have increased the plant height favourably due to cell elongation and increased photosynthetic rate. Similar findings of increased plant height by increased mineral uptake have been reported by Pandian (1989) and Sharief *et al.* (2006).

The increased availability of N through foliar application at critical growth stages might have increased the tiller production by the treatment F_4 at all growth stages. This corroborates with the findings of Chopra and Chopra (2000). The availability of K might have also increased the tiller production (Kulkarni *et al.*, 1975). Similar findings of increased tiller production in rice due to S application at active tillering, maximum tillering and at maturity stages was reported by Blair *et al.* (1979), Ahamad *et al.* (1988), Muraleedharan and Jose (1993). Sudha (1999) also observed significant increase in tiller production of rice with increased S application.

Increase in plant height and tiller number due to foliar application of urea - 5% + SOP -1.5% have attributed to corresponding increase in the number of leaves which in turn might have influenced the LAI. Moreover, increase in LAI due to the application of urea - 5 % + SOP -1.5 % might be attributed to the positive role of S through foliar application of SOP. Similar finding of increased LAI with S application was reported by Sudha (1999). Anu (2001) also reported increased LAI due to N supplementation in rice. Higher LAI due to K application in rice was also noticed by Babu (1996).

There was a progressive increase in DMP throughout the crop growth stages due to the influence of treatments (Fig. 3). The availability of N, K and S at active growth stages might have resulted in the overall growth contributing factors like plant height, number of leaves and number of tillers, which resulted in higher DMP. Similar findings of increased DMP at active tillering, maximum tillering and harvest stages by S application was reported by Suzuki (1978) and (Blair *et al.*, 1979). Jagathjothi *et al.* (2012) reported that the growth attributes and yield of rice were the highest when INM was supplemented with 2% urea phosphate spray at panicle initiation stage and 10 days later.

Application of adjuvants had significant influence on LAI and DMP. Adjuvant I having translocation character registered the highest LAI (4.73) at panicle emergence stage, 3.58 at harvest stage and DMP of 11,028 kg ha^{-1} at harvest stage (Fig. 4.) Adjuvant I having wetting, spreading and deep penetrating properties might have improved contact between spray droplets and plant surface thereby enhancing the absorption by increasing the retention of spray droplets on the plant, increasing penetration through hairs, scales, and other leaf surface structures, preventing crystallization of spray deposits. This might have resulted in better uptake of applied foliar nutrients to crop which improved vegetative growth characters like LAI and DMP. This corroborates with findings of Tu *et al.* (2001)

Interactions had significant influence on LAI at panicle emergence and harvest stages. Among the interactions, f_4a_1 (urea - 5% + SOP -1.5% + adjuvant I) recorded the highest LAI. Adequate and balanced supply of nutrients *viz.*, N, K and S through foliar application along with adjuvants having deep penetrating property, resulted in the improved vegetative growth, as indicated by taller plants, more number of tillers and leaves and increased leaf size leading to larger LAI. Jagathjothi *et al.* (2012) also reported that the combined application of organic and inorganic sources with foliar spray enhanced the growth of rice.

KAU POP (Control 1) registered significantly higher DMP at all growth stages than the application of 5 t FYM alone (Control 2). Readily available nutrients from foliar nutrition along with FYM enhanced the ability of plant to grow well and thus accumulate more dry matter on dry weight basis. This corroborates with the findings of Anu (2001).

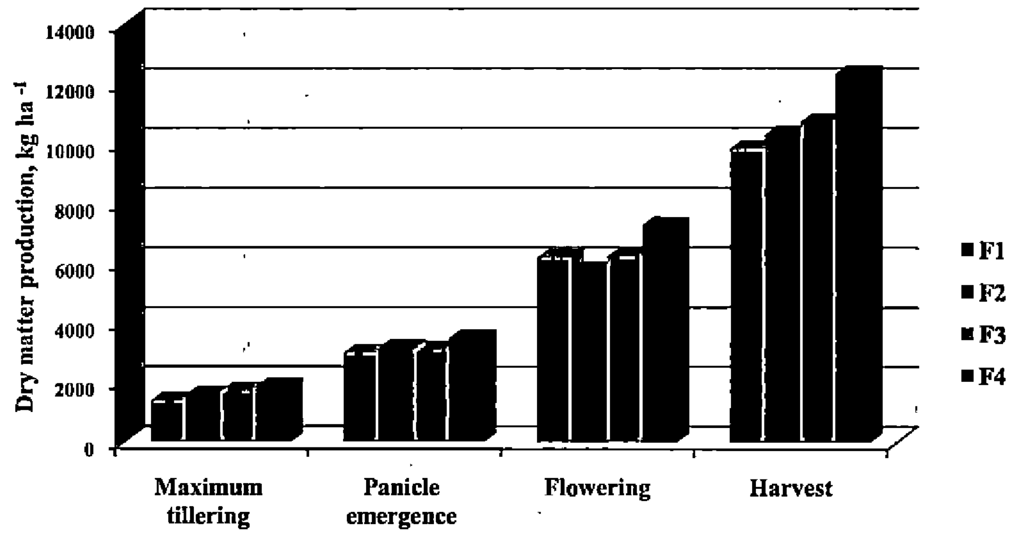

Fig. 3. Effect of foliar nutrients on dry matter production at different growth stages

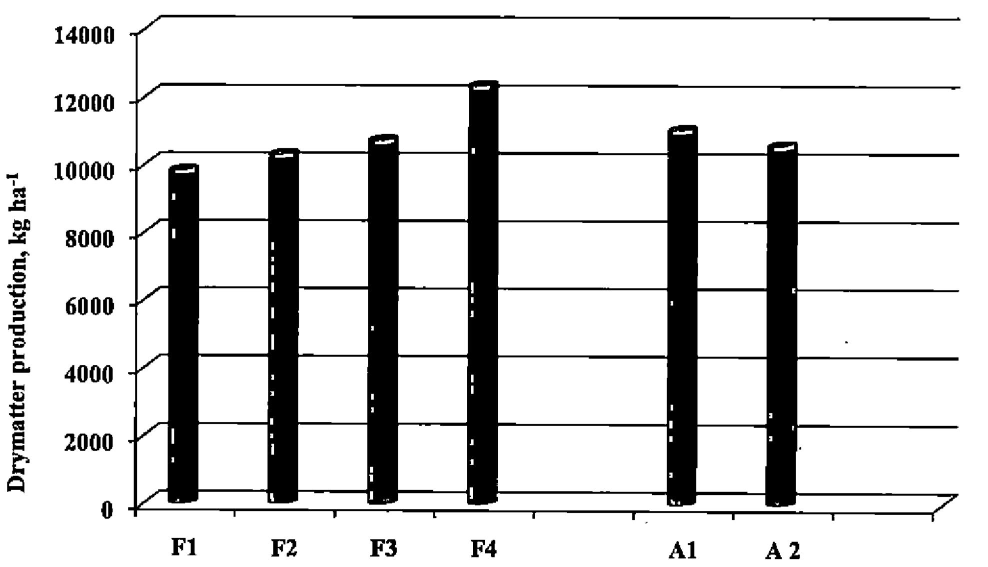

Fig. 4. Effect of foliar nutrients and adjuvants on drymatter production at harvest stage

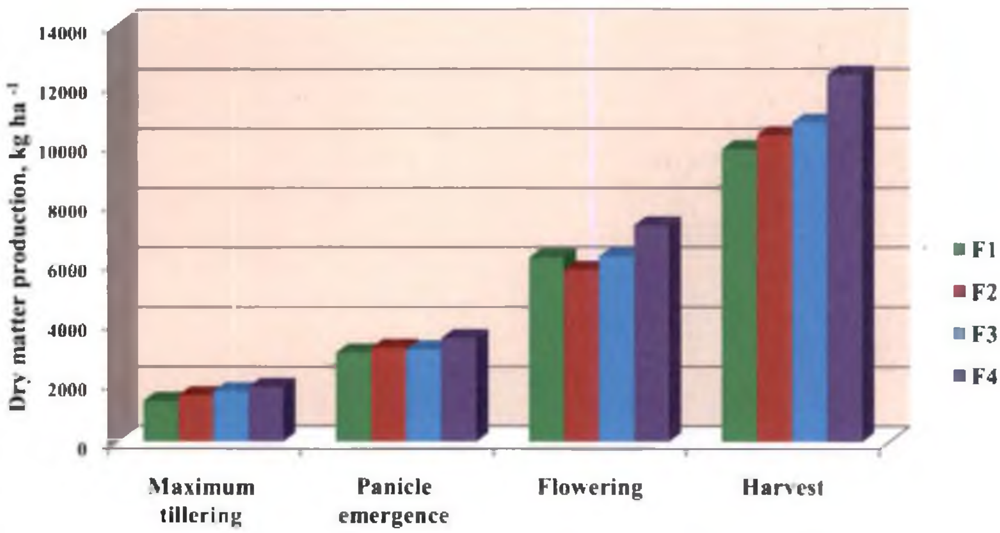

Fig. 3. Effect of foliar nutrients on dry matter production at different growth stages

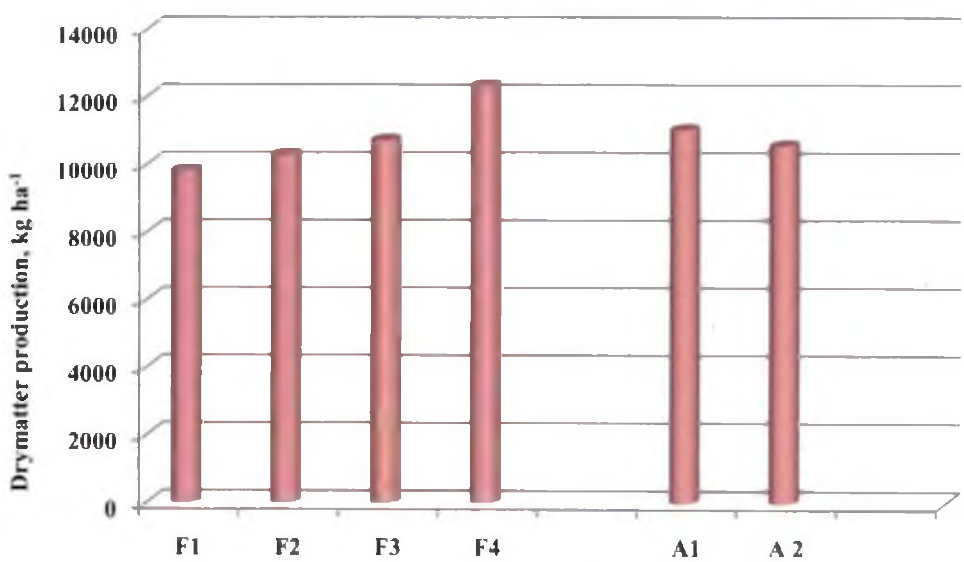

Fig. 4. Effect of foliar nutrients and adjuvants on drymatter production at harvest stage

5.2 YIELD ATTRIBUTES AND YIELD

Significantly lesser number of days was registered for attaining 50 % flowering for the plant grown with F_4 (urea- 5% + SOP 1.5%) and F_3 (urea- 5% + SOP 1.5%). All the yield and yield attributes *viz.*, productive tillers m^{-2} (482.50), panicle length (26.66 cm), spikelets panicle^{-1}, number of filled grains panicle^{1},thousand grain weight (25.98g) (Fig. 5.), grain yield (5.76 t ha^{-1}) and straw yield (6.99 t ha^{-1}) (Fig.6.) were significantly higher with foliar nutrition of urea- 5% + SOP- 1.5% (F_4). Neither foliar nutrients nor adjuvants and their interaction had any significant influence on sterility percentage and grain weight panicle^{-1}. Plants grown under F_4 treatment received higher dose of major nutrients along with S (64.5 kg of N, 30 kg of P, 26.25 kg of K and 4.25 kg S) and these nutrients were continuously available at different growth stages *viz.*, maximum tillering, panicle emergence and flowering. This might have increased the growth characters, yield attributing characters and yield. Similar findings were reported by Lin and Zhu (2000).

The nutrients supplied through foliar application might have resulted in the rapid availability and uptake of nutrients leading to faster crop response compared to soil application. Similar findings have been reported by Fageria *et al.* (2009). Hasewaga *et al.* (2000) also reported that foliar spray of nutrients increased the photosynthesis, dry matter accumulation, tiller number, dry weight, leaf area, number of fertile spikelets in the panicle and grain yield of rice. Similar findings were also reported by Jagathjothi *et al.* (2012). Ali *et al* (2007) also reported that soil application of SOP @ 50 kg K_2O ha^{-1} along with foliar application of the same enhanced the rice yield. Higher straw yield might be due to increased plant height, more number of tillers and higher DMP for these treatments. Ali *et al.* (2005) reported that foliar application of 1.5 % K_2SO_4 produced better paddy and straw yields as compared to KNO_3 and KCl. Similar results had also been obtained by Glass and Siddiqi (1984).

Adjuvant I having penetrating character recorded the highest panicle length (25.58 cm) and grain yield (5.20 t ha^{-1}). The improved penetrating character of the adjuvant with spreading and sticking property might have increased panicle length and grain yield. Similar findings of increased spreading and sticking by adjuvant on leaf surface have been reported by Fernandez and Eichert (2009) and Tu *et al.* (2001).

The interaction effects between the treatments on 50 per cent flowering, productive tillers m^{-2} and panicle length were found to be significant. All the yield attributing characters were improved by the applications of 64.5 kg of N and 26.25 kg of K and 4.25 kg S along with adjuvant having sticking and penetrating property (f_4a_1) which might be due to increased nutrients uptake. Weight of the panicles could be altered to some extent due to different foliar nutrients. It is possible that enhanced nutrient availability through foliar application at different growth stages promoted the supply of assimilates to sink, thus enlarging the size of panicles with more number of spikelets resulted in greater number of filled grains with higher test grain weight.

Dry matter partitioned toward shoot portion and panicles were significantly influenced by foliar nutrients. Among the foliar nutrients, significantly higher shoot weight percentage and panicle weight percentage were noticed with foliar application of urea - 5% and SOP-1.5% (F_4) and it was on a par with F_3. Balanced nutrition is essential for proper dry matter partitioning. Venkateswarlu and Vispearas (1987) reported that even within a crop source- sink balance varies based on the nutrient availability. The balanced availability of major nutrients (N, P, K and S) might have favoured a better drymatter partitioning.

KAU POP registered significantly higher yield and yield attributes than 5 t ha^{-1} FYM alone (control 2). Increased nutrient level enhanced the ability of the plant to grow well which resulted in higher DMP and yield. Yield attributing characters *viz.*, productive tillers m^{-2}, spikelets $panicle^{-1}$, panicle length, number of filled grains

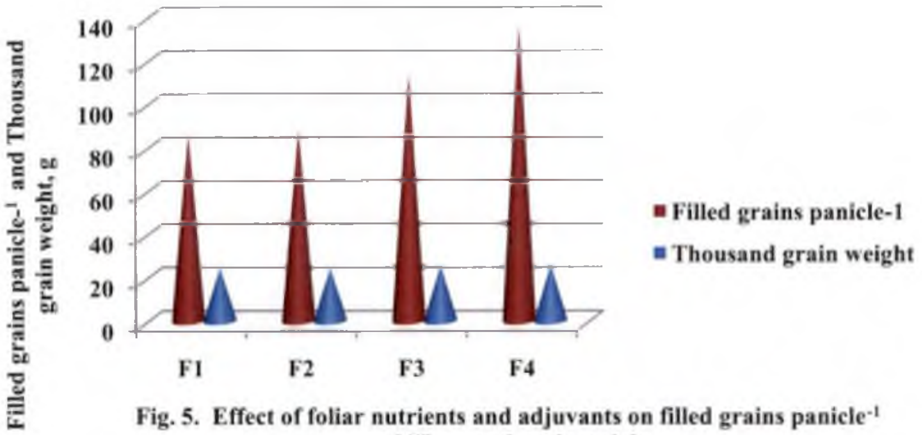

Fig. 5. Effect of foliar nutrients and adjuvants on filled grains panicle^{-1} and Thousand grain weight

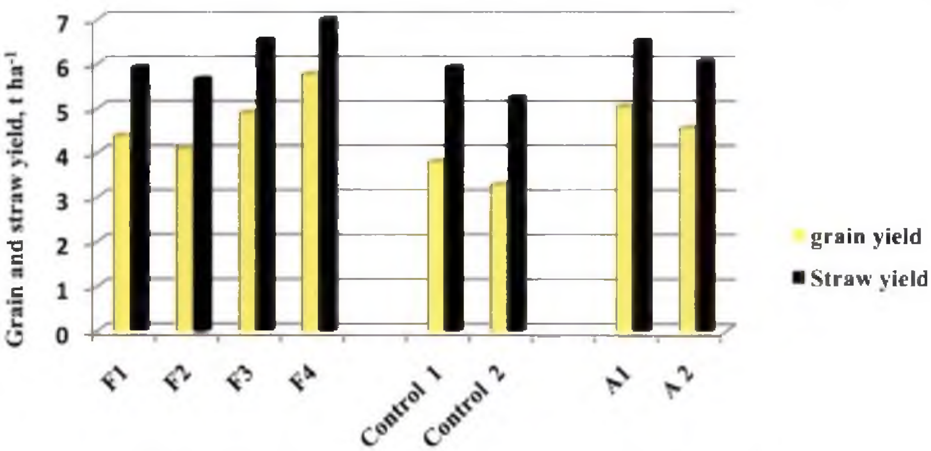

Fig. 6. Effect of foliar nutrients and adjuvants on grain and straw yield

panicle^{-1}, thousand grain weight, grain yield and straw yield were significantly higher in treatments compared to controls. Foliar nutrition along with adjuvant registered higher yield attributes and this might be due to enhanced availability of N, K and S at reproductive stages of the crop.

5.3 PLANT ANALYSIS

5.3.1 UPTAKE OF NUTRIENTS

The results revealed that uptake of N, P and K were significantly influenced by foliar nutrients and adjuvants. Application of urea -5% + SOP -1.5% recorded higher uptake of N, P and K (Fig. 7). The higher DMP recorded by the treatment F_4 might have resulted in the increased uptake of N, P and K. The higher nutrient availability for F_4 treatment might have increased the nutrient uptake. Similar findings of higher N uptake by the application of higher amount of N have been reported in upland rice by Gopalakrishnan (2005). The higher N uptake might also be due to the synergistic effect of N and S and this has been reported earlier by Sudha (1999). The higher P uptake could be due to higher levels of N and K. Similar finding of higher P uptake with high N and K has been reported earlier by Muthuswamy *et al.* (1974) and Reddy *et al.* (1986). The increased availability of S might have also enabled the plant to absorb more P due to synergistic effect and this is in conformity with findings of Sakar *et al.* (1995) and Sudha (1995). The increase in K uptake with S application could be attributed to the synergistic effect of S on K.

Adjuvants also had significant influence on nutrient uptake (Fig. 8). The sticking and penetrating properties of adjuvant I might have extended the time available for the penetration and uptake of nutrients by the plants. Similar findings have also been reported by Hazen (2000).

Interaction between foliar nutrients and adjuvants did not have any significant influence on N, P and K uptake. The treatment combinations compared against

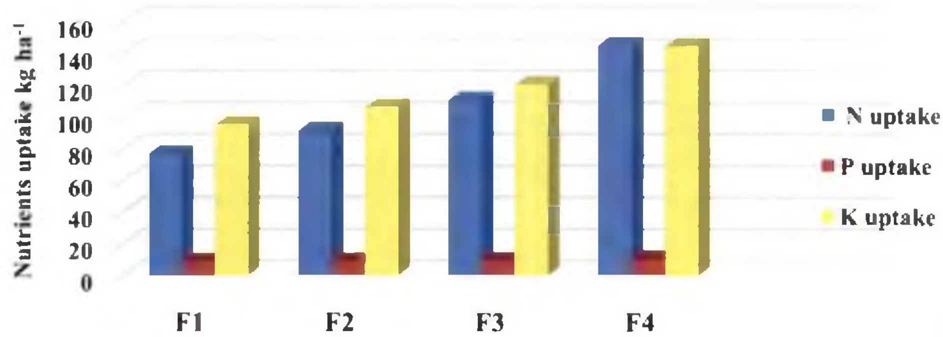

Fig. 7. Effect of foliar nutrients on N, P and K uptake

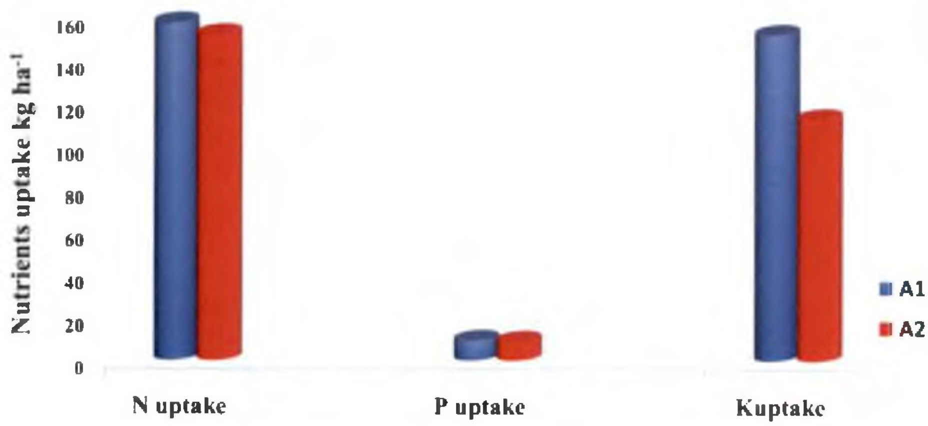

Fig. 8. Effect of adjuvants on N,P and K uptake

controls revealed that treatment mean was significantly superior to both the controls with respect to N uptake while application of 5 t ha^{-1} of FYM was significantly inferior to treatment mean with respect to K uptake. The comparison between controls revealed that KAU POP was significantly superior to the application of 5 t ha^{-1} FYM alone with respect N, P and K uptake. The availability of 60:30:30 kg ha^{-1} N, P_2O_5 and K_2O along with 5 t ha^{-1} FYM might have contributed to the higher uptake of these nutrients for the plants grown with POP recommendation of KAU. Similar findings of maximum NPK uptake with 60:30:45 kg ha^{-1} N, P_2O_5 and K_2O has been reported by Thomas (2000).

5.3.2 Crude protein content of Grain

Foliar nutrients significantly influenced the crude protein content of grain. Foliar nutrition with urea -5% + SOP -1.5% (F_4) recorded significantly higher crude protein content of 8.3 per cent. The higher uptake of N, one of the major plant nutrient essential for protein synthesis, by the treatment F_4 have contributed to the higher protein content as explained by Tisdale *et al.* (1995). The higher availability of N by foliar application of urea @ 5% concentration at panicle emergence and flowering stages might have increased the crude protein content of grains. This corroborates with the finding of Nishizawa *et al.* (1997), Juliano and Duff (1991) and Perez *et al.* (1996).

Adjuvants and their interaction with foliar nutrients had no significant influence on crude protein content. The treatment mean compared against control 1 was not significant, while the treatment mean compared against control 2 revealed that application of 5 t ha^{-1} FYM alone, recorded lower crude protein content (5.47%) compared to all treatment combinations. The comparison between controls revealed significantly superior crude protein content for KAU POP than the application of 5 t ha^{-1} FYM alone. The lowest nutrient content available from 5 t ha^{-1} FYM alone might have resulted in the lowest availability of N and hence the lowest crude protein content in control 2.

5.4 Available Nutrients in Soil

The organic carbon content did not vary significantly with respect to foliar nutrients, adjuvants and their interaction. The available N content varied significantly among treatments and the highest N was observed with the application of urea- 5% + SOP- 1.5% (F_4). Higher N availability for F_4 might be due to the higher application of N to the crop at different growth stages. The availability of N from foliar fertilizers might have also lead to the lower extraction of N from soil. Similar finding of increased available N content in the soil with foliar application of N was reported by Surya (2015).

Considering the effect of treatments against controls it was observed that available N status was significantly higher for controls compared to treatments while the availability of P and K were higher for treatments compared to controls. Between the controls, KAU POP was significantly superior in terms of available P content in the soil.

5.5 Economic analysis

Gross income and net returns, benefit cost ratio, per day return and return per rupee invested showed significant difference among the different foliar nutrients. The highest net return (₹51036 ha^{-1}), benefit cost ratio (1.72), per day return (₹464) were recorded by application of urea -5% + SOP -1.5 % (F_4) followed by urea - 1.5% + SOP -1.5 % (F_3) recording a B:C ratio of (1.51). Adjuvant category I recorded significantly higher net returns, B:C ratio (Fig. 9) and per day return. This might be due to the more grain yield and straw yield. Similar findings of increased benefit cost ratio of production of cereal crop due to higher grain and straw yield have been reported by Sharpley *et al.* (1994).

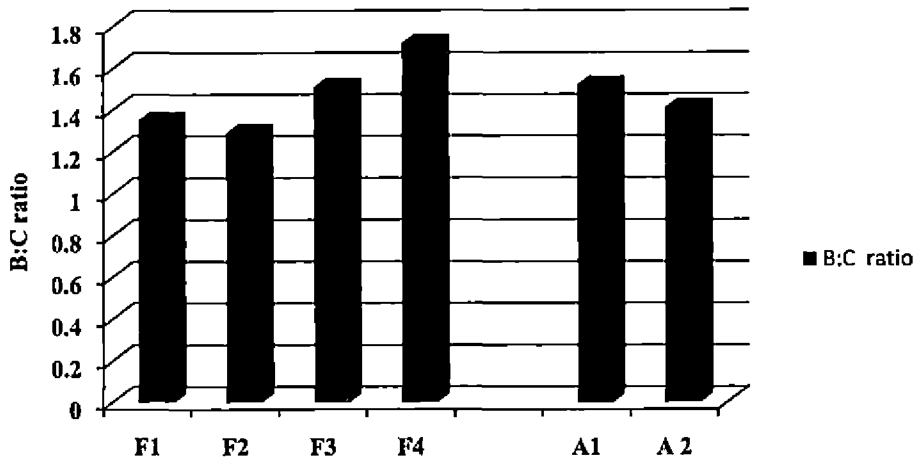

Fig. 9. Effect of foliar nutrients and adjuvants on B:C ratio

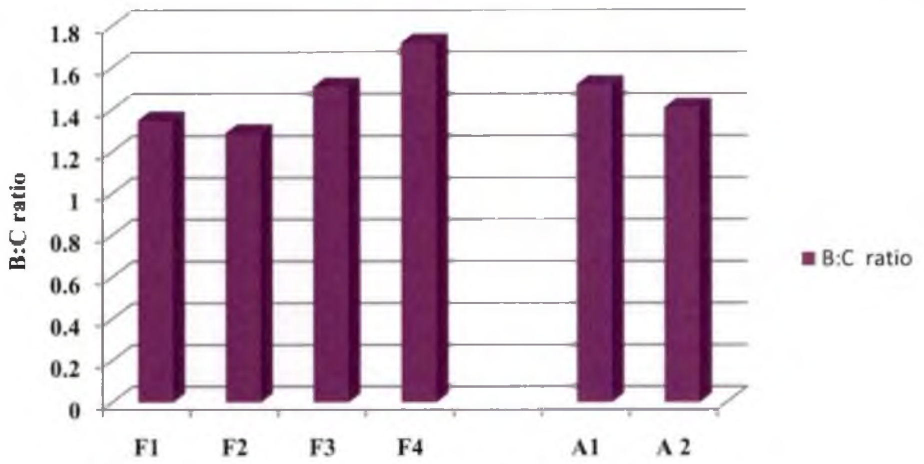

Fig. 9. Effect of foliar nutrients and adjuvants on B:C ratio

The study revealed that application of farm yard manure (5 t ha^{-1}), full dose of P, half dose of N and K (30 :30:15 kg ha^{-1}) along with foliar application of urea 5% + SOP 1.5% with an adjuvant having translocation character at three different growth stages *viz.*, maximum tillering, panicle emergence and flowering stages respectively, resulted in significantly higher grain yield, straw yield, nutrient uptake, net returns and benefit cost ratio in upland rice, variety prathyasa.

SUMMARY

6. SUMMARY

The experiment entitled "Effect of different types of fertilizers as influenced by adjuvants on FUE and yield of upland rice" was undertaken in the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, during May 2015 to September 2015. The main objectives of the study were to assess the possibility of enhancing nutrient use efficiency of rice by using water soluble fertilizers and adjuvants, to study the impact of foliar fertilizers and adjuvants on growth and productivity of upland rice and to work out the economics.

The field experiment was laid out in randomised block design with 10 treatments and three replications. The treatments consisted of four foliar nutrients *viz.*, (F_1) 19:19:19 (1%), (F_2) 13:0:46 (1%), (F_3) urea 1. 5% + SOP 1.5% and (F_4) urea 5% + SOP 1.5%, two adjuvants, adjuvant category I (A_1) having translocating property and adjuvant category II (A_2) and two controls KAU POP (soil application of FYM @ 5 t ha^{-1} + 60:30:30 kg N P_2O_5 and K_2O ha^{-1} (Control 1) and soil application of FYM @ 5 t ha^{-1} (Control 2). Foliar fertilizers were given at maximum tillering, panicle emergence and flowering stages.

The results revealed that growth attributes like plant height, tillers m^{-2}, leaf area index (LAI) and dry matter production (DMP) were significantly influenced by foliar nutrients. Among the foliar nutrients, F_4 (urea 5% + SOP 1.5 %) recorded the highest plant height at harvest stage (101.98 cm). Foliar nutrition with urea -5% + SOP -1.5% recorded higher total number of tillers m^{-2} at all growth stages, at tillering (700.23), panicle emergence (695.87) and flowering stage (693.33). With regard to adjuvants, significant effect on higher tillers m^{-2} was noticed only at harvest stage where adjuvant 1 (A_1) had maximum tiller production (421.54). Significant difference was observed in the tillers m^{-2} between the treatments and the controls at maximum tillering stage.

KAU POP (Control 1) produced significantly lower tiller m^{-2} at maximum tillering stage compared to treatment means. Between the controls, control 1 (KAU POP) was significantly superior to control 2 at maximum tillering stage. The foliar nutrients showed positive influence on LAI at all growth stages. Higher LAI was noticed with F_4 (combined application of urea 5% + SOP 1.5 %) at maximum tillering (3.94) panicle emergence (4.91), flowering (5.02) and harvest (3.89) stages and at maximum tillering stage (F_4) was on a par with (F_3). The effect of adjuvants on LAI was significant only at panicle emergence and harvest stages and at both these stages AI recorded higher LAI. Interaction between the treatments was significant at panicle emergence and harvest stages. Foliar nutrition with urea (5%) + SOP (1.5%) along with adjuvant I (f_4a_1) was significantly superior in terms of LAI compared to other treatment combinations. Significantly higher DMP was noticed with the combined application of urea (5%) + SOP (1.5 %) at all stages of growth, (1850 kg ha $^{-1}$) at maximum tillering, (3489 kg ha $^{-1}$) at panicle emergence, (7268 kg ha $^{-1}$) at flowering, and 12335 kg ha^{-1} at harvest stages respectively. Adjuvant I recorded higher the DMP (11,028 kg ha $^{-1}$) only at harvest stage. The interaction effect was absent in all the stages with regard to DMP.

All the yield attributing characters *viz.*, productive tillers m^{-2} (482.50), panicle length (26.66 cm), spikelets panicle^{-1} (137.22), number of filled grains panicle^{-1} (131.22) and thousand grain weight (25.98 g) were significantly superior with foliar nutrition of urea 5% + SOP 1.5% (F_4). KAU POP produced more filled grains panicle^{-1} compared to treatment means. Foliar nutrition with F_4 registered lesser number of days to attain 50 per cent flowering. The treatment (f_2a_1) (13:0:45 @ 1 per cent along with adjuvant 1) registered significantly longer days to attain 50 per cent flowering (74.03 days) and it was on par with f_2a_2 (73.57 days). Dry matter partitioning towards shoot portion and panicles were significantly influenced by foliar nutrients. Among the foliar nutrients, significantly higher shoot weight percentage and panicle weight percentage were noticed with F_4 and it was on a par with F_3.

Adjuvants and their interaction with foliar fertilizers had no significant influence on the percentage of dry matter that accounted for the panicle weight. Comparison of treatments against controls and comparison between controls were not significant with respect to percentage of dry matter that accounted for the root weight and shoot weight.

Among the foliar nutrients, F_4 (urea 5% + SOP 1.5%) recorded significantly higher grain yield (5.76 t ha^{-1}) and straw yield (6.99 t ha^{-1}). A grain yield (5.02 t ha^{-1}) registered by adjuvant I was higher than adjuvant II (4.54 t ha^{-1}). Considering the effect of treatments against controls, it was observed that the grain yield of control 1(KAU POP) and control 2 (5 t FYM alone) were lower than treatment means and between controls, control 1 (KAU POP) out yielded control 2. KAU POP was significantly superior to control 2 with respect to straw yield. Foliar fertilizer, adjuvants and their interaction did not have any significant influence on harvest index.

Foliar application of urea 5% + SOP 1.5 % (F_4) recorded significantly higher uptake of N (145.35 kg ha^{-1}), P (10.49 kg ha^{-1}) and K (145.05 kg ha^{-1}). The adjuvants chosen for foliar nutrition exerted significant effect on phosphorus uptake. The treatment A_1 (Adjuvant 1) recorded maximum P uptake of 9.41 kg ha^{-1} and K uptake of 120.82 kg ha^{-1}. Significantly higher crude protein content (8.31 per cent) in grain was also registered by F_4.

Economic analysis revealed that gross income (₹ 121494 ha^{-1}), net income (₹ 51036 ha^{-1}), per day returns (₹ 464), return per rupee invested (₹ 2.53) and B:C ratio (1.72) were significantly higher for F_4 (urea 5% + SOP 1.5 %). Adjuvant I recorded significantly higher net income (₹ 37100 ha^{-1}), B:C ratio (1.52) and per day returns (₹ 337) compared to adjuvant II.

Study revealed that, basal application of farmyard manure (5 t ha^{-1}), full dose of P, half dose of N and K (30:30:15 kg ha^{-1}) along with foliar application of urea 5% + SOP 1.5 % with an adjuvant having translocation character at three growth stages *viz.*, maximum tillering, panicle emergence and flowering can be recommended for realizing maximum yield and profit in upland rice.

FUTURE LINE OF WORK

- Combination of different foliar nutrients and adjuvants should be studied in future for stabilizing upland rice productivity.
- To study the response of upland rice to higher concentrations of foliar nutrition.
- Novel customized and fortified nutrients can be exploited for foliar nutrition in upland rice.
- Verification of the present experiment and popularization among farming community.

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7. REFERENCE

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EFFECT OF DIFFERENT TYPES OF FERTILIZERS AS INFLUENCED BY ADJUVANTS ON FUE AND YIELD OF UPLAND RICE

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(2014-11-132)

Abstract of the
thesis submitted in partial fulfilment of the requirement
for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRONOMY
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2015

ABSTRACT

The experiment entitled "Effect of different types of fertilizers as influenced by adjuvants on FUE and yield of upland rice" was undertaken in the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, during May 2015 to September 2015. The main objectives of the study were to assess the possibility of enhancing nutrient use efficiency of rice by using water soluble fertilizers and adjuvants, to study the impact of foliar fertilizers and adjuvants on growth and productivity of upland rice and to work out the economics.

The field experiment was laid out in randomised block design with 10 treatments and three replications. The treatments consisted of four foliar nutrients *viz.*, (F_1) 19:19:19 (1%), (F_2) 13:0:46 (1%), (F_3) urea 5% + SOP 1.5% and (F_4) urea 1.5% + SOP 1.5% and two adjuvants, adjuvant category I (A_1) and adjuvant category II (A_2) with KAU POP (soil application of FYM @ 5 t ha^{-1} + 60:30:30 kg N P_2O_5 and K_2O ha^{-1} (Control 1) and soil application of FYM @ 5 t ha^{-1} (Control 2) as two control treatments. Foliar fertilizers were given in 3 stages *viz.*, at maximum tillering, panicle emergence and flowering.

The results revealed that growth attributes like plant height, tillers m^{-2}, leaf area index (LAI) and dry matter production (DMP) were significantly influenced by foliar nutrients. Among the foliar nutrients, F_4 (urea 5% + SOP 1.5 %) recorded the highest plant height at harvest stage only while tillers m^{-2} and DMP were significantly higher with F_4 at all growth stages. LAI recorded was the highest with F_4 and was on a par with F_3 at all growth stages. Adjuvant category-I recorded the highest LAI at panicle emergence and harvest stages. All growth attributes were superior for Kerala Agricultural University package of practices recommendations (KAU POP) *i.e,* Control 1, compared to the application of 5 t of FYM alone (Control 2). Foliar nutrition with urea 5% + SOP 1.5% along with adjuvant 1 (f_4a_1) recorded the highest LAI at panicle emergence and harvest stages.

All the yield attributing characters *viz.*, productive tillers m^{-2} (482.50), panicle length (26.66 cm), spikelets $panicle^{-1}$ (137.22), number of filled grains $panicle^{-1}$ (131.22) and thousand grain weight (25.98 g) were significantly superior with foliar nutrition of urea 5% + SOP 1.5% (F_4). KAU POP produced more filled grains panicle $^{-1}$ compared to treatments. Foliar nutrition with F_4 registered lesser number of days to attain 50 per cent flowering. Dry matter partitioning towards shoot portion and panicles were significantly influenced by foliar nutrients. Among the foliar nutrients, significantly higher shoot weight percentage and panicle weight percentage were noticed with F_4 and it was on a par with F_3. Among the foliar nutrients, F_4 (urea 5% + SOP 1.5%) recorded significantly higher grain (5.76 t ha^{-1}) and straw yield (6.99 t ha^{-1}). The grain yield (5.02 t ha^{-1}) registered by adjuvant I was higher than adjuvant II (4.54 t ha^{-1}).

Foliar application of urea 5% + SOP 1.5 % (F_4) recorded significantly higher uptake of N (145.35 kg ha^{-1}), P (10.49 kg ha^{-1}) and K (145.05 kg ha^{-1}). Significantly higher crude protein content (8.31 per cent) in grain was also registered by F_4. The disease and pest incidences never reached the threshold level and hence uniform score was given to all plots.

Economic analysis revealed that gross income (₹ 121494 ha^{-1}), net income (₹ 51036 ha^{-1}), per day returns (₹ 464) and B:C ratio (1.72) were significantly higher for F_4. Adjuvant I recorded significantly higher net income (₹ 37100 ha^{-1}), B:C ratio (1.52) and per day returns (₹ 337) compared to adjuvant II.

Based on the present study, basal application of farm yard manure (5 t ha^{-1}), full dose of P, half dose of N and K (30 :30:15 kg ha^{-1}) along with foliar application of urea 5% + SOP 1.5 % with an adjuvant having translocation character at three different growth stages *viz.*, maximum tillering, panicle emergence and flowering can be recommended for realising maximum yield and profit in upland rice.

സംഗ്രഹം

കരനെൽകൃഷിയിൽ പശയുടെ സഹായത്തോടെ പത്രപോഷണത്തിലൂടെ വളപ്രയോഗത്തിന്റെ കാര്യക്ഷമത വർദ്ധിപ്പിക്കുന്നതിനായിട്ടുള്ള ഒരു പരീക്ഷണം 2015 മെയ് മുതൽ സെപ്റ്റംബർ വരെയുള്ള കാലയളവിൽ ഇൻസ്ട്രക്ഷണൽ ഫാമിൽ നടത്തുകയുണ്ടായി. പശയുടെ സാനിധ്യത്തിൽ പത്രപോഷണത്തിലൂടെ നെല്ലിന്റെ വളർച്ച, വിളവ്, സാമ്പത്തിക ലാഭം എന്നിവയിലുണ്ടാകുന്ന മാറ്റങ്ങളെക്കുറിച്ച് പഠിക്കുക എന്നതായിരുന്നു പ്രധാന ലക്ഷ്യം.

പ്രസ്തുത പരീക്ഷണത്തിന് റാൻഡമൈസ്ഡ് ബ്ലോക്ക് ഡിസൈൻ എന്ന പഠനരീതിയാണ് അവലംബിച്ചത്. പ്രത്യാശ എന്ന നെല്ലിനമാണ് പഠന വിധേയമാക്കിയത്. പത്ര പോഷണം ഉൾപ്പെടുന്ന 10 പരിചരണ മുറകളാണ് പരീക്ഷിക്കപ്പെട്ടത്. ഒരു ശതമാനം വീതം 19:19:19 കോംപ്ലക്സ് (F1), പൊട്ടാസ്യം നൈട്രേറ്റ് (F2), 1.5 ശതമാനം യൂറിയ + 1.5 ശതമാനം സൾഫേറ്റ് ഓഫ് പൊട്ടാഷ് (F3), 5 ശതമാനം യൂറിയ +1.5 ശതമാനം സൾഫേറ്റ് ഓഫ് പൊട്ടാഷ് (F4), എന്നീ പോഷക സ്രോതസസുകൾ നെല്ലിന്റെ മൂന്ന് വളർച്ചാ ദശകളിൽ (ചിനപ്പ് പൊട്ടുന്ന സമയം, പൊതിപരുവം, പൂവിടുന്ന സമയം) തളിക്കുകയുണ്ടായി. പത്രപോഷണ സമയത്ത് പോഷക മൂലക സ്രോതസുകളോടൊപ്പം രണ്ടുതരം പശകൾ ഉപയോഗിച്ചു. (A1) പശ ഒന്ന് (ഒട്ടിപ്പിടിക്കുന്നതും, ആഗിരണ സ്വഭാവവും ഉള്ളത്) (A2) പശ രണ്ട് (ഒട്ടിപ്പിടിക്കുന്നത്). മേൽ സൂചിപ്പിച്ച 4x2 പരിചരണ മുറകൾ, കരനെൽകൃഷിക്കുവേണ്ടി കേരളകാർഷിക സർവ്വകലാശാല പാക്കേജ് ശുപാർശയും കൂടാതെ 5 ടൺ കാലിവളം മാത്രം എന്നിവയുമായി താരതമ്യ പ്പെടുത്തുകയും ചെയ്തു.

പോഷകമൂലക സ്രോതസസുകൾ നെല്ലിന്റെ വിവിധ വളർച്ച ദേശകളെ സ്വധീച്ചു. 5 ശതമാനം യൂറിയ + 1.5 ശതമാനം സൾഫേറ്റ് ഓഫ് പൊട്ടാഷ് തളിച്ച പ്ലോട്ടുകളിൽ ചെടിയുടെ ഉയരം ചിതപ്പുകളുടെ എണ്ണം, ഇലയുടെ വിസ്തൃതി, ഉണക്കി സുക്ഷിക്കുമ്പോൾ ഉള്ള തൂക്കം എന്നിവ കൂടുതലായി കണ്ടു.

പത്രപോഷണത്തിനായി തെരെഞ്ഞെടുത്ത പോഷക മൂലകങ്ങളോടൊപ്പം ഉപയോഗിച്ച പശയുടെ സാനിധ്യം നെല്ലിന്റെ വിവിധ വളർച്ച ദശകളെ സ്വാധീനിച്ചു. ഒട്ടിപ്പിടിക്കുകയും ആഗിരണ ശക്തി ഉള്ള പശ (1) കാരണം ചിതപ്പുകളുടെ എണ്ണം ഇലകളുടെ വിസൃതി ഉണക്കി സുക്ഷിക്കുമ്പോൾ ഉള്ള തൂക്കം എന്നിവ കൂടുതലായി കാണപ്പെട്ടു.

നെൽകൃഷിയിൽ വിളവിന്റെ മാനദണ്ഡങ്ങളായ കതിരായ ചിതപ്പുകളുടെ എണ്ണം, ഓരോ കതിരിലുമുള്ള മണികളുടെ എണ്ണം, മണിയുടെ തൂക്കം, ആയിരം മണികളുടെ തൂക്കം എന്നിവയെല്ലാം തന്നെ 5 ശതമാനം യൂറിയയും 1.5 ശതമാനം സൾഫേറ്റ് ഓഫ് പൊട്ടാഷും ഉപയോഗിച്ചപ്പോൾ പാക്കേജ് ശുപാർശയെക്കാൾ വർദ്ധിച്ചതായി രേഖപ്പെടുത്തി. ആഗിരണ ശക്തിയുള്ള പശയുടെ ഉപയോഗം കര നെൽകൃഷിയിൽ വിളവിന്റെ മാനദണ്ഡങ്ങളെ വർദ്ധിപ്പിച്ചതായി രേഖപ്പെടുത്തി. പ്രസ്തുത പരിചരണ മുറ നെല്ലിന്റെ വിളവും, അറ്റാധായവും വർദ്ധിക്കാൻ സഹായിച്ചു.

ഹ്രസ്വകാല മൂപ്പുള്ള നെല്ലിനമായ പ്രത്യാശയ്ക്ക് ഹെക്ടറിന് 5 ടൺ കാലിവളം, 30 കി. പാക്യജനകം, 30 കി ഭാവകം, 30 കി. ക്ഷാരം എന്നിവ അടിവളമായും കൂടാതെ മൂന്നു തവണകളിലായി 5 ശതമാനം വീര്യത്തിൽ യൂറിയയും +1.5 ശതമാനം വീര്യത്തിൽ സൾഫേറ്റ് ഓഫ് പൊട്ടാഷും (ചിനപ്പ് പൊട്ടുന്ന സമയം, പൊതിപരുവം പുഷ്പിക്കൽ സമയം) ആഗിരണ ശക്തിയുള്ള പശയോടൊപ്പം തളിക്കുന്നത് കൂടുതൽ വിളവും അറ്റാധായവും നൽകുന്നതായി രേഖപ്പെടുത്തി.

APPENDIX- 1

Weather data for the cropping period

(May 2015 to September 2015)

Standard week	Temperature (°C)		Bright Sunshine hours	Rainfall (mm)	Relative humidity (%)	
	Maximum	Minimum			Maximum	Minimum
18	33.6	24.5	9.9	0.0	86.0	81.0
19	27.0	25.9	7.6	103.1	91.4	83.6
20	30.8	23.5	6.5	29.3	94.0	89.1
21	32.3	26.1	8.8	97.7	92.1	82.7
22	31.9	25.2	8.4	13.0	90.8	81.0
23	31.9	24.7	9.6	61.5	89.7	79.6
24	31.9	24	8.3	63.0	83.9	10.5
25	31.6	24.4	9.2	47.8	90.3	82.7
26	30.5	24	8.2	166	92.0	86.6
27	31.6	25.3	10.2	5.0	90.1	79.6
28	31.9	25.2	9.7	10.2	88.1	80.9
29	30.6	23.8	9.6	35.1	90.1	81.1
30	31.3	24.1	9.8	3.2	87.9	76.9
31	31.3	24.5	9.9	2.3	87.6	78.1
32	31.8	26.1	9.5	4.4	90.0	76.1
33	32.8	24.5	10.4	57.6	87.9	73.4
34	31.8	24.7	9.6	15.9	91.3	76.7
35	31.9	24.7	10.1	0.0	89.9	81.1
36	31.5	24.2	6.2	101.2	91.7	84.3
37	31.2	24	8.6	67.0	93.4	86.4
38	31	24.6	8.2	66.0	93.1	81.9
39	31.8	24.5	8.2	55.3	88.9	83.0

APPENDIX-II

Average input cost and market price of produce

Sl. No	Items	Cost
	INPUTS	
A	Seed	₹ 36 per kg
B	Labour	
1	Women	₹ 612 per day
2	Men	₹ 612 per day
C	Cost of manures, fertilizers, adjuvants and sources for foliar nutition	
1	Farm yard manure (FYM)	₹ 5 per kg
2	Lime	₹ 15 per kg
3	Urea	₹ 8 per kg
4	Rock phosphate	₹ 10 per kg
5	Muriate of potash(MOP)	₹ 17 per kg
6	19:19:19 complex	₹ 200 per kg
7	Potassium nitrate	₹ 250 per kg
8	Sulphate of potash	₹ 115 per kg
9	Adjuvant Category I	₹ 187.5 per litere
10	Adjuvant Category II	₹ 375 per litere
	OUTPUT	
A	Market price of grain	₹ 15 per kg
B	Market price of straw	₹ 5 per kg